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MINISTRY OF URBAN DEVELOPMENT (MOUD)

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PART B : OPERATION AND MAINTENANCE

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IN ASSOCIATION WITH

WATER AGENCY INC.

MANUAL ON
SEWERAGE AND SEWAGE TREATMENT

PART B : OPERATION AND MAINTENANCE

FINAL DRAFT

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CENTRAL PUBLIC HEALTH AND
ENVIRONMENTAL ENGINEERING ORGANIZATION

MINISTRY OF URBAN DEVELOPMENT
NEW DELHI

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ABBREVIATION

A2O	Anaerobic, Anoxic and Oxic process
AC	Alternating Current
ACB	Air Break Circuit Breaker
ADF	Average Daily Flow
APHA	The American Public Health Association
ASD	Adjustable Speed Device
ASP	Activated Sludge Process
b.e.p	Best Efficiency Point
BFP	Belt Filter Press
BIS	Bureau of Indian Standards
BNR	Biological Nutrient Removal
BNR	Biological Nitrogen Removal
BOD	Biochemical Oxygen Demand
BS	Bridges and Structure
BWSSB	Bangalore Water Supply and Sewerage Board
CBM	Condition Based Maintenance
CCTV	Closed Circuit Television Equipment
CCU	Central Control Unit
CD	Compact Disc
CDM project	Clean Development Mechanism project
CPHEEO	Central Public Health and Environmental Engineering Organisation
CI	Cast Iron
CIPP	Cured-in-Place-Pipe
CMMS	Computerized Maintenance Management System
CMWSSB	Chennai Metropolitan Water Supply and Sewerage Board
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPR	Cardiopulmonary Resuscitation
CT	Current Transformer
CUPS	Control of Urban Pollution Series
CWMS	Computerized Work Management System
DAF	Dissolved Air Floatation
DC	Direct Current
DG	Diesel Generator

DI	Ductile Iron
DLP	Defect Liability Period
DO	Dissolved Oxygen
DEWATS	Decentralised Waste water Treatment Systems
EBPR	Enhanced Biological Phosphorus Removal
EEBA	Emergency Escape Breathing Apparatus
EMB	Eosin Methylene Blue
Env	Environment
EPA	Environmental Protection Agency
ESP	Exchangeable Sodium Percentage
F/M ratio	Food to Microorganisms ratio
FC	Faecal Coliform
FFT	Fast Fourier Transform
FPU	Final Polishing Unit
FRP	Fibre Glass Reinforced Plastic Pipes
GI	Galvanized Iron
GOD	Ground Operated Disconnection
GRP	Glass Fibre Reinforced Plastic
HDPE	High Density Polyethylene
HMI	Human Machine Interface
hp	Horsepower
HRT	Hydraulic Retention Time
HT	High Tension
I / O	Input / Output
ICMR	Indian Council of Medical Research
ID	Internal Diameter
IDLH	Immediately Dangerous to Life or Health
IJOEM	Indian Journal of Occupational and Environmental Medicine
IMLR	Internal Mixed Liquor Recycle
IS	Indian Standards
JASCOMA	Japan Sewer Collection System Maintenance Association
JEFMA	Japan Environmental Facilities Manufactures Association
JICA	Japan International Cooperation Agency
JSWA	Japan Sewage works Association
JTU	Jackson Turbidity Units
LEL	Lower Explosion Limit
LT	Low Tension

LWL	Low Water Level
MBBR	Moving Bed Bio Reactor
MBR	Membrane Bio Reactor
MCC panel	Motor Control Centre panel
MCCB	Moulded Case Circuit Breaker
MCF	Membrane Cartridge Filtration
MF	Micro Filtration
MLd	Million Litres per Day
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
MH	Manhole
MOLE	Ministry of Labour Employment
MOUD	Ministry of Urban Development
MPN	Most Probable Number
MSL	Mean Sea Level
NA	Not Applicable
NF	Nano Filtration
NPSHA	Net Positive Suction Head Available
NPSHR	Net Positive Suction Head Required
NRCD	National River Conservation Directorate
NRCP	National River Conservation Plan
NRV	Non-Return Valve
NUSP	National Urban Sanitation Policy
O&M	Operation and Maintenance
OCR	Over Current Relay
ORP	Oxidation – Reduction Potential
OSHA	Operational Safety and Health Association
OSS	On-site Sanitation System
OTE	Oxygen Transfer Efficiency
OVR	Over Voltage Relay
PAO	Polyphosphate Accumulating Organism
PB fume	Palmer-Bowlus flume
PC	Personal Computer
PC	Power Contactor
PCB	Pollution Control Board
PCCP	Prestressed Concrete Cylinder Pipe
PCOM	Per Capita O&M Cost

PD	Positive Displacement
pH	Potential Hydrogen
PHA	Poly-hydroxyalkanoates
PLC	Programmable Logic Controller
PM	Planned Maintenance
PMC	Project Management Consultants
PR	Protective Relay
PS	Pumping Station
PST	Primary Settling Tank
PT	Potential Transformer
PVC	Polyvinyl Chloride
PWD	Public Works Department
PWSSB	Punjab Water Supply and Sewerage Board
Qty	Quantity
R&D	Research and Development
RAS	Return Activated Sludge
RBC	Rotating Biological Contactor
RCC	Reinforced Cement Concrete
RO	Reverse Osmosis
RPM	Revolutions Per Minute
RTD	Resistance Temperature Detector
SAR	Sodium Absorption Ratio
SASW	Spectral Analysis of Surface Waves
SBR	Sequencing Batch Reactor
SCADA	Supervisory Control and Data Acquisition
SCBA	Self-Contained Breathing Apparatus
SDB	Sludge Drying Bed
SF6	Sulphur Hexafluoride
SLB	Service Level Benchmarks
SLR	Solids Loading Rate
SOR	Surface Overflow Rate
SPDP	Screen Protected Drip-Proof
SRT	Solids Retention Time
SS	Suspended Solids
SS	Stainless Steel
SST	Secondary Settling Tank
STP	Sewage Treatment Plant

SV	Sludge Volume
SVI	Sludge Volume Index
TDS	Total Dissolved Solids
TEFC	Total-Enclosed Fan-Cooled
TM	Trademark
TMP	Transmembrane Pressure
TSS	Total Suspended Solids
TV	Television
TWSSB	Tamilnadu Water Supply and Sewerage Board
UASB	Up flow Anaerobic Sludge Blanket Reactor
UF	Ultra Filtration
ULB	Urban Local Body
UNIDO	United Nations Industrial Development Organization
UP	Uttar Pradesh
UPJN	Uttar Pradesh Jal Nigam
UPS	Uninterruptible Power Supply
UPVC	Unplasticized Polyvinyl Chloride
US EPA, USEPA	United States Environmental Protection Agency
UV	Ultraviolet
UVR	Under Voltage Relay
VCB	Vacuum Circuit Breaker
VFA	Volatile Fatty Acids
VFD	Variable Frequency Drive
VSS	Volatile Suspended Solids
VT	Voltage Transformer
VVVF	Variable Voltage Variable Frequency
WAS	Waste Activated Sludge
WEF	Water Environment Federation
WHO	Word Health Organization
WMS	Work Management System
WRFs	Water Reclamation Facilities
WSP	Waste Stabilization Pond
XLPE	Crosslinked Polyethylene Insulated Cable
YAP	Yamuna Action Plan
3φ3W	3phase 3wire

CHAPTER 1 INTRODUCTION

In engineering parlance, operation refers to daily operation of the components of a sewerage system such as collection system, pumping stations, pumping mains, STP's, machinery and equipment, etc., in an effective manner by various technical personnel, and is a routine function. The term maintenance is defined as the art of keeping the structures, plants, machinery and equipment and other facilities in optimum working order. Maintenance includes preventive maintenance or corrective maintenance, mechanical adjustments, repairs, corrective action and planned maintenance. However, replacements, correction of defects etc., are considered as actions excluded from preventive maintenance. For replacements with regard to sewerage and sewage treatment, the broad categories of infrastructure which need to be addressed are as follows:

- Collection System including house service connections and manholes
- Pumping Stations
- Pumping Mains
- STPs
- Utilization of biological sludge and containment of chemical sludge

There are standard O&M manuals for these in developed countries. However, O&M manual is not yet prepared in detail in India. The following conditions prevail:

- Most of the towns are only partially sewered
- Most of generated greywater continues to flow in road side drains
- Per capita water usage is practically only 25 to 30 % as used in advanced countries
- Water as used is mainly from local groundwater also with high TDS, sulphates etc.
- The sulphates are an agent of corrosion of concrete in sewers
- Wash basins, kitchen sinks etc do not have blenders below the sink
- Detergent powders have significant grit content
- Cattle are also housed inside the cities and their dung washed into sewers
- The cattle shed washing occurs during noon times after the peak flow has passed
- These cattle shed washed dung settles in sewers and builds up to choke
- The budgets of most ULBs are inadequate for purchasing sewer cleaning machines
- Though sewer divers are banned, still manual labour is used to "rod" and clean the sewers
- Pumping stations are not connected by website to know of flooding in the station area
- Removing sewer blocks takes longer times due to problem of manual work
- Instrumentation based remote operation of STPs is a far away situation
- Except a few metro cities, all records continue to be in hard copies only
- There are no newsletters aimed at operators sharing their experiences
- The above position is further complicated by as many as 25 local languages

- Disposal of solid wastes in manholes

These issues as in Indian conditions are directly in contrast to the situations in advanced countries make it necessary to evolve an O&M manual specific to the Indian conditions.

1.1 NEED FOR O&M

Even though we all recognize the reasons as pointed out above, the absence of an O&M manual based on which these defects can be step by step rectified is keenly felt. There is the O&M manual for Water Supply Systems by CPHEEO, but there is no such manual for Sewerage Systems. Moreover, unless there is an O&M manual, ULBs cannot justify budget allocations to meet their obligations under such a manual. The net result is this lack of attention to the important aspect of Operation & Maintenance (O&M) of sewerage systems leads to deterioration of the useful life of the systems necessitating premature replacement of many system components and also affecting overall sanitation. As such, even after creating such assets by investing millions of rupees, they are unable to provide the services effectively to the community for which they have been constructed, as they remain defunct or underutilized most of the time.

Some of the key issues contributing to the poor Operation & Maintenance have been identified as follows:

i. Lack of finance, inadequate data on Operation & Maintenance

ii. Multiplicity of agencies, overlapping responsibilities

iii. Inadequate training of personnel

iv. Lesser attraction of maintenance jobs in career planning

v. Lack of performance evaluation and regular monitoring

vi. Inadequate emphasis on preventive maintenance

vii. Lack of operation manuals

viii. Lack of appreciation of the importance of facilities by the community

ix. Lack of real time field information etc.

x. O&M contractors not having permanent staff.

xi. Connection of road gullies to sanitary sewer system, which are major contributors of slit and floating matter such as plastic bags, wood pieces etc.

xii. Lack of storm sewer system.

xiii. Wastage of potable water, due to supply of unmetered water supply at cheap water tariff and free water connections which add to the load of domestic sewage.

Therefore, there is a need for clear-cut sector policies and legal framework and a clear demarcation of responsibilities and mandates within the water supply sub-sector. From the Indian experience, it has been observed that by and large, about 20 to 40% of the total annual Operation & Maintenance cost goes towards the personnel (Operation & Maintenance Staff), 30 to 50% of the cost is incurred on power charges and the balance is utilized for consumables, repairs and replacement of parts and machinery and miscellaneous charges. In most of the cities in India, the tariffs are so low that they do not even cover the annual Operation & Maintenance cost.

Hence, it is a felt need to bring out this O&M Manual in sewerage systems

The O&M Manual is required to encompass various issues pertaining to an effective O&M such as technical, managerial, administrative, personnel, financial & social aspects etc.

The O&M Manual is a long felt need of the sector. At present, there is no Technical Manual on this subject to benefit the field personnel and to help the O&M authorities to prepare their own specific manuals suitable for their organizations. Therefore, CPHEEO made plans to publish the O&M Manual for Indian Sewerage System with JICA support.

1.2 BASIC CONSIDERATIONS OF O&M

1.2.1 Laws and Regulations related to O&M of Sewerage System

In fact there are no laws directly related to O&M of sewerage systems. The laws which are generally applicable are invariably the municipal bye-laws which are of general nature.

1.2.2 Effluent Standards related to Treatment Plants

The effluent standards related to STPs are very confined to BOD of less than 20 mg/L and SS of less than 30 mg/L. These are more of historical nature.

1.2.3 Environmental Considerations

These are generally problems with Industrial Effluent which get into sewers and which are difficult to control. A conflict exists between the prevention and control of water pollution Act and the Municipal act or Jal Nigam Act of Water and Sewerage Board Act. The sewer system is to be maintained by the municipality, Jal Board or Water Supply and Sewerage Boards. But the power to sanction an industrial effluent to be discharged in the sewers is not with these agencies. It is with the Pollution Control Boards (PCBs). The trouble is when industries are detected to be discharging their effluents without the necessary treatment; the said local agencies do not have legislative powers to put the industry on notice. They have to write to the PCB. The PCB is in no hurry to immediately look into this specifically because for a whole metro city the PCB may have only a handful of engineers and they have lots of situations like these to handle. Hence the backlog is high. Even if a legal process is initiated, the getting orders of the court to effect disconnection of sewer connection are difficult. It looks that one simple way of getting over these is to allow the industry to connect only their toilets, baths, canteen etc. But the real problem is the industries may be surreptitiously using that connection to discharge their effluents also. The monitoring of these is again vested with the PCBs. Thus, a very serious situation exists here. Hence joint subcommittee of ULB and PCB have to be created with powers to recommended interim disconnection.

1.2.4 Budget

Appropriate budgetary provisions for operation and maintenance of sewerage system needs to be provided so that O&M is carried out without any constraints such as human resources, finance, it is dealt with in part C.

1.2.5 Preventive Maintenance

Preventive maintenance is a set procedure whereby each component of the system goes through a systematic check and these components are brought into dependable use. An example can be checking the volume and consistency of oil in the gearbox after a specified number of hours of operation and correcting the situation either by topping up or replacing fully as needed. The preventive maintenance issues, checking parameters and timings are all given by every equipment vendor as a manual. Carrying out these tasks is to be done by the respective equipment vendor under a separate contract called preventive maintenance contract and should be delinked from the O&M contract. Most often this is not fully recognized and what could have been saved by preventive maintenance finally ends up “breakdown repairs.” This situation needs its importance.

1.2.6 Workmanship and Quality of Equipment

Workmanship defines the art or skill of a workman or workwoman. This is an art or skill with which something is made or executed. Materials and equipment shall be new and of a quality equal to or superior to that specified or approved. Work shall be done and completed in a thorough and workmanlike manner and in strict conformance with the plans and specifications. In general, the work performed shall be in full conformity and harmony with the intent to secure the best standard of construction and equipment of the work as a whole or in part.

No material shall be used in the work until it has been found satisfactory by the Engineer. All material and equipment are subject to test to determine their conformity with these specifications. Certified factory and mill tests normally will be acceptable for standard manufactured items. Whenever standard specifications are referred to, they shall be the latest revised edition of the Standard Specifications referred to and shall be considered to be a part of these specifications in so far as they apply. All work and materials shall be subject to inspection by the Engineer.

The Engineer may assign such assistants as he may deem necessary to inspect the materials to be furnished and the work to be done under this contract, and to see that the same strictly conform therewith. The Engineer shall be notified of the time and place of preparation, manufacture or construction of material for work or any part of the work which he may wish to inspect, and of the time and place of making the factory tests required under the contract. Such notification shall be given a sufficient length of time in advance of the beginning of the work on such material or part or of the beginning of such test to allow arrangements to be made for inspecting and testing or witnessing, as the case may be, if such inspection and testing or witnessing are deemed practicable by the Engineer.

All necessary machinery guards, railings and other protective devices shall be provided as specified by the Industrial Safety authority which would be the Inspectorate of Factories. Before final acceptance of the work, the contractor shall cause an inspection to be made by a representative of the inspectorate of factories and shall certify that all safety requirements have been complied with.

1.3 OUTLINES OF O&M

1.3.1 Overview and Contents of O&M

Thus an overview of O&M is taking note of the above issues and suggests appropriate remedies to the present situation which includes finances and manpower and remote control.

1.3.2 Management of Facilities

Proper housekeeping, aesthetics and gardening are the requirement here. With the lifestyle in cities changing to fast-forward, nobody is able to find time for these. In addition, getting labour to do these is also difficult due to extra costs and security issues.

1.3.3 Schedule of O&M

A proper schedule shall have to specify what things are to be attended to at what intervals and to whom it is to be reported to in case of faults. Clearly, this is not the case and it is all emergency repairs all the way.

1.3.4 Response to Accidents

Most times, the local staff may not even know how to do first aid. All the time whenever an accident occurs, it is the fire brigade who will be called upon to the site. Thereafter, it is a standard procedure of getting the victim to the hospital and thereafter the local agencies come into the picture only when defending the compensation money payable to the victim.

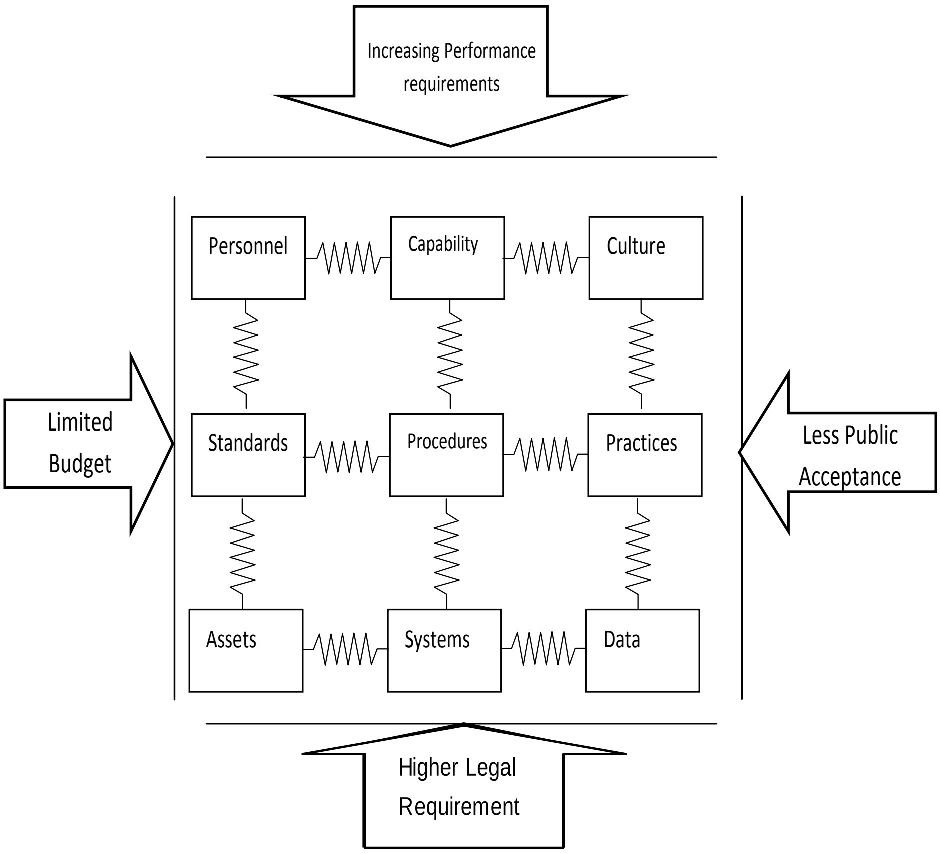
1.3.5 Management of Buildings and Sites

There is the century old practice in Public Works Department (PWD) that civil works life cycle is 30 years and equipments 15 years. Going by this, civil works in sewerage will need strengthening and renewal as the case may be. Similarly equipments will need replacement in 15 years. However, in actual practice, this is not the case. Only when a civil work shows up a crack or a leaky roof, the position is reviewed as an ad hoc repair. Similar is the case of machineries.

1.4 ORGANIZATION OF O&M

1.4.1 Description of O&M Work

A simple understanding of O&M work is the relationship between human resources, equipment availability, financing the O&M and career opportunities for the staff. These are within the local body. The perception by the public and their payment of dues to the local body is the "other side of the coin" as in Figure 1.1.



Source: Ype C Wijnia, 2009

Figure 1.1 Combined tasks and challenges with the O&M

This illustrates O&M of sewerage as responding to the four sided compression of (a) limited budget, (b) performance requirements, (c) less public acceptance and (d) higher legal requirements like staff, salaries, etc. If all these act at the same time, the system has to collapse and if one of them increases the pressure, the ability of the other three to be resilient is needed to remain stable. If this resilience is not there, the shape of the rectangle will be altered and the system may be responding without any control. Thus the work of O&M involves the engineering, financing and administrative interface with the public.

1.4.2 Deployment of Manpower

There are limited promotional avenues for people in the O&M sector. Non-engineers in the O&M sector entering the service will retire without any promotion only if he has no academic qualification. This does not give them any drive to do a sincere job all the time. He will merely be doing a routine type of work. Promotions by way of number of years of experience must be coupled with examination of his experience and given weightage. The staff may be rotated between sewerage and water supply sectors by providing suitable training, so that he does not get into sickness from working in sewerage system throughout his career.

1.4.3 Out sourcing of O&M

Recent trend is to subcontract the O&M work. In this case the contractor hires staff from local market and deploys them on the O&M work. He will only place the staff and earn the money and after paying to the staff earns his profit but he may not have interest in O&M. If the contractor is also the same firm who has built this sewerage system, his interests will be very sincere. In the case of exclusive O&M outsourcing not involving the potential O&M agency in the construction activity of the system involved, the proper qualifications, experience, personnel, etc. are to be ensured.

1.4.4 Training

Development of operational skill is not taught in the schools or polytechnics or colleges. It has to be learnt. This again must be verified once a year to understand whether he has understood correctly and if not in order he has to be put through training. Thus, the training is a continual system.

1.4.5 Monitoring through Information Control Technology

Extracting sewage treatment conditions from water quality information of effluent is very important for operating a sewage treatment plant effectively. An example of a Japanese sewage treatment plant implementing monitoring using control technology is introduced here. For more details, refer to Appendix 1.1

1.4.6 Database for Effective O&M

It is also important to create a database of information obtained through monitoring, and to use this database of past data for operation henceforth. For details of such a database, refer to Appendix 1.2.

1.4.7 Paragraph on Problems in Existing O&M

The problems faced by O&M sector in sewerage are a combination of engineering, finance, staff and management. The engineering problems are absence of adequate innovations of economical design and construction of infrastructure that will reduce the costs and will still render the project functional to the stated goals in the required geographical coverage with lesser expenditure. Examples are possible usage of decentralized systems, twin drain systems and incremental sewerage etc. The finance problems are inadequate revenue as compared to expenditure and norms for budget allocation which is more of historical nature than based on time and motion evaluations as also the symbiosis of the population who are willing to pay only if they feel services are better on the one side and the ULBs who cannot bring up improvements unless the population contributes increased revenue upfront. The staff problems are the lack of promotional avenues for decades on end and also absence of at least the time based scale of pay resulting in inordinate stagnations in posts and staleness especially the field staff like operators, technicians, drivers and other such posts where practically they enter and retire in the same post. The management problems are frequent transfers from one headquarters to another resulting in disturbances to family establishment, education of wards and care of elderly at home and lack of incentives for exceptional performers. These are very easy to attribute but are very difficult to change given the service conditions, rules, regulations etc. Yet another situation which prevails in a democratic governance is to appraise the political governance on the nuances of engineering projects while seeking funds and establishment by putting forth the engineering components and needs to explain them convincingly by the chief executive of the water and sewerage authority depending on how equipped they are to comprehend the enveloping issues. There seems to be a need to position the officers of these organizations who would possess a basic qualification in related engineering whatever be their other attainments in management so that they can effectively conceive and communicate both ways between the political governance who are to deploy the necessary resources and the staff of these organizations who are to implement and carry out the O&M-an aspect in which a country policy seems to be not in place. In addition please also refer to Appendix 1.3 which is an extract from the Evaluation of O&M of STP's in India - CUPS/68/2007.

1.5 COMMUNITY AWARENESS AND PARTICIPATION

1.5.1 Public Relations and Public Opinion related to Sewerage Works

Meeting the public and directly answering their questions on sewerage problems is the solid foundation of goodwill. Mostly officials in charge of sewerage system feel hesitant to meet the public because they do not have the funds to rectify the defects pointed out by the public. Reference to Figure 1.1 is important. Only when the public are met directly, the system drawbacks will come to light. Only then, a basis for calculating the budget allocations can be known. Only then engineers in the field can carry out the remedies needed.

1.5.2 Complaint and Redressal

Most local bodies have launched the internet based complaint recording by the public. It will be good to also publish on the web the complaints received and actions taken up to solve them. Otherwise the public will not know.

1.5.3 Do's and Don'ts for Community

The public are also responsible to maintain the system. They must not put solid wastes, solid vegetable cutbits, meat, plastics, etc. This is even now very well advertised by many local agencies but then the public continue to do these sometimes. Educating them continuously has to be a part of O&M.

1.6 POTENTIAL RISK WITH RESPECT TO SEWERAGE SYSTEM

1.6.1 Provision of Disaster Prevention Systems

Disaster by definition is something which occurs suddenly. For example if a corroded RCC sewer is not properly attended to in time, it will collapse all of a sudden in the crown and all the sewage upstream will get blocked. At the same time, if an earthquake occurs and the sewer collapses by lateral movement, then also, it is the same problem. The former situation can be avoided by monitoring the sewer condition once a year by camera survey. The later cannot be avoided. The lesson is the need for programmed monitoring of sewerage system components.

1.7 SEWERAGE LEDGER

The NUSP and SLB have been explained in Section 1.5 of the Part-A Manual. In order to keep track of their attainment, the upkeep of ledgers is necessary as explained below.

1.7.1 Preparation of Sewerage Ledger

A sewerage ledger can be either a simple ledger or a complicated ledger. The staff must receive situation reports of such activities which he can control. There is a tendency to insist on receiving all sorts of data where it is meant for that person or not. This has to change. For example an administrator must be more concerned about complaint redressal than how much sewage is pumped out. Similarly, the field engineer must know the sewage surface elevations in sewers and whether sewage is overflowing the roads and document the case and put up for funds to solve the situation.

1.7.2 Management and Use of Sewerage Ledger

This is to be done by an independent team not connected with the O&M team. Only then, the real problem will be known and remedies can be taken up. The sewer ledger for compliant redressal must be put on the website to increase the consumer satisfaction in the ledger system.

1.8 BUDGET ESTIMATION FOR O&M

Budget estimation has been explained in Part C Chapter 5.

Revenue generation to ensure self-sustainability is an issue of political and administrative will be to levy and collect practicable costs and there is nothing to strategize in it.

1.9 SUMMARY

This Manual has been prepared with the aim of offering guidelines to workers/operators of sewerage systems on site for operation and work performed by them, and to field engineers for passing on instructions and judgements to the workers and operators. In practice, a sewerage collection system or an STP each requires its own proprietary O&M manual suitable for the work done, the local conditions and the scale of its own facility. It is anticipated that these facilities will refer to the contents of the present manual and prepare make effective use of its own proprietary manual.

1.10 RELATIONSHIP BETWEEN PART-A (ENGINEERING), PART-B (OPERATION AND MAINTENANCE), AND PART-C (MANAGEMENT) OF MANUAL

The Manual on Sewerage and Sewage Treatment (second edition) published in 1993 which has been revised and updated mainly gave thrust to engineering aspects of the sewerage and sewage treatment systems. Though, it covered topics of management and operation and maintenance of sewerage systems but these aspects were not dealt with in detail so as to create awareness amongst the practicing and field engineers regarding the importance of these two topics which are so important for the sustainability of the systems in the long run.

The present Manual on Sewerage and Sewage Treatment has been divided into three sections, as under, which are inter-related to each other as described below:

i) Part-A on ‘Engineering’

ii) Part-B on ‘Operation and Maintenance’

iii) Part-C on ‘Management’

Part-A on ‘Engineering’ addresses the core technologies and updated approaches towards the incremental sanitation from onsite to decentralized or conventional collection, conveyance, treatment and reuse of the misplaced resource of sewage and is simplified to the level of the practicing engineer for his day to day guidance in the field in understanding the situation and coming out with his choice of approaches to remedy the situation. In addition it also includes recent advances in sewage treatment, sludge and septage management to abate pollution of environment. By no means, this is a text book nor it should be. It is a simple to understand guideline for the field engineer.

Part-B on ‘Operation and Maintenance’ addresses the issues of standardizing the human resources and financial resources that are needed to sustain a system created at huge costs without it slipping into an edifice for want of codified requirements of these so that it becomes possible to address these in the estimate stage itself and seek a comprehensive approval of fund allocations and human resources besides ushering in the era of public private partnership to make the projects self-sustaining. It is a simple to understand guidance for the resource seeker and resource allocating authorities.

Part-C on ‘Management’ is a refreshing approach to modern methods of project delivery and project validation and gives a continual model for the administration to foresee the deficits in allocations and usher in newer mechanisms. It is a tool for justifying the chosen project delivery mechanism and optimizing the investments on need based allocations instead of allocations in budget that remain unutilized and get surrendered in end of fiscal year with no use to anyone. It is straight forward and modern approach.

It is very important to mention here in the beginning of this Part B of the Manual that Trade names and technology nomenclatures, etc., are cited only for familiarity of explanations and not a standalone endorsement of these.

CHAPTER 2 SEWER SYSTEMS

2.1 INTRODUCTION

A sewerage system consists of the following:

- House Service Connections

  They connect the house to sewers in the road.

- Sewers

  These are pipe or conduits meant for carrying sewage and are laid along the roads and flow by gravity.

- Lift Stations

  When sewers are at a large depth, lift stations are used which help to move liquids from low elevations to the required elevation.

- Pump Stations

  They transfer the sewage from one location to another

- Sewage Treatment Plants

  They treat the sewage to meet the effluent quality.

- Safe disposal system of final effluent

Sewers are the most important part of a sewerage system. They are laid below the ground and are difficult to repair. Hence great care is needed in their O&M.

In this section, the following is presented:

- Objectives of maintenance
- Type of maintenance
- Necessity of maintenance

2.1.1 Objectives of Maintenance

Quality maintenance of sewerage system consists of the optimum use of labour, equipment, and materials to keep the system in good condition, so that it can accomplish efficiently its intended purpose of collection and transportation of sewage to the treatment plant.

2.1.2 Type of Maintenance

There are three types of maintenance of a sewerage system – preventive, routine and emergency. Preventive or routine maintenance should be carried out to prevent any breakdown of the system and to avoid emergency operations to deal with clogged sewer lines or over flowing manholes or backing up of sewage into a house or structural failure of the system. Preventive maintenance is more economical and provides for reliability in operations of the sewer facilities. Emergency repairs, which would be very rare if proper maintenance is carried out, well also, have to be provided for. Proper inspection and preventive maintenance are necessary.

2.1.3 Necessity of Maintenance

Sewer maintenance functions are most often neglected and given attention only as emergency arises. Adequate budgets are seldom provided for supervision, manpower and equipment, unlike the case for maintenance of other utilities like electric cables, telephone cables, gas and water mains. Such attitude towards sewer maintenance is found even in large cities. Considering the health hazards that the public at large has to face, it is appropriate to provide sufficient funds to take care of men, material, equipment and machinery required for efficient maintenance.

All efforts should be made to see that there is no failure in the internal drainage system of premises; a serious health hazard results when sewage backs up through the plumbing fixtures or into the basements. The householder is confronted with the unpleasant task of cleaning the premises after the sewer line has been cleaned. Extensive property damage may also occur, particularly where expensive appliances are located in the basements.

Maintenance helps to protect the capital investment and ensures an effective and economical expenditure in operating and maintaining the sewerage facilities. It also helps to build up and maintain cordial relations with the public, whose understanding and support are essential for the success of the facility.

2.2 INSPECTION AND EXAMINATION FOR SEWER

2.2.1 Importance of Inspections and Examinations

Sewer collection systems are intended to be a reliable method of conveying sewage from individual dischargers to sewerage treatment plants. Inspection and examination are the techniques used to gather information to develop operation and maintenance programs to ensure that new and existing collection systems serve their intended purposes on a continuing basis. Inspection and testing are necessary to do the following:

- Identify existing or potential problem areas in the collection system,
- Evaluate the seriousness of detected problems,
- Locate the position of problems, and
- Provide clear, concise, and meaningful reports to supervisors regarding problems.

Two major purposes of inspection and examination are to prevent leaks from developing in the sewers and to identify existing leaks so they can be corrected.

A designer’s mistake and the failure in construction are directly responsible for many of the sewer failures. Due to age, deterioration of the material of the sewer by attack of hydrogen sulphide or other chemicals, settlement of foundations and leaking joints may result in the structural failure of the sewer. It takes a very long time from the onset of the first initial defect to the collapse of the sewer. A crack or a leaking joint will allow subsoil water and soil to enter the sewer causing cavities around it leading to slow settlement of foundation and the eventual collapse of the sewer. Very often soil with water is carried away below the bedding along the length of the sewer. The type of break often gives a clue to the cause. A shear failure due to faulty foundation or movement of earth, is a clean vertical break in the pipe or barrel. Excessive loading, either internally or externally, causes horizontal breaks. Breaks caused by internal pressure gives cracks in the sewer while external overload causes the top of the pipe to crush-Regular inspection of the sewer can pinpoint the sewer that needs to be attended to before there is a complete failure or collapse.

For preventing the above serious instances of damages to the sewer system, the maintenance engineer should establish adequate inspection and examination program.

2.2.2 Guidelines for Inspections and Examinations

Documents and data that can give information on the status of sewer facilities are necessary for operation and maintenance of the facilities. However, enormous time and costs are necessary for examining and inspecting the overall information on sewer facilities that extend over a wide area. It is recommended that a preliminary inspection be implemented to acquire with comparative ease documents and data that can be used to decide the facilities to be examined/inspected and their priority, and then decide the facilities to be finally examined and inspected for effective acquisition of data.

The procedure is to first acquire the basic information through preliminary inspection for the examination and inspection of the facilities in this section.

Preliminary inspection ⇨ Inspection and examination

⇩

Judge from inspection result

⇩

Decide the necessary measures (repairs, modifications)

The detailed method for conducting a preliminary inspection is described in the following section.

2.2.3 Preliminary Inspection

During the preliminary inspection of the sewerage system, subsidence, collapse, and overflows on the roads on which sewers are laid, should be confirmed. Deformation or damage to facilities, and deposits of sand and silt are to be confirmed during observation from the manhole. If damage or possibility of damage to the facility or if any of the abnormalities listed below are confirmed during the preliminary inspection, the facility manager should examine and inspect the relevant locations for the following:

- Corrosion, wear, damage or crack in the facility
- Water infiltration
- Corrosion of steps, wear of covers, deformation of manhole, buried manhole
- Abnormal odours
- Clogging and overflowing

The suggested period of preliminary inspection to be carried out is shown in Table 2.1, Table 2.2 and Table 2.3. In addition clause 3.10 of Part A manual also deals with tracer study.

Table 2.1 Preliminary inspection during Defect Liability Period (DLP)

Category / Inspection stages	Manhole	Sewer	Inverted siphon	Any other sewerage infrastructure
Initial/first inspection	During the first 3 months of start of DLP (to expose any hidden construction defects)			
Final inspection	During the last 3 months of DLP			
Additional inspections, if DLP is > 4 years	At a frequency of every 2 years after first inspection during DLP			

Table 2.2 Preliminary inspection for Manholes & Sewers

Category / Roads & Traffic Conditions	Manhole	Sewer
Roads subjected to heavy & mixed traffic	Once a year	Once in 2 years
Roads 2m - 5m wide (6-15 feet) subject to mixed traffic	Once in 2 years	Once in 2 years
Roads and lanes less than 2m wide	Once in 3 years	Once in 3 years
Demarcated & kerbed /raised footpaths (likely along main roads)	Once in 2 years	Once in 3 years

Table 2.3 Preliminary inspection period for other facilities

Category	Inverted siphon	Force main and their appurtenance
Inspection period	Once a year	Once a year

Note: Remedial measures should be implemented immediately upon finding defects/distress/dysfunction in the components of the sewerage system.

2.2.4 Type of Inspections and Examinations

In order to assess the condition of the sewers inspections and examinations are necessary.

There are two basic types of inspection and examination:

- Direct
- Indirect

2.2.4.1 Direct Inspection and Examination

This means a person walking through a sewer and physically inspecting the condition visually. This shall never be done once a sewer has been put into service. Even for new sewers, the inside diameter shall be more than 2 m. All safety precautions needed for working in confined spaces shall be taken. Hitting at the sidewall with a hammer or other devise shall be totally prohibited. The only purpose it will serve will be to get a visual idea of whether the pipe joints are made fully. Once a sewer is put into service, this is to be banned for ever.

2.2.4.2 Indirect Inspection and Examination

These can be classified by a variety of methods as in Table 2.4.

Table 2.4 Classification of inspection

Technology		Sewer type			Pipe material	Pipe diameter mm	Defect detected			
		Gravity	Force main	Lateral			Internal condition	Pipe wall	Leakage	Pipe support
Camera	Digital cameras	●			Any	150-1500	●	●	●	
	Zoom cameras	●			Any	>150	●	●	●	
	Push-camera			●	Any	≤300	●	●	●	
Acoustic	In-line leak detectors	●	●		Any	≥100			●	
	Acoustic monitoring systems		●		PCCP	≥450		●		
	Sonar/ ultrasonic	●	●		Any	≥50	●	●		
Electrical/ electromagnetic	Electrical leak location	●	●	●	Non-ferrous	≥75			●	
	Remote field eddy current	●	●	●	Ferrous, PCCP	≥50		●	●	
	Magnetic flux leakage	●	●	●	Ferrous	50-1400		●		
Laser	Laser profiling	●	●		Any	100-4000	●	●		

Technology		Sewer type			Pipe material	Pipe diameter mm	Defect detected			
		Gravity	Force main	Lateral			Internal condition	Pipe wall	Leakage	Pipe support
Innovative technologies	Gamma-gamma logging	●	●	●	Concrete	Not yet defined				●
	Ground penetrating radar	●	●	●	Any	Not yet defined			●	●
	Infrared thermograph	●	●	●	Any	Not yet defined			●	●
	Micro-deflection	●			Brick	Not yet defined		●		●
	Impact echo/SASW	●			Brick /Concrete	>1800		●		

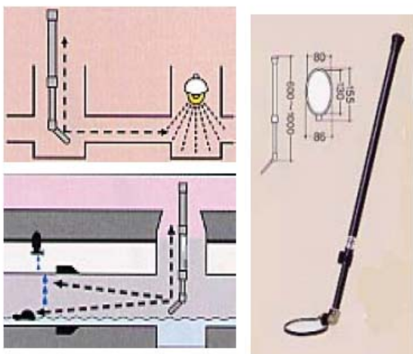
Source: EPA/600/R-09/049 | May 2009

Even though there are so many technologies available as above, the technology to be chosen will depend on the affordability by the user departments. A simpler and applicable technology compilation is as shown in Table 2.5.

Table 2.5 Sewer system inspection technologies considered applicable to Indian conditions

No.	Technology	Applicability		
		Sewer Size	Sewer Material	Sewer Condition
1	Light and Mirror	Up to 300 mm	Any	Empty
2	Closed Circuit Camera	Any size	Any	Empty
3	Sonar Systems	Any size	Any	Fully flowing

The light and mirror is the oldest of known technologies (Figure 2.1). Two successive manholes are opened and vented sufficiently for about an hour. Thereafter a long hand-held mirror secured at 45 degrees to the handle is lowered into the bottom of the manhole and a torch light is focussed on the mirror from the above so that the light beam is deflected by 90 degrees to travel horizontally through the sewer pipe and the light is seen in the opposite manhole. This is easier at dusk. This can tell whether the bore of the pipe is choked or clear.



Source: http://www.sankyotrading.co.jp

Figure 2.1 Mirror Test and Mirror with rod

The closed circuit camera is propelled through the sewer by a remote controlled wired power supply from a van and travels through the sewer and relays the picture of the inside to a TV in the van. The sonar system is similar. A robot is sent through the sewer and it emits high frequency sound waves which impinge on the pipe surfaces and returns to the emitter as a reflection. By knowing the material of construction of the sewer pipe walls, this can be programmed to verify the structural condition of the wall of the sewers.

Indirect inspection is carried out by sending a camera through the sewer for taking photographs or a closed circuit television equipment (CCTV) to send pictures which can be seen on a TV Screen or recorded as video. The CCTV inspection can be used for sewer lines as small as 100 mm. Above 900 mm diameter there are limitations due to lighting problems and camera line angles.

Continual advances are being made in the range of TV cameras and also in quality. The type of camera selected should be robust for use in sewers and be able to give good quality pictures.

Traction of the cameras is by pulling winches, by pushing or self traction. The former two are not used much at present. However, self traction is suitable for use in sewers above 225 mm diameter. Other constraints in the use of self traction are the weight of the trolley and electricity requirements. Heavy silting of sewers precludes the use of self traction. The cameras are attached to trolleys or mounted on pair of skids or single flat tray. Inspection of the sewer by CCTV is limited to the top portion only. The objects under scrutiny are parallel to the camera and viewing is at 40 to 50 degrees. With radial scanning head, inspection normal to the sewer wall is possible.

A typical arrangement is as shown in Figure 2.2.

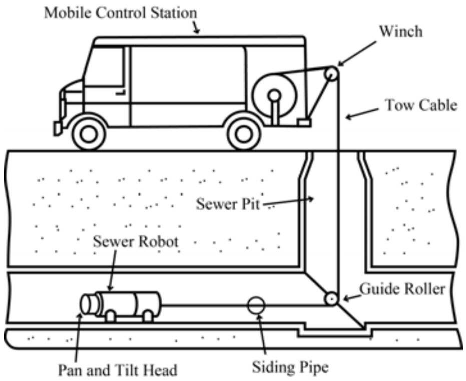


Figure 2.2 Typical CCTV equipment in action

A classical problem encountered in stoneware sewers laid through light forest or heavy garden areas is the roots of trees piercing through the joints and growing there. These become like a plug and choke the sewer. This is shown in Figure 2.3. (Tree roots growing into joints of stone ware sewers when these are laid near light forests and heavy gardens. At right is the photo of the bunch of roots taken by a CCTV camera.)

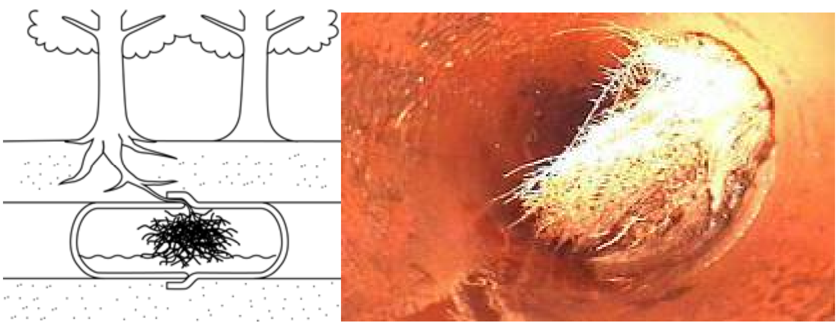


Figure 2.3 Tree roots and sewers

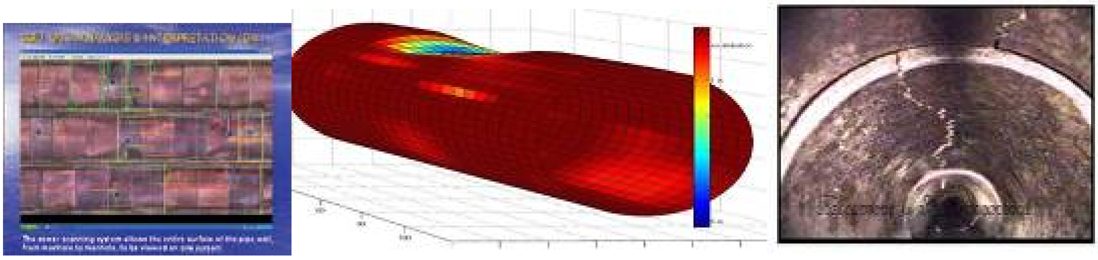


Figure 2.4 Photographs showing structural damage and longitudinal cracked condition of the sewer

Similarly, the structural condition of old sewers like brick arch sewers and concrete pipes can be ascertained by sonar surveys which can provide the frontal image of the wall on a 360-degree vertical spiral around the horizontal axis. These images can be analyzed carefully. The system can also provide information on the deflection and sidewall breakages of the sewer as in Figure 2.4. (The sidewall condition shown as photographs, the structural damage to the crown of the sewer and longitudinal cracked condition of the sewer from the survey)

2.2.5 Sewer Inspection and Examination

If an abnormality is detected during preliminary inspection or through notification from outside, the maintenance engineer should judge the urgency and the content of the abnormality, and then make a proper inspection and study.

2.2.5.1 Visual Examination

Visual examination is an inspection through images or by sight to detect an abnormality.

Visual examination includes direct visual inspection, and indirect visual inspection using pole-mounted inspection camera, and closed-circuit TV equipment (CCTV).

2.2.5.1.1 Manhole Visual Inspection

The visual inspection of manhole is performed by visually checking the manhole cover and its environment, and observing the internal parts of the manhole. To inspect the internal parts of the manhole, the inspector should enter the manhole and check the items listed below. However, refer to the sub-section 2.7.1.2 for details of the inspection items.

- Status of internal surface of manhole
- Status of sewer on the upstream and downstream sides viewed from the manhole
- Status of groundwater infiltration

To inspect the internal parts of the sewer from the manhole, either a mirror or a strong light should be used for observation, or a TV camera meant for inspecting conduits should be used.

- Features of manhole visual inspection
  - Inspection accuracy is high because the inspector actually observes and measures the abnormality personally.
  - Economical compared to inspection using a TV camera.
  - The inspected results become very useful O&M data.
- Procedure for manhole visual inspection is shown in Figure 2.5.

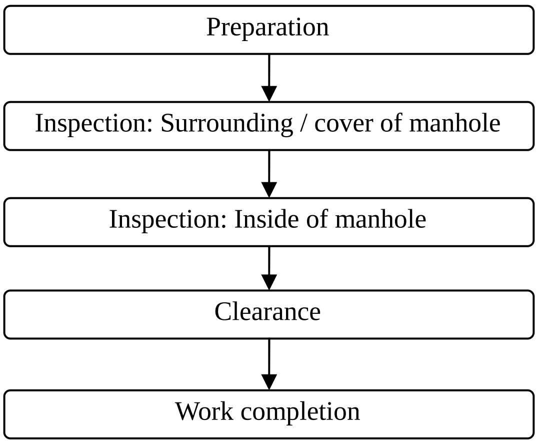


Figure 2.5 Manhole visual inspection procedure

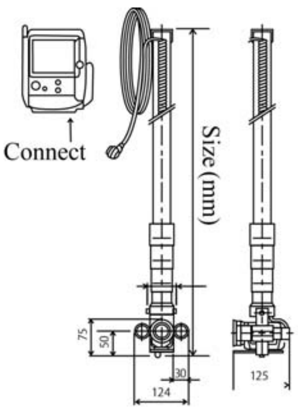
Before entering any manhole, adequate safety measures should be taken in accordance with subsection 2.11.1.2.

2.2.5.1.2 Inspection Using a Pole-mounted TV Camera

As shown in Figure 2.6, a pole-mounted TV camera consists of an extendable operating rod at the front of which a camera and light are fitted. This arrangement is inserted in the manhole from the ground, and the inspector on the ground observes a monitor and inspects the internal parts of the pipe through the camera. This check may also be used for pre-inspections. The method of inspection is shown in Figure 2.7.

The features of direct visual inspection are compared with those of inspection by TV camera and shown below.

- Advantages
  - The inspection is easy and observations can be made in a short period. Moreover, the data of inspection can be recorded as images.
  - Since the inspector works above ground, there is no chance of oxygen deficiency or accidents by fall, and the work is safe.
- Disadvantages
  - The scope of inspection is limited to the area around the mouth of the pipe.
  - Offset in the horizontal direction or fine cracks cannot be detected.
  - The condition of the side surfaces in the sewer pipe cannot be grasped (sides cannot be viewed).



Source: JASCOMA, 2007

Figure 2.6 Pole-mounted inspection camera

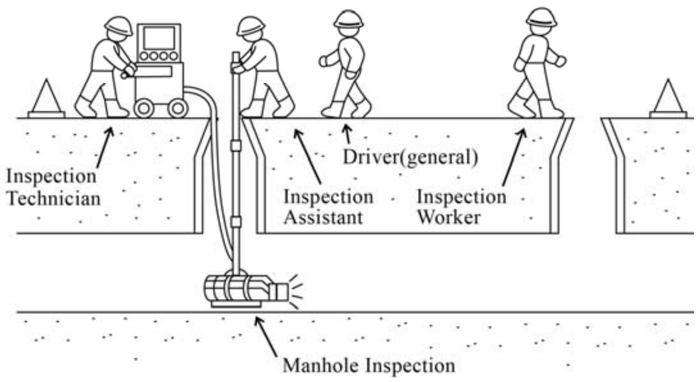


Figure 2.7 Illustration of pole-mounted TV camera inspection

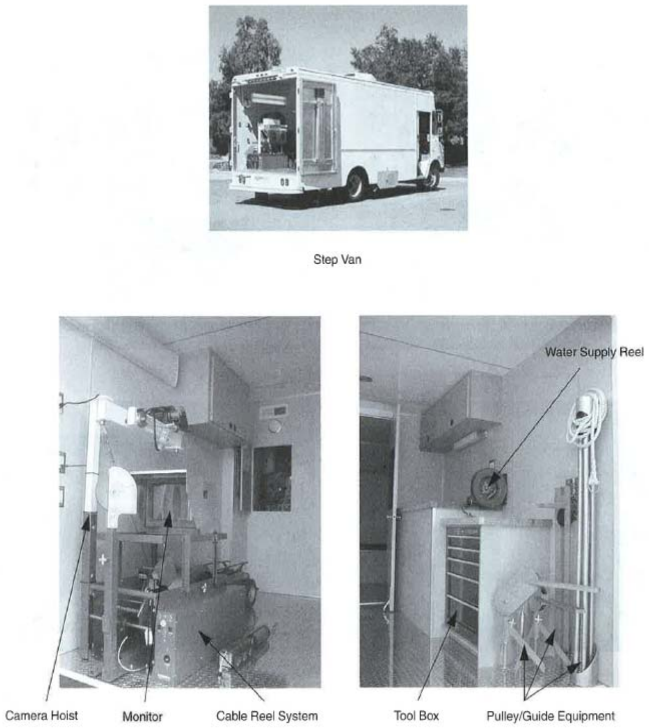
2.2.5.1.3 Inspection using Closed-Circuit Television (CCTV)

Pipes that can be inspected by CCTV have inside diameters ranging from 150 mm to 900 mm, but large diameter pipes may also be inspected by CCTV.

a. Types of TV Camera

TV camera may be the travelling type or the towed type. Either the direct method (taking panoramic shots of the overall scene) or the side view method of taking local shots of only abnormal locations may be used. House connection TV is described in a separate section (2.10.1).

Figure 2.8 shows a sketch of the TV camera and the vehicle on which it is loaded. Figure 2.9 shows an illustration of the TV inspection work.



Source: EPA, 2003

Figure 2.8 Step van CCTV system

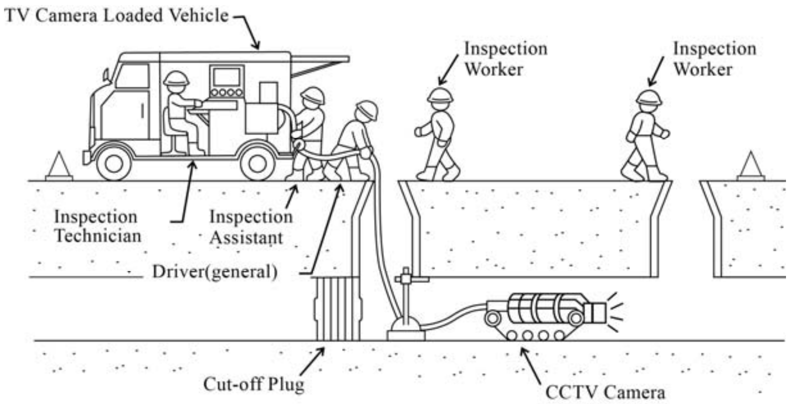


Figure 2.9 Illustration of CCTV camera inspection

- Features of TV camera inspection
  - By merely opening a manhole at one location, inspection using the travelling TV camera is enabled.
  - Continuous inspection up to a maximum distance of 100 to 200 m (cable length) is possible.
  - Connections of the lateral sewer and main sewer and defective locations should be photographed by the side view method.
- TV camera inspection work procedure is shown in Figure 2.10.

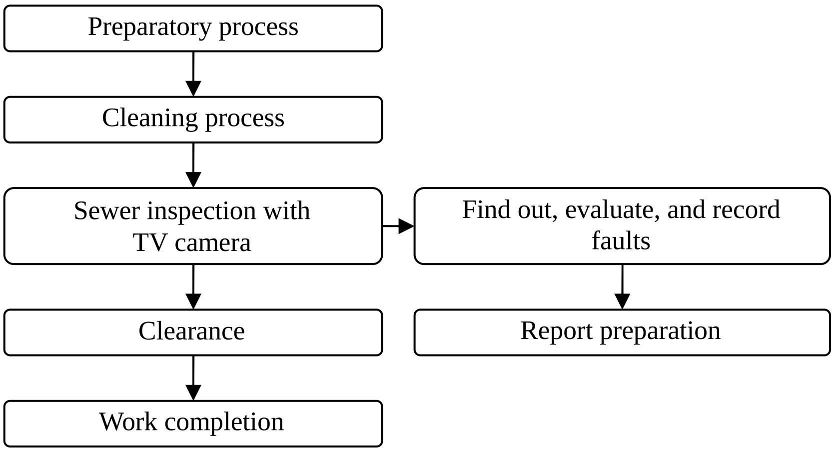
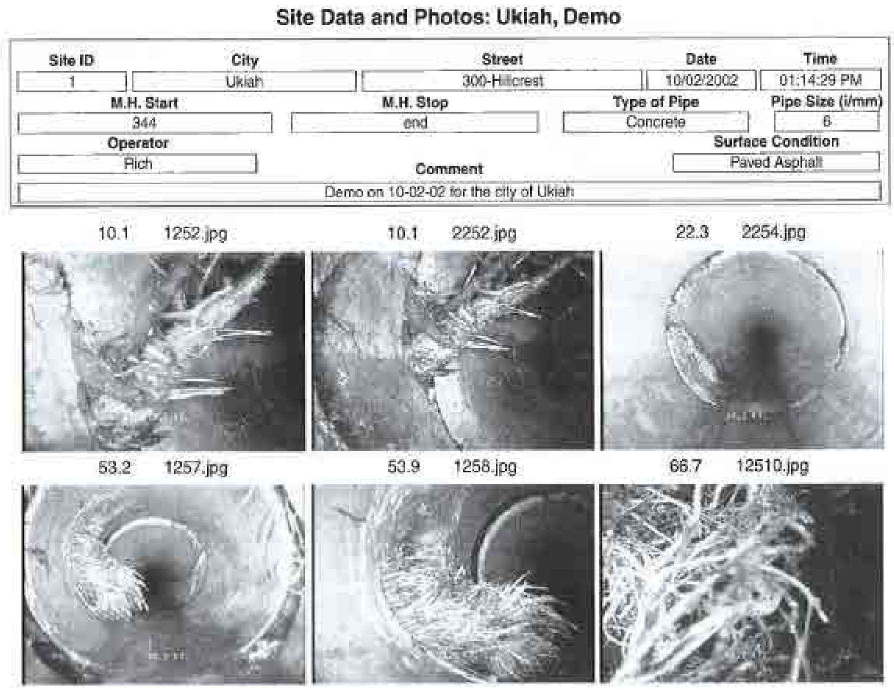


Figure 2.10 Work procedure for TV camera inspection

b. CCTV Camera Inspection Record

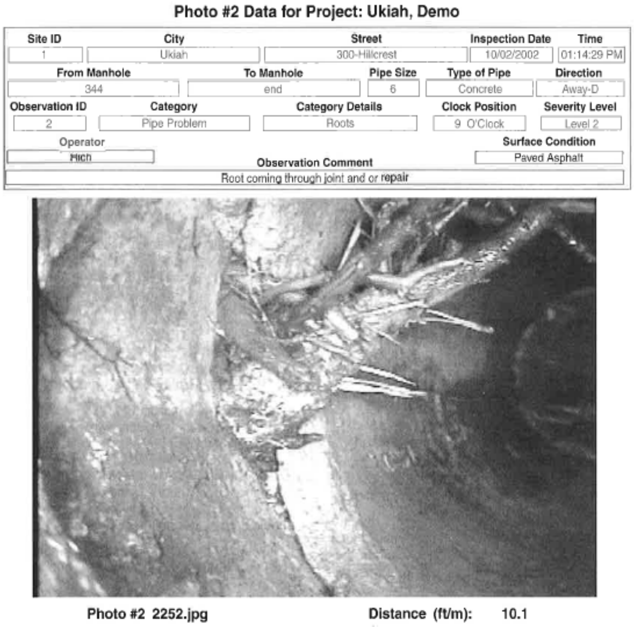
Abnormalities detected in the pipeline during the CCTV camera inspection should be recorded on video tape or as photographs, according to the judgement criteria. Figure 2.11 and Figure 2.12 show examples of the record.

The inspected results should be recorded in the inspection record. Examples of forms of the inspection record are shown in Figure 2.13.



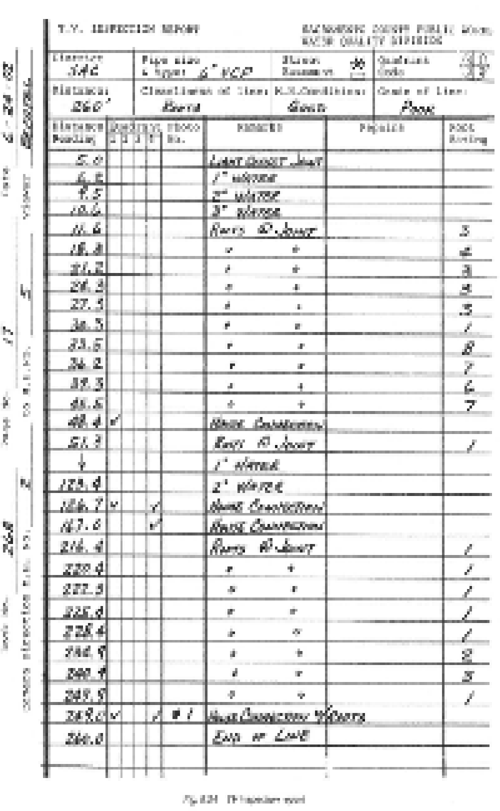
Source: EPA, 2003

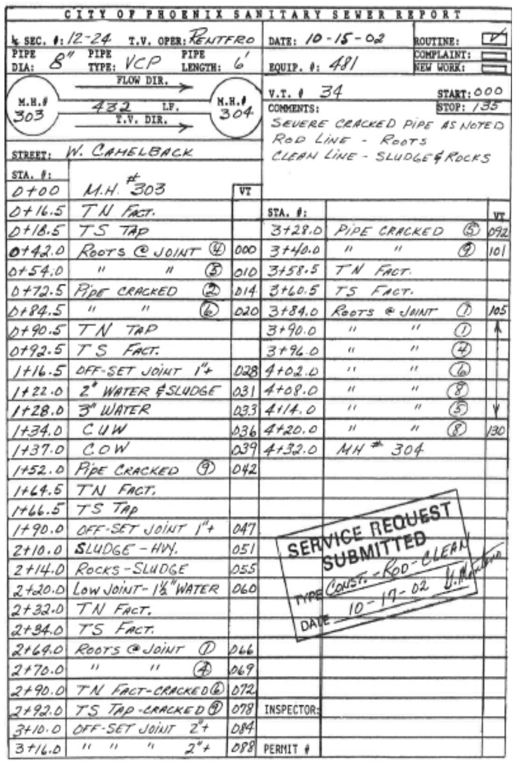
Figure 2.11 CCTV data No1



Source: EPA, 2003

Figure 2.12 CCTV data No2





CITY OF PHOENIX SANITARY SEWER REPORT

¼ SEC. #: 12-24 T.V. OPER: RENTFRO DATE: 10-15-02 ROUTINE: ☑ COMPLAINT: ☐ NEW WORK: ☐

PIPE DIA: 8" PIPE TYPE: VCP PIPE LENGTH: 6' EQUIP. #: 481

M.H. # 303 — FLOW DIR. → 432 LF. T.V. DIR. → — M.H. # 304

V.T. # 34 START: 000 STOP: 135

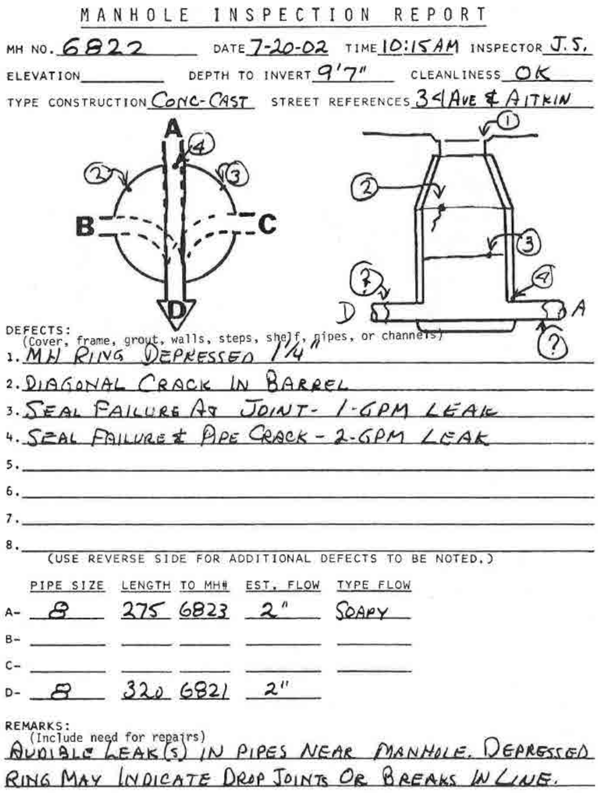
COMMENTS: SEVERE CRACKED PIPE AS NOTED; ROD LINE - ROOTS; CLEAN LINE - SLUDGE & ROCKS

STREET: W. CAMELBACK

STA. #:		VT	STA. #:		VT
0+00	M.H. #303				
0+16.5	TN FACT.				
0+18.5	TS TAP		3+28.0	PIPE CRACKED ⑤	092
0+42.0	ROOTS @ JOINT ④	000	3+40.0	" " ⑨	101
0+54.0	" " ⑤	010	3+58.5	TN FACT.	
0+72.5	PIPE CRACKED ②	014	3+60.5	TS FACT.	
0+84.5	" " ⑥	020	3+84.0	ROOTS @ JOINT ⑦	105
0+90.5	TN TAP		3+90.0	" " ①	↑
0+92.5	TS FACT.		3+96.0	" " ④	
1+16.5	OFF-SET JOINT 1"+	028	4+02.0	" " ⑥	
1+22.0	2" WATER & SLUDGE	031	4+08.0	" " ⑧	
1+28.0	3" WATER	033	4+14.0	" " ⑤	↓
1+34.0	CUW	036	4+20.0	" " ⑧	130
1+37.0	COW	039	4+32.0	MH # 304	
1+52.0	PIPE CRACKED ⑨	042			
1+64.5	TN FACT.				
1+66.5	TS TAP				
1+90.0	OFF-SET JOINT 1"+	047			
2+10.0	SLUDGE - HVY.	051			
2+14.0	ROCKS - SLUDGE	055			
2+20.0	LOW JOINT - 1½" WATER	060			
2+32.0	TN FACT.				
2+34.0	TS FACT.				
2+69.0	ROOTS @ JOINT ①	066			
2+70.0	" " ④	069			
2+90.0	TN FACT - CRACKED ⑥	072			
2+92.0	TS TAP - CRACKED ⑨	078	INSPECTOR:		
3+10.0	OFF-SET JOINT 2"+	084			
3+16.0	" " " 2"+	088	PERMIT #		

SERVICE REQUEST SUBMITTED — TYPE: CONST. - ROD - CLEAN — DATE: 10-17-02

Fig. 5.28 Reviewed TV inspection report



MANHOLE INSPECTION REPORT

MH NO. 6822 DATE 7-20-02 TIME 10:15AM INSPECTOR J.S.

ELEVATION ______ DEPTH TO INVERT 9'7" CLEANLINESS OK

TYPE CONSTRUCTION Conc-Cast STREET REFERENCES 34 Ave & Aitkin

DEFECTS:
(Cover, frame, grout, walls, steps, shelf, pipes, or channels)

1. MH Ring Depressed 1/4"
2. Diagonal Crack in Barrel
3. Seal Failure At Joint - 1-GPM Leak
4. Seal Failure & Pipe Crack - 2-GPM Leak
5.
6.
7.
8.

(USE REVERSE SIDE FOR ADDITIONAL DEFECTS TO BE NOTED.)

	PIPE SIZE	LENGTH	TO MH#	EST. FLOW	TYPE FLOW
A-	8	275	6823	2"	Soapy
B-					
C-					
D-	8	320	6821	2"	

REMARKS:
(Include need for repairs)

Audible Leak(s) in Pipes Near Manhole. Depressed Ring May Indicate Drop Joints Or Breaks In Line.

MANHOLE INSPECTION FORM

Fig. 5.2 Completed manhole inspection report

Source: EPA, 2003

Figure 2.13 Forms of inspection record

2.2.5.2 Inspecting Infiltration of Water

If infiltration of water is more corresponding to the planned water flow in the sewerage plant, the pipelines and treatment facilities will be adversely affected. This also leads to an increase in the treatment costs of the wastewater treatment plant.

The cause of infiltration of water is either the pipeline is inadequate or the drainage system is inadequate. For this reason, inspection of cross connections, flow rate inspection and waterproofing inspections need to be combined and the route of infiltration water should be checked. Flow rate inspections help since useful data for improvements and modifications to the piping facilities can be collected.

2.2.5.2.1 Inspecting Cross Connections

Inspection has to be performed to check that storm water equipment is not connected to the wastewater system in a separate sewer system. The scope of work is from the main pipe of the sewerage works to the house drainage facility.

There are three typical methods for inspecting cross connections.

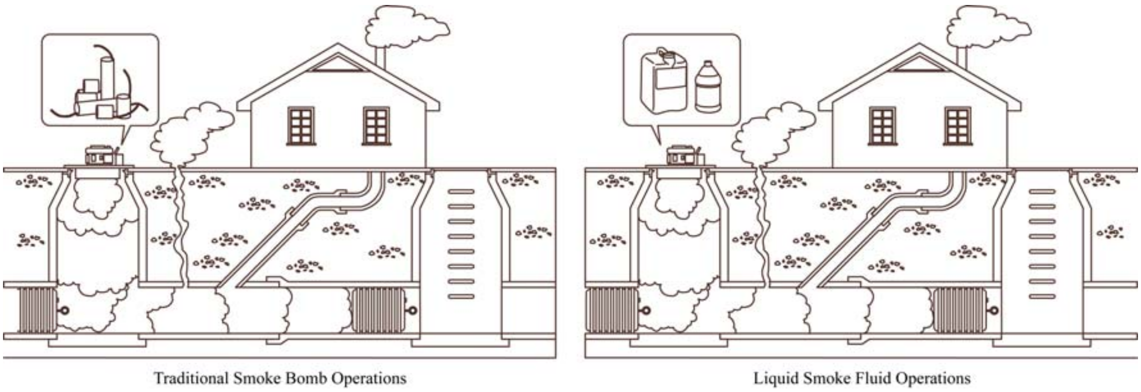
a. Smoke Test

The smoke test makes use of a smoke bomb in a separate sewerage system pipeline. A cross connection can be judged by checking for smoke rising from the house inlet or rain gutter. This test identifies locations where storm water inlet or rain gutter drainage equipment is directly connected to wastewater pipe house inlet, and locations where storm water that has permeated the ground from the ground surface or gutter has indirectly permeated the wastewater pipe or house inlet. Figure 2.14 shows the materials to be used. Figure 2.15

shows illustrative sketches.

Source: EPA, 2003

Figure 2.14 Materials for smoke test



Source: EPA, 2003

Figure 2.15 Illustrative sketches of smoke test

- Features of the smoke test
  - The status of connection of drain pipes in each space can be checked in a short time.
  - Inadequacies in the house drainage facility can be quickly detected.
- Smoke test procedure shown in Figure 2.16.

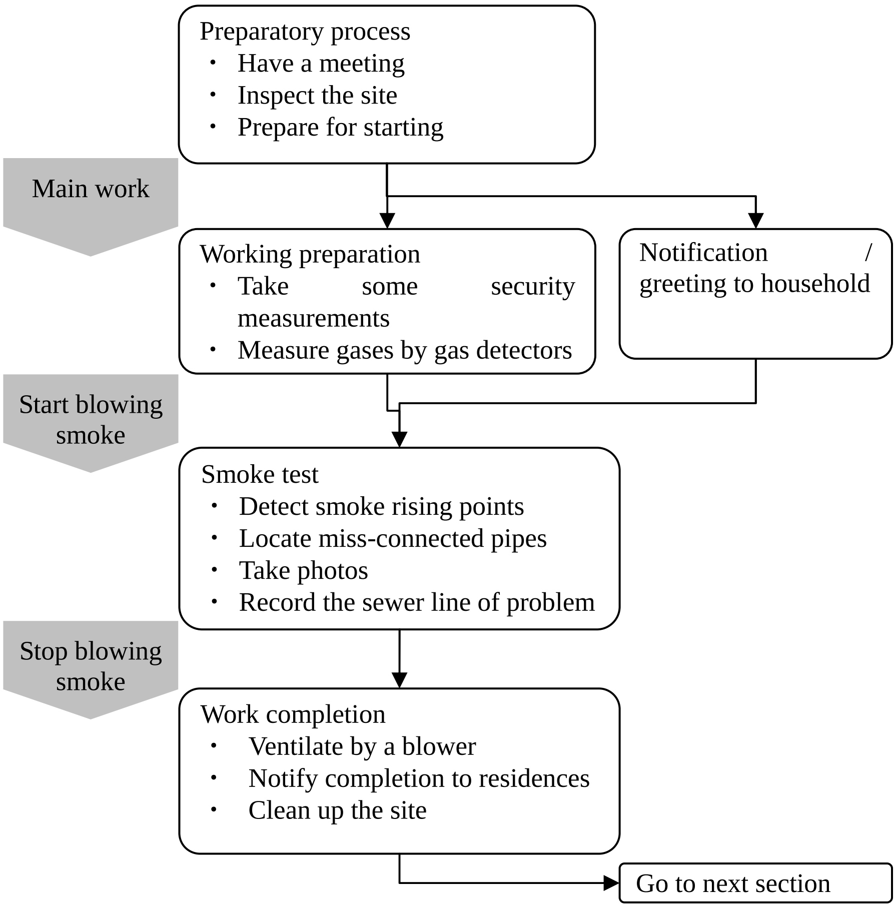


Figure 2.16 Work procedure of smoke test

b. Echo Sound Test

This is a method for confirming that piping facilities are correctly connected, and is also an effective method for knowing the plumbing systems and the routes of wastewater mains and lateral sewers. Ultrasonic waves are used (transmitter and receiver).

Figure 2.17 shows the test method.

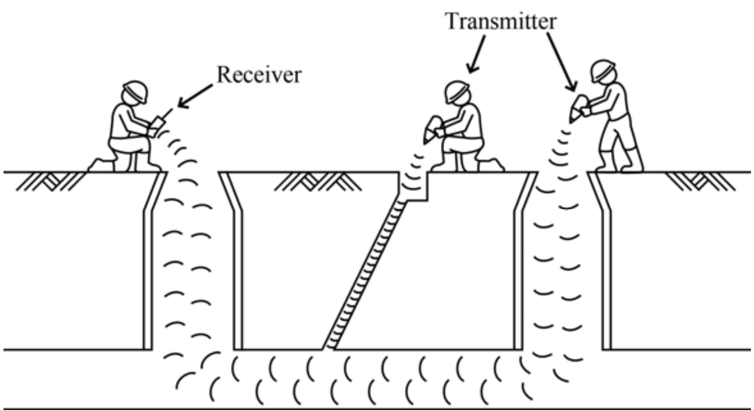


Figure 2.17 Illustration of echo sound test

- Features of the echo sound test
  - Simple method to confirm that a pipe has been connected or not.

- Effective especially in the connections of lateral sewers.
- Cannot judge clogging or trap.

- Echo sound test procedure is shown in Figure 2.18.

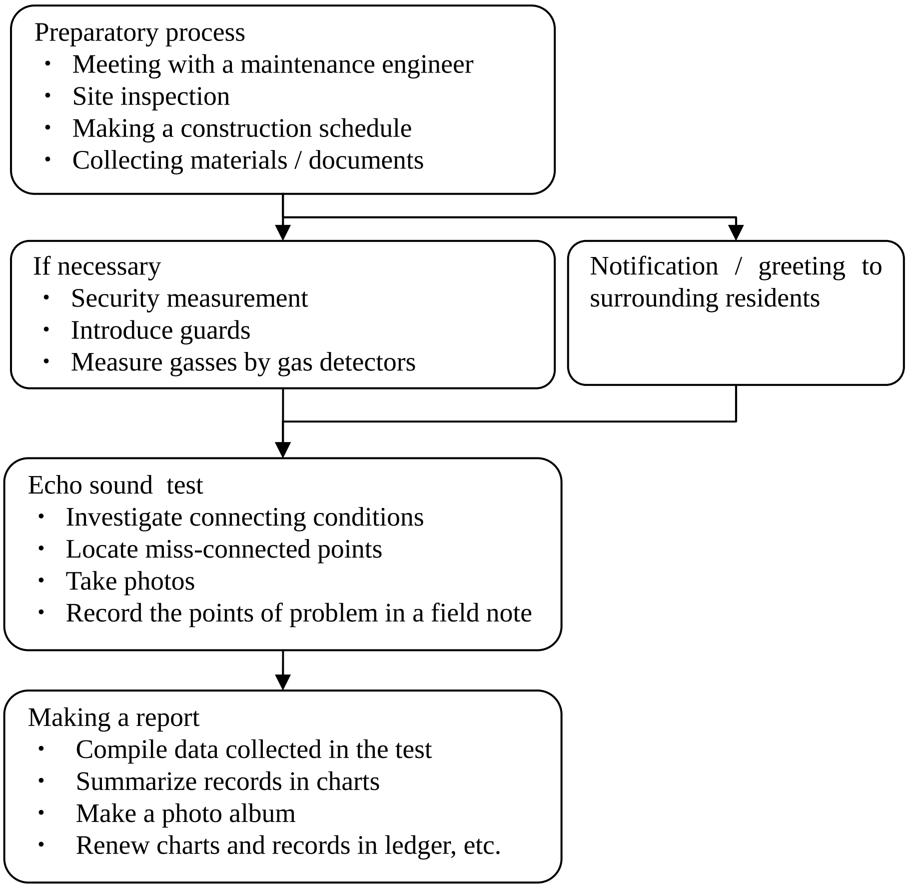


Figure 2.18 Work procedure of echo sound test

c. Dye Test

Harmless fluorescent dye diluted water is made to flow from the upstream side to the treatment plant within the range of wastewater main, lateral sewer and drainage equipment. The water flow route, leakage route and reaching time are examined. Outflow route should be checked quickly if notification of foul odour due to outflow of wastewater particularly from masonry or pump tank is received. The method can also be used for checking the flow status in the pipe and for measuring the flow velocity. The test method is shown in Figure 2.19. In addition clause 3.10 of Part A manual also deals with dye tracer study.

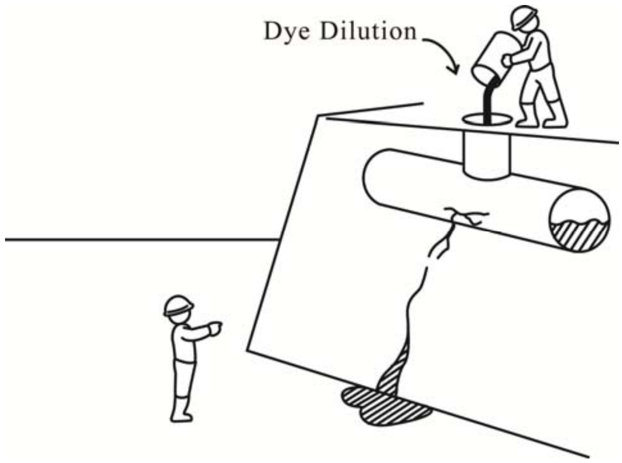


Figure 2.19 Drawing of dye test

2.2.5.2.2 Flow Rate Inspection

- About important areas for inspecting flow rate

Inspection should be carried out at locations where possibility of infiltration is high, e.g. where groundwater level is high, at a part of a river crossing, or at a part adjacent to rivers.

a. Flow Rate Measurement

Simple flow velocity meters (Palmer Bowlus flume, electromagnetic flow meter, water level gauge, ultrasonic flow meter) should be installed tentatively at the mouth of the manhole for flow measurements in the piping facilities and fixed period measurements carried out.

For details of flow meters, refer to Sec. 3.10 of Chapter 3 of Manual Part-A.

b. Pumping Test

This is a method for measuring the flow rate of water that has infiltrated the pipeline. The flow rate of infiltrated water into the space or the system can be known within a short time. However, the flow rate of infiltrated water varies with the variation in groundwater, therefore, precipitation and weather at the time of measurement should be confirmed.

To drain out household wastewater from the test during inspection of each space, a cut-off plug should be installed. This should preferably be implemented during the night time when the volume of household wastewater generated is small. Figure 2.20 shows the pumping test.

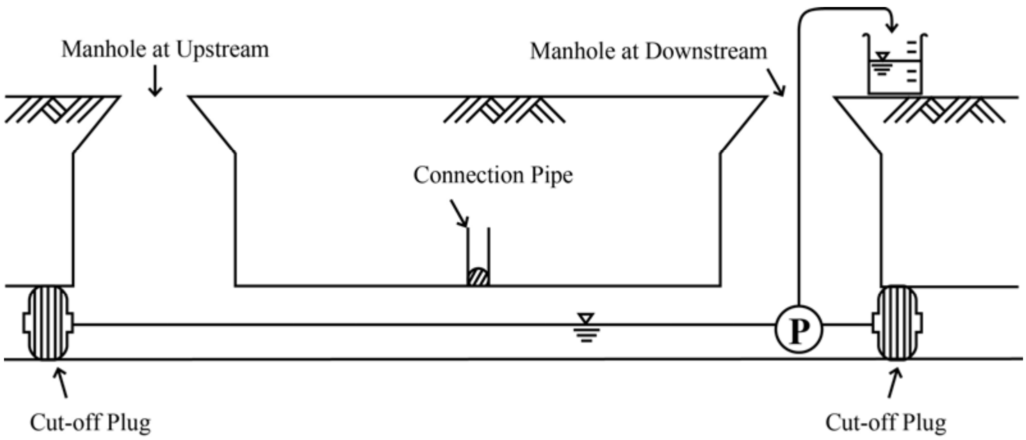


Figure 2.20 Pumping test

- Features of measurements during pumping test
  - The flow rate of infiltrated groundwater for each space or system can be measured within a short time.
  - The measured values differ widely depending on the variation in the groundwater level.
  - During measurements of several spaces or each system, it is difficult to remove household wastewater late at night.
- Work procedure for measurement of pumped water is shown in Figure 2.21.

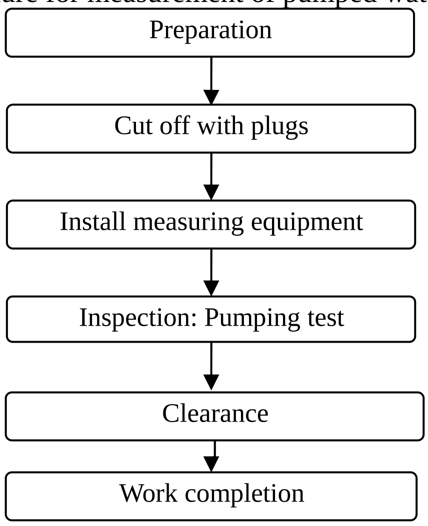


Figure 2.21 Work procedure of pumping test

2.2.5.3 Inspecting Corrosion and Deterioration

The status of deterioration or corrosion within pipe should be judged by TV camera. The materials in the piping facility are of various kinds: concrete pipe, ceramic pipe, hard polyvinyl chloride, brick, HDPE pipe, ductile pipe, and GRP (Glass Fibre Reinforced Plastics) pipe; so the corrosion and deterioration conditions vary.

Methods for inspecting corrosion and deterioration conditions of a sewer include the following:

- Inspection by TV camera of the wall surface condition
- Crack inspection
- Neutralization test

The causes of deterioration of structural concrete parts of the piping facilities are mainly the following:

- Crack in concrete due to concentrated loads (live loads)
- Deterioration of structure due to changes with aging
- Deterioration of concrete structures (concrete corrosion) due to sulphuric acid from the generation of hydrogen sulphide

2.2.5.3.1 Concrete Corrosion

In a facility where wastewater resides for a long period, such as a rising main or an inverted siphon, the wastewater is likely to become anaerobic and dissolved sulphide will be generated, which leads to concrete corrosion because of sulphuric acid. Locations where concrete corrosion is likely to occur in sewerage piping facilities are as given below.

Locations where corrosion is likely to occur:

- Piping facilities at the discharge destination of pressure pipe (including manhole pump)
- Upstream and downstream ends of locations where sump discharge occurs
- Upstream and downstream ends of locations where discharges containing sulphide occurs
- Locations downstream of inverted siphon

For details of the corrosion mechanism, refer to the Part-A Manual (Chap 3).

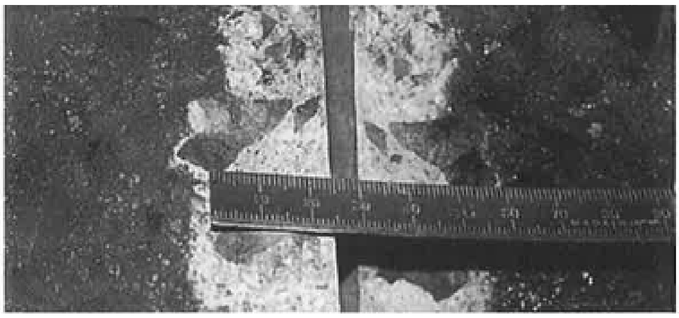
a. pH Measurement of Concrete Surfaces

For sulphuric acid corrosion of concrete, the pH on the surface of concrete is measured by pH test paper or pH meter which is placed on concrete surface directly, and the generation of sulphuric acid in the concrete structure can be confirmed. When sulphuric acid is generated in a manhole, the pH of the concrete surface may indicate strong acidity of 1 to 2.

b. Neutralization test (neutralization depth test by phenolphthalein)

One of the indices for judging durability of reinforced concrete structures is the "neutralization depth." This is the method of judging alkalinity with pH of 10 and above as un-neutralized part and uncoloured parts as neutralized parts, enabling quantitative information to be obtained easily by simple measurement (Figure 2.22).

When neutralization reaches the vicinity of the reinforcement, the reinforcement is likely to be corroded easily. When corrosion of reinforcement progresses, volume expansion of corrosive products causes crack or delamination in concrete, leading to excessive loss in the durability of the structure.
For details of the procedure, refer to BS-103:"Guidelines on Non-destructive Testing of Bridges."



Source: JASCOMA, 2007

Figure 2.22 Neutralization test

2.2.5.4 Other Examinations

Special examinations to study in detail the conditions of a facility are as given below. For more details, please refer to relevant documents for each item. Various kinds of information relevant to analysis for studying gas exploration are given.

- Sewer invert elevation examinations: Understanding pipeline conditions and collating with sewerage facility records.
- Sediment examination: Check sediment material, such as sand and silt, which may have entered damaged sewer or through loose joints from outside the sewer. This

sand and silt may accumulate around the sewer and form voids.

- Dangerous gas detection examination: Confirming gases generated in the piping facilities.

Water quality and gases encountered in a piping facility are closely related. Table 2.6 shows the gas analysis items in a piping facility.

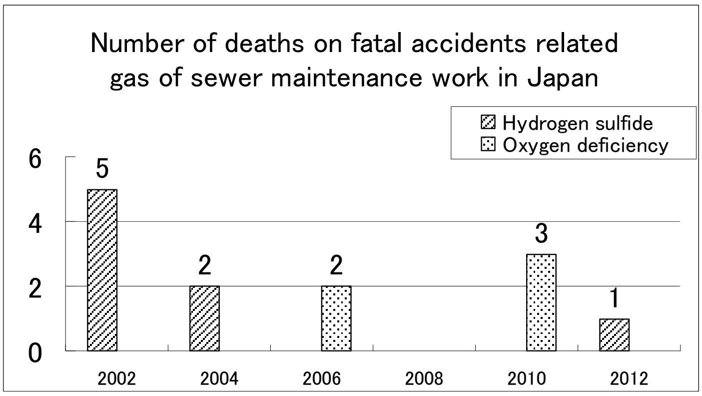
Table 2.6 Gas analysis

Analysis items		Unit
Carbon monoxide	CO	(%)
Carbon dioxide	CO_2	(%)
Hydrogen sulphide	H_2S	(ppm)
Ammonia	NH_3	(ppm)
Oxygen	O_2	(%)
Methane	CH_4	(ppm)
Nitrogen oxide	NO_X	(ppm)

Source: JASCOMA, 2007

Related to O&M of sewerage system, serious accidents due to gases generated from sewerage system are illustrated in Figure 2.23. (Accidents during O&M of Japanese sewerage system: For ten years from 2002 to 2012.) The causes of the gas-related accidents were hydrogen sulphide, carbon monoxide, and oxygen deficiency.

There is no data on accidental death in India and at least there should be such monitoring in India.



Source: JASCOMA, 2012

Figure 2.23 Fatal accident related to gas in Japan sewer works

2.2.5.5 Precautions

Cleaning equipment and machinery for sewers are shown in following sections:

When entering manholes, safety measures during the work should be ensure traffic safety, prevent oxygen deficiency, precautions against hydrogen sulphide, and so on.

For securing workers' safety, manual sewer/septic tank cleaning should be avoided because persons are likely to come in contact directly with sludge and sewage.

Therefore, cleaning machinery and equipment which avoid manpower cleaning are needed. Furthermore, necessary safety measures before entering manholes for cleaning should be taken. "Machinery and equipment for sewer pipes" are explained in the next section, and explanations on "Cleaning of on-site systems" are in Chapter 10.

The contamination of drinking water with sewage may occur when water supply pipe passes through sewer manholes, generally in narrow streets, especially when water supply pipe joints are enclosed in sewer manholes and when ever water supply pipe joints leak, contamination of drinking water supply occurs.” As such, water supply pipe lines should never be enclosed in a sewer manhole. If any, such situation is observed, immediately water supply pipe be made non-functional by stopping flow of drinking water and effected public be supplied clean drinking water by other temporary means, such as water tankers or laying G.I. pipe over the ground/road surface and portion of water supply lines lying in sewer manholes be shifted out of manholes.

Special attention should be paid to decentralized sewer system particularly when small bore sewer system or shallow sewer system is adopted.

2.2.6 Judgement of Inspection and Examination Results

It is necessary to judge whether urgent repairs or modifications are necessary, or normal operation and maintenance are sufficient to ensure that the functions of piping facilities are maintained when an abnormality is detected by studies and analyses. The facility manager should make the judgment considering material of the pipe, age of the pipe, location where buried, quality of wastewater, status of groundwater, regional environment, and so on.

The criteria given below may be used as judgment criteria.

- Emergency response criteria
- Judgment based on results of inspection or examination
- Testing criteria

2.2.6.1 Emergency Response Criteria

Abnormalities related to piping facilities are generally detected from inspections or from outside reports.

Prompt action should be taken when an accident has already occurred. Also, when the events below are confirmed, action should be taken immediately.

- Road surface: Irregularity exists that can cause level difference leading to subsidence or obstruction to operation.
- Manhole: Level difference exists that can lead to obstruction of operation.
- Inverted siphon: Water level on the upstream side is excessively high.

2.2.6.2 Judgement based on the Results of Inspection and Examination

Testing of the overall span and by each pipe should be carried out based on the results of visual inspection. Table 2.7 and Table 2.8 show examples of testing criteria.

The testing of the overall span is divided into the three categories (A, B, and C).

Table 2.7 Testing criteria for overall sewer span

Items		Rating		
		A	B	C
1) Corroded pipe		Reinforcing bars exposed	Aggregate exposed	Rough surface
2) Vertically deflected pipe	ID:< 700 mm	≥ID	ID -1/2 ID	<1/2 of ID
	ID:700－1650 mm	≥1/2 of ID	1/2ID-1/4 ID	<1/4 of ID
	ID: ≥ 1650 mm	≥1/4 of ID	1/4ID-1/8 ID	<1/8 of ID

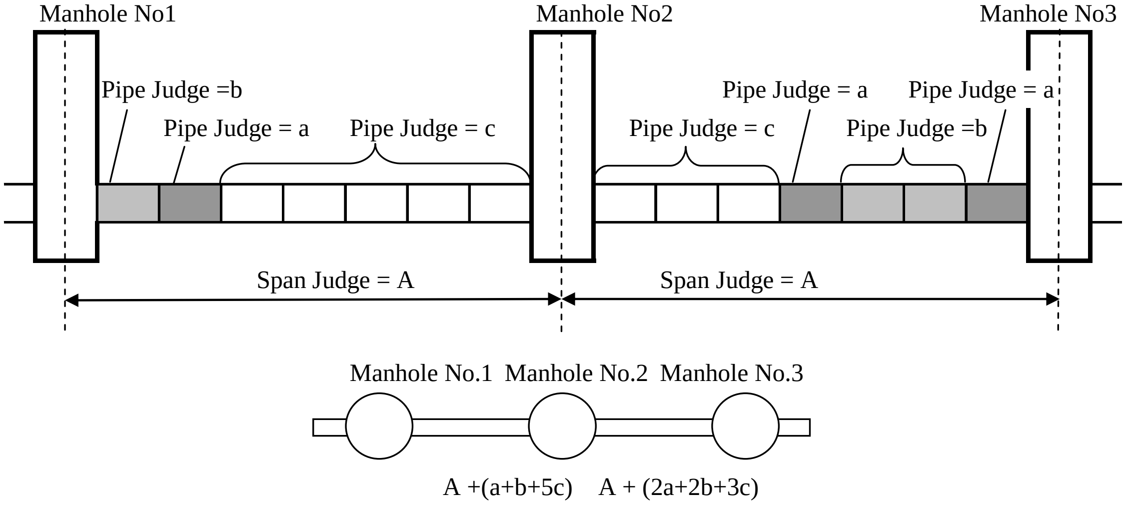
Source: JASCOMA, 2007

Also, the testing of each pipe is divided into the three categories (a, b, and c).

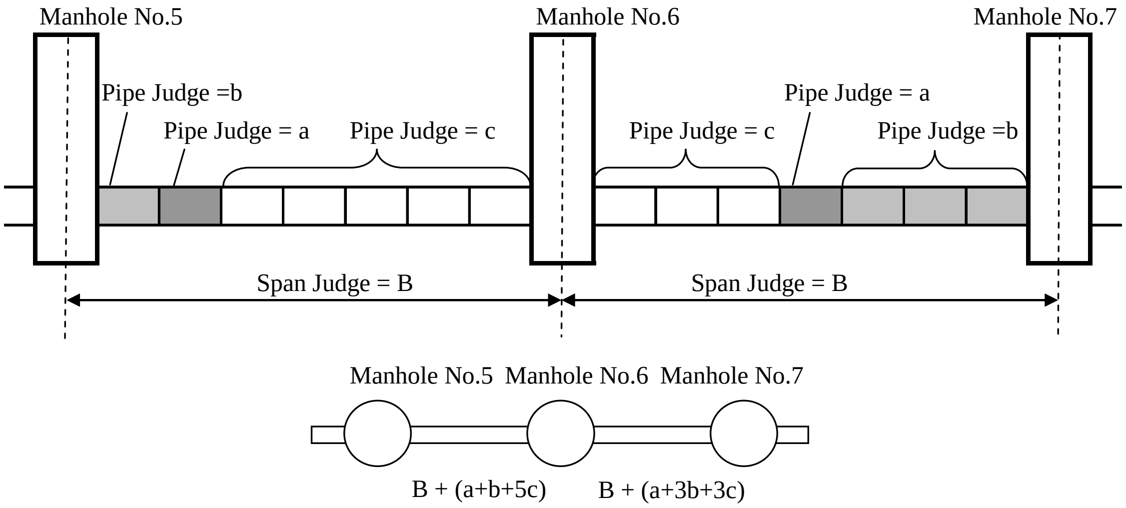
Table 2.8 Testing criteria for each pipe of sewer

<table>
<tr><th colspan="2" rowspan="2">Items</th><th colspan="5">Rating</th></tr>
<tr><th>a</th><th colspan="2">b</th><th colspan="2">c</th></tr>
<tr><td rowspan="4">3)Ruptured pipe</td><td rowspan="2">Reinforced concrete pipes, etc</td><td>Partially missing/holed pipe</td><td colspan="2" rowspan="2">Axial crack of 2 mm width or more</td><td colspan="2" rowspan="2">Axial crack of less than 2 mm width</td></tr>
<tr><td>Axial crack of 5 mm width or more</td></tr>
<tr><td rowspan="2">Stoneware pipes</td><td>Partially missed /holed pipe</td><td colspan="2" rowspan="2">Axial crack shorter than 1/2 of the pipe length</td><td colspan="2" rowspan="2">-</td></tr>
<tr><td>Axial crack of 1/2 of the pipe length and longer</td></tr>
<tr><td rowspan="2">4)Cracked pipe</td><td>Reinforced concrete pipes, etc</td><td>Circumferential crack of 5 mm width or more</td><td colspan="2">Circumferential crack of 2 mm width or more</td><td colspan="2">Circumferential crack of less than 2 mm width</td></tr>
<tr><td>Stoneware pipes</td><td>Circumferential crack of 2/3 of the pipe circumference and longer</td><td colspan="2">Circumferential crack shorter than 2/3 of the pipe circumference</td><td colspan="2">-</td></tr>
<tr><td colspan="2" rowspan="2">5)Gap at coupling pipes</td><td rowspan="2">Slip off
(Joint displacement)</td><td>Reinforced concrete pipes, etc</td><td>≥70 mm</td><td>Reinforced concrete pipes, etc</td><td><70 mm</td></tr>
<tr><td>Stoneware pipes</td><td>≥50 mm</td><td>Stoneware pipes</td><td><50 mm</td></tr>
<tr><td colspan="2">6) Infiltration</td><td>Splashing in</td><td colspan="2">Flowing in</td><td colspan="2">Soaking</td></tr>
</table>

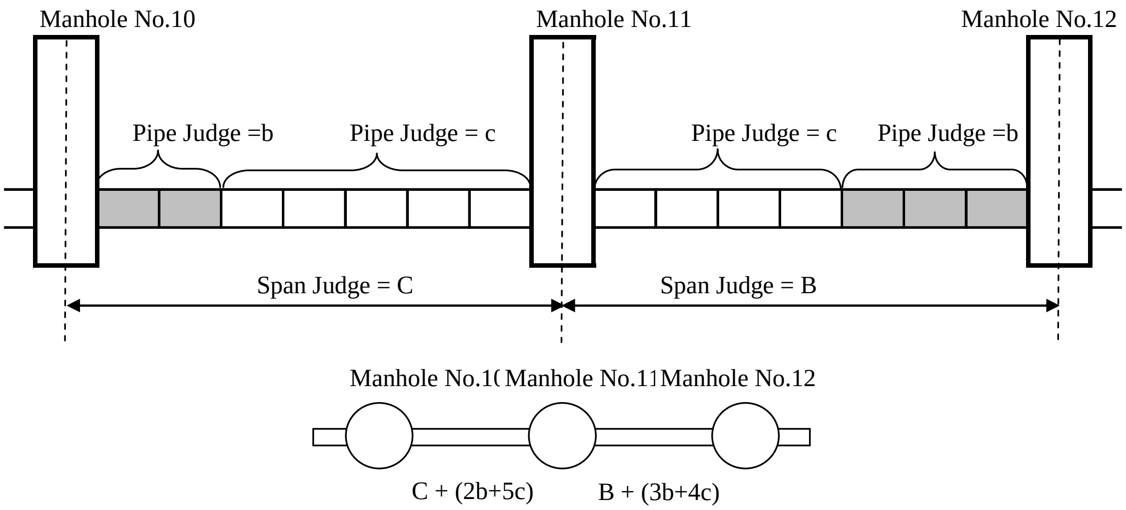
Source: JASCOMA, 2007



Example of Emergency Level -I (In Table 2.9)



Example of Emergency Level -II (In Table 2.9)



Example of Emergency Level -III (In Table 2.9)

Figure 2.24 Illustration of testing criteria for sewer

2.2.6.3 Testing Criteria

Functional degradation, deterioration and abnormalities clarified by inspection and examination should be assessed (Figure 2.24). A maintenance engineer should judge what countermeasure are applied for inspected sewers in accordance with Table 2.9, e.g. by usual operation and maintenance or by emergency repairs and modifications.

Based on the criteria shown in Table 2.7 and Table 2.8, emergency level I is a state where immediate response is necessary.

Emergency level II indicates that simple response may be adopted and radical measures implemented within the next five years.

Furthermore, emergency level III indicates response adopted by operation and maintenance, and implementation of simple response partially.

Table 2.9 Testing criteria for sewer

	Category	Testing criteria	Criteria for measures
Emergency Level I	Important	Either A's are more or a's are more in the testing results	Prompt measures are necessary
Emergency Level II	Medium importance	A's are less frequent and B's are more; or a's are less and b's are more in the testing results	Necessary actions may be taken by provisional measures and the proper measure will be implemented within 5 years
Emergency Level III	Minor importance	No A, Bs are few, C's are many, or a and b are few, c's are many in the testing results	Actions may be taken by provisional measures, if required

A's, B's, and C's are judgement results of Table 2.7, and a's, b's, and c's are judgment results of Table 2.8.

2.2.7 Maintenance of Records and Follow up Action

To reflect the inspection and testing results in appropriate operation and maintenance of piping facilities, the testing results should be recorded and stored in the format shown here.

a. Inspection Sheet

When inspections and examinations are implemented, an inspection sheet should be prepared and recorded as shown in Table 2.10.

Table 2.10 Inspection sheet

<table>
<tr><td colspan="4">Inspection Sheet</td><td>No.</td></tr>
<tr><td colspan="2">Location
(Manhole No. etc)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Inspection Date</td><td></td><td>Inspector</td><td></td></tr>
<tr><td rowspan="5">Inspection items</td><td>Manhole cover</td><td colspan="3">Abrasion, backlash, difference in level, invaded pavement, damaged, location unknown</td></tr>
<tr><td>Inside of manhole</td><td colspan="3">Corrosion, damage to the floor, infiltration, metal steps corroded, inferior pipe end, rubbish, odour</td></tr>
<tr><td>Pipe</td><td colspan="3">Corrosion, damage, coupling displacement, inadequate inclination, infiltration, roots of trees, earth, sand, and mortar, road subsidence</td></tr>
<tr><td>House inlet</td><td colspan="3">Cover (no damage), difference in level, corrosion, damage, damaged invert, earth and sand, location unknown, odour</td></tr>
<tr><td>Lateral</td><td colspan="3">Damage, displacement, earth and sand, road subsidence</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="2">Inspection Date</td><td></td><td>Inspector</td><td></td></tr>
<tr><td colspan="2">Inspection Result</td><td colspan="3"></td></tr>
</table>

Follow up actions	□Necessary □Not necessary	□Contracted □ Self
Date of order		
Date of schedule		
Date of completion		
Remarks		

Source: JASCOMA, 2007

b. Log

Log should be used to record daily work results, which can be used in the operation and maintenance of piping facilities. Format is shown in Table 2.11.

c. Monthly Reports

Daily record should be summarised in monthly reports. Format of monthly report is shown in Table 2.12.

Table 2.11 Daily report

Daily Report													Date		Weather	
Response to complaint / breakdown		Receipt No.	Receipt date	Location: address		Work description				Inspector		Tool/Material		Remarks		
	1															
	2															
	3															
	4															
Trunk cleaning	Diameter (mm)													Name of cleaned area		Daily total
	Crew A													District:		person
	Crew B															person
	Removed sand volume													System No:		m^3
	Cleaned distance															m
Manhole	Direct works		Name of place repaired		Name of drainage area		System No.	Entrusted works		Name of place repaired		Name of drainage area		System No.	Tool/Material	Daily total
	Work description							Work description								

Source: JASCOMA, 2007

Table 2.12 Monthly report

Monthly Report	Date	Weather

Response to complaint / breakdown	Category	1.Lateral	2.Inlet	3.Manhole	4.Ground subsidence	5.Odour	6.Others	Total
	Number							

Trunk cleaning	Diameter (mm)																Total
	Direct crew																
	Entrusted crew																
	Removed sand																
	Cleaned distance																

Manhole repair	Manhole type	1	2	3	4	5	6	7	Special	Direct	Entrusted	Total
	Cover replaced											
	Ring repaired											
	Barrel repaired											
	Noise											

Source: JASCOMA, 2007

2.3 SEWER CLEANING

To operate and maintain a sewer collection system to function as intended, the maintenance engineer should try to strive towards the following objectives:

- Minimize the number of blockages per unit length of sewer, and
- Minimize the number of odour complaints.

For this purpose, sewer cleaning using hydraulic or mechanical cleaning methods needs to be done on a scheduled basis to remove accumulated debris in the pipe such as sand, silt, grease, roots, and rocks. If debris is allowed to accumulate, it reduces the capacity of the pipe and blockage can eventually occur resulting in overflows from the system onto streets, yards, and into surface waters. Roots and corrosion also can cause physical damage to sewers.

2.3.1 Cleaning Equipment and Procedures

Sewer cleaning works require usual implements like pick axes, manhole guards, tripod stands, danger flags, lanterns, batteries, safety lamps, lead acetate paper, silt drums, ropes, iron hooks, hand carts, plunger rods, observation rods, shovels etc.

In addition, sewer cleaning work calls for the following special equipment and devices like a portable pump set running on either diesel or petrol engine, rope and cloth balls, sectional sewer rods, a sewer cleaning bucket machine, a dredger, a rodding machine with flexible sewer rods and cleaning tool attachments such as augers, corkscrews, hedgehogs and sand cups, scraper, and hydraulically propelled devices such as flush hags, sewer balls, wooden bail and sewer scooters, sewer jetting machine, gully emptiers and pneumatic plugs.

2.3.1.1 Manila Rope and Cloth Ball

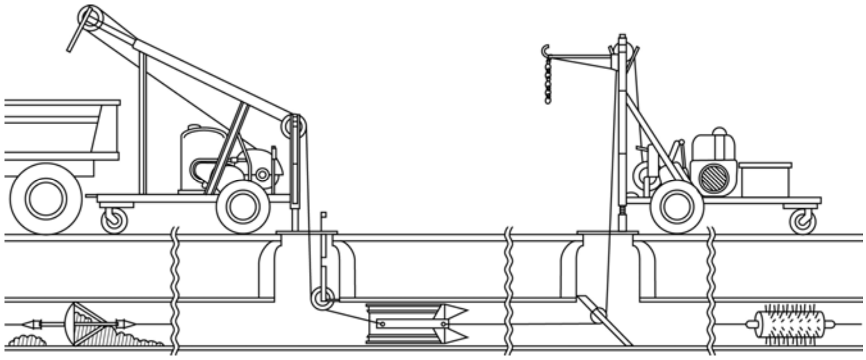
The most common way of cleaning small diameter sewers up to 300-mm diameter is by the use of a manila rope and cloth ball. Flexible bamboo strips tied together are inserted in the sewer line by a person on top. If necessary, another person inside the manhole helps in pushing the rod through the sewer line. When the front end of the bamboo strip reaches the next manhole, a thick manila rope, with cloth ball at one end, is tied to the rear end of the bamboo splits. The bamboo splits are then pulled by another person in the downstream manhole and pushed through the sewer line. As the rope is pulled, the ball sweeps the sewer line and the accumulated grit is carried to the next manhole where it is removed out by means of buckets. This operation is repeated between the next manholes until the stretch of sewer line is cleaned.

2.3.1.2 Sectional Sewer Rods

These rods are used for cleaning small sewers. The sewer rods may be of bamboo or teakwood or light metal usually about one meter long at the end of which is a coupling which remains intact in the sewer but can be easily disjointed in the manhole. Sections of the rods are pushed down the sewer. The front or the advancing end of the sewer rod is generally fitted with a brush, a rubber ring for cleaning or a cutting edge to cut and dislodge the obstructions. These rods are also useful to locate the obstruction from either manhole in case a particular portion of the sewer has to be exposed for attending to the problem.

2.3.1.3 Sewer Cleaning Bucket Machine

The bucket machine consists of two powered winches with cables in between. For cleaning a section of sewer; the winches are centred over two adjacent manholes. To get the cable from one winch to the other, it is necessary to thread the cable through the sewer line by means of sewer rods or flexible split bamboo rods. The cable from the drum of each winch is fastened to the barrel on each end of an expansion sewer bucket fitted with closing device, so that the bucket can be pulled in either direction by the machine on the appropriate end. The bucket is pulled into the loosened material in the sewer until the operator feels that it is loaded with debris. The winch is then thrown out of gear and the opposing winch is put into action. When the reverse pull is starts, the bucket automatically closes and the dirt is deposited in a truck or a trailer. This operation is repeated until the sewer is cleared. Various bucket sizes are available for sewers of 150 mm to 900 mm in size. The machine is also used along with other scraping instruments for loosening sludge banks of detritus or cutting roots and dislodging obstructions (Figure 2.25).



Source: EPA, 2003

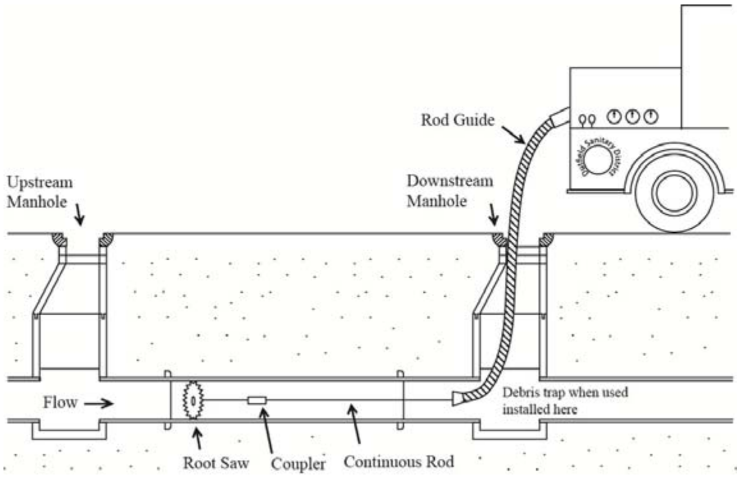
Figure 2.25 Power bucket machine setup

2.3.1.4 Dredger (Clam-shell)

It consists of a grab bucket on a wire rope which is lowered into the manhole in the open condition with the help of a crane and pulley. On reaching the bottom of the manhole the segments are closed, and the accumulated silt is picked up. The bucket is then raised above ground level where the bucket opens and the silt is automatically dropped into a truck or a trailer. The bucket can be closed by wire ropes or by a pneumatically operated cylinder. The disadvantage in this system is that it cannot clean the corners of the catch pits of manholes. Sometimes the deposits at tire corners may become so hard that the same may be required to be chiselled out.

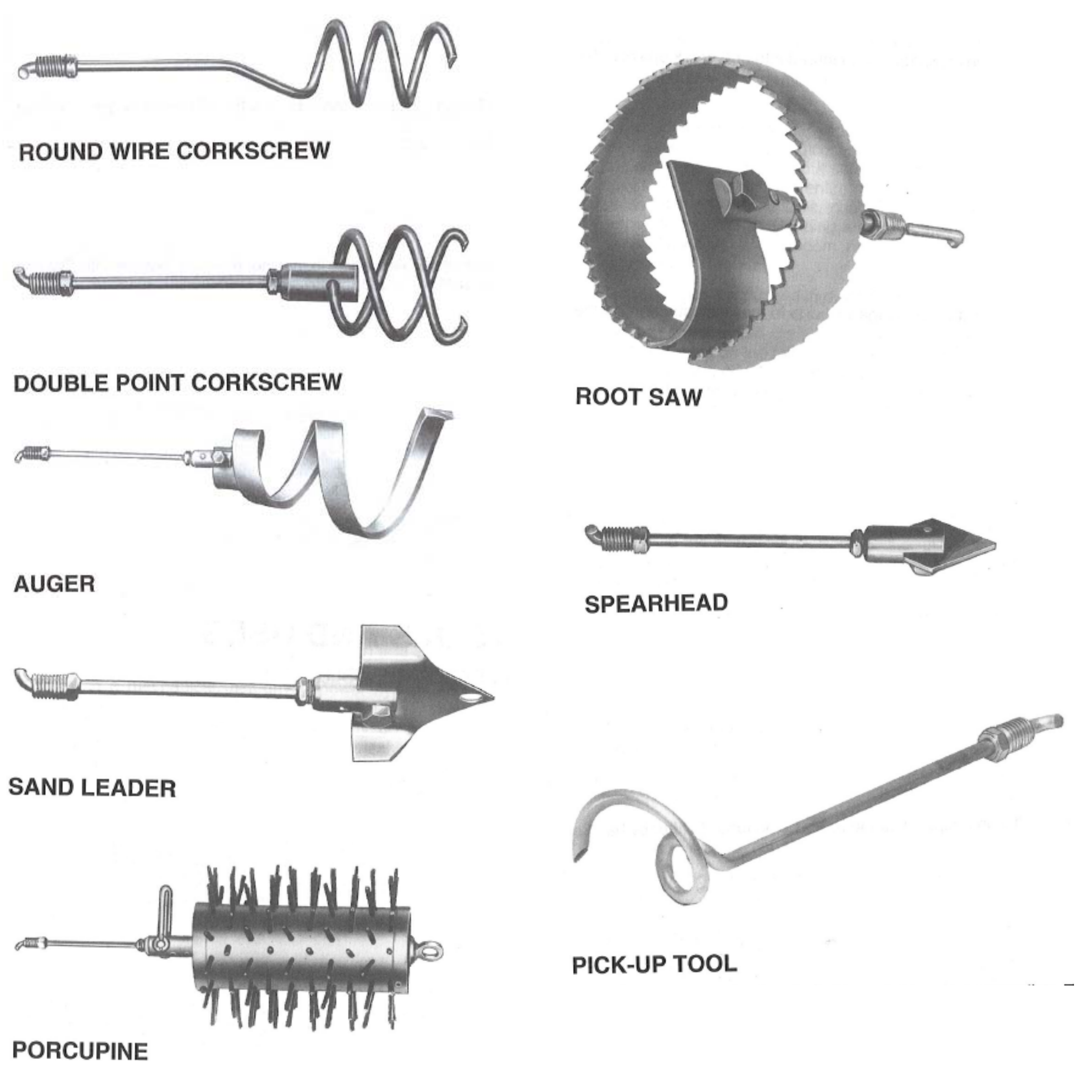
2.3.1.5 Rodding Machine with Flexible Sewer Rods

This consists of a machine which rotates a flexible rod to which is attached a cleaning tool such as auger, corkscrew or hedgehog and sand cups (Figure 2.26). The flexible rod consists of a series of steel rods with screw couplings. The flexible rod is guided through the manhole by a bent pipe. The machine rotates the rod with the tool attached to one end, the other end being fixed to the machine. The rotating rod is thrust into the bent pipe manually with clamps with long handles for holding the rod near the couplings. As the rod is thrust inside, the machine also is drawn towards the manhole. The rod is pulled in and out in quick succession when the tool is engaging the obstruction, so as to dislodge or loosen it. When the obstruction is cleared, the rod is pulled out by means of clamps keeping the rod rotating to facilitate quick and easy removal. The various tools attached to the rods are shown in Figure 2.27.



Source: EPA, 2003

Figure 2.26 Power rodding operation



Source: EPA, 2003

Figure 2.27 Rodding heads

2.3.1.6 Scraper

This method is used for sewers of diameter larger than 750 mm. The scraper is an assembly of wooden planks of slightly smaller size than the sewer to be cleaned. If the scraper cannot be lowered through the opening of manhole, it has to be assembled inside the manhole. The scraper chains, attached to a control chain in the manhole into which it is lowered, are then connected to a winch in the next downstream manhole by means of chains. The winch is then operated to push the debris ahead of the scraper. The heading up of the flow behind the scraper and the water dropping from the top of the scraper will also assist in pushing it in the forward direction. This-ensures that the bottom and the sides of the sewer are cleaned thoroughly. The scraped debris is removed manually.

Circular scrapers are used on small sewers below 350 mm diameter for cleaning the body of the line. They are commonly known as discs and these discs are either collapsible and made of metal or a wooden pair separated by about 200 mm by steel rods.

2.3.1.7 Hydraulically Propelled Devices

The hydraulically propelled devices take advantage of the force of impounded water to effectively clear sewers. Efficiency depends on the hydraulic principle that an increase in velocity in a moving stream is accompanied by a greatly increased ability to move entrained material. The transporting capacity of water varies as the sixth power of its velocity.

a. Flush Bags

A very effective tool for cleaning portions of sewers where rods cannot be used is the sewer flusher or flush bag. The flusher is a canvas bag or rubber bag equipped with a fire hose coupler at one end and a reducer at the other end. The flusher is connected to the fire hose and placed in the downstream end from the point where a choke is located. The bag is allowed to fill up until it expands and seals the sewer. The upstream pressure built up due to this damming effect breaks loose the obstructions.

b. Sewer Balls

These are simple elastic pneumatic type rubber balls which can be blown up to varying degrees of inflation. They are manufactured in sizes from 150 mm to 750 mm diameter when fully inflated. When used in cleaning a sewer, the bail is first inflated and then wrapped in a canvas cloth, the edges of which are sewed together. A trial line, little longer than the distance between the manholes, is attached securely to the covering. The size of the ball and the covering shall be such as to fit fairly snugly into the sewer. Immediately after the ball is thrust into the sewer, sewage commences to back up in the manhole and continues to rise until such time as its pressure is great enough to force sewage under the ball and move it downstream through the pipe. Acting as a compressible floating plug, it affords enough obstruction, so that a continuous high velocity jet spurts under and to some extern around the ball, thereby sluicing all the movable material ahead to the next manhole. If the ball encounters an obstruction which is immovable, the ball merely indents to the necessary degree and moves forward. The only fixed obstruction which will stop the forward progress of the ball is a root mass or some similar obstruction tightly wedged into the pipe. Bricks, stones, bottles, loose metal parts, broken pieces of pipes, sand, gravel and settled sludge are easily moved ahead. If the ball stops momentarily, a pull on the trial line is usually sufficient to set it in motion again. If the pipe is very dirty, the trial line can be tied to a step in the upper manhole and the ball's progress can be retarded to the required degree as the lower manhole is reached, thus giving time for complete removal of accumulated silt and debris which has piled up ahead of the ball. Equipment arrangement is shown in Figure 2.28 and Figure 2.29.

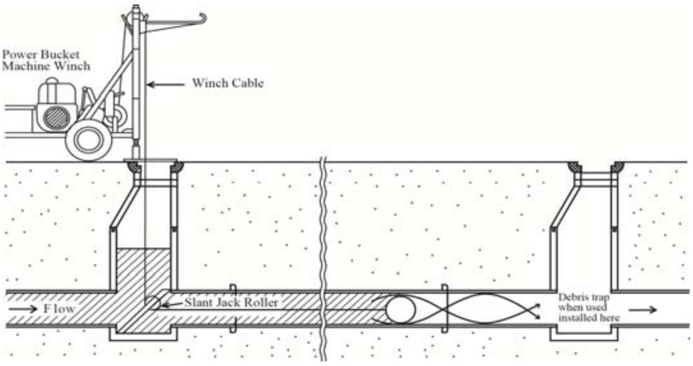
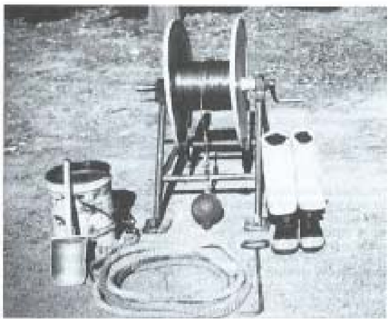


Figure 2.28 Typical setup for hydraulic cleaning using sewer ball



Source: EPA, 2003

Figure 2.29 Balling equipment

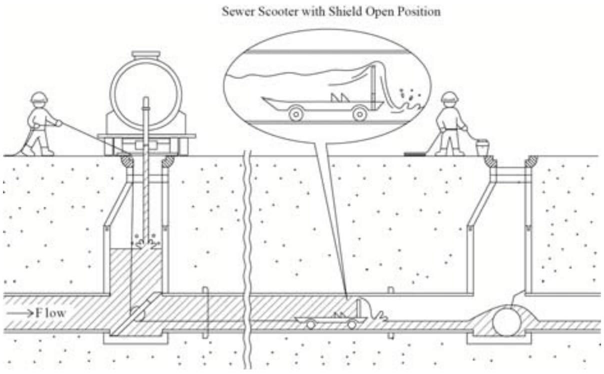
A wooden ball, also called a sewer pile, can also be used for this purpose, particularly for cleaning large outfall sewers. It is dropped into the sewer and owing to its buoyant action rolls along the invert of the sewer. The obstructions caused by it to the flow produce a vigorous scouring action along the invert and the sides which has the effect of removing tree growths and the deposits from the sewers. This method is economical and hence can be used at frequent intervals.

c. Sewer Scooters

This arrangement is an improved version of the scraper and consists of two jacks, a controlling rope and the scooter with a tight fitting shield. In contrast to the scraper, the scooter completely stops any flow of sewage. The scooter, attached to the control rope, is lowered into the manhole and then into the downstream sewer line. The downstream manhole jack is lowered into place from the road and the upper manhole jack set across the top of the manhole.

When the scooter is introduced in the line, it stops the flow of sewage thus building up a head behind the shield. The resulting pressure causes the scooter to move through the sewer until it accumulates enough debris to stop its movement. The head is then allowed to build up approximately one meter before the control rope is pulled, causing the shield to fold back, thus allowing the accumulated sewage to gush into the sewer downstream, flushing the debris ahead to the next manhole from where it is removed. The control rope is released, clearing the shield against the sewage and causing the scooter to advance again until the debris stops its movement. This process is repeated until the scooter reaches the downstream manhole where it may be removed or allowed to continue through the next section.

The operation of the sewer scooter is shown in Figure 2.30.



Source: EPA, 2003

Figure 2.30 Scooter operation

2.3.1.8 Velocity Cleaners (Jetting Machines)

The high velocity sewer cleaner makes use of high velocity water jets to remove and dislodge obstructions, soluble grease, gut and other materials from sanitary, storm and combined sewerage systems. It combines the functions of a rodding machine and gully emptier machine. Basically it includes a high pressure hydraulic pump capable of delivering water at variable pressure up to about 8 MPa through a flexible hose to a sewer cleaning nozzle. The nozzle has one forward facing hole and a number of rear ward facing holes. The high pressure water coming out of the holes with a high velocity breaks up and dislodges the obstructions and flushes the materials down the sewer. Moreover by varying the pressure suitably, the nozzle itself acts as a jack hammer and breaks up stubborn obstructions. (A separate suction pump or air flow device may also be used to suck the dislodged material).

The entire equipment is usually mounted on a heavy truck chassis with either a separate prime mover or a power take off for the suction device. The high pressure hose reel is also hydraulically driven. The truck also carries fresh water tanks for the hydraulic jet and a tank for the removed sludge and the various controls grouped together for easy operation during sewer cleaning. The manufacturer's operating and servicing manuals should be carefully followed for best results in the use of the machine.

2.3.1.9 Suction Units (Gully Emptier)

Suction units create the vacuum required for siphoning of mud, slurry, grit and other materials from sanitary, storm and combined sewerage systems. The vacuum elevated is such as to siphon the materials from the deep manholes catch-pits etc., having depth ranging from 1 m to 8 m in normal cases with an option to suck an additional 4 m with the help of special accessories for the purpose. The unit can be vehicle or trolley mounted.

Silt and heavy particles settled at the bottom can be agitated and loosened by pressurized air with the help of the pump and then sucked in a tank. Once the silt tank is full, the effluent is discharged in the nearby storm water drain or manhole and the operation is repeated until the silt is cleared off the manhole. The silt deposited in the tank is then emptied at the predetermined dumping spot.

2.3.2 Notification to STP

Before clearing a large septic stoppage, be sure to notify the operator on duty at the downstream STP. Septic stoppages develop when the sewer has been blocked for considerable time and/or the air temperature is hot. Under these conditions the wastewater and organic solids turn black and smell like rotten eggs. If a large diameter sewer is blocked and a large volume of wastewater backs up in the pipes, there might not be sufficient fresh water arriving at the treatment plant to dilute the septic waste water. When a large volume of septic wastewater reaches a treatment plant, the treatment processes may fail to do their intended job. By notifying the operator in advance of the location of the stoppage and approximate volume of septic wastewater flowing towards the treatment plant, the operator can be alerted and can prepare to minimize the impact on the treatment processes.

2.3.3 Disposal of Silt and Sludge

Sludge from sewers can be disposed of along with grit and sludge of the STP (if available). Otherwise, the sludge and silt can be co-disposed in an eco-friendly manner with municipal solid waste.

2.3.4 Cleaning Records and their Utilization

Records of all cleaning operations should be entered and filed for future reference. These records should include the data, street name or number, line size, distance, and manhole numbers or identification. Also the kind and amount of materials removed, wastewater flow, and auxiliary water used should be noted. If particular problems were encountered, these too should be noted, especially the exact location of obstructions. A record form sample is shown in Figure 2.31.

During the routine cleaning operations discussed in this chapter, many manholes should be opened and used for high-velocity cleaning or flushing of sewer. Manhole Inspection form detailing its location, condition, and any problems observed should be completed. If this is done each time a manhole is opened during cleaning operations, over time the database for these structures will include up-to-date information on a high percentage of them and allow better decisions to be made in regard to routine maintenance, repair, or rehabilitation.

If pieces of broken sewer are removed, a TV inspection may be needed and repairs may need to be made on the broken sections of pipe.

Recording traffic patterns at a site can be very helpful next time the equipment is set up at the location. Car park (such as over manholes), traffic volume during rush hours, and whether police traffic control should be called for help before going to the site, should be indicated.

Computers are being used in many aspects of operation, maintenance, and recordkeeping of collection system. Computer software packages are available for scheduling preventive maintenance activities, issuing work orders for repairs, keeping track of where work is done, who did the work, when, and the labour and materials required. With the correct software, any information in the computer’s records can be recalled for future use. Computers are also used to keep spare parts inventories and to order spare parts when the supply runs low and before they are needed for scheduled maintenance and repairs.

When marking out records, remember that you or someone else will be referring to them. The more complete the record, the easier the next operation becomes since you have a history of this sewer.

Date:______________ CREW LEADER'S - DAILY REPORT Foreman:________

Name	Hours	Account Number	Equipt. NO.	Miles	Hours	Work Performed

	S	V	OTO	ML	DOCK	EL	Remarks

All work on sewer lines must be shown below.

Bk.	Pg.	Line Description	SR / CR	PM / TV	Rod	Ball	Gr.	Rs.	Footage Totals

Source: EPA, 2003

Figure 2.31 Sewer cleaning records

2.4 SEWER REHABILITATION

2.4.1 Introduction

Deterioration of sewers proceeds over the surface as a whole, and repair takes considerable time, therefore, it is necessary to implement renewal and repair according to a plan on the basis of the results of inspection and examinations. This practice will prevent accidents.

In older cities, most sewers though developed have already exceeded the service life. In such cities, adequate renewal and repair may resolve urgent problems and help extend the service life of the facilities, reducing O&M expenses.

The two terms renewal and repair are clearly segregated as follows. Renewal is not included in O&M duties but in construction because the time of implementation is the starting point of the new service life and changes must be made to fixed assets

a. Renewal

The term means improvement and replacement of facilities not caused by expansion of drainage area.

Improvement: Reconstruction or replacement of the facility that has not yet reached the specified service life.

Replacement: Reconstruction or replacement of the facility that has reached the specified service life.

b. Repair

This refers to partial replacement or repair of damage to the facility. Repair provides utility but not an increase in functions, so it does not contribute to extension of the service life of the facility. Repair simply maintains the capacity and life and does not cause a change in fixed assets.

However, making a clear distinction between O&M and construction duties is often difficult for implementation of renewal and repair according to the plan. In certain cases, it is therefore desirable to plan these duties as one package. Improvement of functions of existing sewers while incorporating elements related to planning and construction projects is generally called rehabilitation. The definition of terms related to rehabilitation is given in Table 2.13.

Table 2.13 Definition of terms

Terms	Definition	Classification
Rehabilitation, reconstruction	All concepts to improve functions of existing sewer pipes.	All measures
Repair	Repair of structural damage or partial renewal of sewer pipes	Structural measures
Renovation	Functional improvement of a certain section while utilizing the existing pipe structures	Structural measures
Renewal	Renewal of new pipes, with basic functions and capacities remaining equal to original pipes.	Structural measures
Replacement	Replacement with new pipes to reinforce functions and capacities	Hydraulic measures
Reinforcement pipes	Installation of new pipes to enhance the flow capacity of the entire system.	Hydraulic measures

Source: JICA, 2011

2.4.2 Rehabilitation Method

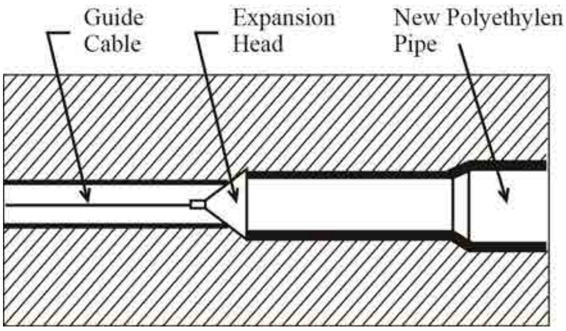
Under the traditional method of sewer relief, a replacement is made or additional parallel sewer line is constructed by digging along the entire length of the existing pipeline, while these traditional methods of sewer rehabilitation require unearthing and replacing the deficient pipe (the dig-and-replace method), trenchless methods of rehabilitation use the existing pipe as a host for a new pipe or liner. Trenchless sewer rehabilitation techniques correct pipe deficiencies that require less restoration and cause less disturbance and environmental degradation than the traditional dig-and-replace method. Trenchless sewer rehabilitation methods include:

- Pipe bursting or in-line expansion
- Slip lining
- Cured-in-place pipe
- Modified cross-section liner

These alterative techniques must be fully understood before they are applied. These four sewer rehabilitation methods are described in detail in the following sections.

2.4.2.1 Pipe Bursting or In-line Expansion

Pipe bursting or in-line expansion is a method by which the existing pipe is forced outward and opened by a bursting tool. During in-line expansion, the existing pipe is used as a guide for inserting the expansion head (part of the bursting tool). The expansion head, typically pulled by a cable rod and winch, increases the area available for the new pipe by pushing the existing pipe radially outward until it cracks. The bursting device pulls the new pipeline behind itself. The pipe bursting process is illustrated in Figure 2.32.

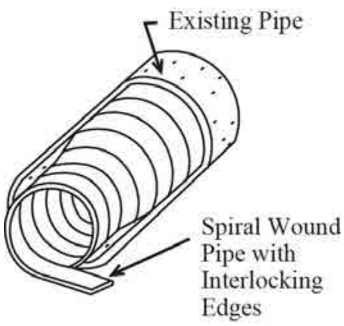


Source: JICA, 2011

Figure 2.32 Pipe bursting process

2.4.2.2 Slip Lining

Slip lining is a well established method of trenchless rehabilitation. During the slip lining process, a new liner of smaller diameter is placed inside the existing pipe. The annular space, or area between the existing pipe and the new pipe, is typically grouted to prevent leaks and to provide structural integrity. If the annulus between the sections is not grouted, the liner is not considered a structural liner. Continuous grouting of the annular space provides the seal. Grouting only the end-of-pipe sections can cause failures and leaks. In most slip lining applications, manholes cannot function as proper access points to perform the rehabilitation. In these situations, an insertion pit must be dug for each pipeline segment. Due to this requirement in most applications, slip lining is not a completely trenchless technique. However, the excavation required is considerably less than that for the traditional dig-and-replace method. System and site conditions will dictate the amount of excavation spared. Methods of slip lining include continuous, segmental and spiral wound methods. All three methods require laterals to be re-connected by excavation or by a remote cutter. In continuous slip lining, the new pipe, jointed to form a continuous segment, is inserted into the host pipe at strategic locations. The installation access point, such as a manhole or insertion pit, must be able to handle the bending of the continuous pipe section. Installation by the segmental method involves assembling pipe segment at the access point. Slip lining by the segment method can be accomplished without rerouting the existing flow. In many applications, the existing flow reduces frictional resistance and thereby aids in the installation process. Spiral wound slip lining is performed within a manhole or access point by using interlocking edges on the ends of the pipe segments to connect the segments. The spiral wound pipe is then inserted into the existing pipe as illustrated in Figure 2.33.

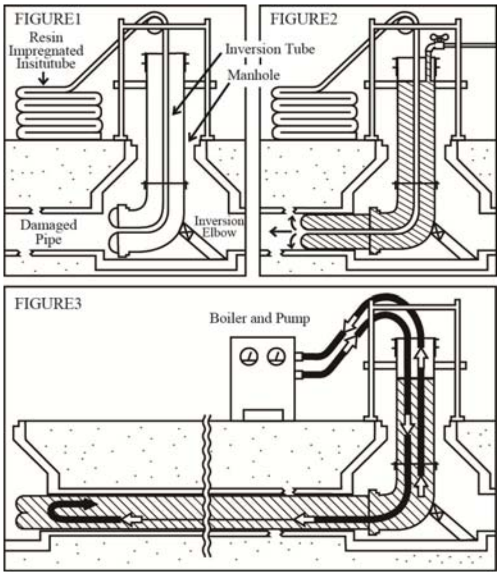


Source: JICA, 2011

Figure 2.33 Spiral wound slip lining process

2.4.2.3 Cured-in-place Pipe

A typical cured-in-place pipe (CIPP) process by the water-inversion method is illustrated in Figure 2.34. During the CIPP renewal process, a flexible fabric liner coated with a thermosetting resin is inserted in the existing pipeline and cured to form to a new liner. The liner is typically inserted in the existing pipe through an existing manhole. The fabric tube holds the resin in place until the tube is inserted in the pipe and ready to be cured. Commonly manufactured resins include unsaturated polyester, vinyl ester, and epoxy, each having distinct chemical resistance to domestic sewage. The CIPP method can be applied to rehabilitate pipe lines with defects such as cracks, offset joints, and structurally deficient segments. The thermosetting resin material bonds with the existing pipe materials to form a tighter seal than most other trenchless techniques. The two primary methods of installing CIPP are winch-in-place and invert-in-place. These methods are used during installation to feed the tube through the pipe. The winch-in-place method uses a winch to pull the tube through the existing pipeline. After being pulled through the pipeline, the tube is inflated to push the liner against the existing pipe walls. The more typically applied inversion-in-place method uses gravity and either water or air pressure to force the tube through the pipe and invert it, or turn the tube inside out. This process of inversion presses the resin-coated tube against the walls of the existing pipe. During both the winch-in-place and invert-in-place methods, heat is then circulated through the tube to cure the resin to form a strong bond between the tube and the existing pipe.



Source: EPA, 1996

Figure 2.34 Cures-in-place pipe installation procedure

2.4.2.4 Modified Cross-section Lining

The modified cross-section lining methods include deformed and reformed methods, swagelining TM, and roll down. These methods either modify the pipe’s cross sectional profile or reduce its cross-sectional area so that the liner can be extruded through the existing pipe. The liner is subsequently expanded to conform to the existing pipe's size. During deformed and reformed pipeline renewal, a new flexible pipe is deformed in shape and inserted into the host pipe. While the method of deforming the flexible pipe varies, with many processes referred to as fold and form methods, a typical approach is to fold the new liner into a “ U” shape, reducing the pipe's diameter by about 30 per cent. After the liner is pulled through the existing line, the liner is heated and pressurized to conform to the original pipe shape. Another method of obtaining a close fit between the new lining and existing pipe is to temporally compress the new liner before it is drawn through the existing pipeline. The swagelining TM and roll down processes use chemical and mechanical means, respectively, to reduce the cross-sectional area of the new liner. During swagelining TM and a typical draw-down process, the new liners are heated and subsequently passed through a reducing die. A chemical reaction between the die and liner material temporarily reduces the liner's diameter by 7 to 15 percent and allows the liner to be pulled through the existing pipe. As the new liner cools, it expands to its original diameter. The roll down process uses a series of rollers to reduce the pipe liner's diameter. As in deform-and-reform methods, heat and pressure are applied to expand the liner to its original pipe diameter after it has been pulled through the existing pipe. Unlike CIPP, the modified cross-section methods do not make use of resins to secure the liner in-place. Lacking resin-coated lining, these methods do not have the curing time requirement of CIPP. A tight fit is obtained when the folded pipe expands to the host pipe's inside diameter under applied heat and pressure. As with the CIPP method, dimples are formed at lateral, junctions and similar methods of reconnecting the laterals can be employed. Materials typically used for modified cross-section linings include Polyvinyl Chloride (PVC) and High Density Polyethylene (HDPE).

2.4.3 Maintenance of Machinery and Apparatus for Rehabilitation

Emergency cleaning and a repair are required in case of an emergency response. Therefore, a maintenance engineer should repair machinery and equipment to the original. In addition, he should have enough maintenance and repair materials required (for example pipes, lid, the mounting tube).

Also, he should stock construction materials such as sand, rock crushing, and asphalt for the cave-in repair of roads.

He should ensure that the materials, equipment and facilities, and necessary safety equipment are in standby state at all times.

2.5 PROTECTION OF SEWER SYSTEMS

A sewer may get damaged if other facilities such as water pipe or electric cable work are done beside or at the cross-section of a sewer. Especially, fluctuations due to ground excavation (pile, underground water drops, and pile method) may have a serious impact.

To avoid damage against sewer, the maintenance engineer should do the following:

- Collect related information about the constructions which are planned around the sewer location,
- Advise appropriate construction methods to minimize impact for sewer, and
- If necessary, request to adopt the protective measures for sewer prior to the work commencement.

Typical protective measures are as follows:

- Protection for existing sewer (an example is shown in Figure 2.35)
- Temporary laying of sewage pipe
- Changing sewer material in advance

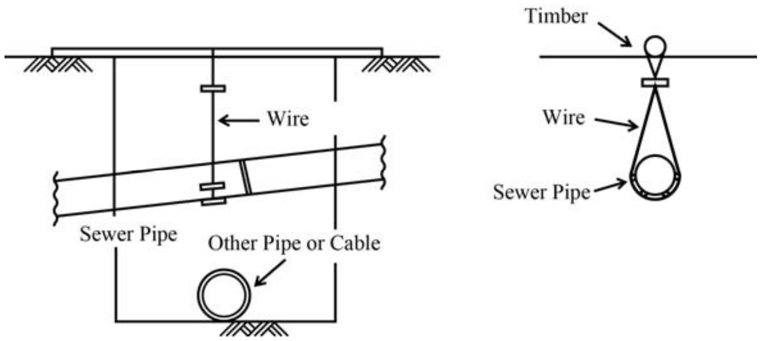


Figure 2.35 Protection method for existing sewer

2.6 PROTECTION AGAINST INFILTRATION AND EXFILTRATION

Infiltration and inflow, while overlooked in many collection systems for decades, have now gained recognition as major defects that can cause failure of a collection system. In most cases, this failure results in hydraulic overloads (too much water) of the collection system or the sewage treatment plant.

In the case of a collection system, hydraulic overloads result in surcharged manholes, overflowing manholes and exposure of community to diseases and pollutants carried by the wastewater in a collection system. This type of failure is also known as a sanitary sewer overflow.

In the case of an STP, infiltration and inflow can result in plant loads exceeding the plant capacity. Bypassing raw sewer to the environment has been the only answer in the past, but this practice is no longer allowed.

2.6.1 Measures against Infiltration of Rainwater

Inflow detection and collection depend upon the type and source of inflow causing the problem. Inflow is water that is not polluted and should not be in a wastewater collection system. Inflow is water that enters a sewer as a result of a deliberate illegal connection or by deliberate drainage of flooded areas into a wastewater collection system.

In many areas the main line portion of the collection system is relatively tight. A major source of infiltration in this situation can be the house service lines. They can be tested for leaks using smoke tests and by development of small cameras and robotic equipment.

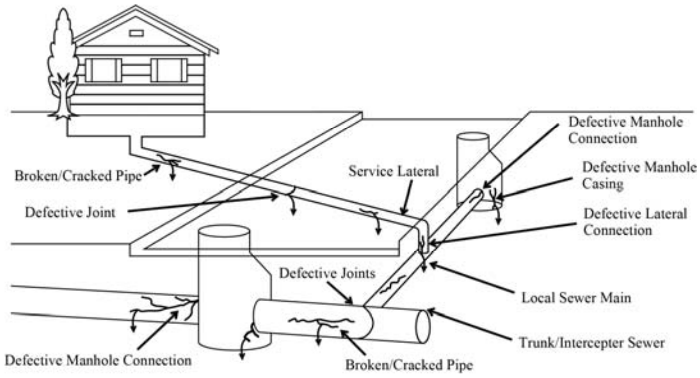
Collection or elimination of inflow/ infiltration depends on the type and location of the source of problem. Typical solutions to inflow/infiltration problems include:

a. Manholes
   - Raise rim elevation by use of grade rings if not located in streets (inflow).
   - Install watertight covers where needed (inflow).
   - Install inflow protection covers (inflow).
   - Seal covers (inflow).
   - Seal or repair barrels (infiltration).

b. Sewer Pipes (Infiltration)
   - Seal segment of damaged pipes and joints.
   - Dig up and replace damaged pipes and joints.
   - Line sewer with a plastic liner and/or fibre liner material.

2.6.2 Measures against Exfiltration of Untreated Sewage

Exfiltration is the leakage of wastewater out of the collection system through broken or damage pipes and manholes (Figure 2.36). All wastewater collection systems, except some constructed in recent years, have many leaks. These systems may exfiltrate wastewater through defective pipe joints and cracks. The wastewater that does exfiltrate may contaminate shallow wells or open ditches where children and pets play. To make an old collection system airtight would be extremely expensive and not very cost-effective. Major points of infiltration or exfiltration in a collection system can be identified by the use of television or smoke testing and can then be corrected.



Source: EPA/600/R-01/034

Figure 2.36 Sewerage leaking locations

The proper selection of corrective or rehabilitation methods and materials depends on a complete understanding of the problems to be corrected, as well as the potential impacts associated with the selection of each rehabilitation method. Pipe rehabilitation methods to reduce exfiltration (and simultaneously infiltration) fall into one of the two following categories:

- External Rehabilitation Methods
- Internal Rehabilitation Methods

Certain conditions of the host pipeline influence the selection of the rehabilitation method. It is therefore necessary to assess these factors to prepare the pipe for rehabilitation. Rehabilitation is proceeded by surface preparation by cleaning the pipes to remove scale, tuberculation, corrosion, and other foreign matter.

The concerned departments, corporation, urban local bodies, town planning authority, jal nigam, etc have to participate in the total sanitation program. These departments should be part of a co-ordination committee constituted at a local level and are required to meet half yearly to plan appropriate co-ordination specific to total sanitation. These meetings however, can be more frequent during specific items such as drought, floods, etc

2.6.2.1 External Sewer Rehabilitation Methods

External rehabilitation methods are performed from above the ground surface by excavating adjacent to the pipe, or the external region of the pipe is treated from within the pipe through the wall. Some of the methods used include:

- External Point Repairs
- Chemical Grouting (Acryl amide Base Gel and Acrylic Base Gel)
- Cement Grouting (Cement , Micro fine Cement, and Compaction)

2.6.2.2 Internal Sewer Rehabilitation Methods

Internal sewer rehabilitation methods are the same as infiltration measures.

2.7 MANHOLES AND APPURTENANCES

Because they are part of the collection system, manholes require the same inspection and attention as the rest of sewer network. When located in streets, these structures are subject to vibrations and pounding of vehicle traffic. Manholes may settle at a different rate than connected sewer, creating cracks in joints. The objectives of manhole inspection are therefore, to determine the proper elevations or grades around the lid, to confirm that the lid is not buried, and to examine structural integrity (look for cracks) of the manhole and its functional capacity. The condition of the pipelines coming into a manhole may be known merely by observing the content and volume of flows from a specific direction.

2.7.1 Inspections and Examinations

Manhole inspection and examination are made by visually inspecting the condition of the cover and the internal parts.

Manhole inspection should be carried out together with the inspection and examination of sewer. It is generally carried out together with the cleaning of the sewer.

Before entering any manhole, adequate safety measures should be taken in accordance with subsection 2.11.1.2.

Safety measures during the work should be formulated giving consideration to traffic safety, oxygen deficiency, poisoning due to toxic gas such as hydrogen sulphide, and so on.

2.7.1.1 Manhole

Damage or wear in the manhole cover obstructs passage and is a risk. The facility manager should inspect the manhole cover for damage, wear, play, non-coincidence of heights of cover and road surface, offset of manhole block, and so on.

Refer to Figure 2.37, Figure 2.38 and Figure 2.39.

Figure 2.37 Wear of cover

Figure 2.38 Offset of manhole block

Figure 2.39 Not coinciding with height of road surface

2.7.1.2 Conditions Inside Manhole

Manhole is an essential facility for operation and maintenance of sewer pipes; it helps operation and maintenance to be performed safely and easily. For smooth flow of wastewater through the sewer pipe, the following are to be properly inspected: scouring of sewer bottom, differential settlement, manhole block, crack in side wall, sediments and condition of mouth of connected sewer pipe.

Inspection should be performed on ground, while examination should be performed by the relevant person entering the manhole and working inside.

The inspection items and their descriptions are given in Table 2.14.

Table 2.14 Inspection and examination items for manhole

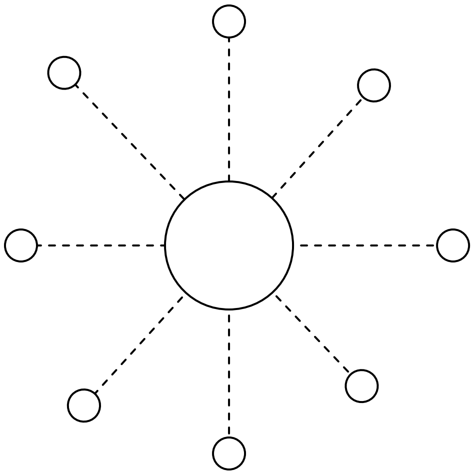
Item inspected		Description of inspection
Exterior condition	Ground surface	a. Check for crack, subsidence, and cave-in b. Check for overflow stream c. Check for any invaded pavement d. Check surrounding condition
	Manhole cover	a. Visual check for backlash, abraded surface, and corrosion (Check if any mark on external or internal surface of cover is erased.) b. Check for any malfunction of float preventive function, locking device, fall preventive function, etc. c. Others (damage on rising spacer, difference in grade of cover and grade ring, damaged grade ring, caved in manhole cover, offset, etc.)
Interior condition	Flow and sediment	a. Check for stagnant water or flow b. Check for any accumulation of sand and soil, pieces of wood, and mortar including remains of construction works and illegal disposals. c. Check for appearance of inverts such as scouring, damage, etc.
	Damage	a. Check steps for corrosion, rattling, and missing items (No.). b. Check blocks for damage, crack, corrosion, gap, and deteriorated caulking. c. Check barrel and base for damage, crack, and corrosion. d. Check for any improper joint of main sewers and laterals. e. Check for any irregular subsidence.
	Infiltration	a. Check for infiltration
Others		a. Check inflow for unacceptable or inferior quality. b. Check for toxic gases or odour.

Source: JASCOMA, 2007

Table 2.15 shows an example of the form for recording inspections.

Table 2.15 Inspection record

Manhole maintenance	Manhole No. - -		
Manhole type	Type no: Specific ( )	Constructed year	FY (______)
		Type of cover	Nodular graphite cast iron (flat, tapered), Gray cast iron, Concrete



Manhole	Fair / Poor
Steps	Total no.
	Fair no. Poor no.
Water depth downstream	cm

No.	Pipe diameter	Type	Depth to base	Condition

Replace cover Month / Year	M/Y /	/	/	/	/	/	/	/	/
Cleaning Month / Year	M/Y /	/	/	/	/	/	/	/	/
Inspection Month / Year Conditions	M/Y /	/	/	/	/	/	/	/	/
	M/Y /	/	/	/	/	/	/	/	/

(Condition)

Cover	a) Wear, b) Backlash, c) Difference in level, d) pavement hiding the manhole, e) Damaged, f) Location unknown
Interior	g) Corrosion, h) Damage base, i) Infiltration, j) Corroded steps, k) Inferior pipe joint, l) Rubbish, m) Odour
Sewer	n) Corrosion, o) Damage, p) Coupling displacement, q) Inadequate inclination, r) Infiltration, s) Roots of trees, t) Silt, soil, and mortar, u) Road subsidence

Source: JASCOMA, 2007

2.7.2 Judgement of Examination Results

Judgement criteria for inspection and examination show ranked levels of abnormal locations, and can be used for judging the need for cleaning and repairs and for selecting repair methods, etc.

Judgement criteria are used to categorize by symptom the abnormal locations detected during inspection and examination, to assess the risk level and their effect level on others, to judge the need for cleaning and repairs and to select repair methods, etc.

2.7.3 Cleaning

Manhole cleaning should be performed by the most appropriate work method that suits the actual conditions of the work location.

In manholes at starting point, junction manholes, and manholes at sharp curve of sewers, sand and silt get deposited and environmental problems such as foul odours occur. For this reason, periodic cleaning is necessary. Moreover, when large debris flows in, it should be removed immediately otherwise there is a possibility of an overflow accident, float-off and dispersion of cover.

Manhole inspection should be generally carried out together with the cleaning of the sewer. The work on the silt and sand in the bottom part should be pursuant to cleaning of the sewer pipe, while the dirt on the side wall should be cleaned by high-pressure jet washing vehicle.

2.7.4 Rehabilitation

Degradation of functions due to damage should be confirmed and necessary repairs and rehabilitation of the manhole should be carried out.

Manhole repair methods may be classified into watertight construction method, lining method, partial repair method (open-cut method), and manhole cover replacement method. (Refer to Sec. 3.37 of the Design Manual)

Before repairs, the objectives of the repairs should be clarified, work conditions studied, and items below should be paid attention to, and then repairs should be carried out.

- If cover is worn out or damaged, it should be replaced immediately.
- If steps are corroded, and if they need to be replaced, they should be replaced with corrosion resistant fittings.

If internal parts of manhole and sewer bottom are damaged or worn out, they should be replaced immediately.

2.8 CROSS DRAINAGE WORKS

For sewer collection system, cross drainage work in an inverted siphon is a typical work. Therefore, in this section, maintenance work is described hereafter.

2.8.1 Inspection and Examination

Inspection of inverted siphon should be carried out by inspection methods similar to those of the manhole (Table 2.16). However, inspection of inverted siphon should be carried out considering the characteristics listed below.

- The inverted siphon pipe is always in full flow, and the inverted siphon chamber in the upstream part is constructed such that suspended substances and sand/silt are likely to accumulate and deposit easily. There are risks of corrosion or gas generation in the facility because of the decomposition of these substances.
- The inverted siphon chamber is provided with a flashboard, and it should be checked to confirm that it is usable.

Table 2.16 Typical inspection items for inverted siphon

Item Inspected	Points Inspected
Flow condition	・Check difference in levels at upper and lower chambers of inverted siphon. ・Check for absence of any suspended debris.
Structural condition	・Check for improper functioning of gate, stop log, etc.

Source: JASCOMA, 2007

2.8.2 Criteria for Judging Examination Results

Judgement criteria for inspection and examination show ranked levels of abnormal locations, and can be used for judging the need for cleaning and repairs and for selecting repair methods. The judgement criteria for inverted siphon should be the same as the judgement criteria for sewer pipe.

2.8.3 Cleaning

The construction of the inverted siphon is such that wastewater always remains in it at all times, so sand, silt and sludge is likely to deposit easily. This requires periodic cleaning so as to prevent overflow and foul odour problems beforehand.

An effective cleaning method should be selected when cleaning the inverted siphon, and work that gives adequate consideration to safety measures should be implemented. Cleaning should be performed at least once a year.

a. Replacing water in the inverted siphon

The submersible pump and generator used for replacing water in the inverted siphon should be selected appropriately considering the influent flow rate and the head, and a replacement plan with adequate margin should be formulated.

b. Cleaning of inverted siphon manhole

The main cleaning methods of sand trap of inverted siphon manhole are vacuum truck cleaning and manual cleaning. Table 2.17 gives the description.

Table 2.17 Cleaning method

Cleaning method	Application
Cleaning by vacuum vehicle	Cleaning of manholes for inverted siphons by means of vacuum vehicles.
Manual cleaning	If a cleaning by vacuum vehicle is difficult, inverted siphons are cleaned by crew getting down into the siphon or by using a crane equipped truck.

Source: JASCOMA, 2007

c. Cleaning of inverted siphon sewer

Inverted siphon sewer should be cleaned together with the cleaning of general sewers. After sucking up the wastewater in the manhole by submersible pump, the manhole on the upstream side should be cleaned, and then the manhole on the downstream side and the insides of the sewer should be cleaned. The ease or difficulty of work depends on the pipe diameter, number of cables and closing equipment, but work should be performed according to sewer cleaning by combining mechanical and manual means. Figure 2.40 shows the cleaning work.

If the head exceeds 20 m, especially powerful vacuum trucks may need to be used.

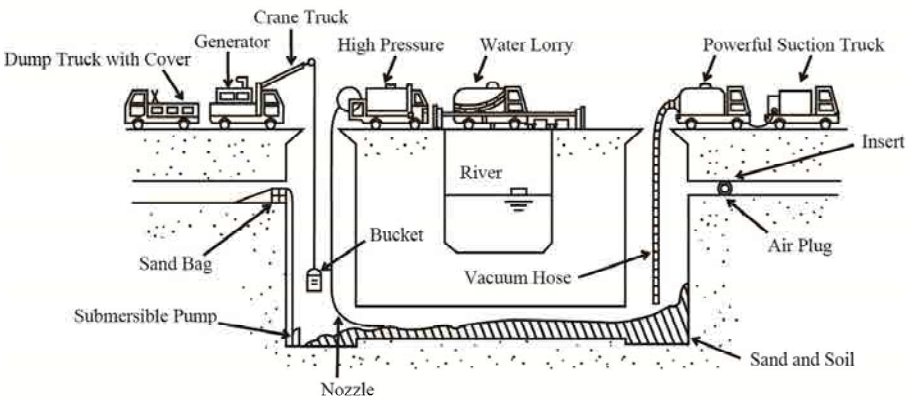


Figure 2.40 Inverted siphon cleaning work

2.9 PRESSURE SEWER

2.9.1 Pressurized Sewers

Pressure sewers are meant for collecting sewage from multiple sources to deliver to an existing collection sewer, and/or to the STP. These sewers are not dependent on gravity.

The principle advantages are the ability to sewer areas with undulating terrain, rocky soil conditions and high groundwater tables as pressurized sewers can be laid close to the ground and anchored well without infiltration. Exfiltration can be quickly detected and corrected. Moreover, this sewer allows smaller diameter pipes and road crossings by CI or DI pipes with trenchless technology to be laid inside a casing pipe and installation without disrupting traffic, without opening trenches across paved roadways, or moving existing utilities, etc.

A disadvantage is the need to ensure unfailing power supply to the grinder pump

2.9.2 Vacuum Sewer System

The vacuum sewer collects sewage from multiple sources and conveys it to the STP. As the name suggests, a vacuum is maintained in the collection system and when a house sewer is opened to atmospheric pressure, sewage and air are pulled into the sewer, whereby the air forms a “plug” in the line, and air pressure pushes the sewage towards the vacuum station. This differential pressure comes from a central vacuum station. These sewers can take advantage of available slope in the terrain, but have a limited capacity to pull water uphill may be to approximately 9 m. A disadvantage is the need to ensure unfailing power supply to the grinder pump.

2.9.3 O&M System

Neither pressurized sewer system nor vacuum sewer system is used in the public sewer systems in India. Therefore, O&M is not explained here. Only system characteristics of pressurized sewer and vacuum sewer are shown in Table 2.18.

Table 2.18 Pressurised sewer and vacuum sewer

	Vacuum sewer	Pressurised sewer
Collection principle	Sewage pulled and conveyed by vacuum force.	Sewage pressurized and conveyed by a grinder pump.
Typical facility configuration	A vacuum valve unit for one or some households, vacuum sewer laterals, and a lift station	A grinder pump unit for one or some households, and pressurized sewer laterals.
Pipe diameter	Typically ϕ 100 to 250 mm	Typically ϕ 32 to 150 mm
Laying depth	Can be laid in a shallow depth without gradient.	Can be laid in a shallow depth.
Topographical	Adequate for flat terrain which can	Applicable for wide range of terrain

	Vacuum sewer	Pressurised sewer
requirements	hold certain degree of vacuum force so that sewage can be pulled, and for densely populated area to some extent.	types.
Power source	Required for lift station	Required for each grinder pump unit.
O&M cost	O&M cost and energy cost for vacuum valve unit and lift station. Generally, higher than that of gravity sewer.	O&M cost and energy cost for grinder pump unit. Generally, higher than that of gravity sewer.

Source: JASCOMA, 2007

2.10 HOUSE SERVICE CONNECTION

House connections or service connections to the public or municipal sewer should preferably be approved by the Maintenance Engineer. It is necessary to ensure that the fittings and pipes in the houses are according to the byelaws or rules or regulations in force. If such byelaws, rules or regulations do not exist, then reference may be made to the relevant IS code of practice. House connections may be of minimum size of 150 mm in diameter and should preferably be connected to the Municipal or Public sewer through a manhole. When “Y or T” connections are allowed, extreme care must be taken when breaking the sewer pipe line and inserting the “Y or T” saddle.

Similarly, the connection to the manhole must be properly done and closed. Care has to be taken so that the brick bats or other materials of construction are not allowed to fall and lie in the manhole. This extraneous material is largely responsible for persistent clogging of the sewer lines.

It should also be ensured that the house fittings are properly trapped not only to prevent the ingress of sewer gases into the houses but also to ensure that large objects do not find their way into the sewers. Similarly, it should be ensured that any liquid or material which is likely to be injurious to the material of the sewer line or to prejudicially interfere with its contents or be a hazard to the workmen engaged in the maintenance of the sewer lines, like very hot water, acids, chemicals, etc., are not allowed.

Release of sewer house connections need to be regulated and done by the ULB approved agency/ plumber in the presence of supervisor in charge of O&M

2.10.1 Inspection and Examination

Inspection of lateral sewer and house inlet (household) should be carried out if deemed necessary from documents and data, and cross connections and mains should be studied. Clogging of lateral sewer and sedimentation of house inlet are the items to be inspected.

Examination of lateral sewer by TV camera should be carried out after high pressure washing of the lateral sewer. The insides of the pipe should be examined by TV camera, and recorded on video tape. TV camera for lateral sewer is used as a direct view camera, and the camera head is pushed by a rod towards the main from the public inlet. Also, there is a method of examination by which the camera head is pushed in by a hard cab tire cable. Figure 2.41 and Figure 2.42 show working diagrams of examination of lateral sewer by TV camera.

Source: EPA, 2003

Figure 2.41 Portable TV system for small-diameter pipe

Source: EPA, 2003

Figure 2.42 Applications of portable TV system in difficult to access locations

- Features of examination of lateral sewer by TV camera
  - If power supply is ensured, the vehicle loaded with TV camera can work even in locations where access for humans is not possible.
  - By connecting the monitor to the vehicle loaded with TV camera, character data can be displayed on the monitor screen.
  - The standard examination distance per location during examination of lateral sewer by TV camera is 5 m maximum.
- Procedure for examination of lateral sewer by TV camera is shown in Figure 2.43.

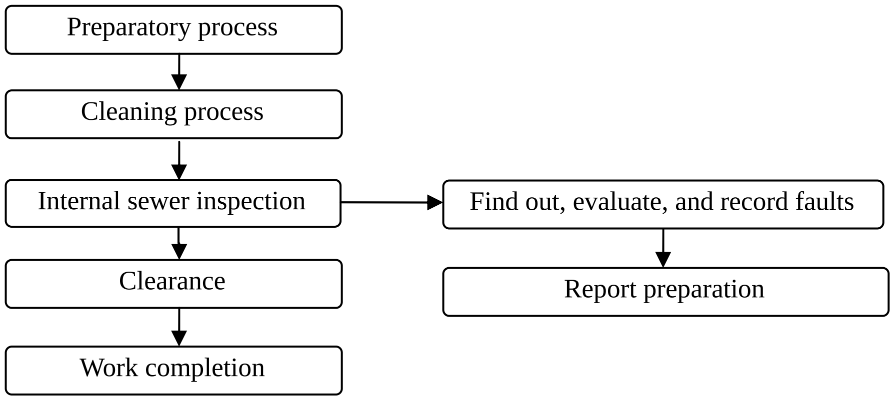


Figure 2.43 Work procedure for examination of lateral sewer by TV camera

2.10.2 Criteria for Judging Examination Results

These criteria should adhere to the inspection criteria for sewer pipes.

2.10.3 Cleaning

Cleaning should conform to the cleaning procedure for sewer pipes.

2.10.4 Rehabilitation

Rehabilitation should conform to the rehabilitation procedure for sewer pipes.

2.11 SAFETY PRACTICES

You are in an occupation that has an overall accident frequency rate that is relatively higher than any other industry. Your employer has the responsibility of provide you with a safe place to work. But you, as the operator have the overall responsibility for your treatment plant and must ensure it’s a safe place to work. This can only be done by constantly thinking of safety and working safely.

You have the responsibility of protecting yourself and other plant personnel or visitors by establishing safety procedures for your plant and then ensuring they are followed. Train yourself to analyze jobs, work areas and procedures from a safety standpoint. Learn to recognize potentiality hazardous actions or conditions. When you do recognize a hazard, take immediate steps to eliminate it through corrective action. If correction is not possible, guard against the hazard by proper use of warning signs and devices/by establishing and maintaining safety procedures, as an individual, you can be held liable for injuries or property damage which results from an accident caused by your negligence.

Remember “accidents don’t happen - they are caused!” Behind every accident there is a chain of events which leads to an unsafe act unsafe condition/or a combination of both.

Accidents may be prevented by using common sense, applying a few basic safety rules and acquiring a good knowledge of the hazards unique to your job as a plant operator.

2.11.1 Accidents related to Sewer Facilities

2.11.1.1 Need for Traffic Control

The primary function of streets is to provide for the movement of traffic. A common secondary use within the right-of-way of streets is for the placement of public and private utilities such as sanitary sewers. While the movement of traffic is very important, streets need to be constructed, reconstructed, or maintained, and utility facilities need to be repaired, modified, or expanded Consequently, traffic movements and street or utility repair work must be regulated to provide optimum safety and convenience for all.

Working in a roadway represents a significant hazard to a collection system operator as well as pedestrians and drivers. Motor vehicle drivers can be observed random things like reading, talking on cell phones, etc., rather than concentrating on driving. At any given time of the night or day, a certain percentage of drivers can be expected to be driving while under the influence of drugs or alcohol. Given the amount of time collection system operators' work in traffic while performing inspection, cleaning, rehabilitation, and repairs, the control of traffic is necessary if we want to reduce the risk of injury or death while working in this hazardous area. The purpose of traffic control is to provide safe and effective work areas and to warn, control, protect, and expedite vehicular and pedestrian traffic. This can be accomplished by appropriate and prudent use of traffic control devices.

Most states, counties, and cities have adopted regulations to control traffic and reduce the risk under different circumstances. This section illustrates examples of traffic control which may or may not meet the specific requirements of the laws in your geographical area, but should serve to make you aware of various aspects of traffic control.

At any time traffic is affected, appropriate authorities in your area must be notified before leaving for the job site. These could be state, country or local depending on whether it is a state, country or local street. Frequently, a permit must be issued by the authority that has jurisdiction before traffic can be diverted or disrupted. In some cases, traffic diversion or disruption may have an impact on the emergency response system in your area, such as access by fire or police, and so these agencies may be involved as well in most cases, you will need to plan ahead to secure permits and notify authorities. This may mean only a phone call or two or it could mean several days' or weeks' advance planning if you need to make extensive traffic control arrangements.

Upon arrival at the job site, look for a safe place to park vehicles. If they are to be parked in the street to do the job, route traffic around the job site before parking vehicles in the street. If practical, park vehicles between oncoming traffic and the job site to serve as a warning barricade and to discourage reckless drivers from ploughing into operators.

2.11.1.2 Safety Measure to be taken before any manhole entry

All workers assigned to enter sewer manholes should be provided with proper safety equipment. Following safety equipment is recommended:

- Approved gas detector (Properly calibrated)
- Fresh air blower
- Safety harness, rope and tripod safety system
- Approved hard hat

Following guidelines may be adopted to ensure safety in manhole:

a. Oxygen content must be at least 19.5% in the confined space of the manhole measured at all levels (bottom, middle and top). Safe oxygen level is considered if it ranges between 19.5% and 21%. Nobody should enter the manhole if oxygen level is below 19.5% and more than 21%.

b. Ventilate the sewer line by opening at least two or three manholes on both sides where work is to be carried out. This is mandatory where adequate blowers for ventilating sewers are not available. The manholes should be opened at least one hour before the start of operation. The opened manhole must be properly fenced or barricaded to prevent any person specially children from accidentally falling into the sewer. Dummy cover with BRC welded fabric or wire-net may be used.

c. Fresh air blower ventilation system should be used as far as practicable. It is desirable to operate blowers for at least 30 minutes before start and during the cleaning operation.

d. Measure gas inflammability in manholes using detector.

e. Presence of toxic gases may be tested before entry of a person in manhole/ sewer line and also in between if the operations are for longer period.

f. All workers should use safety harness and life line before entering the sewer line. At least one support person at the top must be provided for each person entering the manhole. The person entering the manhole/ sewer line must be monitored using signal/camera /CCTV etc., throughout the operation period.

g. Structural safety of manhole rungs or steps must be tested before entering the manhole. Portable aluminium ladder must be available during the work period where necessary. The portable ladder must be properly seated or fixed during use.

h. Ensure that no material or tools are located near the edge which can fall into the manhole and injure the work-men.

i. Lower all tools to the workmen in a bucket fixed with rope and pulley.

j. Lighting equipment used during sewer cleaning must be explosion and fire-proof.

k. Caution signboards must be displayed around open manholes during working period.

l. Smoking, lighting open flames or gadgets producing sparks must be prohibited inside the manhole as well as in the immediate vicinity of open manholes.

m. All workers entering the manhole must be provided with protective gear and proper equipment. Use of portable gear and equipment must be monitored strictly.

n. Gas masks for respiratory protection must be available for use by the workers. The workers must be trained to use the gas masks properly.

o. Sewer inspection and examination guidelines referred to in Section 2.2.5 may be followed as and when necessary.

(Honourable Supreme Court of India has directed the need for proper equipment, adequate protection and safety gear to sewer workers who enter into the manhole for cleaning blocks. Ref: Delhi Jal Board versus National Campaign for Dignity & Rights of Sewerage and Allied Workers and others.). Please refer to Appendix 9.3 of this manual.

When entering a large sewer system, you may be required to use special equipment. The type of equipment might include atmospheric monitoring devices with alarms. In the event of a sudden or unpredictable atmospheric change, an emergency escape breathing apparatus (EEBA) with at least a 10-minute air supply should be worn for escape purposes.

2.11.2 Measures against Accidents

Safety measures are dealt with in Chapter 9.

2.11.3 Information to Prevent Accidents and Records

Information to prevent accident and records are dealt with in Chapter 9.

2.12 TROUBLESHOOTING

Refer to appendices for troubleshooting for sewerage collection system.

2.13 SUMMARY

The purpose of maintenance of sewerage collection system is to minimize stoppage of functions. The following cycle should be adhered to:

O&M engineers find out problems related to their sewer system based on information obtained from inspections or examinations on the facilities. To solve the problems, they need to make a decision on rehabilitation actions considering prioritization of each facility.

When the facilities are rehabilitated, records of inspections as well as those of rehabilitation should be kept.

The following cycle (Figure 2.44) is regarded as essential to achieve the goal of sewer system O&M: “Inspection”, “Condition assessment”, “Decision making on rehabilitation actions”, “Rehabilitation”, and “Next inspection.”

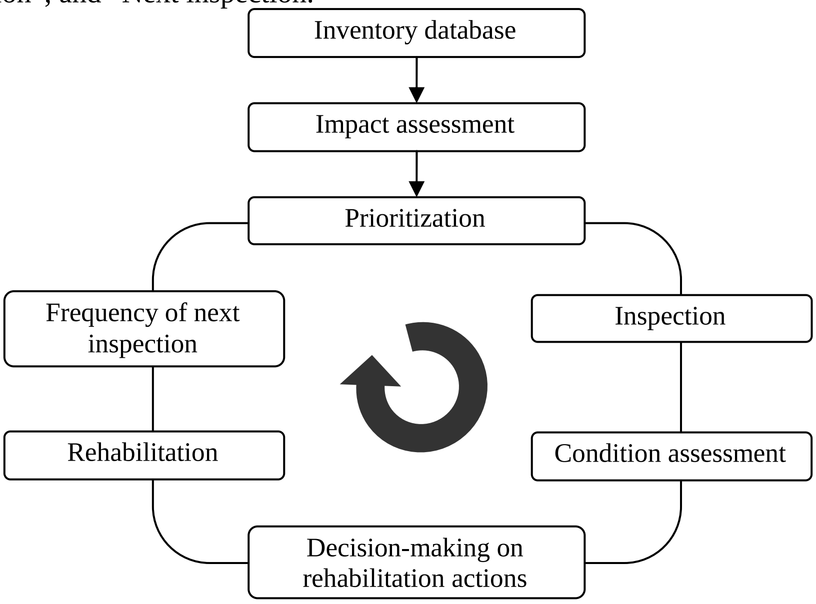


Figure 2.44 O&M cycle

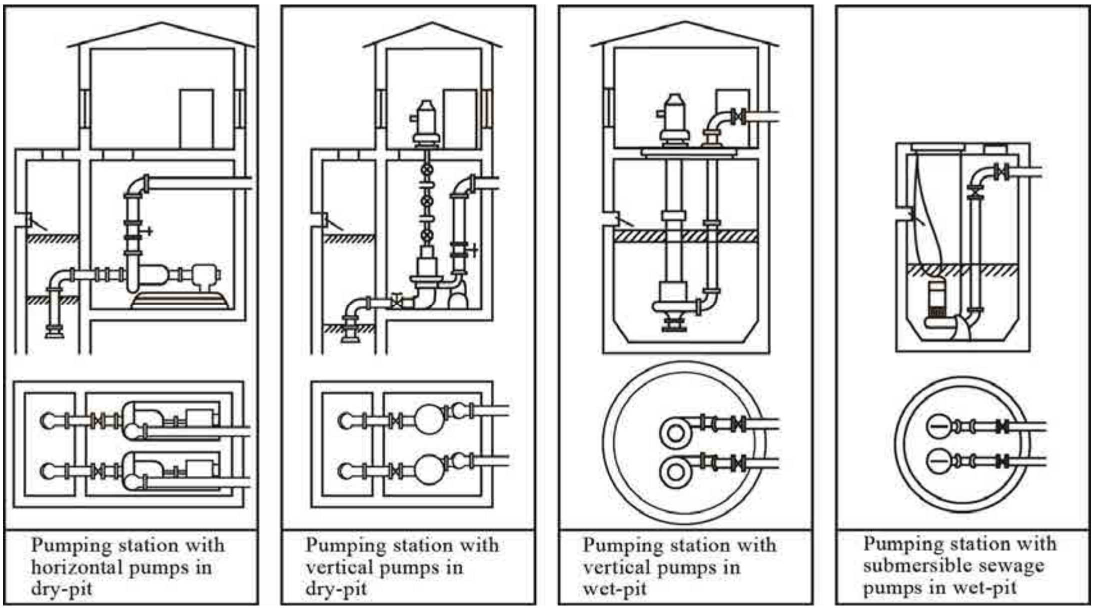
CHAPTER 3 PUMPING STATION

3.1 INTRODUCTION

Pumping stations handle sewage either as in-line for pumping the sewage from a deeper sewer to a shallow sewer or for conveying to the treatment plant or for outfall pumping. They are required where low lying development areas cannot be drained by gravity to existing sewerage infrastructure, and/or where development areas are too far away from available sewerage infrastructure to be linked by gravity means. Proper O&M of pumping systems applies to all the components of such systems.

3.2 TYPES AND STRUCTURE OF PUMPING STATIONS

The type of pumping stations can be (a) Horizontal pumps in dry pit, (b) Vertical pumps in dry pit, (c) Vertical pumps in suction well and (d) Submersible pumps in suction sump. All these types include a sewage receiving sump which is called suction sump or wet well and various types of pump arrangements as shown in Figure 3.1.



(a) (b) (c) (d)

Source: CPHEEO, 1993

Figure 3.1 Typical dry-well and wet-well installations

3.2.1 Dry Pit

The size of the dry pit should be adequate for the number of pumps planned and should be such as to handle the sewage load at the desired pumping capacity. Allowance should also be made for future requirements so that additional or larger pumps can be installed.

In this configuration, two pits (dry-pit and wet-pit) are required: one to hold the fluid, and one to house the pumps and appurtenances. This option is required for fluids that cannot be primed or conveyed long distances in suction piping. It is typically used to pump large volumes of raw sewage, where uninterrupted flow is critical and sewage solids could clog suction piping. It also is used to pump solids in pipe galleries between digesters or other solids-handling equipment. While construction costs may be higher and a heating, ventilation, and cooling system is necessary when installed below grade, this configuration is best for O&M activities because operators can see and touch the equipment.

3.2.2 Suction Sump or Wet Well

Sewage sump is a compartment or tank in which sewage is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well.

Sewage sump design depends on the type of pumping station configuration (submersible or dry-well) and the type of pump controls (constant or variable speed). Wet-wells are typically designed large enough to prevent rapid pump cycling but small enough to prevent a long detention time and associated odour release.

Sewage sumps should always hold some level of sewage to minimise odour release. Bar screens or grinders are often installed in or upstream of the wet-well to minimise pump clogging problems.

Instead of manually operated screens at the bottom which requires the staff to get down into the screen sump, it is better to install mechanical bar screens which can automatically remove the screenings and lift the same above ground level safely. There can also be two such screens one after the other for coarse screenings and fine screenings. This will require rectangular channels to maintain longitudinal non-turbulent linear flow.

3.2.3 Lift Stations

In general, lift stations are invariably used in gravity sewer network where depth of cut poses a problem in high water prone areas. The procedure is to sink a wet well on the road shoulder or an acquired plot after the shoulder and divert the deeper sewer there. The submersible pump set will lift the sewage and discharge it to the next on line shallow sewer. This is a very useful practice in such locations.

Equipment located in the wet well should be minimised, including suction and discharge valves, check valves, or other equipment that require routine, periodic maintenance. This equipment can be located in small equipment manholes located adjacent to the wet well to facilitate accessibility and maintenance for the operator.

3.2.4 Operation and Maintenance

Pumping machinery and pumping station are very important components of sewerage systems. Pumping machinery is subjected to wear, tear, erosion and corrosion due to its nature of functioning, and therefore it is vulnerable to failures. Generally, failures or interruptions are mostly attributed to pumping machinery rather than any other component. Therefore, correct operation and timely maintenance and upkeep of pumping stations and pumping machinery are of vital importance. Sudden failures can be avoided by timely inspection, follow up actions on observations of inspection and planned periodical maintenance. Downtime can be reduced by maintaining inventory of fast moving spare parts.

Obviously due attention needs to be paid to all such aspects for efficient and reliable functioning of pumping machinery.

3.2.4.1 Operation of the Pumps

The following points should be observed while operating the pumps.

a. Dry running of the pumps should be avoided.

b. Centrifugal pumps should be primed before starting.

c. Pumps should be operated only within the recommended range of the head-discharge characteristics of the pump.

   – If pump is operated at a point away from duty point, the pump efficiency normally reduces.

- Operation near the shut-off point should be avoided, as it causes substantial recirculation within the pump, resulting in overheating of water in the casing and consequently, overheating of the pump.

d. Voltage during operation of pump-motor set should be within ±10% of rated voltage. Similarly, current should be below the rated current shown on the name plate of the motor.

e. When parallel pumps are to be operated, the pumps should be started and stopped with a time lag between two pumps to restrict change of flow velocity to minimum and to restrict the dip in voltage in the incoming feeder. The time lag should be adequate to allow the head on the pump to stabilise, as indicated by a pressure gauge.

f. When the pumps are to be operated in series, they should be started and stopped sequentially, but with minimum time lag. Any pump next in sequence should be started immediately after the delivery valve of the previous pump is even partly opened. Due care should be taken to keep open the air vent of the pump next in sequence, before starting that pump.

g. The stuffing box should allow a drip of leakage to ensure that no air passes into the pump and that the packing gets adequate water for cooling and lubrication. When the stuffing box is sealed with grease, adequate refill of the grease should be maintained.

h. The running of the duty pumps and the standby pumps should be scheduled so that no pump remains idle for a long period and all pumps are in ready-to-run condition. Similarly, unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously.

i. If any undue vibration or noise is noticed, the pump should be stopped immediately and the cause for vibration or noise should be checked and rectified.

j. Generally, the number of starts per hour shall not exceed four. Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contact. Although overloading lasts only for a few seconds, it reduces the life of the equipment.

k. Troubles in a sewage pumping station can be mostly traced to the design stage itself. This is all the more true when too much grit is likely to come into the sewage pumping stations from sewages at monsoon time, which is difficult to handle. Hence sewer collection system should not be allowed to collect any storm water from the roads.

3.2.4.2 Undesirable Operations

The following undesirable operations should be avoided.

a. Operation at higher head

A pump should never be operated at a head higher than the maximum recommended head otherwise such operation may result in excessive recirculation in the pump, and overheating of the water and the pump. Another problem that arises if a pump is operated at a head higher than the recommended maximum head is that the radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft which may cause failure of the pump shaft. As a useful guide, appropriate marking should be made on the pressure gauge. Efficiency at a higher head is normally low so such an operation is also inefficient.

b. Operation at lower head

If a pump is operated at a lower head than the recommended minimum head, the radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft which may cause failure of the pump shaft. As a useful guide appropriate marking should be made on both pressure gauge and ammeter. Efficiency at a lower head is normally low, so such an operation is also inefficient.

c. Operation on higher suction lift

If a pump is operated on suction lift higher than the permissible value, pressures at the eye of impeller and the suction side fall below vapour pressure. This results in flashing of water into vapour. These vapour bubbles collapse during passage, resulting in cavitation in the pump, causing pitting on the suction side of impeller and casing, and excessive vibrations. In addition to mechanical damage due to pitting, pump discharge also reduces drastically. Typical damage to impeller and sometimes to the casing is shown in Figure 3.2.

Source: http://greathub.hubpages.com/hub/piping-and-pipes#

Figure 3.2 Typical cavitation damage of an impeller

d. Operation of the pump with low submergence

Minimum submergence above the bell-mouth or foot valve is necessary so as to prevent entry of air into the suction of the pump, which gives rise to the vortex phenomenon, causing excessive vibration, overloading of bearings, reduction in discharge and in the efficiency. As a useful guide, the lowest permissible water level should be marked on the water level indicator. Usually the pump manufacturer indicates the minimum height of submergence.

e. Operation with occurrence of vortices

If vibration continues even after taking all precautions, vortex may be the cause. Vortex should be stopped by using anti vortex fittings as described in Part A of the manual: “Pumping-station maintenance.”

A well-planned maintenance program for pumping systems can reduce or prevent unnecessary equipment wear and downtime. (The following maintenance information applies to both sewage and solids pumping systems.)

The following is a maintenance checklist for a basic pumping-station:

- Check the wet-well level continuously (whenever necessary).
- Record each pump’s “run time” hours (as indicated on the elapsed-time meters) at least once in a day and confirm that the pumps’ running hours are equal.

- Ensure that the control-panel switches are in their proper positions.
- Ensure that the valves are in their proper positions.
- Check for unusual pump noises.
- At least once a week, manually pump down the wet well to check for and remove debris that may clog the pumps.
- Inspect the float balls and cables and remove all debris to ensure that they operate properly. Untangle twisted cables that may affect automatic operations.
- If a pump is removed from service, adjust the lead pump selector switch to the number that corresponds to the pumps remaining in operation. (This allows the lead pump levels to govern the operating pump's starts and stops.).

3.2.4.3 Piping and Appurtenance Maintenance

Properly maintaining pumping-station pipelines and other appurtenances can minimize pump loads. Excessive head losses on either the suction or discharge side of a pump can increase energy use and the wear rate and consequently, the O&M costs. Excessive head losses also may lead to process or treatment problems because solids move slower, so the proper solids balance is not maintained. Operators can monitor head losses by routinely checking the pressure gauges on both sides of the pumps.

When operators notice excessive head losses (indicated by a pressure drop on the suction side of the pump or an increase in pressure on the discharge side), they should determine whether the losses are a result of partial clogging, a restriction somewhere in the line, or materials built up on the pipe wall. To find clogs, operators should start by checking the pressure at various points in the suction and discharge piping, and look for spots with abrupt head loss (such as valves or other constrictions). If something is caught in a valve or other appurtenance, the operator should stop the pump and physically open out the valve head, remove the blockage. In smaller pumps, it is easier to remove the entire valve, disassemble and remove blockage, reassemble and refit. During such time, other pumps shall be run. Scum build-up problems typically are addressed via source control (for instance, by installing grease traps in the collection system at locations suspected or known to generate grease, such as restaurants, etc.).

3.3 GATES, VALVES AND ACTUATORS

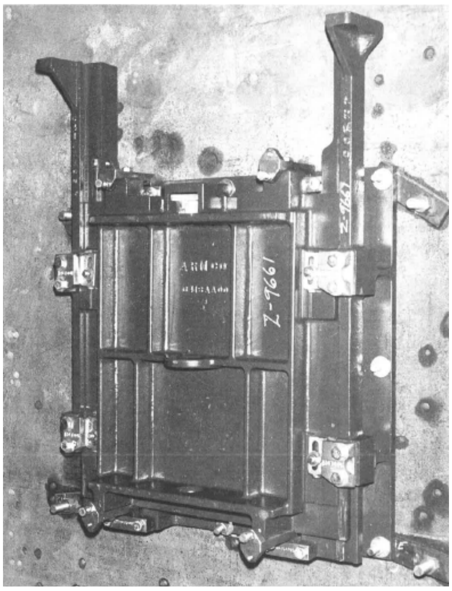
3.3.1 Sluice Gate

A sluice gate (Figure 3.3) is traditionally a wooden or metal plate which slides in grooves in the sides of the channel. Sluice gates are commonly used to control water levels in sewerage treatment plants.

Attention should be paid to the following points for proper operation:

a. Test for proper operation

Operate inactive sluice gates by smearing grease on stem threads.



Source: EPA, 2008

Figure 3.3 Sluice gate

b. Clean and paint

Clean sluice gate with wire brush and paint with proper corrosion-resistant paint.

c. Adjust for proper clearance

For gates seated against pressure, check and adjust top, bottom, and side wedges until each wedge applies nearly uniform pressure against gate in the closed position. This shall be done by the manufacturer and not the operator.

d. Check for the following:

- Ensure unobstructed operation of gate and headstock.
- Ensure that the spindle is not touching the stem guide.
- Remove foreign matter like paint, concrete, etc. in the fully open position of gate.

e. Do's for sluice gates

- Operate the gate at least once in every three months.
- Check the nuts of all construction and foundation bolts once in a year. Tighten the bolts, if loose.
- Examine the entire painted surface for any signs of damage to the protective paint.

f. Don'ts for sluice gates

- Do not remove lock plates until the gate has been properly installed.
- Do not keep the gate out of operation for more than three months.
- Do not forget to set the stop nut in the correct position.
- Do not disturb the adjustment of wedge block bolts/studs.
- Do not over torque the crank handle/hand wheel.

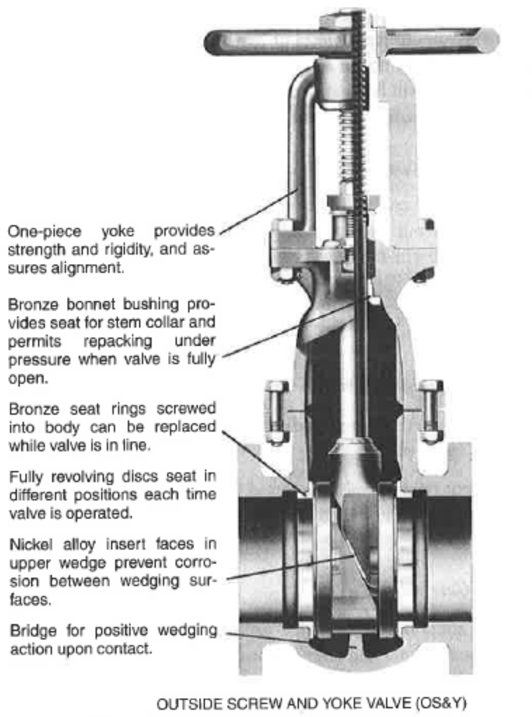
3.3.2 Valve

On the delivery side of centrifugal pumps, a non-return valve is necessary to prevent back-pressure from the delivery head on the pump, when the pump is shut off. To avoid water-hammer, which is likely to be caused by the closure of the valve, the valve may be provided with an anti-slam device, which may be either a lever and dead-weight type, a spring-loading type or the dash pot type.

Pumps may be run in parallel operation with different permutation of the standbys. Isolation valves would be needed to isolate those pumps which are to be idle. Generally, the isolating valves are gate valves, which should preferably be of the rising stem type, since this type offers the advantage of visual indication of the valve-position. For exterior underground locations, gate valves are generally used.

3.3.2.1 Gate Valve

A gate valve is a valve that opens by lifting a round or rectangular gate/wedge out of the path of the fluid (Figure 3.4).The distinct feature of a gate valve is that the sealing surfaces between the gate and seats are planar. The gate faces can form a wedge shape or they can be parallel. Typical gate valves should never be used for regulating flow, unless they are specifically designed for that purpose.



Source: EPA, 2008

Figure 3.4 Gate valve

Gate valves require the following maintenance:

a. Replace packing

Modern gate valves can be repacked without removing them from service. Before repacking, open the valve wide. This prevents excessive leakage when the packing or the entire stuffing box is removed. It draws the stem collar tightly against the bonnet bushing on a rising stem valve.

b. Operate valve

Operate inactive gate valves to prevent sticking.

c. Lubricate gearing

Lubricate gate valves as recommended by manufacturer. Lubricate thoroughly any gearing in large gate valves. Wash open gears with solvent and lubricate with grease.

d. Lubricate rising stem threads

Clean threads on rising stem gate valves and lubricate with grease.

e. Lubricate buried valves

If a buried valve works hard, lubricate it by pouring oil down through a pipe that is bent at the end to permit oiling the packing follower below the valve nut.

3.3.2.2 Non-Return Valve (Check Valve)

Normally, a check valve is installed in the discharge of each pump to provide a positive shutoff from force main pressure when the pump is shut off and to prevent the force main from draining back into the wet well.

The most common type of check valve is the swing check valve which is shown in Figure 3.5. This valve consists of a valve body with a clapper arm attached to a hinge that opens when the pump starts operating and closes to seat when the pump is shut off.

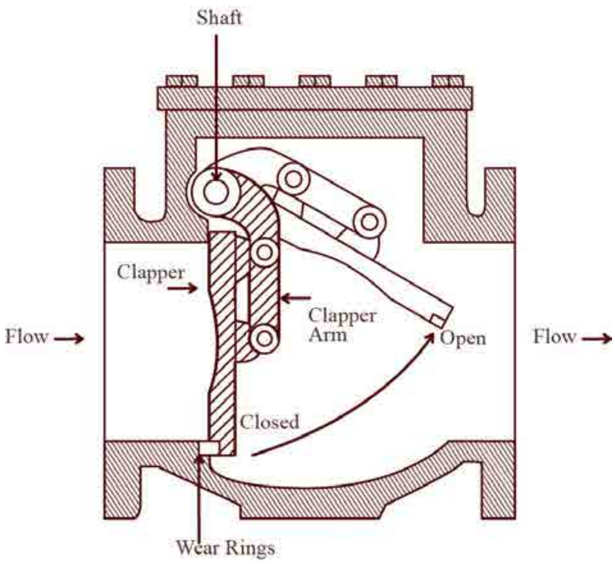


Figure 3.5 Check valve

Check valves must close before the water column in the pipe reverses flow; otherwise, severe water hammer can occur when the clapper arm slams against the valve body seat. If this occurs, an adjustment of the outside weight or spring is usually required. A traditional clapper type of check valve has a lever on the extended shaft which allows adjustment of the weight on the arm or spring to vary the closing time. Wear occurs within the valve primarily on the clapper hinge-and-shaft assemblies and should be checked annually for looseness.

Preventive maintenance (To be done only by the manufacturer)

a. Inspect Clapper Facing

Open valves to observe condition of facing on swing check valves equipped with neoprene seats on clapper.

If metal seat ring is scarred, dress it with a fine file and lap with fine emery paper wrapped around a flat tool.

b. Check Shaft Wear

Check shaft wear on balanced disc check valve since disc must be accurately positioned in the seat to prevent leakage.

3.3.2.3 Non-Return Valve (Ball Type)

Non-return valve (Figure 3.6) is depending on a light weight and suitable coated ball moving inside the flowing pipe to occupy an elevated angular position while the fluid is in pumping and dropping back to close the reverse flow through the pipe. Because it is a sphere sitting over a circular opening, it is expected to seat properly and seal the reverse flow. The material of the ball, the coating and its sturdiness against dents caused by the slide are important matters. The ball is replaced by opening the top flange after switching off the pump. This can be installed in any position, vertical or horizontal.

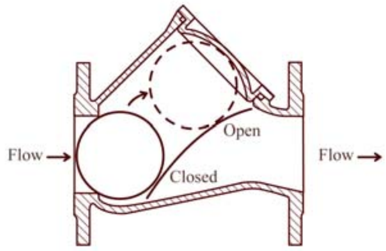


Figure 3.6 Typical ball type check valve

When flow occurs, the ball is lifted into the angular piping and is held there because its weight is lighter than the sewage and the velocity of flow. When the flow stops, it slides back and seals.

3.3.2.4 Butterfly Valve

Butterfly valves are another type of valve that have been successfully used as suction and discharge isolation valves in pumping stations. They are frequently used in sewage plants where waste streams with a high solids content are encountered, such as in sludge pumping systems.

A butterfly valve consists of the valve body and a rotating disc plug that operates through 90 degrees.

This is usually a disc rotated by 90 degrees by external handle. In the open position, the disc is in line with the flow. In the closed position, the disc is at 90 degrees to the flow and it stops the flow. Usually, the axis is vertical although horizontal axis arrangement may also be used in smaller sizes. The closing and opening can be manual or mechanized. The butterfly valves occupy less space and are generally preferred for pipe sizes larger than 150 mm.

Many agencies specify butterfly valves as opposed to gate valves because they are less susceptible to plugging.

Butterfly valves require the following preventive maintenance to be done by the manufacturer:

a. Adjust gland

The adjustable gland holds the plug against its seat in the body and acts through compressible packing, which functions as a thrust cushion.

Keep gland tight enough at all times to hold plug in contact with its seat. If this is not done, the lubricant system cannot function properly, and solid particles may enter between the body and plug and cause damage.

b. Lubricate all valves

Apply lubricant by removing lubricant screw and inserting stick of butterfly valve lubricant for stated temperature conditions.

Be sure to lubricate valves that are not used often to ensure that they are always in operating condition. Leave lubricant chamber nearly full so that extra supply is available by turning screw down. Use lubricant regularly to increase valve efficiency and service, promote easy operation, reduce wear and corrosion, and seal valve against internal leakage.

3.3.3 Actuators

These are replacements for physical operation by the operators. Actuators are used for automation of valves. An actuator rotates the valve spindle or lifts and drops the same.

a. Electric geared motor actuator

The actuator consists of a rotor stator unit driving an output shaft through a single stage worm reduction gear, which incorporates an automatic mechanical device for changing manual drive to power drive. The actuator includes a travel limit switch unit and a torque switch unit, and is of totally enclosed construction. When power fails, electric motor driven gear actuators retain their positions. When power supply returns, pay attention how the valves move.

Electric motor driven gear actuator is shown in Figure 3.7.

Figure 3.7 Electric motor driven gear actuator

b. Solenoids

Solenoids are the most common actuator components. Basically, it consists of a moving ferrous core (a piston) that moves inside wire coil. Normally the piston is held outside the coil by a spring. When a voltage is applied to the coil and current flows, the coil builds up a magnetic field that attracts the piston and pulls it into the centre of the coil. The piston can be used to supply a linear force. Diaphragm valve have small holes on it. The holes should be free from clogging by debris otherwise the diaphragm may not open.

c. Pneumatics

Pneumatic systems are very common, and have much in common with hydraulic systems with a few key differences. The reservoir is eliminated as there is no need to collect and store the air between uses in the pneumatic system. Also because air is a gas, it is compressible and regulators are not needed to recirculate flow; however, since the gas is compressible, the systems are not as stiff or strong.

In general, the pneumatics are liable to cause accidents such as when the air hose suddenly pull out of the hose clamp and jets high pressure air on persons nearby, and should normally be avoided. The electric geared motor type is preferred.

Pneumatic valve is shown in Figure 3.8.

Figure 3.8 Pneumatic valve

d. Hydraulic system

Actuator (hydraulic motor and hydraulic cylinder) is operated by hydraulic fluids (hydraulic oil), which is pressurised by hydraulic pump driven by an electric motor. Smooth movement and variable speed can be achieved. Moreover, the installed relief valve can prevent the system from breakdown. It should be noted that hydraulic oil leaks as pressure increases. Check for oil leakage regularly. Hydraulic system should be kept clean because it is vulnerable to dust or rust. Take precautions to avoid fires because the hydraulic oil is combustible.

In all cases, preventive maintenance by manufacturer shall be done periodically and a wall chart exhibited on site.

3.4 SCREEN

Screenings in sewage from the incoming sewer at the depth below ground level need be separated and lifted above ground level and removed there from either by mechanical or manual method.

3.4.1 Types of Screens

3.4.1.1 Coarse Screens

Coarse screens are usually bar screens consisting of vertical or inclined bars spaced at equal intervals across a channel through which sewage flows. The openings are usually 25 mm. Hand-cleaned screens are usually inclined at 45 degrees to the horizontal.

3.4.1.2 Medium Bar Screens

Medium bar screens have clear openings of 12 mm.

3.4.1.3 Fine Screens

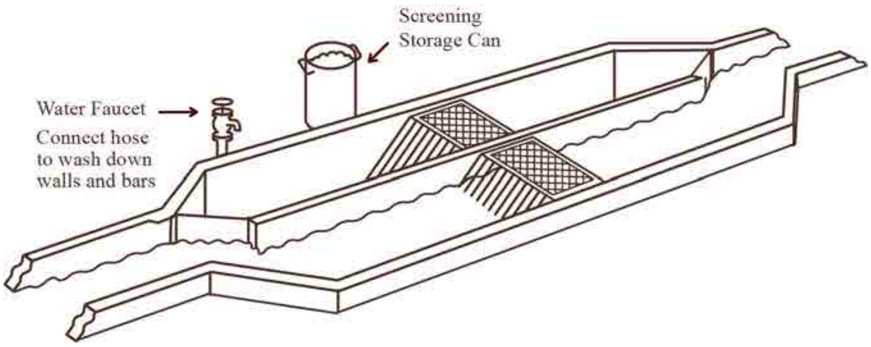
Fine screens are mechanically-cleaned devices. Fine screens may be of the drum or disc type, mechanically cleaned and continuously operated. They are also used for protecting beaches where sewage without any treatment may be discharged into the sea for disposal by dilution.

3.4.2 Screenings Removal Method

3.4.2.1 Manual Bar Screen

Hand cleaned screens should be cleaned as often as required to prevent backing up of sewage.

A manually-cleaned bar screen is shown in Figure 3.9.



Source: EPA, 2008

Figure 3.9 Manual bar screen

The following are important for O&M of manual bar screen:

a. Preventive maintenance for checking and repairing the following once a week

- Check whether the standing platform is at least 2 m wide with the first 1 m as slotted. An example of a risky platform is presented in Figure 3.10, in which there is no space for the operator to stand after he has lifted and dumped screenings on it. Because of the lack of space, he may move backwards and fall into the sewage channel. Also, screens should be inclined to the horizontal by an angle of 60 degrees or more, otherwise, the operator has to bend forward. The rear side of the platform should have handrails. If handrails are not provided, enter this point in the site book.
- Check the condition of ladders and paint them periodically.
- Verify that there are no broken metal parts that protrude outside.
- Once a month check the rigidity of handrails.
- Verify the platform for its sturdiness by gently setting the foot on it.

Figure 3.10 An example of risky platform

Verify that the lighting is not in front or behind the operator. It should be above the operator, at least 2.5 m high and mounted on the sidewall.

These lights should not have local on-off switches.

Verify that the operator platform and slotted platform have 3-m head room and roof so that the operator is not drenched and he can lift the cleaning rake freely.

b. Regular maintenance on a daily basis and repairs

- Verify that the screen rods have not broken loose.
- Verify that the cleaning rake is well washed in running water after each use.
- Verify that gum boots are kept inside a locker covered with mesh.
- Verify that disposable gloves are available for all 3 shifts and a stock of one month is available.
- Verify that helmet is available.

c. Operation

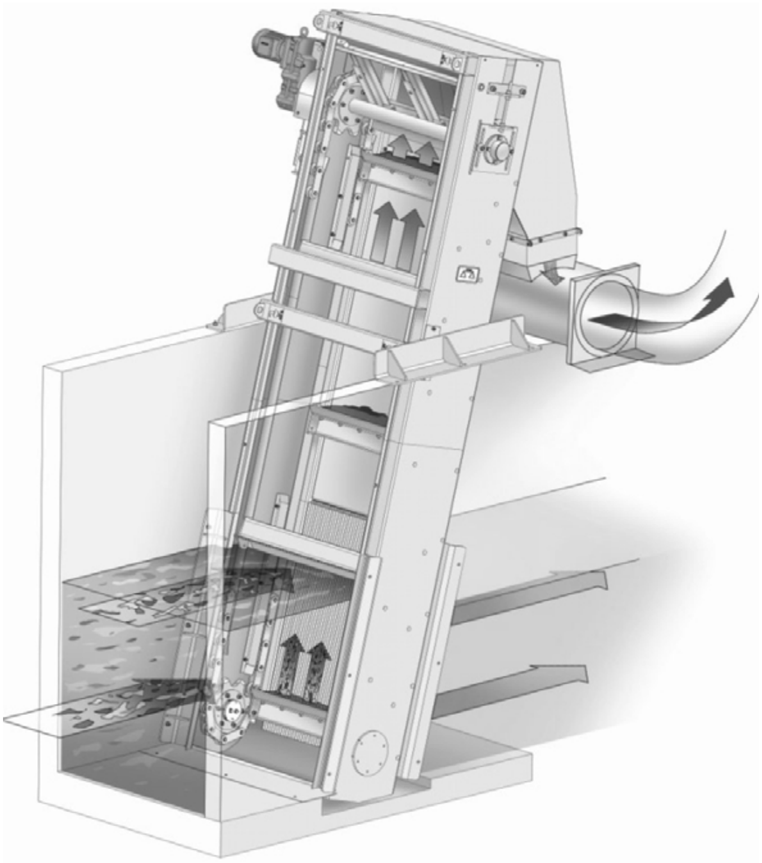
- Before daily operation, verify all the above. If these points are not met, do not enter the screen area. Enter all missing items in the site register.
- If all items are in order, do the cleaning once in four hours in each shift.
- Ensure that operators do not stand one behind the other. This may cause an accident because while pulling the rake backwards, the operator in the front may hit and push the operator in the rear into the sewage channel.
- Once the screens are cleaned and screenings are deposited on the slotted platform allow them to drip dry till the next cleaning after 4 hours.
- Push the screenings with the rake to the side of the platform to drop them into the tipper positioned there.
- Move the tipper to the vermin compost site, dump the contents in the pit and cover with earth as prescribed in Sec.3.4.4 "Disposal of Screenings."

3.4.2.2 Mechanical Screen (Intermittent and Continuous)

Mechanically cleaned racks are generally erected almost vertically. Additional provision should be made for manual raking in case the mechanical rakes are temporarily out of order. Plants using mechanically-cleaned screens have controls for

- Manual start and stop
- Automatic start and stop by clock control
- High level switch
- High level alarm
- Starting switch or overload switch actuated by loss of head and
- Overload alarm.

There are various types of mechanisms in use, the more common being travelling rakes that bring the debris up out of the channel and drop them into hoppers or other debris containers (Figure 3.11).

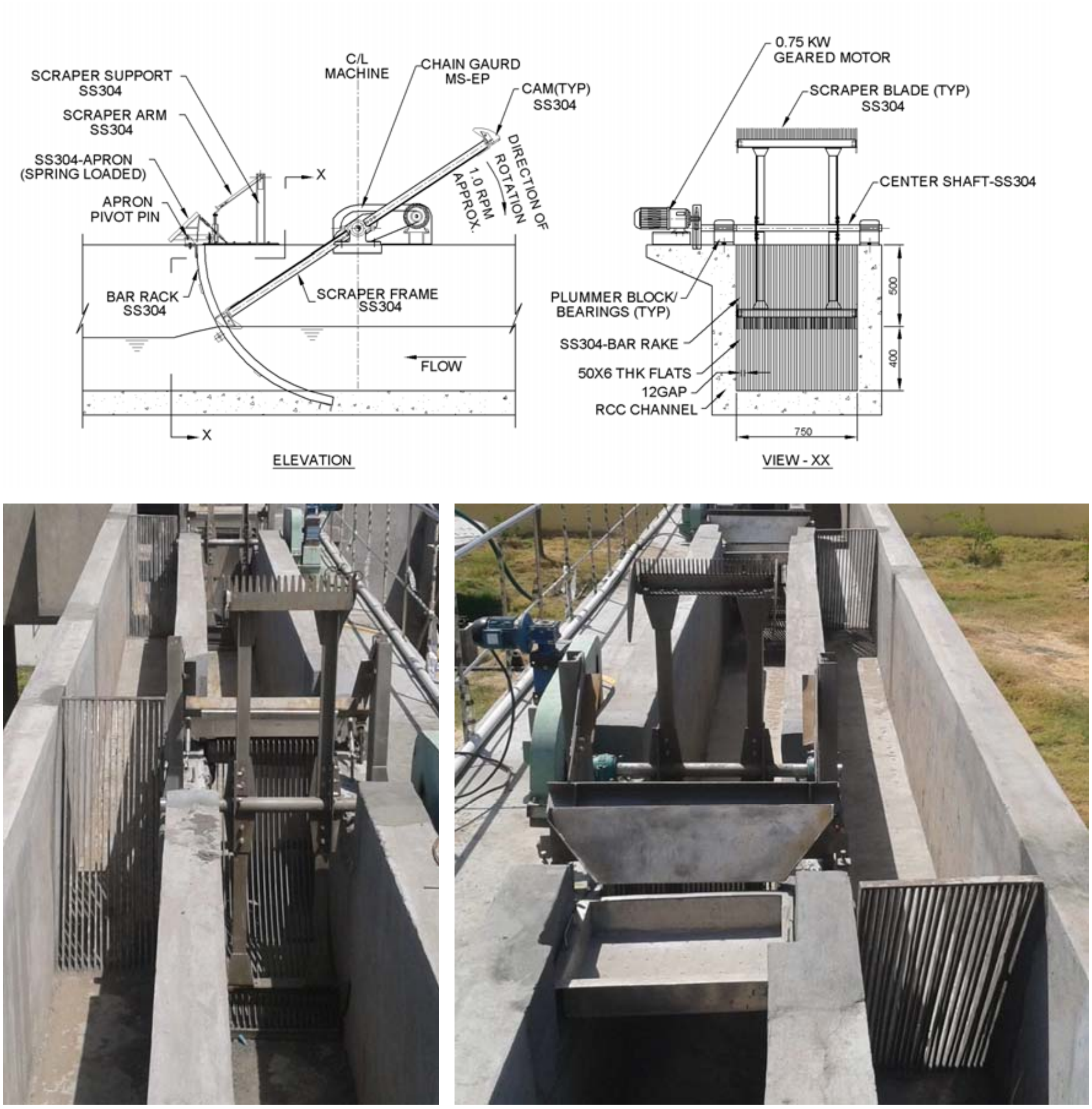


Source: WEF, 2010

Figure 3.11 Mechanically-cleaned bar screen

The rotary drum screen by United Nations Industrial Development Organization (UNIDO) (Figure 3.12) type arc screens is also included here.

In the drawing, the screening rods are in the form of arcs. The cleaning takes place when the meshing teeth at both ends of a diametrical rotating arm plough through the screen openings and push the screenings upwards. Upon exiting the upper end of the screen which is well above the operating sewage level, a built in spring loaded arrangement in the diametrical rods jacks out the meshing teeth gently, which pushes the screenings gently into a collection trough. The screenings can be manually removed or a conveyor belt can collect the droppings and drop them into a container on the ground through a drop chute.



Source: TWSSB, 2012

Figure 3.12 UNIDO type arc screen

Refer to Sec.5.6 of Part A of the manual for details of screens.

a. Preventive Maintenance

- Verify the equipment manufacturer’s manual for preventive maintenance instructions and carry out the same (if permitted to be done by the operator).
- Switch off electrical power before doing any work on the mechanical screen.

b. Regular maintenance on a daily basis and repairs

- Before you start the day’s work, check for any friction between metal parts. If friction exists and the sound is disturbing, disconnect the electric supply and divert all sewage to manual screens. Enter this action in the site register. Do not perform repairs by yourself because it is dangerous.
- Check the alignment of the tipper plates. If the screenings are slipping back and are not going up, allow the machine to work and do not stop it. Enter the

abnormality in the site register and request for visit by the manufacturer's engineer. Do not perform repairs by yourself because it is dangerous.

c. Operation

- Before you start the day's work, do not approach the mechanical screen unless you are wearing, electrical gloves, safety helmet, and safety boots.
- Before you start the day's work, switch off the mechanical screen and restart it. Watch for any friction or sparks. If you notice sparks, disconnect the electric supply and divert all sewage to manual screens. Enter the abnormality in the site register. Sometimes, these sparks can be dangerous and may cause electrocution.
- Follow the procedure for disposing screenings as described earlier.

3.4.3 Accessories (Conveyors)

Belt conveyors are used in conveying the screenings to the trolley parked by the side of the screen chamber. Generally these are meant only for mechanical screens. For manually operated screens, the water content has to first drip out fully before the screenings can be put on the conveyor. In the case of mechanical screens, the angle is close to vertical, the height is more and dewatering is automatic, but this is not the case with manual screens. If it is to be used, then the conveyor belt has to be behind the operator. The operator first picks up the screenings, drops it on the slotted platform and allows four hours for the screenings to drip fully. Thereafter, he can lift it by the same fork and turn it around 180 degrees and place it on the conveyor belt behind him. On the other hand, in smaller plants he can directly push the screenings to the slotted platform and into the trolley on the ground after the sidewall. All the guidelines for preventive maintenance, regular day to day maintenance and operation, and site register entries by the operator are the same as before.

3.4.4 Disposal of Screenings

Screenings generally consist of non-bio degradable stuff like plastic sachets, milk packets, shampoo packets, etc., with very little organic content. Hence, it is best disposed of as a secure landfill, which should be prevented from direct rainfall and also flow of overland rainwater. The procedure specified by the pollution control authority should be adhered to without fail.

3.5 GRIT REMOVAL

The different types of grit removal equipment are given in Part A of the manual. These are velocity controlled channels, detritors, aerated grit chambers, vortex type, etc.

3.5.1 Preventive Maintenance

Almost all these equipment are patented. Each manufacturer has proprietary schedules for preventive maintenance. These schedules should be followed. Preventive maintenance should be done only by the manufacturer or the erection contractor who has installed these equipment, and not by the operators.

3.5.2 Regular Day to Day Maintenance

The operator should hose the mechanical parts using the high pressure hose, and pump the final treated sewage so that slime does not accumulate.

Where flap gates or turnstiles are provided, the operator should necessarily "exercise" these once a day.

The operator should not enter the chambers unless the sewage entry is blocked, the chamber has been dry for at least two hours and the operator is wearing an oxygen mask.

In the case of velocity controlled channels, the trip switch controlled travelling bridge with suspended suction hoses for each channel all connected to a vacuum pump set are standard items. If this system fails and grit accumulates in the channel, each channel should be taken out of sewage flow. The scour valve should be opened below the chamber and the sewage after filtering through the in-built filter port should be allowed to drain to the site drain. Thereafter, the chamber should be allowed to air dry for at least two hours, high pressure water jetting, draining and air drying cycle carried out at least three times. Subsequently, labourers can be deployed to scrap the grit provided that the labourers wear goggles, gloves, safety shoes and oxygen masks.

3.5.3 Disposal of Grit

The grit is usually pre-rinsed in the grit removal chamber itself before it is evacuated from it. Figure 3.13 shows a typical grit chamber.

Clean grit is characterised by the lack of odour. Washed grit may resemble particles of sand and gravel, interspersed with inert materials from households. Grit washing mechanism has to be included whenever the detention time is more and flow through velocity is less. Unless washed, it may contain considerable amount of organic matter. This becomes an attraction to rodents and insects and is also unsightly and odorous. The grit should be contained in a secure landfill as directed by the local pollution control authority or disposed along with the municipal solid wastes, if permitted.

Figure 3.13 Typical grit chamber

3.6 PUMP EQUIPMENT

The types of pumps are dealt with in Part A of the manual. These are horizontal centrifugal, vertical shaft centrifugal, dry submersible and wet submersible pumps.

3.6.1 Preventive Maintenance

This shall be done only by the manufacturer / his authorized service agency / properly trained staff. The operator shall not carry out preventive maintenance.

3.6.2 Regular Day to Day Maintenance

This should include the tasks as given in Table 3.1.

Table 3.1 Tasks to be addressed in day-to-day regular maintenance

Description	Comments	Maintenance Interval			
		Daily	Weekly	Monthly	Yearly
Earthing	Check whether earthing is proper	yes			

Description	Comments	Maintenance Interval			
		Daily	Weekly	Monthly	Yearly
Visual Appraisal	Check that safety aids and first aid are in place		yes		
Gland packing	Check for leaks and condition of mechanical seals			yes	
Alignment	Check alignment using computerized monitor				yes
Oil & Grease	Check lubrication as per manufacturer's procedure			yes	
Motors	Check vibration and temperature		yes		
Mountings	Check for vibrations from foundation bolts			yes	
Bearings	Check for unusual sounds			yes	
Pump sequence	Start & stop the pumps as per duty condition	yes			
Foundation	Check for spalling or cracking			yes	

Proper operation of submersible pump systems requires that minimum submergence should be maintained always. This is for two primary reasons:

- Prevention of motor overheating
- Prevention of "vortexing" and associated problems

The following should be inspected:

- Inspect seal for wear or leakage and repair, if required.
- Visually inspect the oil in the motor housing.
  - Remove pipe plug from housing.
  - Make sure oil is clean and clear, light amber in colour and free from suspended particles.
  - Milky white oil indicates the presence of water.

If the system fails to operate properly, carefully read the instructions and perform maintenance recommendations.

3.6.3 Operation and Maintenance

Before starting the pump, check the following:

- Check insulation resistance by megger at free end of cable and verify with pump manual.
- Check continuity between ends of motor in the same phase and in all phases.
- Check resistance across moisture sensing wires and verify with pump manual.
- Physically rotate the coupling joint and verify smooth movement.
- Check for leaky oil plug and fix it before starting.
- Check for the bulbs indicating the on–off status of the pump and replace fused bulbs.
- Look for warning lamps for alerting the pumped liquid entering the oil chamber.
- Close the discharge valve before starting the pump. This is also taken care by check valve.
- Open the discharge valve gradually and not all of a sudden.
- While the pump is running at full flow, check the power consumed to be within duty point.
- If the power consumed is very high, stop the pump and inform the manufacturer.

- Switch off the pump only after the discharge valve is closed.

3.6.4 Accessories

3.6.4.1 Oil and Grease

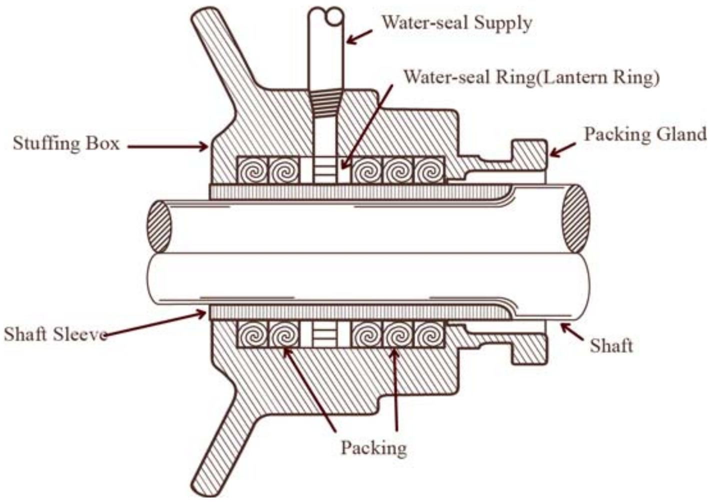
- Pumps, motors, and drives should be oiled and greased strictly in accordance with the recommendations of the manufacturer. Cheap lubricants may often become the most expensive in the end.
- Oil should not be put in the housing while the pump shaft is rotating because a considerable amount of oil will be picked up and retained due to the rotary action of the ball bearings. When the unit comes to rest, an overflow of oil will occur around the shaft or oil will flow out of the oil cup.

3.6.4.2 Bearing

- Pump bearings should usually last for many years if serviced properly and used correctly.
- There are several types of bearings used in pumps such as ball bearings, roller bearings, and sleeve bearings. Each bearing has a special purpose, such as thrust load, radial load, and speed. The type of bearing used in each pump depends on the manufacturer's design and application.
- Whenever a bearing failure occurs, the bearing should be examined to determine the cause and, if possible, to eliminate the problem.

3.6.4.3 Packing Gland

- Check packing gland, which is the unit's most abused and troublesome part. (Figure 3.14)



Source: EPA, 2008

Figure 3.14 Packing gland

- If the stuffing box leaks excessively when gland is pulled up with mild pressure, remove the packing and examine the shaft sleeve carefully.
- Replace grooved or scored shaft sleeve because packing cannot be held in stuffing box with roughened shaft or shaft sleeve.
- Replace the packing a strip at a time, tamping each strip thoroughly and staggering the joints. Position the lantern ring (water sealing) properly.
- If grease sealing is used, completely fill the lantern ring with grease before putting remaining rings of packing in place.
- The proper size of packing should be available in the plant's equipment files.

3.6.4.4 Mechanical Seal

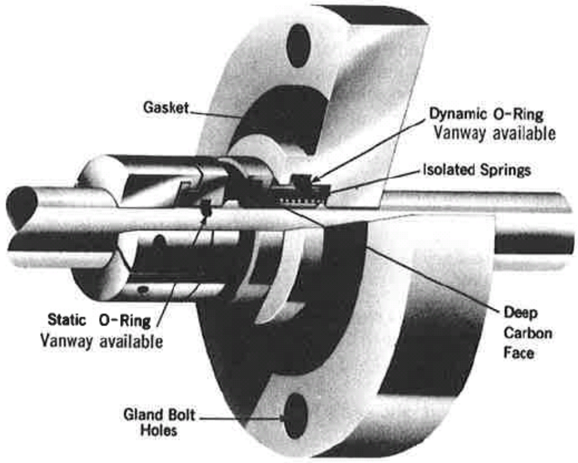
Many pumps use mechanical seals instead of packing. (Figure 3.15)

- Mechanical seals serve the same purpose as packing; that is, they prevent leakage between the pump casing and shaft. The seals have two faces that mate tightly and prevent water from passing through them.
- The different materials are selected for their best application. Some of the factors for selection of material are:
  - Liquid and solids being pumped
  - Shaft speed
  - Temperature
  - Corrosion resistance
  - Abrasives
- Initially, mechanical seals are more expensive than packing when installed in a pump. This cost is recovered through maintenance savings over a period of time.
- Some of the advantages of mechanical seals are as follows:
  - They last from three to four years without any maintenance, resulting in labour

savings.

- Usually, there is no damage to the shaft sleeve at the time of their replacement.
- Continual adjusting, cleaning, or repacking is not required.

The construction of a mechanical seal is shown below.



Source: EPA, 2008

Figure 3.15 Mechanical seal

- Whatever be the method used, the mechanical seal must be inspected frequently.
- Grease cups must be kept full at all times and inspected to make sure they are operating properly. When a pump is fitted with a mechanical seal, it must never run dry or the seal faces will be burned and ruined.
- Mechanical seals should not leak from the gland. If a leak develops, the seal may require resurfacing or it may have to be replaced.
- Repair or replacement of mechanical seal requires the pump to be removed and dismantled.
- Seals are quite delicate and special care must be taken when installing them. Mechanical seals differ widely in their construction and installation, and the seal manufacturer's instructions must be followed.

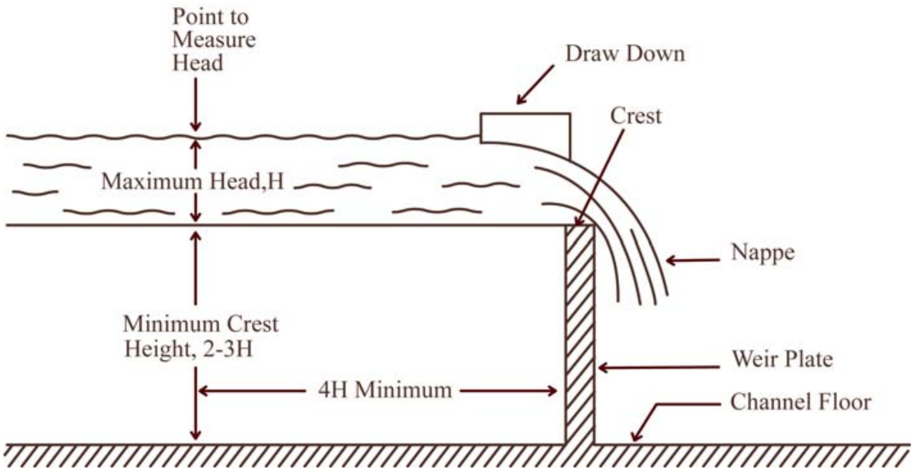
3.7 FLOW MEASURING DEVICES

Flow, similar to water level (Refer to Sec.6.5.2 “Level Measuring Equipment”), is one of the most important wastewater parameters to be measured. The various types of flow-measuring devices have three basic criteria that determine their performance: area, velocity, and device characteristics. The two basic types of flow measurement are open-channel and closed-pipe. For good measuring-device performance, both types require approach conditions free of obstructions and abrupt changes in size and direction. Obstructions and abrupt changes produce velocity-profile distortions that lead to inaccuracies.

3.7.1 Weir Flow-Meter

A weir measures the liquid flowing in open channels or partially filled pipes under atmospheric pressure. (Figure 3.16) This device causes the flow to take on certain characteristics (such as shape and size) depending on the device used. Changes in flow-rate produce a measurable change in the liquid level near or at the device. This level is related to flow-rate by an appropriate mathematical formula. The specific device determines the location and accuracy of level measurements and is extremely important for accurate performance.

Measurement errors occur if the actual crest height differs from the designed height due to accumulated matter on the channel floor. Remove sediment, if necessary. Floating matter or surface wave may cause incorrect level measurements and lead errors in flow measurements. Therefore, floating matter should be removed immediately.



Source: WEF, 2008

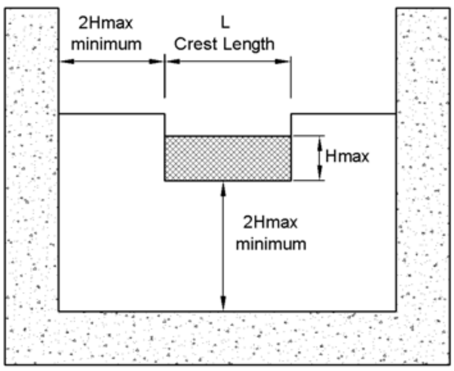


Figure 3.16 Typical weir; generated elevation

Equation for rectangular weir is shown below.

$$Q = 1.85 \times (L - 0.2H) \times H^{1.5} \quad (3.1)$$

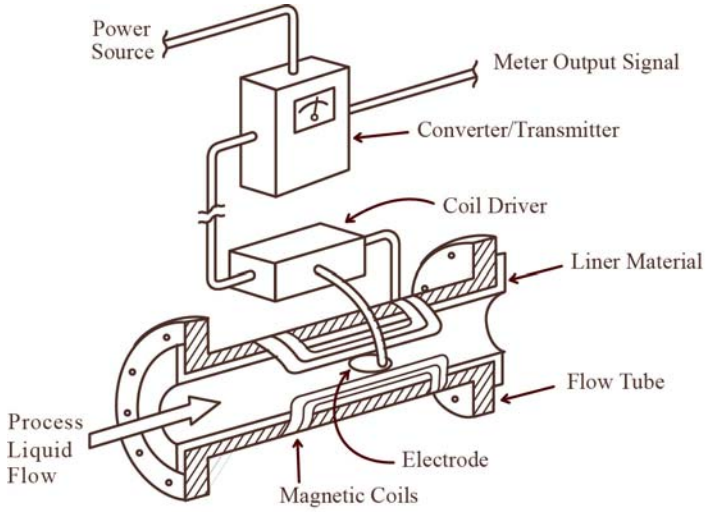
Where Q is cum/sec and H is in m

Refer to Sec.3.10 of Part A of the manual for equations to calculate flow rate with various types of weirs.

3.7.2 Electromagnetic Flow-Meter

Magnetic flow meters are used extensively in applications ranging from filtered effluent to thickened or digested solids. (Figure 3.17) They function by electromagnetic induction, in which the induced voltage generated by a conductor moving through a magnetic field is linearly proportional to the conductor's velocity. As the liquid (the conductor) moves through the meter (generating the magnetic field), the voltage produced is measured and converted to a velocity and, thus, a flow-rate. Magnetic meters require a full pipe for proper operation. Proper grounding is important for certain brands. In applications where greasing of electrodes is likely, additional equipment for degreasing the electrode may be required. Magnetic flow meters provide no obstructions and are manufactured with abrasion-and corrosion-resistant liners, which is why they are frequently used in solids metering. Repairs should be done only by manufacturer's representatives.

Electromagnetic flow meters rarely break down because they have no moving parts. Dirt on sensors should be cleaned because that may cause error in measurements.

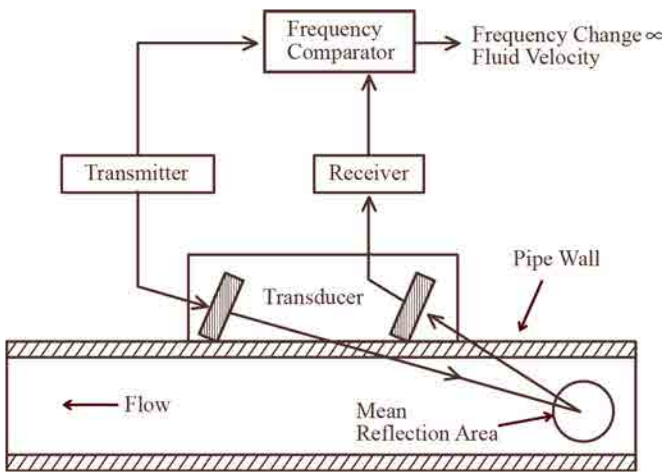


Source: WEF, 2008

Figure 3.17 Magnetic flow meter

3.7.3 Ultrasonic Flow-Meter

Ultrasonic flow meters are based on the measurement of ultrasonic wave water-transit time or frequency shift caused by the flowing fluid. An instrument that measures wave-transit time is called a time-of-flight or counter-propagation ultrasonic flow meter (Figure 3.18). Ultrasonic waves of known frequency and duration are beamed across the pipe at known angles. The waves are sensed either directly by an opposing receiver or indirectly as reflected waves. The changes in wave transit time or frequency caused by the flowing liquid are linearly proportional to the liquid velocity. This velocity is converted from flow and output to a display by conversion electronics. The presence or absence of air bubbles and density of solids in the fluid being metered affect the meters. Operators should follow the manufacturer's specifications and carefully match the meters to the application.



Source: WEF, 2008

Figure 3.18 Reflecting ultrasonic flow meter

3.7.4 Fluorescent Tracers

Florescent tracer method requires the use of a tracer like Rhodomine B Dye which is injected using a peristaltic pump from a small volume of a known concentration of dye solution. The dye is injected into the gravity or pumping main. After travelling and getting mixed, the dye concentration is measured there. The mass is the same in the beginning and after travelling. The instrument used is called Fluorometer. The dye will automatically degrade. It does not affect the water body.

3.8 PREVENTIVE MAINTENANCE

Equipment becomes more complex with the application of advanced technologies and automation systems in recent years. Thus, high technical knowledge is required and technicians, technical tools, and special instruments are necessary for implementing preventive maintenance of the equipment. Unlike O&M contractors, manufacturers can provide such skilled staff and special tools. The manufactures can provide safe and secure maintenance based on their long experience and abundant information on their products. Preventive maintenance after expiry of warranty period should be provided by the manufacturers continuously.

A good maintenance program is essential for a pumping station to operate continuously at peak design efficiency. A successful maintenance program will cover everything from mechanical equipment, such as pumps, valves, scrapers, and other moving equipment, to the care of the plant grounds, buildings, and structures. For preventive maintenance, it is advisable to follow a schedule for the maintenance of the equipment. The schedule covers recommendations for checks and remedial actions to be observed at different intervals such as daily, monthly, quarterly, semi-annually, annually and bi-annually.

Operators should receive training to obtain more knowledge of characteristics and structure of machinery and to improve their maintenance skill.

a. Mechanical Maintenance

Mechanical maintenance is of prime importance as the equipment must be kept in good operating condition for the plant to maintain peak performance. Manufacturers provide information on the mechanical maintenance of their equipment. Operators should thoroughly read manuals on the plant equipment, understand the procedures, and contact the manufacturer or the local representative if there are any questions. The instructions should be followed very carefully when performing maintenance on equipment. Operators also must recognise tasks that may be beyond their capabilities or repair facilities, and should request assistance when needed.

b. Maintenance of Civil Structures

Building maintenance is another program that should be maintained on a regular schedule. Buildings in a treatment plant are usually built of sturdy materials to last for many years. Buildings must be kept in good condition by repairs. For selecting paint for a treatment plant, it is always a good idea to have a painting expert help the operator select the types of paint needed to protect the buildings from deterioration. The expert also will have some good ideas as to colour schemes to help blend the plant in with the surrounding area. Consideration should also be given to the quality of paint. A good quality, more expensive material will usually give better service over a longer period of time than the economy-type products.

Building maintenance programs depend on the age, type, and use of a building. New buildings require a thorough check to ensure that essential items are available and are working properly. Older buildings require careful observation and prompt attention to detect leaks, breakdowns, and replacements beforehand. Attention must be given to the maintenance requirements of many items in all plant buildings, such as electrical systems, plumbing, heating, cooling, ventilating, floors, windows, roofs, and drainage around the buildings. Regularly scheduled examinations and necessary maintenance of these items can prevent many costly and time-consuming problems in the future.

In each plant building, periodically check all stairways, ladders, catwalks, and platforms for adequate lighting, head clearance, and sturdy and convenient guardrails. Protective devices should be around all moving equipment. Whenever any repairs, alterations, or additions are made, avoid building accident traps such as pipes laid on top of floors or hung from the ceiling at head height, which could create serious safety hazards.

Keep all buildings clean and orderly. Janitorial work should be done on a regular schedule. All tools and plant equipment should be kept clean and in their proper place. Floors, walls, and windows should be cleaned at regular intervals to maintain a neat appearance.

c. Valve Maintenance

Valves should be lubricated regularly (according to the manufacturer’s instructions), and valve stems should be rotated regularly to ensure ease of operation. These activities should be part of a regular pump-maintenance program.

d. Electric Actuator Maintenance

- Declutch and operate the manual hand wheel.
- Check oil level and top up, if required.
- Re-grease the grease lubricated bearing and gear trains, as applicable.
- Check the insulation resistance of the motor.
- Check for undue noise and vibration and take necessary rectification measures.
- Tighten limit switch cam ends. Check for setting; readjust, if necessary.
- Examine all components and wiring thoroughly and rectify as necessary.
- Change oil or grease in the gear box and thrust bearing.
- Check the condition of the gears and replace them if teeth are worn out.

e. Flow Meter Maintenance

Each individual sensing meter will have its own maintenance requirements.

The single most important item to be considered in sensor maintenance is good housekeeping. Always keep sensors and all instrumentation very clean. Good housekeeping, the act of providing preventive maintenance for each of the various sensors, includes ensuring that foreign bodies do not interfere with the measuring device. Check for and remove deposits that will build up from normal use. Repair the sensor or measuring device whenever it is damaged.

External connections between the sensing and conversion and readout devices should be checked to ensure such connections are clean and connections are firm. Be sure no foreign obstruction will interfere or promote wear. On mechanical connections, grease as directed; on hydraulic or pneumatic connections, disconnect and ensure free flow in the internal passage.

f. Maintenance of Pumps

The maintenance schedule should list out items to be attended to at different periods, such as daily, semi-annually, annually, and others:

i. Daily Observations

- Leakage through packing
- Bearing temperature
- Undue noise or vibration
- Pressure, voltage and current readings

ii. Semi-annual Inspection

- Free movement of the gland of the stuffing box
- Cleaning and oiling of the gland bolts
- Inspection of packing and repacking, if necessary
- Alignment of the pump and the drive
- Cleaning of oil-lubricated bearings and replenishing fresh oil. If bearings are grease-lubricated, the condition of the grease should be checked and replaced to correct quantity, if necessary.
- An anti-friction bearing should have its housing packed with grease so that the void spaces in the bearings and the housing are 1/2 to 2/3 filled with grease. A fully packed housing will cause the bearing to overheat and will result in reduced life of the bearing.

iii. Annual Inspection

- Cleaning and examination of all bearings for flaws developed, if any
- Examination of shaft-sleeves for wear or scour. Cleaning and examination of all bearings for flaws developed, if any
- Checking clearances

Clearances at the wearing rings should be within the limits recommended by the manufacturer. Excessive clearances indicate a drop in the efficiency of the pump. If the wear is on only one side, it means misalignment. Not only should the misalignment be corrected, but also the causes of the misalignment should be investigated and the clearances reset to the values recommended by the manufacturers. If the clearance on wear is seen to be 0.2 or 0.25 mm more than the original clearance, the wearing ring should be renewed or replaced to obtain the original clearance. These are to be done by the equipment representative.

- Impeller-hubs and vane-tips should be examined for any pitting or erosion.
- End-play of the bearings should be checked.
- All instruments and flow-meters should be re-calibrated.
- Pump should be tested to ensure proper performance is being obtained.
- In the case of vertical turbine pumps, the inspection can be bi-annual. Annual inspection is not advisable because it involves disturbing the alignment and clearances.

iv. Annual Maintenance and Repairs

- Consumables and lubricants

Adequate stock of such items as packing glands, belts, lubricating oils, greases should be maintained.

– Replacement of spares

To avoid downtime, a stock of fast-moving spares should be maintained. A set of recommended spares for two years of trouble-free operation should be ordered along with the pump.

– Repair workshop

The repair workshop should be equipped with tools such as bearing-pullers, clamps, pipe-wrenches, and other general-purpose machinery such as welding set grinder, blower, drilling machine.

3.9 TROUBLESHOOTING

Refer to Appendix 3.1 to Appendix 3.3.

3.10 RECORD KEEPING

The purpose of recording data is to track operational information that will identify and duplicate optimum operating conditions.

A record of equipment performance and repairs allow operations or maintenance personnel to properly evaluate equipment's effectiveness and determine if the equipment meets the objectives to justify its purchase and installation. As a minimum, the following basic information should be maintained for each equipment in the pumping station:

- Plant equipment identification number
- Manufacturer
- Model number and serial number
- Type
- Dates of installation and removal from service
- Reasons for removal
- Location when installed
- Calibration data and procedures
- Hours required to perform maintenance
- Cost of replacement parts
- Operations and maintenance manuals, references and their locations
- Apparatus failure history

An example of an annual inspection report for pumping station is shown in Table 3.2. Inspection reports should be prepared for each pumping station according to the equipment installed.

Table 3.2 Annual inspection report for pumping station

Pumping station annual inspection report					
Date:					
Mechanical:	General condition of equipment				
	Sewage pump			Sump pump	Remarks
	No.1	No.2	No.3		
1.Pump					
Bearings					
2.Gates					

Pumping station annual inspection report					
Gate operator (manual)					
Gate operator (motor)					
Stems					
3.Crane and hoist					
4.Siphon breaker					
5.Trash racks					
Drive chain					
Bearings					
Gear reducers					
Electrical:	Date:				
1.Motors					
2.Mortor bearing					
3.Swichgear controls					
4.Control panels					
General:					
1.Water levels	Elevation		Remarks		
Forebay					
Sumps					
Building and grounds:	Date:				
	Remarks				
1.Sump					
2.Forebay					
3.Discharge chamber					
4.Gatewell to river outlet					
5.Structure					
6.Fire extinguishers					
7.Tools and cabinets					
8.Painting					
9.Caulking					
10.Grating, rails and ladders					
11.Water system and plumbing					
12.Louvers and ventilators					
13.Windows					
14.Doors					
Remarks					

Source: JICA, 2011

Recommended maintenance/inspection tasks for equipment in pumping stations are summarised by frequencies and are listed in Table 3.3. Because the required maintenance/inspection and their frequencies may differ depending on the equipment installed, maintenance plans should be prepared according to manufacturer’s instruction manuals of related equipment.

Table 3.3 Recommended maintenance for pumping equipment

	Start up	Monthly	3-Mo	6-Mo	1Yr	5Yr	Opr hrs
Trash rake		GI,O,CL			CL		
Motors				AL	PG	CL	
Heaters	GI						
Gear reducers		GI		CH			
Drive chain	PG						PG
Pillow blocks				PG			
Torque limit coupling					PG		
Shear pin and sprocket		GI					
Trip cam		GI					

	Start up	Monthly	3-Mo	6-Mo	1Yr	5Yr	Opr hrs
Control panel					GI,CL		
Sub-station drainage					GI		
Building structure			GI				
Trash-rack				GI			
Toilet facility				GI			
Domestic water				GI			
Holding tank			GI		PO		
Siphon breakers			GI				
Unit heaters					GI		
Fire extinguishers		GI		GI			
Switch gear	GI						
Bus and connections					GI,CL		
Instruments and lamps	GI				GI,CL		
Heaters					GI		
Lighting panel	GI				GI		
Control panel	GI				GI		
Grounding					GRT		
Float control	GI				GI		
Main pump motors starts							
Entrance channel						GI,RS	
Sump					GI,RS		
Gates				GI,O,CL			
Stem	GI			CL,SG			
Thrust nut	GI			CL,SG			
Manual operators					PG		
Motor operators					GI,CL		

Legend

O	Operate	GRT	Ground resistance test
CH	Change	TO	Test oil
CL	Clean	GI	General inspection
MR	Megger and record	AL	Add lubricant
PG	Pressure grease	PO	Pump out
SG	Surface grease	TS	Test
RC	Remove condensate	RS	Remove silt

Source: JICA, 2011

3.11 DUTIES OF SITE ENGINEER IN CHARGE AND HIGHER UPS

The site engineer should first check the entries of the operator in the previous three shifts and take corrective action, or alert the supervisor by e-mail and make an entry in the site register. If the site engineer cannot correct the problem within two weeks, he should directly send an e-mail message to the plant in charge. If no action is taken even after two weeks, the complete responsibility will rest with the plant in charge from then onwards, including the responsibility for any accidents/fatalities caused by not taking the requisite action.

3.12 IF THE PS IS UNDER O&M BY THE CONTRACTOR

The references to operator, site engineer and plant in charge inevitably apply to the staff of the contractor. The engineer in charge of supervising the contractor's work should review the site register once a fortnight and institute such remedies as available under the contract.

3.13 SUMMARY

The most important thing for O&M of pumping stations is to minimize suspension time due to facility failures and to maximize the life of pumps.

For accomplishing these targets, the following causes of breakdown of pumps should be eliminated:

- Inflow of screenings into pumping stations
- Overloading of pumps

Preventive maintenance is also essential for detecting abnormalities in their early stages.

CHAPTER 4 SEWAGE TREATMENT FACILITIES

4.1 INTRODUCTION

Sewage treatment is a multi-stage process designed to clean water and protect natural water bodies. Municipal sewage contains various wastes. If untreated or improperly collected and treated, this sewage and its related solids could hurt human health and the environment.

A treatment plant's primary objectives are to clean the sewage and meet the plant's permit requirements. Treatment plant personnel do this by reducing the concentrations of solids, organic matter, nutrients, pathogens, and other pollutants in sewage. The plant must also help protect the receiving water body, which can only absorb so many pollutants before it begins to degrade, as well as the human health and environment of its employees and neighbours.

One of the challenges of sewage treatment is that the volume and physical, chemical, and biological characteristics of sewage continually change. Some changes are the temporary results of seasonal, monthly, weekly, or daily fluctuations in the sewage volume and composition. Other changes are long-term, the results of alterations in local populations, social characteristics, economies, and industrial production or technology. The quality of the receiving water and the public's health and well-being may depend on a treatment plant operator's ability to recognize and respond to potential problems. These responsibilities demand a thorough knowledge of existing treatment facilities and sewage treatment technology.

4.2 PUMP EQUIPMENT

Refer to Chapter 3. (Sec.3.6 "Pump Equipment")

4.3 FINE SCREEN AND GRIT CHAMBER

Refer to Chapter 3. (Sec.3.4 "Screen" and Sec.3.5 "Grit Removal")

4.4 OIL AND GREASE REMOVAL

4.4.1 Manual Process

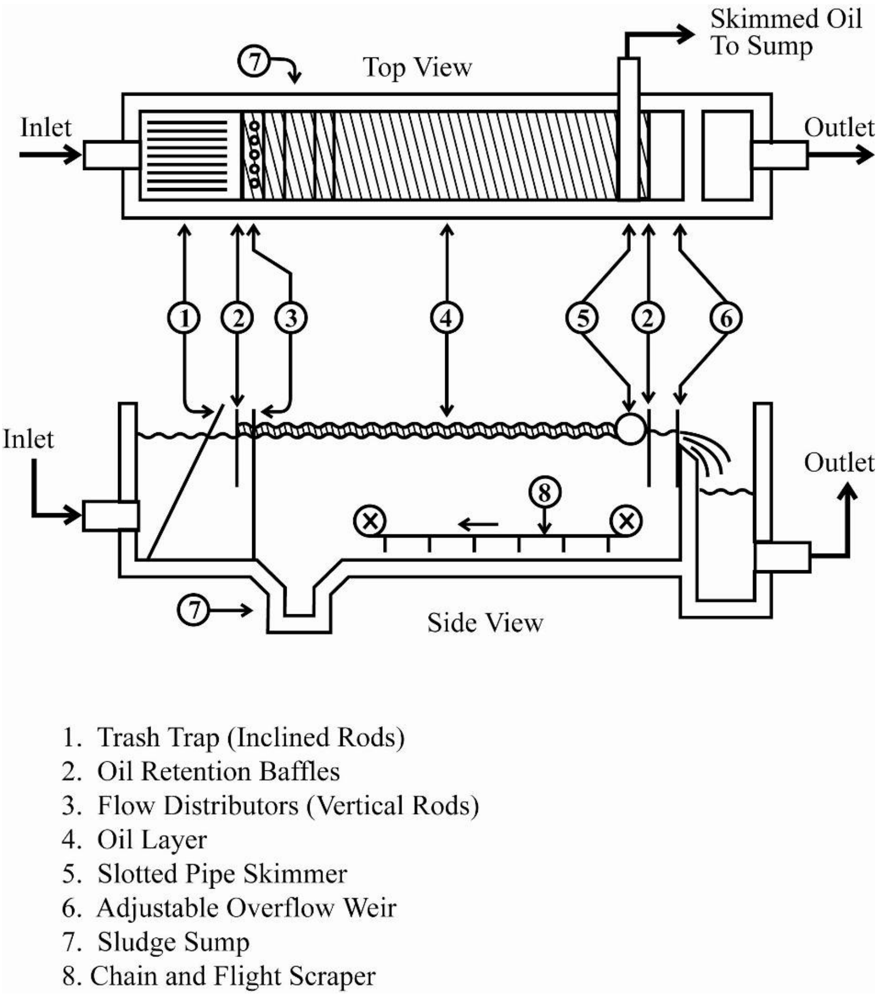
The oil and grease removal unit consists of simple tanks with an underflow baffle where the floating oil and grease is detained on top of the sewage. These are fit only for small STPs of about 1 MLd capacity or less. The floating oil and grease is removed by a rotating slotted pipe as in Figure 4.1.

In actual operation, the scum of oil and grease is removed by rotating the slit pipe so that the scum flows over the slit, through the pipe and goes to a holding high-density polyethylene tank below the pipe on the outside. The scum is then sold to pollution board-authorized oil re-refining firms. The grit that settles in the trough below is drained to a sump and pumped to the beginning of the grit chamber.

The maintenance is very simple and requires periodic cleaning only.

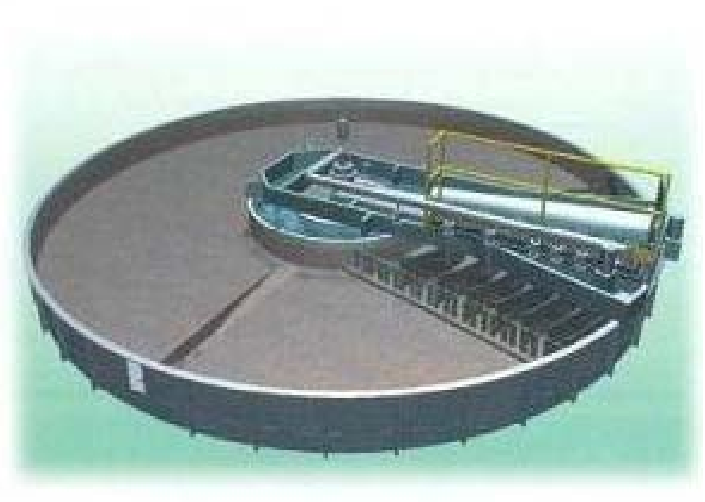
4.4.2 Floatation Process

This process involves floating the oil and grease by either fine bubbles of compressed air or directly by steam liberated near the floor. The same figure as in Figure 4.1 can also be used by releasing fine bubbles of compressed air at the floor or steam near the floor. Commercially, the air is dispersed into very fine particles with the raw sewage and released under gravity in a shallow tank where the fine bubbles take the oil along with them to the surface and are skimmed off by a scoop pips as in Figure 4.2. The unit is typically called a dissolved air floatation (DAF) unit. The schematic of this is shown in Figure 4.3. A parallel plate separator is shown in schematic in Figure 4.4.



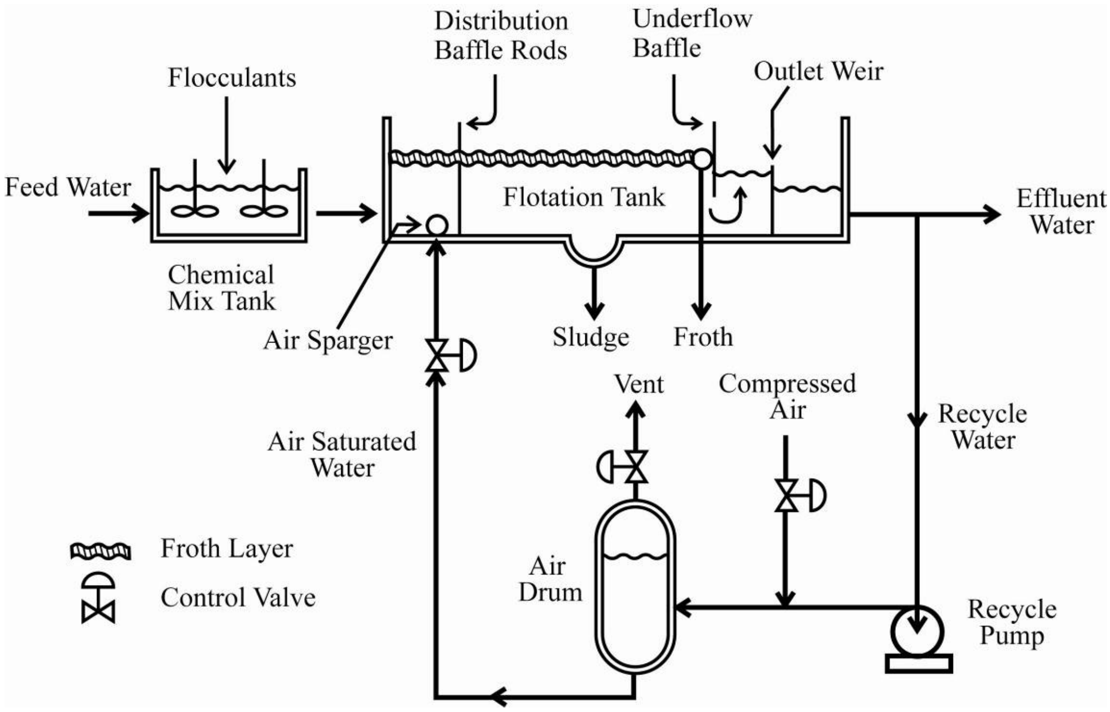
Source: http://en.wikipedia.org/wiki/Industrial_wastewater_treatment

Figure 4.1 Typical gravity type oil and grease removal unit



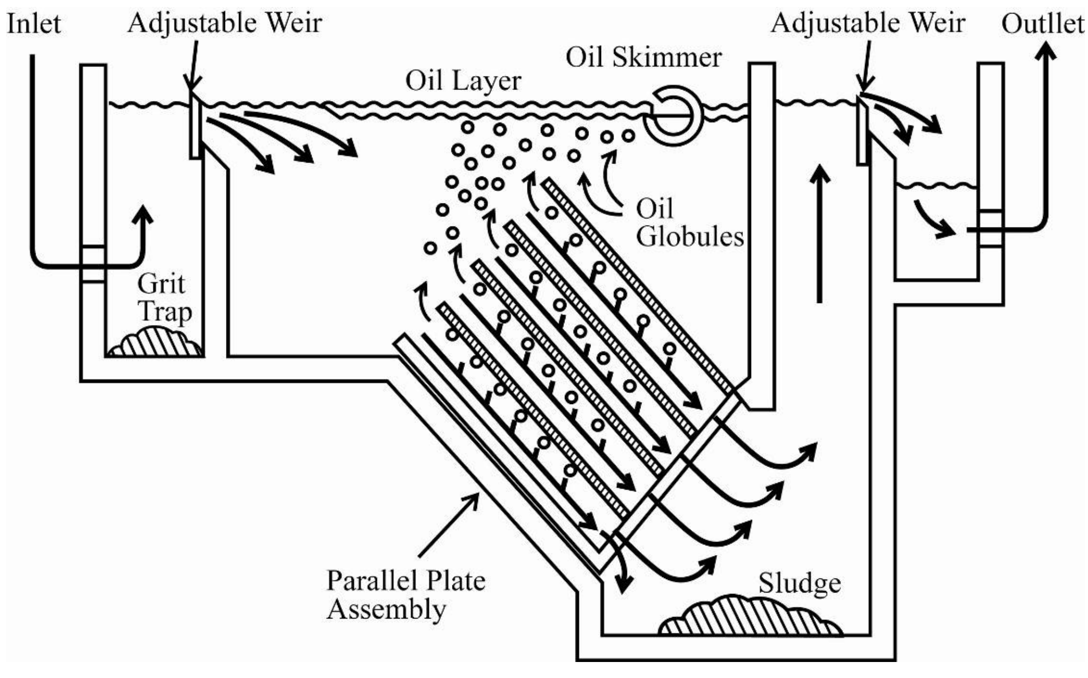
Source: http://www.tradeindia.com

Figure 4.2 DAF unit



Source: http://www.sciencedirect.com

Figure 4.3 Schematic of DAF unit



Source: http://en.wikipedia.org/wiki/Industrial_wastewater_treatment

Figure 4.4 Parallel plate separator

All these units are almost patented types and there are no fixed O&M guidelines. Each unit has to follow the guidelines of the respective manufacturer.

4.5 EQUALIZATION

Flow equalization can be either inline or offline. With inline flow equalization, all of the flow enters the flow equalization basin, and a constant outflow rate is maintained. With offline flow equalization, only that portion of the flow above a given flow rate (typically the average flow) is diverted into the flow equalization basin. The accumulated flow is then released during low-flow periods to bring the total flow to average flow for the day.

The inline flow equalization is the easiest to control. Typically, the flow is pumped out using flow-controlled variable-speed pumps or is pumped in and flows out by gravity using a flow control valve and flow meter. If the latter is used, careful selection of the flow control valve is needed to prevent clogging, even if screened or primary treated sewage is to be equalized.

For offline flow equalization, flow control gates or variable speed pumps can be used. If a constant elevation side weir is used, achieving a controlled flow rate over the side weir is difficult and is not recommended. Variable speed pumps are a better choice.

4.5.1 Operation

Fill-and-draw mode is the most efficient method of operating an equalization basin for flow dampening. The basin is filled during the day when peak flows are occurring, and then it is drawn down at night when the plant is receiving low flows and, hence, is more capable of treating excessive flow. If an equalization basin is not operated in fill-and-draw mode, it will act as a mass loading equalization basin only, assuming the basin is completely mixed.

The successful operation of equalization basins requires proper mixing and aeration. Design of mixing equipment provides for blending the contents of the tank and preventing deposition of solids in the basin.

Mechanical aerators, which offers one method of providing both mixing and aeration, have oxygen transfer in clean water under standard conditions, but the oxygen-transfer efficiency (OTE) in sewage is lower. Minimum operating levels for floating aerators typically exceed 1.5 m and vary with the power and design of the unit. Low-level shutoff controls are needed to protect the unit. If the equalization basin floor is subject to erosion (earthen basins), concrete pads on the basin floor are recommended. Baffling may be necessary to ensure proper mixing, particularly with a circular tank configuration.

Below are some of the recommended monitoring elements required in flow equalization basins.

- Basin liquid level
- Basin dissolved oxygen level
- Influent pH
- Mixers and/or aeration blower status
- Influent/effluent status pumps
- Influent/effluent flow

4.5.2 Maintenance

Because grit removal is rarely provided ahead of equalization, grit will accumulate in the basins. Therefore, provisions for collecting these solids should be made in the design. If the primary purpose of the equalization basin is flow dampening, then after the basin has been emptied following the peak flow event, primary sludge solids will be present on the basin bottom. Water cannons or strategically placed cleaning hoses, ideally supplied with plant effluent water, will allow for cleaning the basins. Other equalization basin types that do not operate in a fill/draw mode still will accumulate solids after a time and will have to be emptied for cleaning. The time between cleanings is dependent on the influent sewage characteristics and will likely have to be established by plant operation staff based on operational experience.

4.6 PRIMARY TREATMENT

4.6.1 Primary Sedimentation Tank Management

This is a simple gravity controlled separation for removing the settleable solids and the Biochemical Oxygen Demand (BOD) that is removed along with it.

4.6.2 Preventive Maintenance

Preventive maintenance of the equipment should be done by the equipment supplier as per the manual.

4.6.3 Day to Day Maintenance

The most important is the daily cleaning of the overflow weirs and the weekly scraping of the floor and walls of the launder. Also periodical checking of the walkway for corrosion is important. In actual day to day working, the operator should not lean or put his weight on the handrails.

4.6.4 Troubleshooting

Troubleshooting is as given in Appendix 4.1.

4.7 ACTIVATED SLUDGE PROCESS (ASP)

The activated sludge process is still the most widely used biological treatment process for reducing the concentration of organic pollutants in sewage. Well-established design standards based on empirical data have evolved over the years.

The activated sludge process has been designed in many different modifications. The process selected depends on the treatment objectives, site constraints, operational constraints, etc. The process can be categorized by loading rates, reactor configuration, feeding and aeration patterns, and other criteria including numerous biological nutrient removal (BNR) processes. Typical plan layout is illustrated in Figure 4.5.

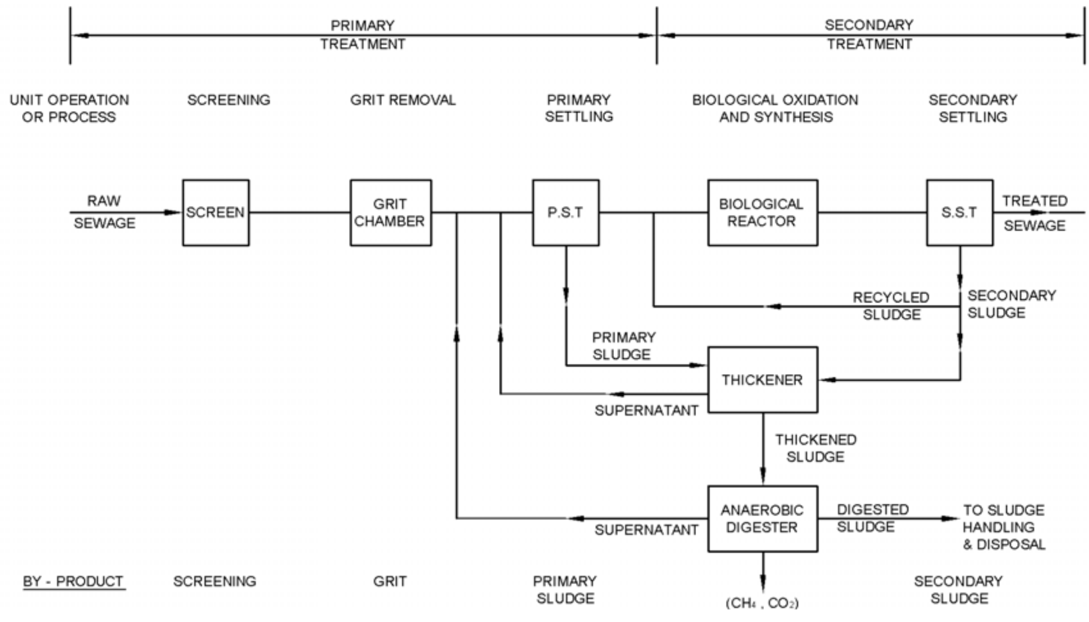


Figure 4.5 Typical plan layout of activated sludge plant

4.7.1 Description of Activated Sludge Process (ASP)

4.7.1.1 Biological Treatment Processes

In the biological treatment of sewage, the stabilisation of organic matter is accomplished biologically using a variety of microorganisms, principally bacteria. Microorganisms convert the colloidal and dissolved carbonaceous matter into gases and non-degradable matter and incorporate it into their cell tissue. The resulting cell tissue, having a specific gravity slightly greater than that of treatment achieved, is only to the extent of the portion of organic matter that has been converted to various gaseous and non-degradable end products because the cell tissues, which itself is organic, and will be measured as BOD in the effluent.

Conversion of organic matter can be accomplished aerobically, anaerobically or facultatively. Oxidation of organic matter to various end products is carried out to obtain the energy required for the synthesis of new cell tissues. In the absence of organic matter, the cell tissue is endogenously respired to obtain energy for maintenance. In most treatment systems, these three reactions, oxidation, synthesis and endogenous respiration occur simultaneously.

The microbial mass comprises a heterogeneous population of microorganisms, mostly heterotrophic bacteria. Various groups of organisms carry out their metabolic reactions independently as well as sequentially. The selection of organism in the treatment process occurs naturally, depending upon the sewage characteristics and the environmental conditions maintained.

4.7.1.2 Design and Operational Parameters

The ASP operation is commonly controlled by maintaining the design Mixed Liquor Suspended Solids (MLSS), or sometimes, by maintaining design Food to Microorganisms (F/M) ratio. The latter approach takes care of fluctuations in the quality of raw sewage. If actual F/M is to be assessed, then measurement of active biomass measured as Mixed Liquor Volatile Suspended Solids (MLVSS) – is needed, which is often difficult to measure and may also give an erroneous result in case of industrial effluent containing suspended organic waste solids. The solid retention time (SRT), which is directly related to F/M, is not being used for operational control. Some of the important design and operational parameters are described and discussed in following sections.

Operational parameters and their formula are explained in Appendix 4.2. Examples of their calculations are described in Appendix 4.3.

4.7.1.3 Choice between SRT and F/M as Operation Control Parameter

The evaluation of the active mass of microorganism often makes the use of F/M as a control parameter impractical. Biological solids are commonly measured by measuring volatile suspended solids. This parameter is not entirely satisfactory because of the variety of volatile matter not related to active cellular material.

On the other hand, the evaluation of SRT as a plant control parameter is simple. Since SRT is the ratio of total suspended solids in the system and that wasted per day, it requires only measurement of total suspended solids. The proportion of active biomass in solids in the system and that in solids wasted, either from the aeration tank or from the recycle line, is the same. Use of SRT as a plant controlling parameter becomes simpler if sludge wasting is done directly from aeration tank, as the ratio of “total solids in system to solids wasting per day” reduces to the ratio of “aeration tank volume to volume of sludge wastes per day,” provided the mass of solids escaped in treated effluent is negligible.

4.7.1.4 Effect of SRT on Settling Characteristics and Drainability of Sludge

It has been established that as a system is operated at higher solids retention time, the settling characteristics of the biological floc improve. For domestic sewage, SRTs of the order of 3 to 4 days are required to achieve effective settling. Further, it is established that drainability of waste sludge also improves when a system is operated at higher SRT. The SRT at which a process is operated approximately represents the average age of biomass present in the process. As the biomass ages, it contains increasing proportion of dead cells and inert matter. Presence of higher proportion of mineralised sludge in a process operated at high SRT is responsible for better setting characteristics and better drainability of sludge.

4.7.1.5 Effect of SRT on Excess of Sludge Production

SRT is inversely related to F/M ratio. A higher operational SRT represents a low F/M ratio, a condition of limiting substrate. Bacteria undergo endogenous respiration or decay under a limiting substrate environment. More biomass undergoes endogenous respiration, resulting in less net bacterial growth. Therefore, excess sludge production is reduced as a system is operated at high SRT. Further, since the settling characteristic of sludge improves at high SRT, concentrated underflow can be withdrawn from the secondary sedimentation tank. This also results in reduction in volume of excess sludge as for a fixed mass of excess sludge.

4.7.1.6 Excess Sludge Wasting

Excess bio-sludge is commonly wasted from return sludge line. It can also be wastes directly from aeration tank. If excess bio-sludge is directly wasted from aeration tank, then increased volume of sludge is a disadvantage. However, if excess bio-sludge is mixed with influent of primary settling tank and wasted as mixed sludge of primary settling tank, then direct wasting from aeration tank has no influence on final volume of sludge and therefore, can easily be adopted. The operator of a plant needs to have an idea of actual volume of excess sludge wasting required.

4.7.1.7 Return Sludge Flow

Sufficient return sludge capacity should be provided if the biological solids are not to be lost in the effluent. However, a return flow rate higher than that is required unnecessarily increases solids loading on settling tank and results in withdrawal of dilute sludge. The ratio of return sludge flow to average flow can be set on the basis of sludge volume index (SVI). SVI is defined as the volume in mL occupied by one gram of activated sludge mixed liquor solids, dry weight, after settling of 30 min. in a 1,000 mL graduated cylinder. The procedure of SVI measurement is as follows (Figure 4.6).

a. Collect a sample of mixed liquor or return sludge.

b. Carefully mix sample and pour into 1,000 mL graduate cylinder. Vigorous shaking or mixing tends to break up floc and produces slower setting or poorer separation.

c. Record settleable solids percentage at regular intervals.

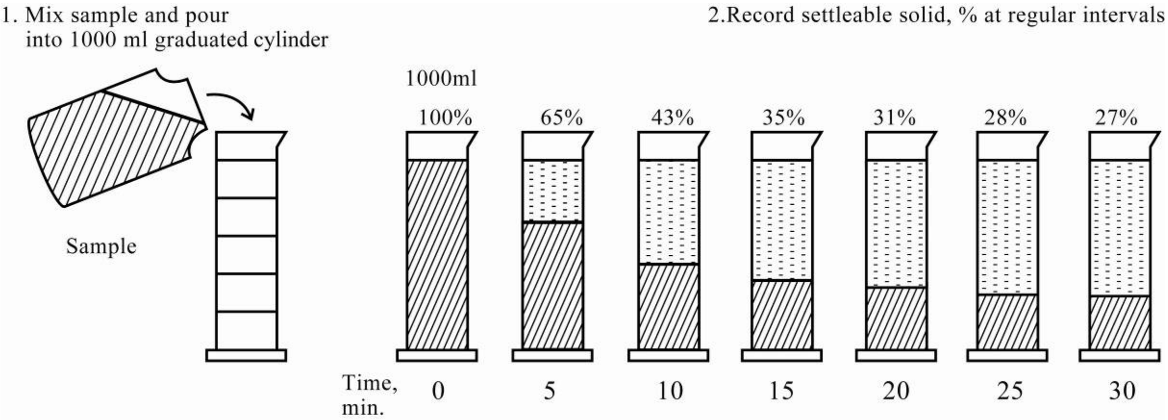


Figure 4.6 Sludge settling analysis

$$\text{SVI (ml/g)} = \frac{\text{Sludge in settled mixed liquor in 30 min(ml/L)}}{\text{Suspended matter in mixed liquor (mg/L)}} \times \frac{1{,}000\ \text{mg}}{1\text{g}} \quad (4.1)$$

Table 4.1 provides SVI values and probable indication of settling properties of activated sludge.

For all cases refer to remedies in Troubleshooting in Appendix.

Table 4.1 Relations between Sludge Volume Index and settling characteristics of sludge

SVI	Indication
Less than 50 ml/g	Pin floc potential
50 to 100 ml/g	Good range
100 to 150 ml/g	Filament growth
150 to 200 ml/g	Bulking at high flows
200 to 300 ml/g	Bulking
More than 300 ml/g	Severe bulking

Source: JICA, 2011

Quantity of return sludge flow is keyed to settled sludge volume. The ratio of recirculated sludge flows to the settled sludge volume. V_{30} should be equal to the flow entering the clarifier to the clarifier volume (Figure 4.7).

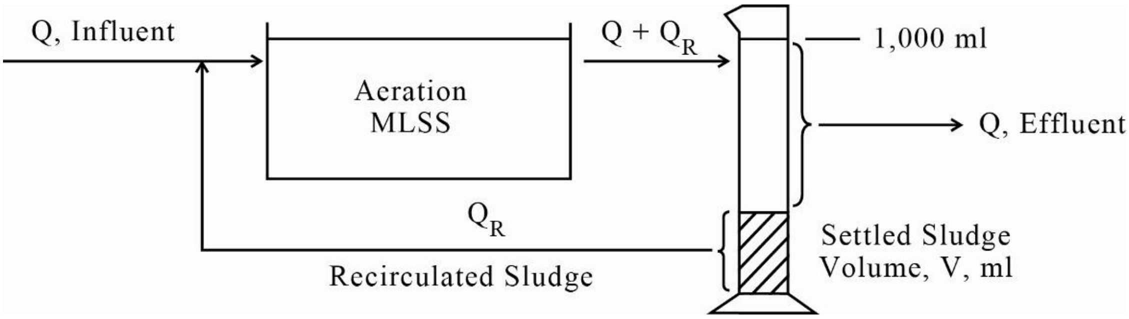


Figure 4.7 Recirculated sludge flow ratio

4.7.2 Conventional Activated Sludge Process

The conventional activated sludge process typically consists of a concrete biological reactor followed by a concrete clarifier. Sewage and return activated sludge (RAS) enter together at one end of the reactor and leave mixed at the other end. This mixed liquor flows into the clarifier where it is allowed to settle and the treated effluent separates from the activated sludge. The effluent from the process flows over the clarifier weirs while the settled activated sludge is either recycled to the reactor or wasted out of the system. (Figure 4.8)

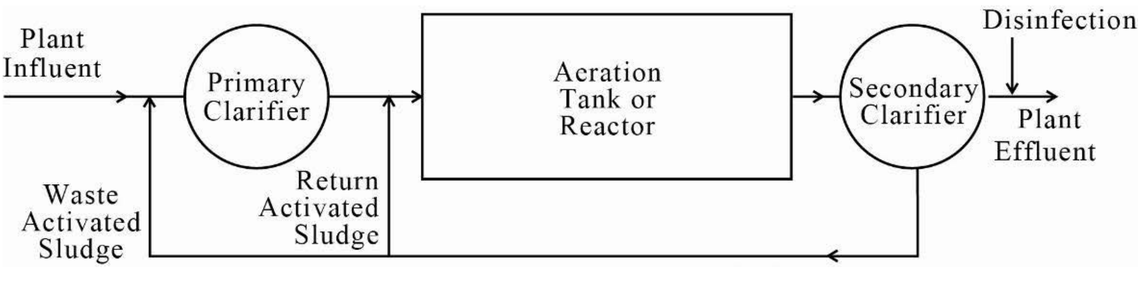


Figure 4.8 Conventional activated sludge process

4.7.2.1 Start Up

Start-up help should be available from the design engineer, vendors, nearby operators, or other specialists. The equipment manufacturers or contractor should be under contractor start-up instruction and assistance. During start-up, they should be present to be sure that any equipment breakdowns are not caused by improper start-up procedures.

The operator may have several options in the choice of start-up procedures with regard to number of tanks used and procedures to establish a suitable working culture in the aeration tanks. The method described in this section is recommended because it provides the longest possible aeration time, reduces chances of solids washout, and provides the opportunity to use most of the equipment for a good test of its acceptability and workability before the end of the warranty.

First, start the air blowers and have air passing through the diffusers before primary effluent is admitted to the aeration tanks. This prevents diffuser clogging from material in the primary effluent and is particularly important if fine bubble diffusers are used.

Fill both aeration tanks to the normal operating water depth, thus allowing the aeration equipment to operate at maximum efficiency. Using all of the aeration tanks will provide the longest possible aeration time. The operators are trying to build up a micro organism population with a minimum amount of seed organisms, and you will need all the aeration capacity available to give the organisms a chance to reach the settling stage.

After a biological culture of aerobes is established in the aeration tanks, sufficient oxygen must be supplied to the aeration tank to overcome the following demands:

- DO (Dissolved Oxygen) usually is low in both influent sewage and return sludge to the aerator.
- Influent sewage may be septic, thus creating an immediate oxygen demand.
- Organisms in the presence of sufficient food create a high demand for oxygen.

The effluent end of the aerator should have a dissolved oxygen level of at least 1.0 mg/L. DO in the aerator should be checked every two hours until a pattern is established.

Thereafter, DO should be checked as frequently as needed to maintain the desired DO level and to maintain aerobic conditions in the aerator. Daily flow variations will create different oxygen demands. Until these patterns are established, you will not know whether just enough or too much air is being delivered to the aeration tanks. Frequently, excess air is provided during early mornings when the inflow waste load is low. Air supply may be too low during the afternoon and evening hours because the waste load tends to increase during the day.

If sewage enters the tank before air is coming out of the diffusers, the diffusers could become plugged. If the plant is the diffused-air type with air lift pumps for return sludge, the air line valve to the air lifts (pumps) will have to be closed until the settling compartment is filled. Otherwise, all the air will attempt to go to the empty compartment and no air will go to the diffusers. Once the settling compartment is filled from the overflow from the aeration tank, the air lift valves may be opened. They will have to be adjusted to return a constant stream of water and solids to the aeration tank. This adjustment is usually two to three turns open on the air valve to each air lift.

There may be a build-up of foam in the aeration compartment during the first week or so of start-up. A 25-mm water hose with a lawn sprinkler may be used to keep it under control until sufficient mixed liquor solids are obtained.

Try to build up the solids or mixed liquor suspended solids (MLSS) as quickly as possible during start-up. This can be achieved by not wasting sludge until the desired level of MLSS is achieved.

4.7.2.2 Routine Operation and Maintenance

4.7.2.2.1 Aeration Tanks

The operational variables in an activated sludge plant include:

- Rate of flow of sewage,
- Air supply,
- MLSS,
- Aeration period,
- DO in aeration and settling tanks, and
- Rate of sludge return and sludge condition.

The operator should possess a thorough knowledge of the type of system adopted, namely, conventional, high rate, extended aeration or contact stabilisation so that effective control of the variables can be exercised to achieve the desired efficiency of the plant.

Inspection of mechanical aerators should be done for:

- Bearings,
- Bushes, and
- Transmission gears.

and they should be lubricated as per the schedule suggested by the manufactures.

The whole unit should be thoroughly inspected once a year, including replacement of worn out parts and painting with anti-corrosive paints to achieve the desired efficiency of the plant. A record of operations should be maintained.

When inhibitory substance for activated sludge (such as industrial sewage) is contained in influent, treatment in reactors may be affected. To avoid such an inhibition, colour and odour of plant influent should be checked through daily inspections such as at the grit chambers or the primary sedimentation tanks where sewage flows in at first. If any abnormal condition is observed, report to a person in charge of water quality or the plant manager.

4.7.2.2.2 Sewage Flow

Since the activated sludge treatment is biochemical in nature, conditions in the aeration tank should be maintained uniform at all times. A sudden increase in the rate of flow or sludge of flow should be avoided. If supernatants from digester containing more than 3,000 mg/L of SS are taken into the settling tank, then they should be pre-treated as otherwise heavy load will be imposed on the activated sludge system. Measurement of sewage flow and the BOD applied to the aeration tank should be made.

4.7.2.2.3 Air Supply

Frequent checks of DO at various points in the tank and at the outlet end should be made; it should not be less than 1 mg/L. It will help in determining the adequacy of the air supply. The uniformity of air distribution can be easily checked by observing bubbling of the air at the surface, which should be even over the entire surface area of the tank. If the bubbling looks uneven, clogging of diffusers is indicated. Clogging is also confirmed by the increase of 0.01 to 0.015 MPa in the pressure gauge reading. Adding chlorine gas to air may help in removing clogging of diffusers on air side if it is due to organic matter. Other methods of cleaning will have to be resorted to if this procedure does not clear up the clogging. Air flow meters should be checked periodically for accuracy; air supply and air pressures should be recorded hourly and daily, respectively, to avoid over-aeration or under-aeration. Mechanical or surface aerators should be kept free from fungus or algae growths by cleaning them periodically.

4.7.2.2.4 Mixed Liquor Suspended Solids

Control of the concentration of solids in the mixed liquor of the aeration tanks is an important operating factor. It is most desirable to hold the MLSS constant at the suggested concentration. The test of MLSS should be done at least once a day on large plants, preferably during peak flow. As the MLSS will be minimum when the peak flow starts coming in and will be maximum in the night hours when the flow drops, operating MLSS value would be the average hourly value in a day; the same should be verified at least once a month. In case of very large plants, regular daily check is desirable.

4.7.2.2.5 Return Sludge

The return sludge pumps provided in multiple units should be operated according to the increase or decrease in return sludge rate of flow required to maintain the necessary MLSS in aeration unit, based on the SVI. The SVI should be determined daily to know the condition of sludge. A value of over 200 definitely indicates sludge bulking.

A good operation calls for prompt removal of excess sludge from the secondary tanks to ensure that the sludge is fully aerobic. This should be measured daily and recorded. The excess sludge is taken to the digester directly or through the primary settling tank.

4.7.2.2.6 Foaming

Foaming or frothing is sometimes encountered in activated sludge plants when the sewage contains materials which reduce the surface tension, the synthetic detergents being the major offender. Froth, besides being unsightly, is easily blown away by wind and contaminates all the surfaces it comes into contact with. It is a hazard to workmen because it creates a slippery surface even after it collapses. Foam problems can be overcome by the application of a spray of screened effluent or clear water, increasing MLSS concentration, decreasing air supply or addition of other special anti-foam agents. The presence of synthetic anionic detergents in sewage also interferes with the oxygen transfer and reduces aeration efficiency.

4.7.2.2.7 Microscopic Examination

Routine microscopic examination of solids in aeration tank and return sludge to identify the biological flora and fauna present will enable good biological control of the aeration tanks.

4.7.2.2.8 Records

Activated sludge operation should include recording of flow rates of sewage and return sludge, DO, MLSS, MLVSS, biota, SRT (sludge age), air, BOD, COD (Chemical Oxygen Demand) and nitrates in both influent and effluent.

4.7.2.2.9 Biological Uptake Rate Procedure

After deaerating the sample of at least 250 ml of mixed liquor with sodium meta bi sulphite start the diffuser and record the dissolved oxygen with time by a dissolved oxygen probe and plot the saturation deficit with time in semi log paper. The slope of the graph is the uptake rate. Generally this is not for a plant control test. It is used for alpha value by comparing it with the value for tap water.

4.7.2.2.10 Nutrient Control

Nutrient control should be referred subsection 5.8.1.7.6, 5.8.1.7.7, and 5.8.1.7.8 in the Part A manual.

4.7.2.2.11 DO Saturation

DO saturation table should be referred Table 5.9 and 5.10 in the Part A manual.

4.7.2.3 Aeration Equipment

4.7.2.3.1 Air Blowers

The blower system is designed to provide sufficient airflow to meet the system process requirements. Blower systems are available with either positive displacement (PD) or centrifugal type units. Typically, PD units are used for plants with smaller air volume requirements. Output airflow from a PD blower remains relatively constant with varying discharge pressure. Centrifugal blower systems are generally equipped with additional controls to regulate the flow as the discharge pressure varies.

a. Positive Displacement Blowers

The positive displacement blower provides a constant volume (cubic meters) output of air per revolution for a specific set of rotors or lobes. Blower output is varied by changing rotor or lobe speed (RPMs or revolutions per minute). The higher the RPM, the greater is the air output.

Small positive displacement blowers ranging from 3 to 28 m^3/min. are usually installed to be operated at a fixed volume output. These smaller units are directly driven by electric motors through a direct coupling or through sheaves and belts.

If a change in air volume output is required, it is accomplished by changing the motor to one with a higher or lower RPM or by changing sheaves to increase or decrease blower rotor or lobe rotation (RPM), thus increasing or decreasing air output.

Note: These small units are commonly used with package plants, pond aeration systems, small aerobic digesters, gas mixing in digesters and gas storage compressors.

Large positive displacement blowers ranging from 57 to 570 m^3/min. may also be driven by internal combustion engines or variable speed electric motors in order to change blower volume outputs as required in activated sludge plants. By increasing or decreasing engine or motor RPM, the positive displacement blower output can be increased or decreased.

The air lines are connected to the blower through a flexible coupling in order to keep vibration to a minimum and to allow for heat expansion. When air is compressed, heat is generated; thus increasing the discharge temperature as much as 56 °C or more.

A check valve follows next, which prevents the blower from operating in reverse should other blowers in the same system be operating while this blower is off.

The discharge line from the blower is equipped with an air relief valve which protects the blower from excessive back pressure and overload. Air relief valves are adjusted by weights or springs to open when air pressure exceeds a point above normal operating range, around 0.04 to 0.07 MPa in most sewage treatment plants. An air discharge silencer is also installed to provide decibel noise reduction. Ear protective devices should be worn when working near noisy blowers.

The impellers are machined on all exterior surfaces for operating at close tolerances; they are statically and dynamically balanced. Impeller shafts are made of machined steel and are securely fastened to the impellers. Timing gears accurately position the impellers.

Lubrication to the gears and bearings is maintained by a lube oil pump driven from one of the impeller shafts. An oil pressure gauge monitors the system oil pressure. An oil filter is located in the oil sump to ensure that the oil is free from foreign materials. An oil level is maintained in the gear housing so that gears and bearings will received splash lubrication in case of lube oil pump failure. Air vents are located between the seals and the impeller chamber to relieve excessive pressure on the seals.

b. Centrifugal Blowers

The centrifugal blower is a motor connected to a speed-increasing gear-driven blower (Figure 4.9) that provides a variable air output.

Minimum through maximum air output is controlled by guide vanes, which are located on the intake side of the blower. These vanes may be positioned manually by operating personnel or may be controlled by plant instrumentation based on either DO levels in the aeration tanks or the plant influent flows.

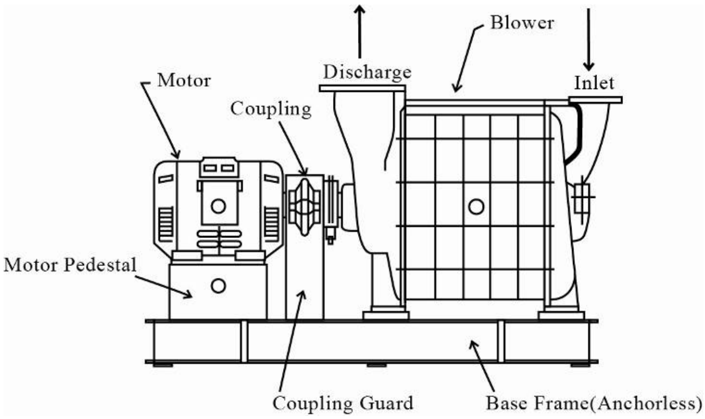


Figure 4.9 Schematic of centrifugal blowers

The blower consists of an impeller, volute casing, shaft and bearings, speed-increasing gear box and an electric motor or internal combustion engine to drive unit. Air enters the volute casing through an inlet nozzle and is picked up by the whirling vanes of the impeller where it is hurled by centrifugal force into the volute casing. Air enters the volute in its smallest section and moves in a circular motion to the largest section of the volute where it is discharged through the discharge nozzle.

Air lines are connected to the blower through flexible couplings in order to keep variation to a minimum and to allow for heat expansion. The air suction line is usually equipped with a manually operated butterfly valves are usually electrically or pneumatically operated.

The impeller is machined on all surfaces for operating at close tolerances and is statically and dynamically balanced. The impeller shaft is supported in a shaft bearing stand which contains a thrust bearing and journal bearings.

Lubrication to the bearings and gears is maintained by a positive displacement main oil pump that is driven by the speed-increasing gear unit. An auxiliary electrically operated centrifugal oil pump is also used to provide oil pressure in the event of failure of the main oil pump and to lubricate the blower shaft bearings before start-up and after shutdown. The oil reservoir is located in the blower base plate. Cartridge type or disc-and–space type oil filter is based on the degree of filtration required.

Due to the very high speeds at which these blower units operate and the resultant high oil temperature, an oil cooler unit is installed. This unit, in most cases, is a shell and tube, oil-to water heat exchanger.

c. Air Filters

Filters remove dust and dirt from air before it is compressed and sent to the various plant processes. Clean air is essential for the protection of blowers and downstream equipment

– Large objects entering the impellers or lobes may cause severe damage on blowers.
– Deposits on the impellers or lobes reduce clearances and cause excessive wear and vibration problems on blowers.

  - Clean air prevents fouling of air conduits, pipes, tubing or dispersing devices on diffusers.

The filters may be constructed of a fibre mesh or metal mesh material that is sandwiched between the screen material and encased in a frame. The filter frames are then installed in a filter chamber. Other types of filters include bags, oil-coated travelling screens and electrostatic precipitators.

The preventive maintenance schedule for the blowers is as follows:

- Weekly
  - Maintain proper lubricant level
- Quarterly
  - Check for abnormal noises and vibration
  - Check if air filters are in place and not clogged
  - Check motor bearing for rise in temperature
  - Check that all covers are in place and secure
  - Lubricate motor ball bearings
  - Check that electrical connections are tight
  - Check wiring integrity
- Biannually
  - Lubricate motor sleeve bearing
  - Inspect and clean rotor ends, windings and blades
  - Check that electrical connections are tight and corrosion is absent
- Annually
  - Check bearing oil

4.7.2.3.2 Air Distribution

The air distribution system (Figure 4.10) is to deliver air from the blowers to air headers in the aeration tanks and other plant processes and consists of:

- Pipes,
- Valves, and
- Metering devices.

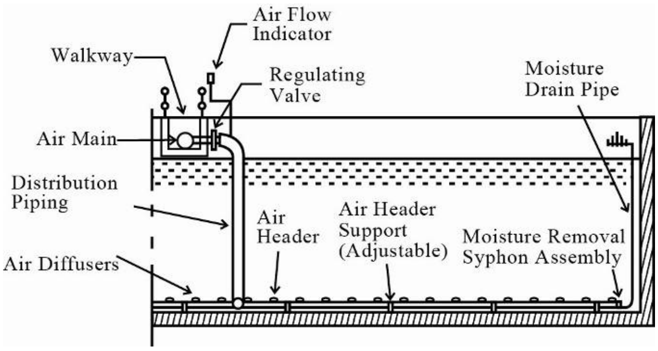


Figure 4.10 Typical air distribution system in aeration tank

An air metering device should be located in a straight section of the air main on the discharge side of the blower.

Air headers are located in or along the aeration tank and are connected to the air distribution system from which they supply air to the diffusers. The two most common types of air headers are the swing header and the fixed header.

The swing header is a pipe with a distribution system connector fitting, a valve, a double pivot upper swing joint, upper and lower riser pipes, pivot elbow, levelling tee and horizontal air headers. An air blow off leg, as an extension of the lower tee connection, is fabricated with multiple alignment flanges, gaskets, and jack screws for levelling of the header.

The fixed header is a pipe with a distribution system connector fitting, a valve, union, a riser pipe, horizontal air headers and header support “feet.” These headers are generally not provided with adjustable levelling devices; they rely on the fixed levelling afforded by the “feet” attached to the bottom of the horizontal air headers. Raising and lowering the air header is commonly found in package plants, channel aeration and grit chamber aeration. Header valves are used to adjust the air flow to the header assembly and to block the air flow to the assembly when servicing the header or diffusers.

4.7.2.3.3 Diffusers

An air diffuser or membrane diffuser is an aeration device used to transfer air and oxygen with oxygen into sewage. Oxygen is required by microorganisms/ bacteria resident in the water to break down the pollutants. Diffusers use the followings to produce fine or coarse bubbles.

- Rubber membrane, or
- Ceramic elements.

The shapes of the diffusers can be:

- Disc,
- Tube, or
- Plate.

a. Bubble size

The subject of bubble size is important because the aeration system in a sewage treatment plant consumes an average of 50 to 70 per cent of the energy of the entire plant. Increasing the oxygen transfer efficiency decreases the power the plant requires to provide the same quality of effluent water.

- Fine bubble

  - Fine bubble diffusers produce a plethora of very small air bubbles which rise slowly from the floor of tank and provide substantial and efficient mass transfer of oxygen to the water.
  - Fine bubble diffusers evenly spread out (often referred to as a “grid arrangement”) on the floor of a tank and provide the operator of the plant a great deal of operational flexibility.
  - This can be used to create zones with high oxygen concentrations (oxic or aerobic), zones with minimal oxygen concentration (anaerobic) and zones with no oxygen (anoxic). This allows for more precise targeting and removal of specific contaminants.
- Coarse bubble
  - There are different types of coarse bubble diffusers from various manufactures, such as the stainless steel wide band type coarse bubble diffuser.
  - Fine bubble diffusers have largely replaced coarse bubble diffusers and mechanical aerators in most of the developed world and in much of the developing world.

b. Maintenance

The preventive maintenance schedule of bubble diffusers is as follows:

- Daily maintenance
  - Check biological reactor surface pattern.
  - Check air mains for leaks.
  - Check and record operating pressure and airflow.
- Weekly maintenance
  - Purge water and moisture from distribution piping.
  - Bump diffuser system.
- Annual maintenance
  - Drain biological reactor.
  - Remove excess solids that may accumulate in the reactor.
  - Clean diffusers.
  - Check that retaining rings are in place and are tight.
  - Check that fixed and expansion joint retaining rings are tight.

4.7.2.3.4 Surface Aerators

A surface aerator is a mechanical aeration device for various types of aerobic sewage treatment systems. Surface aerators may be either stationary or floating. The major components of the mechanical surface aerators are motor, gear box and impeller/ aerator/ propeller. More commonly, these components come combined; but for the purpose of maintenance, they can be easily separated.

Floating aerators generally employ reinforced fibreglass foam filled pontoons connected to the aerator platform by a triangular tubular structural frame. The platforms are sized to provide adequate work area around the drive. Pontoons are placed to minimise any interference with the flow pattern and maximise stability. Each of the pontoons has a ballast compartment which can be filled with water or other liquid or other suitable material to adjust submergence and level the unit.

4.7.3 Extended Aeration Process

This is a modification of the activated-sludge process using long aeration periods to promote aerobic digestion of the biological mass by endogenous respiration (Figure 4.11). The process includes stabilization of organic matter under aerobic conditions and disposal of the gaseous end products into the air. Effluent contains finely divided suspended matter and soluble matter.

Extended aeration is similar to a conventional activated sludge process except that the organisms are retained in the aeration tank longer and do not get as much food. The organisms get less food because there are more of them to feed. Mixed liquor suspended solids (MLSS) concentrations are from 3,000 to 5,000 mg/L and F/M ratio is 0.1 to 0.18. In addition to the organisms consuming the incoming food, they also consume any stored food in the dead organisms. The new products are carbon dioxide, water, and a biologically inert residue. Extended aeration does not produce as much waste sludge as other processes; however, wasting still is necessary to maintain proper control of the process.

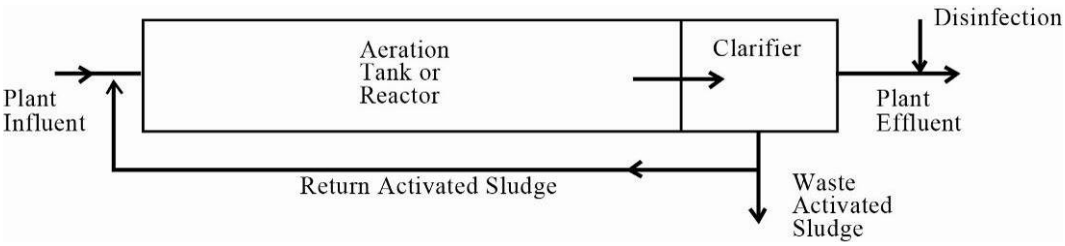


Figure 4.11 Types of extended aeration plants

4.7.3.1 Operation of Aeration Equipment

Aeration equipment should be operated continuously. In a diffused-air system, the operator controls air flow to the diffuser with the header control valve. This valve forces excess air to the air lifts in the settling compartment. Good treatment rarely results from interrupted operation and should not be attempted. The operator can judge how well the aeration equipment is working by the appearance of the water in the settling compartment and the effluent that goes over the weir. If the water is murky or cloudy and the aeration compartment has a rotten egg (H_2S) odour, not enough air is being supplied. The air supplied or aeration rate should be increased slightly each day until the water is clear in the settling compartment. If the water is clear in the settling compartment, the aeration rate is probably sufficient. Try to maintain a DO level of around 2 mg/L throughout the aeration tank, if the operator has a DO probe or lab equipment to measure the DO. Try to measure the DO at different locations in the aeration tank as well as from top to bottom.

4.7.3.2 Operation and Maintenance

Two methods are commonly used to supply oxygen from the air to the bacteria-mechanical aeration and diffused aeration. Both methods are mechanical processes with the difference being whether the mechanisms are at or in the aerator or at a remote location. Mechanical aeration devices agitate the water surface in the aerator to cause spray and waves by paddle wheels mixers, rotating brushes or some other method of splashing water into the air or air into the water so that oxygen can be absorbed. Mechanical aerators in the tank tend to be lower in installation and maintenance costs. Usually, they are more versatile in terms of mixing, production of surface area of bubbles, and oxygen transfer per unit of applied power. Diffused air systems use a device called a diffuser to break up the air stream from the blower system into fine bubbles in the mixed liquor. The smaller the bubble, the greater is the oxygen transfer due to the greater surface area of rising air bubbles surrounded by water. Unfortunately, fine bubbles will tend to regroup into larger bubbles while rising unless they are broken up by suitable mixing energy and turbulence.

Record the pumping time and weekly waste solids for this time period if results are satisfactory. If the extended activated sludge plant does not have an aerobic digester, applying waste activated sludge to drying beds may cause odour problems. If odours from waste activated sludge drying beds are a problem, consider the following solutions:

- Waste the excess activated sludge into an aerated holding tank. This tank can be pumped out and the sludge disposed of in an approved sanitary landfill. If aerated long enough, the sludge could be applied to drying beds.
- The excess or waste activated sludge can be removed by a septic tank pumper and disposed of in an approved sanitary landfill.
- Arrange for disposal of the excess activated sludge at a nearby treatment plant. Annually, check the bottom of the hoppers for rocks, sticks, and grit deposits. Also, check the tail pieces of the air lifts to be sure that they are clear of rags and rubber goods and in proper working condition.

Frequency and amount of wasting may be revised after several months of operation by examining:

- The amount of carryover of solids in the effluent
- The depth to which the solids settle in the aeration compartment when the aeration device is off (should be greater than one-third of the distance from top to bottom)
- The appearance of floc and foam in the aeration compartment as to colour, settleability, foam makeup, and excess solids on the water surface of the tank
- Results of laboratory testing; a white fluffy foam indicates low solids content in the aerator while a brown, leathery foam suggests high solids concentrations. If the operator notices high effluent solids levels at the same time each day, the solids loading may be too great for the final clarifier. Excessive solids indicate the mixed liquor suspended solids concentration is too high for the flows and more solids should be wasted.

4.7.3.3 Normal Operation

Extended activated sludge plants should be visually checked every day. Each visit should include the following:

- Check the appearance of the aeration and final clarification compartments.
- Check the aeration unit for proper operation and lubrication.
- Check the return sludge line for proper operation. If air in the air lift is not flowing properly, briefly close the outlet valve, which forces the air to go down and out the tail piece. This will blow it out and clear any obstructions. Reopen the discharge valve and adjust to desired return sludge flow.
- Check the comminuting device for lubrication and operation.
- Hose down the aeration tank and final compartment.
- Brush the weirs when necessary.
- Skim off grease and other floating material such as plastic and rubber goods.
- Check the plant discharge for proper appearances, grease, or material of sewage origin that is not desirable.

4.7.3.4 Abnormal Operation

Remember that changing conditions or abnormal conditions can upset the microorganisms in the aeration tank. As the temperature changes from season to season, the activity of the organisms speeds up or slows down. Also, the flows and waste (food as measured by BOD and suspended solids) in the plant influent change seasonally. All of these factors require the operator to gradually adjust aeration rates, return sludge rates, and wasting rates. Abnormal conditions may consist of high flows or solids concentrations as a result of storms or weekend loads.

4.7.3.5 Countermeasures

Extended aeration plant problems may be caused by solids in the effluent, odours, and foaming. These problems could be caused by under-or- over aeration, too little or too much solids in the aeration tank, improper return sludge rate, improper sludge wasting or disposal of waste activated sludge, and abnormal influent conditions such as excessive flows or solids or toxic wastes. When problems develop in the activated sludge process, try to identify the problem, the cause of the problem, and select the best possible solution. Remember that the activated sludge process is a biological process and may require from three days to a week or longer to show any response to the proper corrective action. Allow seven or more days for the process to stabilize after making a change in the treatment process.

a. Solids in the Effluent

   i. If effluent appears turbid (muddy or cloudy), the return activated sludge pumping rate is out of balance. Try increasing the return sludge rate. Also, consider the possible presence of something toxic to the microorganisms or a hydraulic overload washing out some of the solids.

   ii. If the activated sludge is not settling in the clarifier (sludge bulking), several possible factors could be causing this problem. Look for too low a solids level in the system, low dissolved oxygen concentrations in the aeration tank, strong, stale, septic influent, high grease levels in influent, or alkaline wastes from a laundry.

   iii. If the solids level is too high in the sludge compartment of the secondary clarifier, solids will appear in the effluent. Try increasing the return sludge pumping rate. If odours are present and the aeration tank mixed liquor appears black as compared with the usual brown colour, try increasing aeration rates and look for septic dead spots.

   iv. If light-coloured floating sludge solids are observed on the clarifier surface, try reducing the aeration rates. Try to maintain the dissolved oxygen at around 2 mg/L throughout the entire aeration tank.

b. Odours

   i. If the effluent is turbid and the aeration tank mixed liquor appears black as compared with the usual brown colour, try increasing aeration rates and look for septic dead spots.

   ii. If clumps of black solids appear on the clarifier surface, try increasing the return sludge rate. Also, be sure the sludge return line is not plugged and that there are no septic dead spots around the edges or elsewhere in the clarifier.

   iii. Examine the method of wasting and disposing of waste activated sludge to ensure this is not the source of the odours.

   iv. Poor housekeeping could result in odours. Do not allow solids to accumulate or debris removed from sewage to sit around the plant in open containers.

c. Foaming/Frothing

Foaming is usually caused by too low a solids level while frothing is caused by too long a solids retention time.

i. If too much activated sludge was wasted, reduce wasting rate.

ii. If over aeration caused excessive foaming, reduce aeration rates.

iii. If plant is recovering from overload or septic conditions, allow time for recovery.

iv. Foaming can be controlled by water sprays or commercially available defoaming agents until the cause is corrected by reducing or stopping wasting and building up solids levels in the aeration tank.

v. Learn more about the operation of an activated sludge process under both normal and abnormal conditions. There operator will also find a troubleshooting guide for activated sludge plants.

4.7.3.6 Maintenance

Maintenance of equipment in extended aeration plants should follow the manufacturer's instructions. Items requiring attention include:

a. Plant Cleanliness

Wash down tank walls, weirs, and channels to reduce the collection of odour-causing materials.

b. Aeration Equipment:

i. Air blowers and air diffusion units

ii. Mechanical aerators

c. Air Lift Pumps

d. Scum Skimmer

e. Sludge Scrapers

f. Froth Spray System

g. Weirs, Gates, and Valves

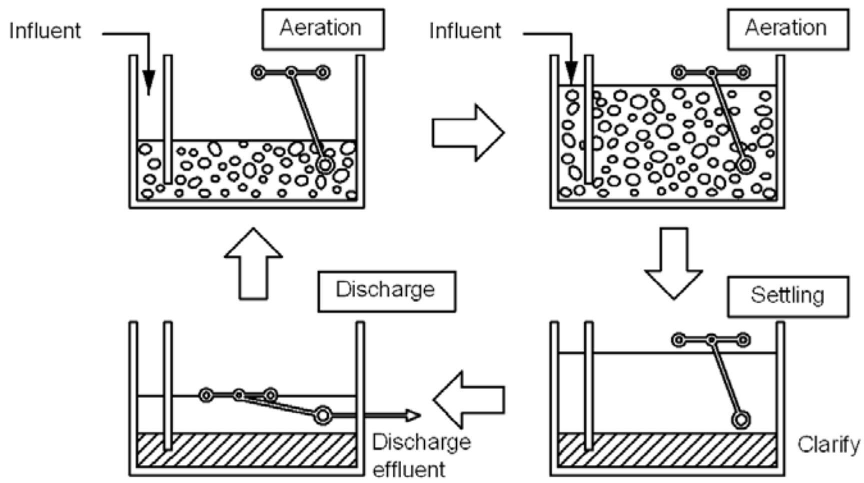
h. Raw Sewage Pumps

4.7.4 Sequencing Batch Reactor (SBR)

In SBR operations, the cycle processes Fill-react, React, Settle and Decant are controlled by time to achieve the objectives of the operation. Each process is associated with particular reactor conditions (turbulent/quiescent, aerobic/anaerobic) that promote selected changes in the chemical and physical nature of the sewage. These changes lead ultimately to a fully treated effluent. Figure 4.12 shows a typical SBR operation.

- Fill or Fill-react

The purpose of Fill-React operation is to add substrate (raw sewage) to the reactor. The addition of substrate can be controlled either by limit switches to a set volume or by a timer to a set time period. If the volume is set, the Fill-React process typically allows the liquid levels in the reactor to rise from 50-80 per cent to 100 per cent. If controlled by time, the Fill-React process normally lasts approximately 25 per cent to 50 per cent of the full cycle time. Period of aeration and/or mixing during Fill are critical to the development of organisms with good settling characteristics and to biological nutrient removal (Nitrogen (N), Phosphorus (P)). An advantage of the SBR system of time control is its ability to modify the reactor conditions during the phases to achieve the treatment goals. This phase ends when the liquid level in the tank reaches a predetermined level.



Source: Nishihara Environment Co., Ltd.

Figure 4.12 Operating cycles of intermittent SBR process

- Settle

The purpose of Settle is to allow solids separation to occur, providing a clarified supernatant to be discharged as effluent. In the SBR, this process is normally more efficient than in a continuous flow system, because in the Settle mode the reactor contents are completely quiescent. The Settle process is controlled by time and is usually fixed between 30 minutes to an hour so that the sludge blanket remains below the withdrawal mechanism during the next phase.

- Decant/Discharge

The purpose of Decantation is to remove the clarified, treated water from the reactor.

Sludge wasting is another important step in SBR operation that greatly affects process performance. It is not included as one of the three basin processes because there is no set time period within the cycle dedicated to wasting. The amount and frequency of sludge wasting is determined by process requirements, as with conventional continuous flow systems. In an SBR operation, sludge wasting usually occurs during the Settle or Decant phases. A unique feature of the SBR system is that there is no need for a RAS system. Since the aeration and settling occurs in the same tank, no sludge is lost in the reaction phase and none has to be returned from clarifier to maintain the sludge content in the aeration tank. This eliminates the need for the hardware and controls associated with the conventional RAS system. The sludge volume and, thus, sludge age in the reactor of the SBR system is controlled by sludge wasting only.

The manual given by the equipment supplier should be followed. Usually these units are controlled automatically by programmable logic controllers (PLCs). The precaution needed is to make sure that power supply is available continuously. If power supply fails, immediately bring the genset on-line. If there is no genset or if there is no diesel, do not operate the SBR and close it. Inform the plant in charge and also report to the official responsible for overall O&M in the head office directly.

4.7.4.1 Process Control

The SBR has in built process control. Depending on the BOD load, it adjusts the Dissolved Oxygen (DO) supply by sensing the residual DO and varying the speed of air compressor and hence the rate of air supply. The most important thing for day to day testing is to understand the SBR as designed. It may have fully aerobic or anoxic and aerobic or anaerobic, anoxic and aerobic.

If anaerobic cycle is there, check whether the floor level mixer is working and if it is out of order, start the installed standby mixer. If both are not in order, enter in the site register and inform the plant in charge. Make sure that hydrogen sulphide gas is not sensed in the ambient air near the SBR. If it is sensed by smell, then going near the tank is not advisable. Make sure it is entered in the site register and it is reported directly to the plant in charge. The operator should not try and remedy the position. The supervisor should institute and take steps to get the designer, contractor and O&M team together and rectify the situation. There is a theory that COD to sulphate ratio is deciding the process. This needs to be checked up and corrected. A method of correcting the imbalance will be to recycle the treated effluent from a treated sewage sump to dilute the COD of incoming sewage. The daily tests shall be pH, COD and dissolved phosphate measured by colorimetric method or Nessler Tubes of 50 ml with fresh standards prepared every week. BOD can be a weekly test.

In the anoxic cycle, check whether the floor level mixer is working and if it is out of order, start the installed standby mixer. If both are not in order, enter it in the site register and inform the plant in charge. Daily tests will be nitrate estimated by Nesslerization procedure in 50 ml Nessler tubes. The test is to be done in the beginning, in the mid cycle and at the completion of the cycle of anoxic phase. If there is no reduction in the nitrate, then something is not in order. Proceed to check the MLVSS. It should be at least 75 %. If this is not so, enter the value in the site register and inform the plant in charge. The supervisor should institute and take steps to get the designer, contractor and O&M team together and rectify the situation.

In the aeration cycle, check the residual DO. This is to be indicated by the built in sensor. If the sensor is not working use the Winkler method by collecting the mixed liquor and filtering it through Whatman filter paper number 4 in a BOD bottle and with the tip of the funnel connected by a rubber tubing so that the filtrate enters the BOD bottle in the submerged condition always and avoids additional aeration. A procedure for easy use in the field for instantly testing the BOD is to use a “BOD tube.” This has been introduced in the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) by M/S Severn Trent of UK as part of a twinning arrangement. Details of the tube can be obtained from CMWSSB. A photograph of the CMWSSB chemist using the tube is shown in Figure 4.13.

The principle of the test is related to the BOD caused by colloidal and suspended organics as relatable to the BOD. The BOD related to suspended solids is inbuilt in the calibration. This tube is developed only for sewage and not for industrial effluents. The test is performed by holding the tube as in the photo after filling the treated sewage to incremental heights and finding out at which point, the black coloured + mark at the bottom vanishes. There is a reading etched on the side of the tube and this is read at the sewage level when the + mark vanishes from sight. The principle is the colloidal solids and SS have their portion of BOD. The more the volume needed to “hide” the bottom + mark, the less is the colloidal solids and SS and hence, the lesser is the BOD due to this portion. It is a combination of nephelometry and theory. Usually the results are within 90%.

- The BOD tube

  The Palintest Tube is a specially calibrated plastic tube and is the simplest possible method of performing the instantaneous probable BOD and SS tests on secondary treated sewage in the field to help the operator to get a feel of these parameters quickly. The test kit is a tube graduated at 30 to 500 turbidity units. A double length tube with additional graduations from 5 to 25 turbidity units is optionally available. These were calibrated by the Department of Public Health Engineering, University of Newcastle upon Tyne. It has an etched black cross mark at bottom.

- Procedure
  - Hold the tube vertically over a white surface and view downwards.
  - Gradually pour secondary sewage and watch the cross mark.
  - Stop pouring when the cross mark is no longer visible.
  - Read the graduation at the top of the sample in the tube.
  - This represents the turbidity in Jackson Turbidity units (JTU).
  - For secondary sewage, the graduation may also be taken as SS.
  - Half the value of JTU plus 5 is also the probable BOD.

Source: CMWSSB

Figure 4.13 Use of a BOD tube for instantaneous assessment of the BOD at site

If the DO is lesser than 20 % of the design value, enter it in the site register and inform the plant in charge. Check the MLVSS if the above situation occurs. This can be a weekly test. Check the COD.

In the settling cycle, check the SS of the decanted effluent and its COD. There is no need to check the BOD at the end of every cycle. Prepare a curve of BOD to COD for the treated sewage and verify the BOD by testing for the COD. This will show the trend every two hours itself instead of 3 days for BOD actual test. This can however be a weekly test. If the SS and BOD varies by more than 10 % in the treated sewage, enter the values in the site register and inform the plant in charge. The decanter cannot be subjected to preventive maintenance in a functioning SBR. The raw sewage has to be bypassed with prior permission of the supervisor before this is carried out. The electrical drive of the decanter will require its greasing in some equipment. Make sure there is a grease guard and grease does not fall into the SBR basin. Where the rope and pulley method is used, change the rope every month.

4.7.4.2 Records

The limited parameters as above and the flow rate and cycle times are the records.

4.7.4.3 Housekeeping

In all SBR systems, verify build up of slime on the sidewalls in the freeboard. If noticed, scrub it down into the basin itself during the filling phase. This can be done by the operator standing on the peripheral walkway and using a long handle wire brush. If there is no such walkway, leave the slime as it is.

4.7.5 Oxidation Ditch

An oxidation ditch is a modified activated sludge biological treatment process that utilizes long Solids Retention Times (SRTs) to remove biodegradable organics. Oxidation ditches are typically complete mix systems, but they can be modified to approach plug flow conditions. (Note: As conditions approach plug flow, diffused air must be used to provide enough mixing. The system will also no longer operate as an oxidation ditch). Typical oxidation ditch treatment systems consist of a single or multichannel configuration within a ring, oval, or horseshoe-shaped basin. As a result, oxidation ditches are called "racetrack type" reactors. Horizontally or vertically mounted aerators provide circulation and aeration in the ditch.

Preliminary treatment, such as bar screens and grit removal, normally precedes the oxidation ditch. Primary settling prior to an oxidation ditch is sometimes practiced, but is not typical in this design.

Flow to the oxidation ditch is aerated and mixed with return sludge from a secondary clarifier. A typical process flow diagram for an activated sludge plant using an oxidation ditch is shown in Figure 4.14.

There is usually no primary settling tank or grit removal system used in this process. Inorganic solids such as sand, silt, and cinders are captured in the oxidation ditch and removed during sludge wasting or cleaning operations. The raw sewage passes directly through a bar screen to the ditch.

The bar screen is necessary for the protection of the mechanical equipment such as rotor and pumps. Comminutors or barminutors may be installed after the bar screen or instead of a bar screen. The oxidation ditch forms the aeration basin and here the raw sewage is mixed with previously formed active organisms. The rotor is the aeration device that entrains (dissolves) the necessary oxygen into the liquid for microbial life and keeps the contents of the ditch mixed and moving. The velocity of the liquid in the ditch must be maintained to prevent settling of solids, normally 0.3 to 0.45 m/sec. The ends of the ditch are well rounded to prevent eddying and dead areas, and the outside edges of the curves are given erosion protection measures.

The mixed liquor flows from the ditch to a clarifier for separation. The clarified water passes over the effluent weir and is chlorinated. Plant effluent is discharged to either a receiving stream, percolation ditches, or a subsurface disposal or leaching system. The settled sludge is removed from the bottom of the clarifier by a pump and is returned to the ditch or wasted. Scum that floats to the surface of the clarifier is removed and either returned to the oxidation ditch for further treatment or disposed of by burial.

Since the oxidation ditch is operated as a closed system, the amount of volatile suspended solids will gradually increase. It will periodically become necessary to remove some sludge from the process. Wasting of sludge lowers the MLSS (mixed liquor suspended solids) concentration in the ditch and keeps the microorganisms more active.

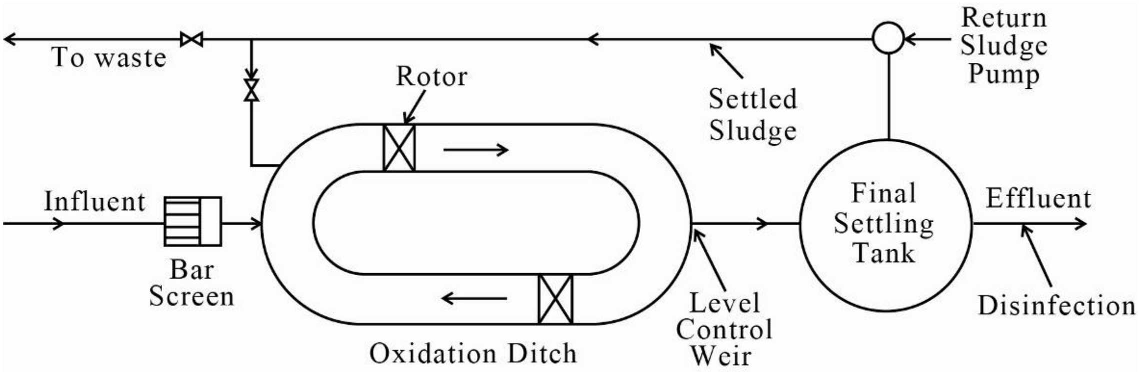


Figure 4.14 Oxidation ditch

4.7.5.1 Operation

Process controls and operation of an oxidation ditch are similar to the activated sludge process. To obtain maximum performance efficiency, the following control methods must be maintained.

a. Proper Food Supply for the Microorganisms

Influent flows and waste characteristics are subject to limited control by the operator. Municipal ordinances may prohibit discharge to the collection system of materials that are damaging to treatment structures or to human safety. Control over wastes dumped into the collection system requires a pre-treatment facility inspection program to ensure compliance. Alternate means of disposal, pre-treatment, or controlled discharge of significantly damaging wastes may be required in order to permit dilution to an acceptable level by the time the waste arrives at the treatment plant.

b. Proper DO Levels

Proper operation of the process depends on the rotor assembly supplying the right amount of oxygen to the waste flow in the ditch. For the best operation, a DO concentration of 0.5 to 2.0 mg/L should be maintained just upstream of the rotors. Over oxygenation wastes power and excessive DO levels can cause a pinpoint floc to form that does not settle and is lost over the weir in the settling tank. Control of rotor oxygenation is achieved by adjusting the ditch outlet level control weir.

The level or elevation of the rotors is fixed but the deeper the rotors sit in the water, the greater the transfer of oxygen from the air to the water (greater DO). The ditch outlet level control weir regulates the level of water in the oxidation ditch.

c. Proper Environment

The oxidation ditch process with its long-term aeration basin is designed to carry MLSS concentrations of 3,000 to 5,000 mg/L. This provides a large organism mass in the system. Performance of the ditch and ditch environment can be evaluated by conducting a few simple tests and general observations. The colour and characteristics of the floc in the ditch as well as the clarity of the effluent should be observed and recorded daily. Typical tests are settleable solids, DO upstream of the rotor, pH, and residual chlorine in the plant effluent.

Laboratory tests such as BOD, COD, suspended solids, volatile solids, total solids, and microscopic examinations should be performed periodically by the plant operator or an outside laboratory. The results will aid operator in determining the actual operating efficiency and performance of the process.

Oxidation ditch solids are controlled by regulating the return sludge rate and waste sludge rate. Remember that solids continue to deteriorate as long as they remain in the clarifier. Adjust the return sludge rate to return the microorganisms in a healthy condition from the final settling tank to the oxidation ditch. If dark solids appear in the settling tank, either the return sludge rate should be increased (solids remaining too long in clarifier) or the DO levels are too low in the oxidation ditch.

Adjusting the waste sludge rate regulates the solids concentration (number of microorganisms) in the oxidation ditch. The appearance of the surface of the oxidation ditch can be a helpful indication of whether the sludge wasting rate should be increased or decreased. If the foam on the surface is white and crisp, reduce the wasting rate. If the foam on the surface is thick and dark, increase the wasting rate. Waste activated sludge may be removed from the ditch by pumping to a sludge holding tank, to sludge drying beds, to sludge lagoons, or to a tank truck. Ultimate disposal may be to larger treatment plants or to approved sanitary landfills.

Remember that this is a biological treatment process and several days may be required before the process, responds to operation changes. Make operator changes slowly, be patient, and observe and record the results.

d. Proper Treatment Time and Flow Velocities

Treatment time is directly related to the flow of sewage and is controlled by an adjustable weir. Velocities in the ditch should be maintained at 0.3 to 0.45 m/sec to prevent the deposition of floc. With this in mind, the ditch contents should travel the complete circuit of the ditch, or from rotor to rotor every 3 to 6 minutes. If the rotors are operated by time clocks (30 minutes off and 30 minutes on, for example), the velocities in the ditch must be sufficient to re-suspend any settled material.

e. Proper Water/Solids Separation

MLSS that have entered and settled in the secondary clarifier are continuously removed from the clarifier as return sludge, by pump, for return to the oxidation ditch. Usually, all sludge formed by the process and settled in the clarifier is returned to the ditch, except when wasting sludge. Scum that is captured on the surface of the clarifier also is removed from the clarifier and either returned to the oxidation ditch for further treatment or disposed of by burial.

f. Observations

Some aspects of the operation of an oxidation ditch plant can be controlled and adjusted with the help of some general observations. General daily observations of the plant are important to help operator determine whether or not the oxidation ditch is operating as intended. These observations include colour of the mixed liquor in the ditch, odour at the plant site, and clarity of the ditch and sedimentation tank surfaces.

i. Colour

Operator should note the colour of the mixed liquor in the ditch daily. Mixed liquor from a properly operating oxidation ditch plant should have a medium to rich dark brown colour. If the MLSS, following proper start-up, changes colour from a dark brown to a light brown and the MLSS appears to be thinner than before, the sludge waste rate may be too high, which may cause the plant to lose efficiency in removing waste materials. By decreasing sludge waste rates before the colour lightens too much, operator can ensure that the plant effluent quality will not deteriorate due to low MLSS concentrations.

If the MLSS becomes black, the ditch is not receiving enough oxygen and has gone anaerobic. The oxygen output of the rotors must be increased to eliminate the black colour and return the process to normal aerobic operation. This is done by increasing the submergence level of the rotor.

ii. Odour

When the oxidation ditch plant is operating properly, there will be little or no odour. Odour, if detected, should have an earthy smell. If an odour other than this is present, operator should check and determine the cause. Odour similar to rotten eggs indicates that the ditch may be going anaerobic, requiring more oxygen or a higher ditch velocity to prevent deposition of solids. The colour of the MLSS could be black if this were the case. Odour may also be a sign of poor housekeeping. Grease and solids build-up on the edge of the ditch or sedimentation tank will go anaerobic and cause odours. In an oxidation ditch, odours are much more often caused by poor housekeeping than by poor operation.

iii. Clarity

In a properly operating oxidation ditch, a layer of clear water or supernatant is usually visible about a meter upstream from the rotor. The depth of this relatively clear water may vary from almost nothing to as much as five or more cm above the mixed liquor. The clarity will depend on the ditch velocity and the settling characteristics of the activated sludge solids.

Two other good indications of a properly operating oxidation ditch are the clarity of the settling tank water surface and the oxidation ditch surface free of foam build-up. Foam build-up in the ditch (normally not enough to be a nuisance) is usually caused by insufficient MLSS concentration. Most frequently foam build-up is only seen during plant start-up and will gradually disappear.

Clarity of the effluent from the secondary clarifier discharged over the weirs is the best indication of plant performance. A very clear effluent shows that the plant is achieving excellent pollutant removals. A cloudy effluent often indicates a problem with the plant operation.

4.7.5.2 Equipment Maintenance

Regularly scheduled equipment maintenance must be performed according to manufacturers' instruction manuals. Operator should check each piece of equipment daily to see that it is functioning properly. There may have very few mechanical devices in the oxidation ditch plant, but they are all important.

The rotors and pumps should be inspected to ensure that they are operating properly. If pumps are clogged, the obstructions should be removed. Listen for unusual noises. Check for loose bolts. Uncovering a mechanical problem in its early stages could prevent a costly repair or replacement at a later date.

Lubrication should also be performed with a fixed operating schedule and properly recorded. Follow the lubrication and maintenance instructions furnished with each piece of equipment. Make sure that the proper lubricants are used. Over lubrication is wasteful and reduces the effectiveness of lubricant seals and may cause overheating of bearings or gears.

4.7.6 Chemical Clarification

Chemicals are used for a variety of municipal treatment applications, such as to enhance flocculation/sedimentation, condition solids, add nutrients, neutralize acid base, precipitate phosphorus, and disinfect or to control odours, algae, or activated-sludge bulking.

Chemical precipitation is a widely used, proven technology for the removal of metals and other inorganics, suspended solids, fats, oils, greases, and some other organic substances (including organophosphates) from sewage.

Precipitation is assisted through the use of a coagulant, an agent which causes smaller particles suspended in solution to gather into larger aggregates. Frequently, polymers are used as coagulants. The long-chain polymer molecules can be either positively or negatively charged (cationic or anionic) or neutral (non-ionic). Since sewage chemistry typically involves the interaction of ions and other charged particles in solution, these electrical qualities allow the polymers to act as bridges between particles suspended in solution, or to neutralize particles in solution. The specific approach used for precipitation will depend on the contaminants to be removed, as described below.

4.7.6.1 Metals Removal

Water hardness is caused primarily by the dissolution of calcium and magnesium carbonate and bicarbonate compounds in water, and to a lesser extent, by the sulphates, chlorides, and silicates of these metals. The removal of these dissolved compounds, called water softening often proceeds by chemical precipitation. Lime (calcium oxide), when added to hard water, reacts to form calcium carbonate, which itself can act as a coagulant, sweeping ions out of solution in formation and settling.

To do this with lime alone, a great deal of lime is typically needed to work effectively; for this reason, the lime is often added in conjunction with ferrous sulphate, producing insoluble ferric hydroxide. The combination of lime and ferrous sulphate is only effective in the presence of dissolved oxygen, however. Alum, when added to water containing calcium and magnesium bicarbonate alkalinity, reacts with the alkaline substances to form an insoluble aluminium hydroxide precipitate.

Soluble heavy metal ions can be converted into insoluble metal hydroxides or carbonates through the addition of hydroxide compounds. Additionally, insoluble metal sulphides can be formed with the addition of ferrous sulphate and lime.

Once the optimal pH for precipitation is established, the settling process is often accelerated by addition of a polymer coagulant, which gathers the insoluble metal compound particles into a coarse floc that can settle rapidly by gravity.

4.7.6.2 Phosphorus Removal

Metal salts (most commonly ferric chloride or aluminium sulphate, also called alum) or lime, have been used for the removal of phosphate compounds from water. When lime is used, a sufficient amount of lime must be added to increase the pH of the solution to at least 10, creating an environment in which excess calcium ions can react with the phosphate to produce an insoluble precipitate (hydroxyl apatite). Lime is an effective phosphate removal agent, but results in a large sludge volume.

When ferric chloride or alum is used, the iron or aluminium ions in solution will react with phosphate to produce insoluble metal phosphates. The degree of insolubility for these compounds is pH dependent.

4.7.6.3 Suspended Solids

Finely divided particles suspended in solution can escape filtration and other similar removal processes. Their small size allows them to remain suspended over extended periods of time.

More often than not, the particles populating sewage are negatively charged. For this reason, cationic polymers are commonly added to the solution, both to reduce the surface charge of the particles, and also to form bridges between the particles, thus causing particle coagulation and settling.

Alternatively, lime can be used as a clarifying agent for removal of particulate matter. The calcium hydroxide reacts in the sewage solution to form calcium carbonate, which itself acts as a coagulant, sweeping particles out of solution.

4.7.6.4 Additional Considerations

The amount of chemicals required for treatment depends on the pH and alkalinity of the sewage, the phosphate level, and the point of injection and mixing modes, among other factors.

Competing reactions often make it difficult to calculate the quantities of additives necessary for chemical precipitation. Accurate doses should be determined by jar tests and confirmed by field evaluations. Chemicals are usually added by a chemical feed system that can be completely enclosed and may also include storage space for unused chemicals.

Choosing the most effective coagulant depends on jar test results, ease of storage, ease of transportation, and consideration of the operation and maintenance costs for associated equipment.

Chemical precipitation is normally carried out through a chemical feed system, most often a totally automated system providing for automatic chemical feeding, monitoring, and control. Full automation reduces manpower requirements, allows for less sophisticated operator oversight, and increases efficiency through continuous operation.

An automatic feed system may consist of storage tanks, feed tanks, metering pumps (although pumpless systems do exist), overflow containment basins, mixers, aging tanks, injection quills, shot feeders, piping, fittings, and valves.

Chemical feed system storage tanks should have sufficient capacity to run for some time without running out and causing downtime. At least a one month supply of chemical storage capacity is recommended, though lesser quantities may be justified when a reliable supplier is located nearby, thus alleviating the need for maintaining substantial storage space. Additive chemicals come in liquid and dry form.

4.7.6.5 Jar Testing

Secondary treated sewage from STPs may sometimes carry over the microbes from the clarifier. When chlorination of the treated sewage is to be carried out, these suspended microbes will consume the added chlorine before the organic matter in the treated sewage can be oxidized and pathogenic faecal organisms can be killed. Hence, it may be necessary to carry out coagulation, flocculation and sedimentation before chlorine is applied. For details of the theory of coagulation, flocculation and sedimentation, the CPHEEO Manual on Water Supply and Treatment may be consulted. The purpose of a jar test is to find out which chemical and at what dosage is needed to improve the clarity of secondary treated sewage. In general, such coagulation, flocculation and sedimentation are not recommended for raw sewage because the disposal of the resulting sludge becomes difficult due to a mix of biological and chemical sludge. At the same time, the phosphorous present in sewage at even as low as 1 mg/l is known to form a coating around the flocs and prevent them from settling and this in fact increases the turbidity of raw sewages. This is the reverse of addition of phosphate to cooling waters to prevent the precipitated scales from settling out in the heat exchanged surfaces.

Jar testing entails adjusting the amount of treatment chemicals and the sequence in which they are added to samples of raw sewage held in jars or beakers. The sample is then stirred so that the formation, development, and settlement of floc can be watched just as it would be in the fullscale treatment plant. (Floc forms when treatment chemicals react with material in the raw sewage and clump together.)

A typical laboratory bench scale jar test apparatus can be shown in Figure 4.15. The apparatus allows for six samples each of 1-2 Litre in size, to be tested simultaneously.

Source: http://www.neutecgroup.com

Figure 4.15 Typical jar testing apparatus

The procedure of jar testing is as follows;

The following jar test procedure uses alum (aluminum sulfate) a chemical for coagulation/ flocculation in sewage treatment, and a typical six jar tester.

a. First, using a 1,000 millilitre (mL) graduated cylinder, add 1,000 mL of raw water to each of the jar test beakers. Record the temperature, pH, turbidity, and alkalinity of the raw water before beginning.

b. Prepare a stock solution by dissolving 10.0 grams of alum into 1,000 mL distilled water. Each 1.0 mL of this stock solution will equal 10 mg/L (ppm) when added to 1,000 mL of water to be tested.

c. Using the prepared stock solution of alum, dose each beaker with increased amounts of the solution. See Table 4.2 below for an example of the increments and dosage:

d. After dosing each beaker, turn on the stirrers. This part of the procedure should reflect the actual conditions of the plant as much as possible. Meaning, if the plant has a static mixer following chemical addition, followed by 30 minutes in a flocculator, then 1.5 hours of settling time before the filters, then the test also should have these steps. The jar test would be performed as follows: Operate the stirrers at a high RPM for 1 minute to simulate the rapid mixer.

e. Reduce the speed of the stirrers to match the conditions in the flocculator and allow them to operate for 30 minutes. Observe the floc formation periodically during the 30 minutes.

f. At the end of the 30 minutes turn off the stirrers and allow settling. Most of the settling will be complete after one hour.

g. Use a pipette to draw a portion from the top of each beaker, and measure its turbidity.

h. Plot supernatant turbidity versus alum dose (Figure 4.16) for the sewage sample and comment on their shapes.

i. Find out the optimum alum dose. i.e., 25 mg/L from Figure 4.16

If none of the beakers appear to have good results, then the procedure needs to be run again using different dosages until the correct dosage is found

Table 4.2 Dosing in Jar Test

Jar No.	ml Alum Stock Added	mg/L Alum Dosage
1	1.0	10.0
2	1.5	15.0
3	2.0	20.0
4	2.5	25.0
5	3.0	30.0
6	3.5	35.0

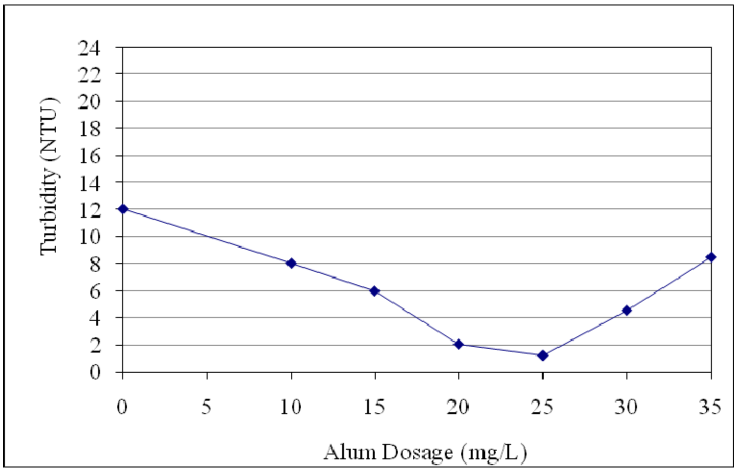


Figure 4.16 Supernatant turbidity vs. Alum dose

4.8 AERATED LAGOON

The aerated lagoon process consists of aeration of the facultative pond of the stabilization pond by means of an aerator. (Refer to Section 4.13 “Waste stabilization pond”)

Aerated lagoons are generally provided in the form of simple earthen basins with inlet at one end and outlet at the other to enable the sewage to flow through while aeration is usually provided by mechanical means to stabilize the organic matter. The major difference between activated sludge systems and aerated lagoons is that in the latter settling tanks and sludge recirculation are absent.

4.8.1 Process Control

Daily tests will be for SS and COD. The BOD will be obtained from the standard curve made out for this sewage from a curve of BOD to COD. The BOD tube is also useful. There is nothing much to do by way of process control in aerated lagoon except making sure that all surface aerators are in working condition. Some aerated lagoons have a final section of the lagoon itself as the settling compartment. Some other lagoons have a dedicated clarifier outside the lagoon. In such a case, the return sludge is also provided in some STPs. This return sludge arrangement must run continuously. The excess sludge disposal is not provided for in aerated lagoons normally. In case of clarifiers it may be used. Mechanical dewatering facilities are generally not advised because the MLSS concentrations will be much lesser than in conventional ASPs. Sludge drying beds with green cover to prevent direct rainfall on the beds is the answer to such situations.

The DO concentration in an aerated lagoon is the best means to determine if the lagoon is operating properly. Typical practice is to maintain 1 to 2 mg/l DO in the lagoon. A minimum DO level of 1 mg/l should be maintained in the lagoon during the heaviest loading periods. Often the heaviest oxygen demand is during the night when the algae are respiring. The pH range in the lagoon should range from 7 to 8. The pH can exceed 9 during algal blooms, especially in low-alkalinity sewage. Surface mechanical aerators when used, should produce good turbulence and a light amount of froth.

4.8.2 Records

The limited parameters as above and the flow rate and cycle times shall be maintained as records.

4.8.3 Housekeeping

Keep the bunds free of any grass or weeds. Do not allow tree branches of trees to hang over the lagoon. Follow all guidelines for motors. If high speed floating aerators are used, pull them out of the lagoon before attending to it. Check if the power cable is having sufficient slack. Verify that the power cable is tied at about 3-m centres to vertical secure posts. Do not enter the lagoon unless you are wearing a life vest and are on a boat with an aide if the aerators are not connected by a platform.

In all aerated lagoons, weeds and over hanging tree branches shall be avoided. A photo of such a situation is shown in Figure 4.17.

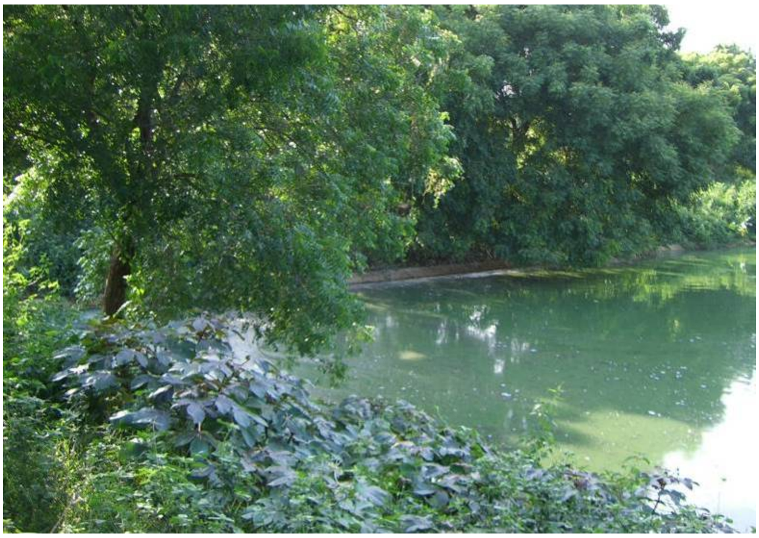


Figure 4.17 Overhanging tree branches and the small area of the lined bund may be seen

- The tree roots will enter the lining and break the concrete slab joints easily.
- Once this occurs, the slabs will lose their strength and start falling down into the lagoon itself.
- Once this sets in, the earth in the bund will be easily eroded in rains and the bund will cave in.
- This leads to the lagoon sewage running out on land and polluting the land and water in wells and streams.
- The hanging tree branches will be dropping leaves which will support growth of mosquitoes.
- Manual scraping shall be done from the top of bund and not by persons entering the lagoon.
- In such cases, the branches shall be cut and the cut portions sealed with cow dung.

The biggest danger is if the bund gets broken and sewage escapes; it is very difficult to control

- Reconstructing the bund is also a problem when raw sewage keeps coming daily.
- Stopping the sewage escaping from the broken bund can be done by the following:
  - Pack cement bags with mix of 90 % clay and 10% sewage and stack them one over the other.
  - These have to be dumped to form a cofferdam inside the sewage spread.
  - Thereafter, the reconstruction of the bund can be taken up easily.

4.9 ATTACHED GROWTH SYSTEMS

One of major attached growth systems adopted in sewage treatment lately is a "fixed film synthetic media filter", which consists of synthetic media such as inclined corrugated media placed in cube sized packs and the inclinations changed to opposite directions in successive layers as shown in Figure 4.18.

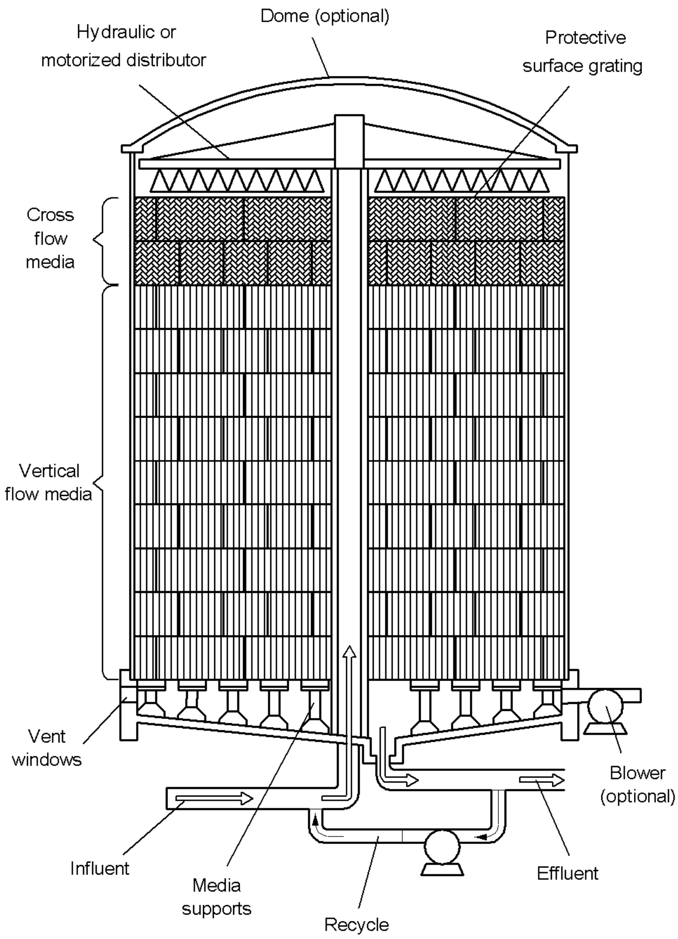


Figure 4.18 Fixed film synthetic media filters

Primary sedimentation is a pre-requirement in these applications. In Figure 4.18, the applied sewage is distributed from the top of the media pack by stationary or hydraulically driven reverse jet arms on opposite radii or rotated by a mechanical drive. The requirements to apply the sewage on the entire plan are to uniformly and simultaneously allow the gas exchange by releasing at the top and fresh air automatically forcing itself from the bottom. The microbial films develop on the fixed media and bring about the metabolism as the sewage passes over them as a film. In due course of time, the thickness of the film increases and results in sloughing and getting carried away to secondary settling tanks. Recirculation of the treated effluent is sometimes practiced before sedimentation so that the enzymes released by the microbes are returned to the reactor for solubilising the sewage organicmatter.

4.9.1 Operation

Many operating problems may be avoided by changing one or more of the following process control variables: distribution rates, and clarifier operation.

a. Distribution Rates

As a principal process control measure, operators can control the rates at which sewage and filter effluent are distributed to the filter media. Recirculation can serve several purposes, as follows:

- Reduce the strength of the sewage being applied to the filter.
- Increase the hydraulic load to reduce flies, snails, or other nuisances.
- Maintain distributor movement during low flows.
- Produce hydraulic shear to encourage solids sloughing and prevent ponding.
- Reseed the filter’s microbial population.
- Provide uniform flow distribution.
- Prevent filters from drying out.

b. Clarifier Operation.

The manner in which secondary clarifiers are operated can significantly affect the filter performance. Although clarifier operation with fixed film reactors is not as critical as that with suspended-growth systems, operators must still pay close attention to final settling.

Sludge must be removed quickly from the final settling tank before gasification occurs or denitrification causes solids to rise. Use of the secondary clarifier as a principal means of thickening (rather than simply for solids settling) may not produce the best effluent quality, especially during summer months, when denitrification is likely to occur. The sludge blanket depth in the secondary clarifier should be limited to 0.3 to 0.6 m. Continuous pumping or intermittent pumping with automatic timer control are used to accomplish solids wasting.

4.9.2 Maintenance

Planned maintenance will vary from plant to plant, depending on unique design features and equipment installed. Although this chapter cannot address all of these items, a summary of the most common and important maintenance tasks follows.

Table 4.3 is a guide to planned maintenance.

Table 4.3 Planned maintenance for fixed film synthetic media filters

Rotary Distributors
Observe the distributor daily. Make sure the rotation is smooth and that spray nozzles are not plugged.
Lubricate the main support bearings and any guide or stabilizing bearings according to the manufacturer’s instructions. Change lubricant periodically, typically twice a year. If the bearings are oil-lubricated, check the oil level, drain condensate weekly, and add oil as needed.
Time the rotational speed of the distributor at one or more flow rates. Record and file the results for future comparison. A change in speed at the same flow rate indicates bearing trouble.
Flush distributor arms monthly by opening end shear gates or blind flanges to remove debris. Drain the arms if idle during cold weather to prevent damage via freezing.
Clean orifices weekly with a high-pressure stream of water or with a hooked piece of wire.

Rotary Distributors
Keep distributor arm vent pipes free of ice, grease, and solids. Clean in the same manner as the distributor arm orifices. Air pockets will form if the vents are plugged. Air pockets will cause uneven hydraulic loading in the filter, and nonuniform load and excessive wear of the distributor support bearing.
Make sure distributor arms are level. To maintain level, the vertical guy wire should be taken up during the summer and let out during the winter by adjusting the guy wire tie rods. Maintain arms in the correct horizontal orientation by adjusting horizontal tie rods.
Periodically check distributor seal and, if applicable, the influent pipe to distributor expansion joint for leaks. Replace as necessary. During replacement check seal plates for wear and replace if wear is excessive. Some seals should be kept submerged even if the filter is idle or their life will be severely shortened.
Remove ice from distributor arms. Ice buildup causes nonuniform loads and reduces main bearing life.
Paint the distributor as needed to guard against corrosion. Cover bearings when sandblasting to protect against contamination. Check oil by draining a little oil through a nylon stocking after sandblasting. Ground the distributor arms to protect bearings if welding on distributor and lock out the drive mechanism at the main electrical panel. Adjust secondary arm overflow weirs and pan test sewage distribution on filter as needed.
Fixed nozzle distributors
Observe spray pattern daily. Unplug block nozzles manually or by increasing hydraulic loading. Flush headers and laterals monthly by opening end plates. Adjust nozzle spring tension as needed.
Filter media
Observe condition of filter media surface daily. Remove leaves, large solids and plastics, grease balls, broken wood lath or plastic media, and other debris. If ponding is evident, find and eliminate the cause. Keep vent pipes open, and remove accumulated debris. Store extra plastic media out of sunlight to prevent damage via ultraviolet rays. Observe media for settling. After they are installed, media settle because of their own weight and the weight of the biofilm and water attached to its surface. Settling should be uniform and should stabilize after a few weeks. Total settling is typically less than 0.3 m for random plastic media, less for plastic sheet media, and nearly zero for rock. If settling is nonuniform or excessive, remove some of the media for inspection.
Observe media for hydraulic erosion, particularly in regions where reversing jets hit the media.
Underdrains
Flush out periodically if possible. Remove debris from the effluent channels.
Media containment structure
Maintain spray against inside wall of filter to prevent filter fly infestation and to prevent ice buildup in winter.
Practice good housekeeping. Keep fibreglass, concrete, or steel outside walls clean and painted, if applicable. Keep grass around structures cut, and remove weeds and tall shrubs to help prevent filter fly and other insect infestations. Remember, using insecticides around treatment units may have adverse effects on water quality or biological treatment units.
Filter pumps
Check packing or mechanical seals for leakage daily. Adjust or replace as needed. Lubricate pump and motor bearings as per manufacturer's instructions. Keep pump motor as clean and dry as possible. Periodically check shaft sleeves, wearing rings, and impellers for wear; repair or replace as needed. Perform maintenance of speed reducer, coupling, and other appurtenant equipment maintenance according to manufacturer's instructions.
Secondary clarifier
Lubricate drive motor bearings, speed-reducing gear, drive chains, work and spur gears, and the main support bearing for the solids-collection equipment according to the manufacturer's instructions. Flush scum troughs and grease wells daily. Maintain solids withdrawal equipment. Clean effluent wells and baffles at least weekly. Paint or otherwise protect equipment from corrosion as needed.
Appurtenant equipment
Maintain piping, valves, forced draft blowers, and other appurtenant equipment according to the manufacturer's instructions.

Source: WEF, 2008

The information provided in Table 4.3 is not equipment or plant-specific. Therefore, both the manufacturer's literature and engineer's operating instructions should be consulted and followed. The frequency of maintenance procedures depends on sitespecific conditions. However, until operating experience is gained, frequent plant inspections and maintenance should continue. Maintenance schedules should consider the increased performance of fixed film synthetic media filters in warm weather months, which may reduce the effect of removing process units from service.

4.10 MOVING BED BIO REACTOR (MBBR)

4.10.1 Configuration

The moving bed biofilm reactor (MBBR) is based on the biofilm carrier elements. Several types of synthetic biofilm carrier elements have been developed for use in activated sludge processes. These biofilm carrier elements may be suspended in the activated sludge mixed liquor in the reaction tank by air from the diffusers in aerobic reactors and by means of propeller mixers in anaerobic and anoxic reactors. The carrier elements are retained by suitably sized sieves or plates.

These processes are intended to enhance the activated sludge process by providing a greater biomass concentration in the aeration tank and thus offer the potential to reduce the basin size requirements. They have also been used to improve the volumetric nitrification rates and to accomplish the denitrification in aeration tanks by having anoxic zones within the biofilm depth. Because of the complexity of the process and issues related to understanding the biofilm area and activity, the process design is empirical and based on prior pilot-plant or limited full-scale results. Typical diagram of MBBR is shown in Figure 4.19.

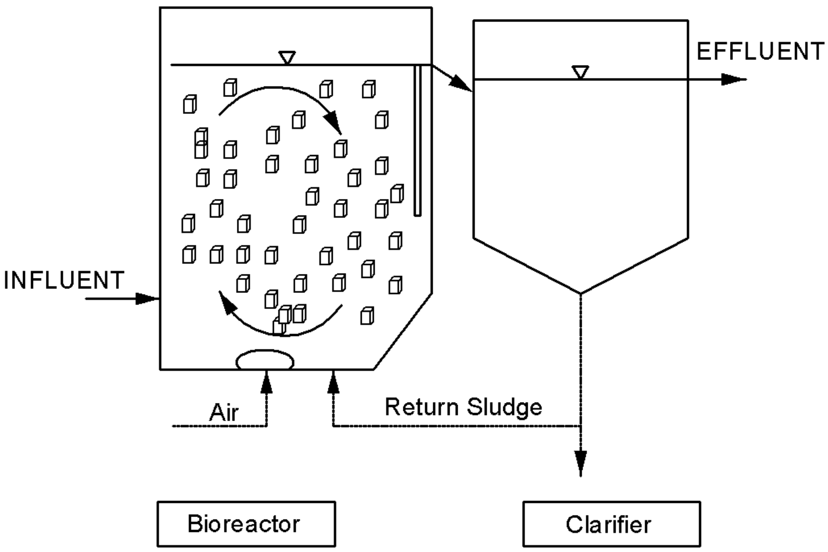


Figure 4.19 Moving bed bioreactor

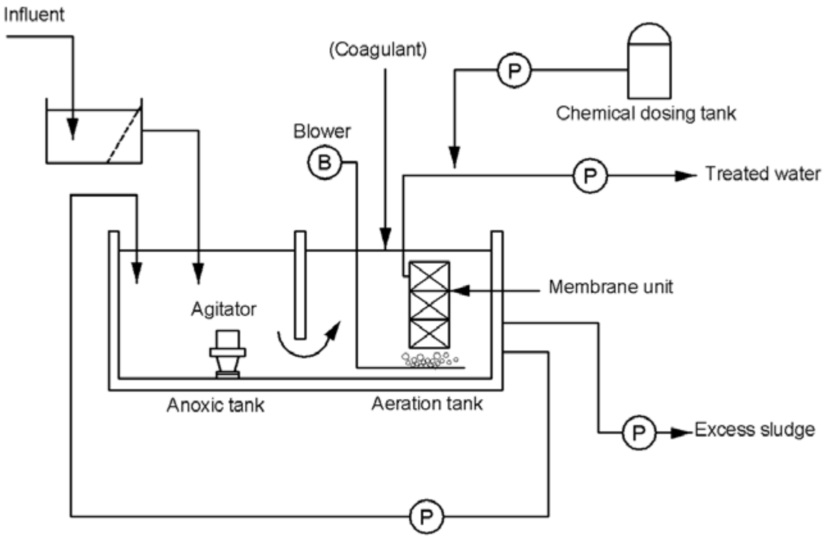
4.10.2 Operation and Maintenance

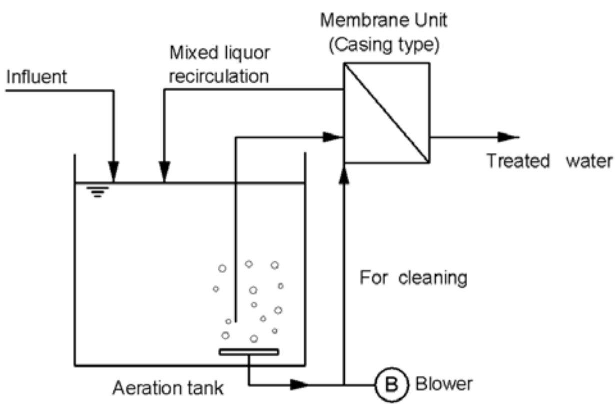
There are now more than 10 different variations of the processes in which a biofilm carrier material of various types is suspended in the aeration tank of the activated sludge process.

Differently varied processes have their own characteristics and require specific O&M. Therefore, operators should have thorough knowledge on their systems and implement daily O&M according to the manufacturers' instruction manuals. Refer to Part-A 5.16.13 MBBR for system description on the varieties of MBBR.

4.11 MEMBRANE BIO REACTOR (MBR)

The membrane bio reactor (MBR) process is a combination of activated sludge process and membrane separation process. Low pressure membranes (ultra filtration or microfiltration) are commonly used. Membranes can be submerged in the biological reactor or located in a separate stage or compartment and are used for liquid-solid separation instead of the usual settling process. (Figure 4.20)





Source: JSWA

Figure 4.20 Configuration of membrane bioreactor system

Basically, primary sedimentation tank, final sedimentation tank and disinfection facility are not installed in this process. The reaction tanks comprise an anoxic tank and an aerobic tank, and the membrane modules are immersed in the aerobic tank. Pre-treated, screened influent enters the membrane bioreactor, where biodegradation takes place. The mixed liquor is withdrawn by water head difference or suction pump through membrane modules in a reaction tank, being filtered and separated into solid and liquid. Surfaces of the membrane are continuously washed down during operation by the mixed flow of air and liquid generated by air diffuser set at the bottom of the reaction tank. Permeate from the membranes constitutes the treated effluent.

4.11.1 Operation

All MBR systems require some degree of pumping to force the water flowing through the membrane. One type of membrane systems uses a pressurized system to push the water through the membranes. The major systems used in MBRs draw a vacuum through the membranes so that the water outside is at ambient pressure. The advantage of the vacuum is that it is gentler to the membranes; the advantage of the pressure is that throughput can be controlled. Both systems also include techniques for continually cleaning the system to maintain membrane life and keep the system operational for as long as possible. All the principal membrane systems used in MBRs use an air scour technique to reduce build-up of material on the membranes. This is done by blowing air around the membranes out of the manifolds.

The permeate from an MBR has low levels of suspended solids, i.e., the levels of bacteria, BOD, nitrogen, and phosphorus are also low. Disinfection is easy and may not even be required, depending on permit requirements.

The solids retained by the membrane are recycled to the biological reactor and build up in the system. As in conventional biological systems, periodic sludge wasting eliminates sludge build-up and controls the SRT within the MBR system. The waste sludge from MBRs goes through standard solids-handling technologies for thickening, dewatering, and ultimate disposal. Chemical addition increases the ability of solids to settle. As more MBR facilities are built and operated, a more definitive understanding of the characteristics of the resulting sludge will be achieved. However, experience to date indicates that conventional sludge processing unit operations are also applicable to the waste sludge from MBRs.

4.11.2 Maintenance

The key to the cost-effectiveness of an MBR system is membrane life. If membrane life is curtailed such that frequent replacement is required, costs will increase significantly. Membrane life can be increased in the following ways:

Good screening of larger solids before the membranes to protect the membranes from physical damage.

Throughput rates that are not excessive, i.e., that do not push the system to the limits of the design. Low rates reduce the amount of material that is forced into the membrane, and thereby reduce the amount that has to be removed by cleaners or that will cause eventual membrane deterioration.

Mild cleaners - cleaning solutions most often used with MBRs include regular bleach (sodium) and citric acid, are regularly used. The cleaning should be in accordance with manufacturer’s recommended maintenance protocols.

4.12 UP FLOW ANAEROBIC SLUDGE BLANKET REACTOR (UASB)

The Up flow Anaerobic Sludge Blanket reactor (UASB) (Figure 4.21), maintains a high concentration of biomass through formation of highly settleable microbial aggregates. The sewage flows upwards through a layer of sludge. Separation between gas-solid-liquid takes place at the top of the reactor phase. Any biomass leaving the reaction zone is directly recirculated from the settling zone. The process is suitable for both soluble wastes and those containing particulate matter. The process has been used for treatment of municipal sewage at few locations and hence performance data and experience available presently are limited.

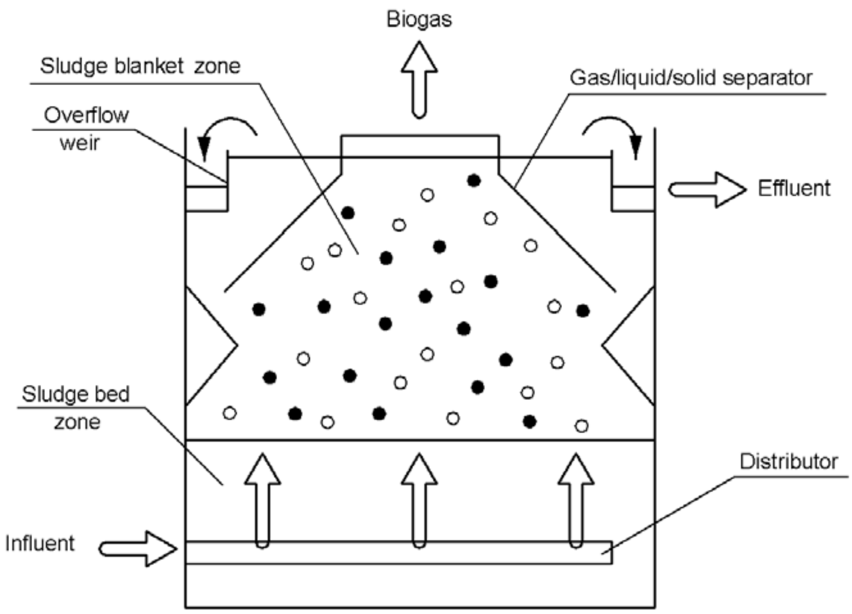


Figure 4.21 Schematic diagram of an up flow anaerobic sludge blanket reactor

4.12.1 Plant Commissioning and Operation

Two to three months are needed to build up a satisfactory sludge blanket without the addition of "seed" sludge from a working UASB. A shorter time is needed, if seeding is done.

During the start-up period, COD removal in the UASB gradually improves as sludge accumulation occurs. This may be called the sludge accumulation phase. The end of the sludge accumulation phase is indicated by sludge washout. At this time, the reactor is shut down to improve the quality of the sludge. This may be called the sludge improvement phase. After sludge improvement, blanket formation starts. Once the blanket is formed, again some surplus sludge washout could occur and to stabilise the stable operation, the excess sludge needs to be removed periodically. The excess sludge so removed can be sent directly to the sludge treatment process.

The sludge accumulated in the UASB is tested for pH, volatile fatty acids (VFA), alkalinity, COD and SS. If the pH reduces while VFA increases, new material should not be fed until the pH and VFA stabilise.

Daily operation of the UASB requires minimum attention. No special instrumentation is necessary for control, especially where gas conversion to electric power is not practiced. As stated, surplus sludge is easy to dry over an open sand bed. The reactor may need to be emptied completely once in five years, while any floating material (scum) accumulated inside the gas collector channels may have to be removed every two years to ensure free flow of gas.

4.12.2 Daily Operation and Maintenance of UASB

a. Cleaning of Effluent Gutters

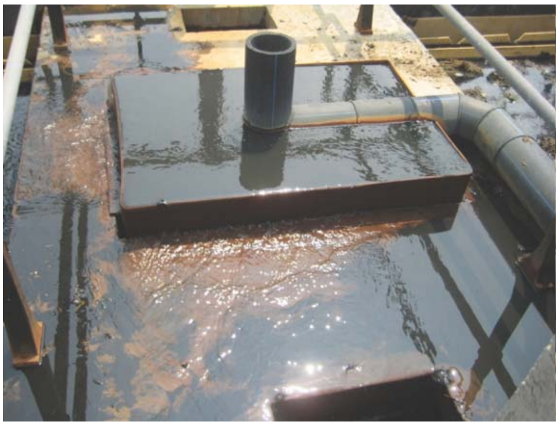
All V-notches must be cleaned in order to maintain the uniform withdrawal of UASB effluent coming out of each V-notch. The irregular flow from each V-notch results in the escape of more solids washout. Similarly, blocking of the V-notches of the effluent gutters will lead to uneven distribution of sewage in the reactor. Therefore, the effluent gutters have to be inspected on a regular basis to remove any material blocking and even the outflow over the V-notches in the gutters. The regular maintenance involves cleaning of

V-notches with a broom three times a day (Figure 4.22) and removing sludge with a brush or with a water jet once a day.

Figure 4.22 Cleaning of effluent gutters

b. Unclogging Feeder Pipes

The feeder pipes should be checked regularly for clogging. Flexible iron rods can be used for this purpose. A submersible pump can be used to unclog the feeder pipes as in Figure 4.23. The appropriate valve can be closed and the treated sewage can be pumped through the clogged feeder pipe and this will unclog the feeder pipe. The valve can be opened after the feeder pipe is free of the blockage. Compressed air if available at the location can also be used to unclog the feeder pipe. An air lift pump can also be used for this purpose. These feeder pipes are generally clogged due to rags and floating material. It is necessary to provide a fine screen or extra prevention at the screen to capture floating material at the pre-treatment unit itself.



Clogged inlet pipes

Submersible pump

Cleaning of feed pipes by submersible pumps

Clean feed pipes (equal flow distribution)

Source: PWSSB

Figure 4.23 Cleaning of feed inlet pipes

c. Removal of Floating Mat

Floating mat must be removed from the top of the surface of reactor with a rake. The removed material should be disposed at the dumping site.

d. Check of Leakage of Biogas

The gas collectors should be checked for leakage. Leakage is easily detected by applying soap solution to the piping. This should be done on a regular basis. If the gas collectors are leaking, the valve at the end of one bay in the gas leak should be first closed and then repaired as soon as possible. Regular maintenance includes opening of hatch boxes and removing floating layer inside the gas collectors.

e. Scrubbing of Biogas

Waste at the Top of UASB Reactor

The risk of the corrosion of dual fuel engine parts, as biogas contains H_2S, can be minimised if biogas can be scrubbed before using it as fuel for dual fuel gas engines.

f. Check for Sludge Withdrawal Ports

The ports of the sludge withdrawal must be free from any clogging which reduces the chances of checking of sludge height in reactor.

The feeder pipes should be checked regularly for clogging. Flexible iron rods can serve the purpose. A submersible pump can be used to unclog the feeder pipes.

g. Methanogenic Activity

Successful operation of a UASB reactor depends upon maintaining a satisfactory balance between methane and acidogenic bacteria. The methane formers are susceptible to changes in environmental conditions such as pH, temperature etc. The methanogenic activity must be analysed monthly.

h. Proper Sludge Wasting

Sludge must be removed or transferred from the UASB reactor occasionally based on the sludge yield or concentration of TSS or VSS (Volatile Suspended Solids). Higher sludge withdrawal points to a poor performance of the reactor in terms of treatment.

i. Biogas Analysis

The biogas analysis is used largely at sewage treatment plants where information on fuel value of gas is important. In addition, knowledge of gas composition can be of considerable help in the control of digestion units. Sudden changes in gas composition can signal a change either in the operation of the treatment unit or in the amount or composition of incoming sewage. Such changes can thus be used as a warning sign to suggest the need for closer observation and control of treatment unit.

j. H_2S Determination

The determination of hydrogen sulphide will continue to be an important consideration wherever gas is used for fuel in gas engines, particularly in areas where the sulphate content of sewage is very high.

k. Sludge Pumping Station Maintenance

After every sludge withdrawal operation, clean the pipeline by opening the top flushing valve until all the sludge in the pipeline is washed out. The sump has to be cleaned with water.

Never keep the sludge in the sump, it may damage the pumps. Before getting into the sumps for any maintenance, keep the top cover open for an hour before anybody gets in so that any accumulated biogas will vent to the atmosphere. Keep the valve chamber dry and valves clean. Check the electrical components regularly.

l. Biogas Holder Operation and Maintenance

The biogas produced in the reactors is taken in the common FRP (Fibre Glass Reinforced Plastic) pipes to the biogas holder. The biogas before going to the gas holder passes through moisture trap. The gas coming to the gas holder is measured through gas flow metres connected to FRP pipe after the moisture trap

The biogas before going to the holder is branched off. One branch is taken to the flaring system, the other to the biogas engine. Before going to the engine, the gas is measured from the flow meter provided on pipeline going to the engine. Sluice valves are provided on the lines to isolate the flow which is manually operated.

In case of sudden reduction in dome levels, the reactor FRP dome connector and its connection to the gas pipe header should be checked with soap water for any leakage of gas. This is one of the reasons for having a gas holder level trap.

The typical UASB preventive maintenance check list is below.

- Date and time
- Check and clean weir levels of division boxes

- Clean-up- feed inlet points
- Cleaning of V-notches
- Removal of sludge from effluent gutter by water jet or brush
- Removal of floating layer on the top of reactor
- Cleaning and scrubbing of effluent channels
- Check gas pipes for leakage
- Leakage greasing of spindle of sludge valves
- Cleaning of sludge sump

4.12.3 Routine Maintenance

4.12.3.1 Quarterly Maintenance

- The spindles of the valves have to be greased every three months.
- The glands and packing of the valves have to be checked every three months and replaced, if necessary.

4.12.3.2 Annual Maintenance

The reactor should be emptied after the first year of full operation to check the complete feeder and sludge withdrawal systems, especially the valves and the internal pipes for any accumulation of debris, sludge etc.

- A first check of the complete system including valves and holes should be made after one year, or earlier when required. Routine check can be established on the basis of the first inspection observation.
- The effluent gutters should be checked for levelling and alignment once a year. Each gutter should be horizontally levelled and all gutters in one reactor should be at the same level.
- Electrical wiring should be checked every year.
- Corrosion on electrical connections should be removed every year.
- The cement structures should be checked yearly and repaired when necessary.
- The sludge filtrate water pumps should be maintained.

4.12.3.3 Five-Yearly Maintenance

Every five years, the following maintenance should be carried out.

- Each reactor should be alternately put out of operation.
- Clean the inside concrete surface.
- Apply new coating of epoxy to the concrete surface.
- Check quality of feed inlet pipes and replace when necessary.
- Check fixing of the feed inlet pipes, both at the distribution boxes and at the bottom. Change corroded fixing material when necessary.
- Check position of PVC sheets.
- Check the fixing-material of the PVC sheets and replace when necessary.

- Check the quality of gas collectors and carry out repairs where necessary.

4.12.4 Decision Schemes for Sludge Removal

The removal of sludge is subject to a number of choices-how much sludge should be removed, from where should be removed, etc.

4.12.5 Shut-Down and Standstill

At shutdown of the plant, the sludge will settle at the bottom of the reactor. The biological activity of the sludge decreases slowly during standstill. Care should be taken to ensure that the sludge is not exposed to aerobic conditions. This might occur, for instance, when the reactor is flushed with clean water for prolonged periods.

At shutdown of the plant, the gas production will decrease. At a prolonged period of plant standstill, the pressure in the gas collection system can drop and air may enter into the system. In this situation, internal parts of the gas flare, the gas metre and the pressure/vacuum release valves that normally are not in contact with the atmospheric air start to corrode. These parts have to be protected, for instance by greasing.

If the water level in the tank is lowered during shutdown, the limited capacity of the vacuum release valves should be kept in mind. It is possible that imploding of the gas collectors may occur due to fast withdrawal of the reactor contents. At lowering of the water level in the reactor, it is advised to open the manholes on the top of the gas collectors. Only after re-establishing the maximum water level, the manholes can be closed and sealed.

In general, any type of work on the gas collectors requires the opening of the manholes as the explosive moisture of air and methane can develop in or around the gas collectors. When it is necessary to enter the reactor while sludge is present, it should be realised that methane is being formed continuously. A proper ventilation of the reactor is necessary. Very strict rules concerning open fire, spark emission, etc, should be followed. When entering the reactor plant, personnel should wear respiration equipment. Measurement of explosion risk and hydrogen sulphide concentration should be taken frequently when repair work is carried out.

4.12.6 Operational Cautions

- Do not get upon the UASB unless you have a gas mask, safety shoes, goggles and helmets.
- Do not carry any ignitable matters on your person.
- Once you reach the walking platform at top, check the H_2S by hand held meter.
- Unless it registers safety, immediately climb down the UASB.
- Once all the above are ensured, proceed to check any overflows of sewage and if so, stop the UASB.
- Check for corrosion at least once in 6 months and get it rectified.

4.12.7 Final Polishing Unit (FPU)

Not much maintenance is required for this unit. The algal growth needs to be maintained, and the dead algae floating on the top of water surface has to be periodically removed. The baffles provided at the outlet unit have to be cleaned regularly. Keep the floating material away from the unit. See that dead algal do not pass out into the pond. Sewage flow should be maintained to avoid development of anaerobic/septic conditions. These ponds should be de-sludged/de-silted regularly depending on the depth of sludge accumulation. Maintenance record should be maintained.

4.12.8 Duckweed Pond

The bund sides shall not be grown over by weeds. Figure 4.17 illustrates the same.

4.13 WASTE STABILIZATION POND (WSP)

Waste stabilization ponds are open, flow-through earthen basins specifically designed and constructed to treat sewage and biodegradable industrial wastes. Waste stabilization ponds provide comparatively long detention periods extending from a few to several days.

There are three principal types of WSP:

- Anaerobic,
- Facultative, and
- Maturation ponds.

Anaerobic ponds and facultative ponds are designed for BOD removal, and maturation ponds are designed for faecal bacterial removal. These three types of WSP are arranged in a series – first an anaerobic pond, then a facultative pond, and finally (and if needed to achieve the required effluent quality) one or more maturation ponds.

Apart from the above three types, there is another type of WSP called aerobic pond, which are seldom used. When used, follow the same procedures as in facultative ponds.

4.13.1 Start-up Procedures

Pond systems should preferably be commissioned at the beginning of the hot season so as to establish as quickly as possible the necessary microbial populations to effect waste stabilization. Prior to commissioning, all ponds must be free from vegetation. Facultative ponds should be commissioned before anaerobic ponds: this avoids odour release when anaerobic pond effluent discharges into an empty facultative pond. It is best to fill facultative and maturation ponds with freshwater (from a river, lake or well; mains water is not necessary) so as to permit the gradual development of the algal and heterotrophic bacterial populations. Primary facultative ponds may advantageously be seeded in the same way as anaerobic ponds. If freshwater is unavailable, facultative ponds should be filled with raw sewage and left for three to four weeks to allow the microbial population to develop; a small amount of odour release is inevitable during the period.

4.13.2 Routine Maintenance

The maintenance requirements of ponds are very simple, but they must be carried out regularly. Otherwise, there will be serious odour, fly and mosquito nuisance. Maintenance requirements and responsibilities must therefore be clearly defined at the design stage so as to avoid problems later. Routine maintenance tasks are as follows:

- Removal of screenings and grit from the inlet works
- Cutting the grass on the embankments and removing it so that it does not fall into the pond (this is necessary to prevent the formation of mosquito-breeding habitats; the use of slow-growing grasses minimises this task)
- Removal of floating scum and floating macrophytes, such as. Lemna, from the surface of facultative and maturation ponds (this is required to maximize photosynthesis and surface re-aeration and prevent fly and mosquito breeding)
- Spraying the scum on anaerobic ponds (which should not be removed as it aids the treatment process), as necessary, with clean water or pond effluent, or a suitable biodegradable larvicide, to prevent fly breeding
- Removal of any accumulated solids in the inlets and outlets

- Repair of any damage to the embankments caused by rodents, rabbits or other animals
- Repair of any damage to external fences and gates

And precautions and practices are described below:

- The scum has a tendency to form at the corners of the ponds and supports mosquito growth.
- In anaerobic ponds, during times of low pH odour is produced. In such occasions, addition of sodium hydroxide is required to raise the pH to 7. The advantage of sodium hydroxide is it produces less sludge. In case production of sludge is not a concern then lime can be added to raise the pH to 7. Once the pH is raised to 7 odour can be eliminated.
- Anaerobic ponds, low pH produces odours. In such cases addition of NaOH it produces less sludge, or lime can be added to raise the pH to 7 to eliminate odour caused by H_2S
- The scum need not be taken out of the ponds at any cost.
- When scum has accumulated to dense zones in the corners, they need to be removed.
- What is needed is beating the surface of the scum by a light long pole while standing at the bank.
- This releases the gases that are supporting the scum layer and automatically the mat sinks back.
- These are dealt with like any other foods which are stabilized by the organisms of the pond.
- Fish shall not be allowed to breed in any of the ponds.
- The precautions of operating manually the scum removal shall be totally adopted.
- Sometimes sludge removal would become necessary.
- Thumb rule will be to verify the depth of sludge and de-sludge once it is about 30 % of depth.

4.13.3 De-Sludging

The biggest challenge to an operator in the management of pond systems is to identify when a pond requires de-sludging, and to carry out the de-sludging thereafter; it is more important to deal with the sludge thus taken out without giving rise to environmental problems. These issues are addressed in this section so as to help the operator develop adequate confidence in this task.

4.13.3.1 When to De-Sludge

When raw sewage without grit removal is admitted to the pond, a general rule of thumb to calculate the grit accumulation can be taken as 0.5 meters for a ten year period. Similarly, the accumulation of sludge can be taken as 0.7 meters for a ten year period. Thus, in the illustrative design, it can be seen that the total depth has adequate allowance for these plus the required minimum depth of liquid depth for the treatment. In the absence of adequate design reference, the build-up of sludge to a height wherein it will start overflowing through the outlet is the upper limit. However, if that is allowed, there is no space for the liquid holding capacity and treatment efficiency will suffer. Hence, the operator must clearly know the basis on which the pond has been designed and commence de-sludging when that depth is reached by the sludge accumulating from the bottom. If even that information is not available, the operator must make a decision.

4.13.3.2 The white towel test

The white towel test is used to understand the depth of the sludge and this will help in deciding desludging Malan (1964). White towelling material is wrapped along one-third of a sufficiently long pole, which is then lowered vertically into the pond until it reaches the pond bottom; it is then slowly withdrawn. The depth of the sludge layer is clearly visible since some sludge particles will have been entrapped in the towelling material Figure 4.24. The sludge depth should be measured at various points throughout the pond, away from the embankments, and its mean depth calculated. Duncan Mara (2004)

Source: Duncan Mara, 2004

Figure 4.24 The White Towel test

4.13.3.3 De-Sludge Procedure

Measure the depth of the pond from the top of the bund to the bottom. To do this, use the effluent chamber that may be outside the pond. Usually, these chambers have the same or slightly larger depth than the pond. If there is no effluent chamber, assemble a long casuarina sturdy pole of about some 6 meters long and start sliding it slowly on the inside slope so that the pole follows the gradient and stops at the bottom of the pond which could be sensed by the strong reaction for a gentle push of the pole. Mark the top of the bund elevation on the pole with a gentle cut in the hacksaw. Pull the pole out and measure the distance of the cut from the bottom of the pole after laying the pole flat on the ground. Record the distance. Repeat the measurement on all sides of the pond. If the readings are within plus or minus 5%, take the average. If not repeat the measurement at different locations until you get a reading within plus or minus 5%. Let us say this reading is 5 meters. Nail a perpendicular small pole to one end of the longer pole such that the distance of protrusion of this short pole is a meter. Then slide the long pole horizontally over the bund top by resting it on the bund top and checking the horizontality with a spirit level by placing it on the long pole such that the free end of the short pole touches the inner side of the bund. Mark the location with a gentle double cut by a hacksaw on the long pole where the inner side slope of the bund crosses the long pole. Measure this length. Let us say this is 2 meters. The total depth of the lagoon will now be calculated as [1 / 2] x [5] = 2.5 meters. Next, measure the inclined length of the waterline from the inner edge of the inside slope of the bund. Let us say this is 1.4 meters. The freeboard will now be calculated as [1.4 / 2] = 0.7 meters. The design liquid depth is 2.5-0.7 = 1.8 meters. In this depth, it is now necessary to measure the depth of sludge accumulation such that at least 1.2 meters of liquid depth is available for treating the sewage.

This measurement requires the use of the serrated glass tube as described earlier and in addition, support from fire service personnel, life vests for all those on board the paddle boat, minimum of two persons, a good fibreglass or wooden boat doubly checked for water tightness, an experienced boatman and oxygen masks for all those on board the boat. Once all these are assembled, the boat has to be rowed to the three or four random locations and the glass tube exercise has to be carried out. After driving the glass tube into the hardness of the bottom clay, rotate it gently in-situ and lift with an unscrewing motion. Do not pull straight. Gently release the tube from the clay by feeling it and raise by changing the grip on the tubes and allowing the tube to go up freely. Once out of the water surface, keep it on the floor of the boat vertically and allow the contents to settle down for 30 minutes. Thereafter paint on the glass tube with a good paint the level at which the sludge is seen. Then return to the shore and lay the tube horizontally over the ground and use a water jet or air jet to clear the tube contents. If the chemist requires it, collect the sludge and give it to him for analysis. On any account, do not use a mechanized boat. The methane gas present on the surface of the pond can be ignited by the spark of the motor with unpleasant consequences.

Another method is to take a slim bamboo pole with a height equal to the depth of the pond plus 2 m as the optimum. A white fluffy towel is wrapped around end of the pole for a height equal to the designed liquid depth of the pond. It should be tied securely and tightly in not less than three to four wrappings. Thereafter set sail on a good manual paddle boat over the pond as described earlier. Lower the pole with the white towel end into the pond till the pole has reached the bottom. Hold steady for about 15 minutes. Then raise the pole. The darkish or blackish colour at the bottom end as seen on the towel is the mark of the depth of sludge. Rinse it well by repeatedly dipping into the liquid upper layers before proceeding to the next random location and repeat the testing.

- Repeat the above depth measurements slowly without hurry. Always do this in clear non-rainy weather. Make sure you have at least four readings, which are fairly close.
- Once the sludge depth is thus measured, consult the chemist for any tendency of efficiency drop in the pond for BOD removal. If the chemist feels that there is a steady decline and efficiency is going down, consult the plant superintendent.
- As a rule of the thumb, if the liquid height is less than 1.2 meters in a facultative or anaerobic pond, it is time for de-sludging. Take the decision jointly and never by yourself.
- The best method of de-sludging is to take one pond out of operation during the beginning of summer and pump out the water portion to the other ponds. Thereafter, it normally takes two months for a sludge depth of about 2 meters to dry out.
- Deploy manpower equipped with oxygen mask to gently turn the dried sludge upside down uniformly over the whole area so that drying is hastened. Never use a machine during this operation as methane may get released.
- Once this is completed and the sludge is dried, deploy scraper equipment like a “Procaine” and evacuate the sludge over the bund and on to the ground on the earth

side of the bund.

- The sludge can be heaped into a pile by manual labourers who should wash their hands thoroughly with soap after finishing their work.

4.13.3.4 Special cautions for anaerobic pond / maturation pond

All the points listed earlier in aerated lagoon and facultative ponds apply here also except that the depth of sludge before de-sludging will be according to the original design. The boat ride to measure the sludge depth shall not be used in these ponds. Instead, the white towel test shall be conducted and a long boom crate shall be used without making any person stand at the end of the boom.

4.13.4 Process Control

There is nothing much to control in the process of purification of sewage in WSP except making sure that the sludge accumulation does not exceed 30% of the total liquid depth or the design depth of sludge.

4.13.5 Record Keeping

4.13.5.1 Records necessary for Anaerobic Pond

- Daily tests and records will be the flow and SS
- Monthly tests shall be the BOD after filtering through Whatman 42 filter paper and pH

4.13.5.2 Records necessary for Facultative Pond

- Daily tests and records will be the flow and SS
- Weekly tests will be identification of organisms as per "Standard Methods" drawings
- Monthly tests shall be the BOD after filtering through Whatman 42 filter paper and pH

4.13.5.3 Records necessary for Maturation Pond

- Daily tests and records will be the flow and SS
- Monthly tests shall be the BOD after filtering through Whatman 42 filter paper and pH
- Yearly test of faecal and total coliforms at the peak summer and peak monsoon shall be conducted.

4.14 FARM FORESTRY

Please hand over the O&M work to the local forestry department who are competent in this.

4.15 FISH POND

New sewage treatment plants should not use the fish pond as a means of treatment. In regard to the existing fish ponds the concerned pollution control board and the department of health may decide.

4.16 SECONDARY SEDIMENTATION TANK

A typical plant may have clarifiers located at two different points. The one that immediately follows the bar screen, comminutor, or grit channel is called the primary sedimentation tank, merely because it is the first sedimentation tank in the plant. The other, which follows other types of treatment units, is called the secondary sedimentation tank or the final sedimentation tank. The two types of sedimentation tanks operate almost exactly the same way. The function of a primary clarifier is to remove settleable and floatable solids. The reason for having a secondary sedimentation tank is that other types of treatment following the primary sedimentation tank convert more solids to the settleable form, and they have to be removed from the treated sewage. Because of the need to remove these additional solids, the secondary clarifier is considered part of these other types of processes.

The main difference between primary and secondary sedimentation tanks is in the density of the sludge handled. Primary sludge is usually denser than secondary sludge. Effluent from a secondary clarifier is normally clearer than primary effluent.

Solids that settle to the bottom of a sedimentation tank are usually scraped to one end (in rectangular clarifiers) or to the middle (in circular clarifiers) into a sump. From the sump, the solids are pumped to the sludge handling or sludge disposal system. Systems vary from plant to plant and include sludge digestion, vacuum filtration, filter presses, incineration, land disposal, lagoons, and burial.

Disposal of skimmed solids varies from plant to plant. Skimmed solids may be buried with material cleaned off the bar screen, or pumped to the digester. Even though pumping skimmed solids to a digester is not considered good practice because skimmings can cause operational problems in digesters, it is a common practice.

4.16.1 Operation

Of all the different types of clarifiers that an operator must regulate, secondary clarifiers in the activated sludge process are the most critical and require the most attention from the operator.

- Levels of sludge blanket in the clarifier
- Concentration of suspended solids in the clarifier effluent
- Control and pacing of return sludge flows
- Concentration of dissolved oxygen (DO) in the clarifier effluent
- Level of pH
- Concentration of RAS

4.16.2 Maintenance

Annually, during periods of low flow, each clarifier should be shut down for inspection, routine maintenance, and any necessary repairs. Even though the clarifier and all equipment are working properly, an annual inspection helps to prevent serious problems and failures in the future when harmful consequences can result.

During normal operations, operator should schedule the following daily activities:

a. Inspection

Make several daily inspections with a “stop, look, listen, and think” routine.

b. Cleanup

Using water under pressure, wash off accumulations of solid particles, grease, slime, and other material from walkways, handrails, and all other exposed parts of the structure and equipment.

c. Lubrication

Grease all moving equipment according to manufacturer's specifications and check oil levels in motors where appropriate.

4.17 ADVANCED TREATMENT

Advanced sewage treatment processes typically are used to further reduce the concentrations of suspended solids, nutrients (nitrogen or phosphorus) and soluble organic chemicals in secondary treatment effluent. These processes may be physical, chemical, biological, or a combination of these processes.

4.17.1 Sand Filtration

Sand filters have influent and effluent distribution systems consisting of pipes and fittings. Head loss is a measure of solids trapped in the filter. As the filter becomes filled with trapped solids, the efficiency of the filtration process falls off, and the filter must be backwashed. Filters are backwashed by reversing the flow so that the solids in the media are dislodged and can exit the filter; sometimes air is dispersed into the sand bed to scour the media.

Sand filters can be automatically backwashed when the differential pressure exceeds a preset limit or when a timer starts the backwash cycle.

4.17.2 Multimedia Filtration

A multimedia filter operates with the finer, denser media at the bottom and the coarser, less dense media at the top. A common arrangement is given as below.

- Top: Anthracite
- Middle: Sand
- Bottom: Garnet

These media can be used alone, such as in sand filtration, or in a multimedia combination.

Some mixing of these layers occurs and is anticipated. During filtration, the removal of the suspended solids is accomplished by a complex process involving one or more mechanisms, such as:

- Straining,
- Sedimentation,
- Interception,
- Impaction, and
- Adsorption.

The size of the medium is the principal characteristic that affects the filtration operation. If the medium is too small, much of the driving force will be wasted in overcoming the frictional resistance of the filter bed. If the medium is too large, small particles will travel through the bed, preventing optimum filtration. As same as “sand filtration”, back wash is required to keep adequate filtration efficiency.

4.17.3 Membrane Filtration (MF, UF, NF, RO)

Membrane filtration is used for polishing water for specific uses like industry process water, or for aquifer infiltration. In India, membrane filtration is widely used in the water and sewage sectors. (Figure 4.25)

MF – Microfiltration membranes are porous membranes with pore sizes between 0.1 and 1 micron (1 micron=1,000 nanometre). They allow almost all dissolved solids to get through and retain only solids particles over the pore size.

UF – Ultra filtration membranes are asymmetric or composite membranes with pore sizes around between 0.005 and 0.05 micron. They allow almost mineral salts and organic molecules to get through and retain only macromolecules

NF – Nano filtration membranes are reverse osmosis membranes with pore sizes around 0.001 micron. They retain multivalent ions and organic solutes that are larger than 0.001 micron.

RO – Reverse osmosis membranes are dense skin, asymmetric or composite membranes that let water get through and rejects almost all salts.

4.17.4 Operation and Maintenance

a. Operational Unit Processes

All membrane filtration systems have associated operational unit processes that are essential for maintaining and optimizing system performance and therefore critical to the successful implementation of the technology. These operational processes include backwashing, chemical cleaning, and integrity testing. For the purposes of this discussion, pre-treatment and post-treatment are also considered operational unit processes associated with membrane filtration. Each of these processes and its role in the operation of a membrane filtration system are described in the following sections. Although not every membrane filtration system utilizes all of these processes, many utilize each process to some degree.

b. Pre-treatment

Pre-treatment is typically applied to the feed water prior to entering the membrane system in order to minimize membrane fouling, but in some cases may be used to address other water quality concerns or treatment objectives. Pre-treatment is most often utilized to remove foulants, optimize recovery and system productivity, and extend membrane life. Pre-treatment may also be used to prevent physical damage to the membranes. Different types of pre-treatment can be used in conjunction with any given membrane filtration system, as determined by site-specific conditions and treatment objectives. Pilot testing can be used to compare various pre-treatment options, optimize pre-treatment, and/or demonstrate pre-treatment performance. Several different types of commonly used pre-treatment for membrane filtration systems are discussed in the following subsections.

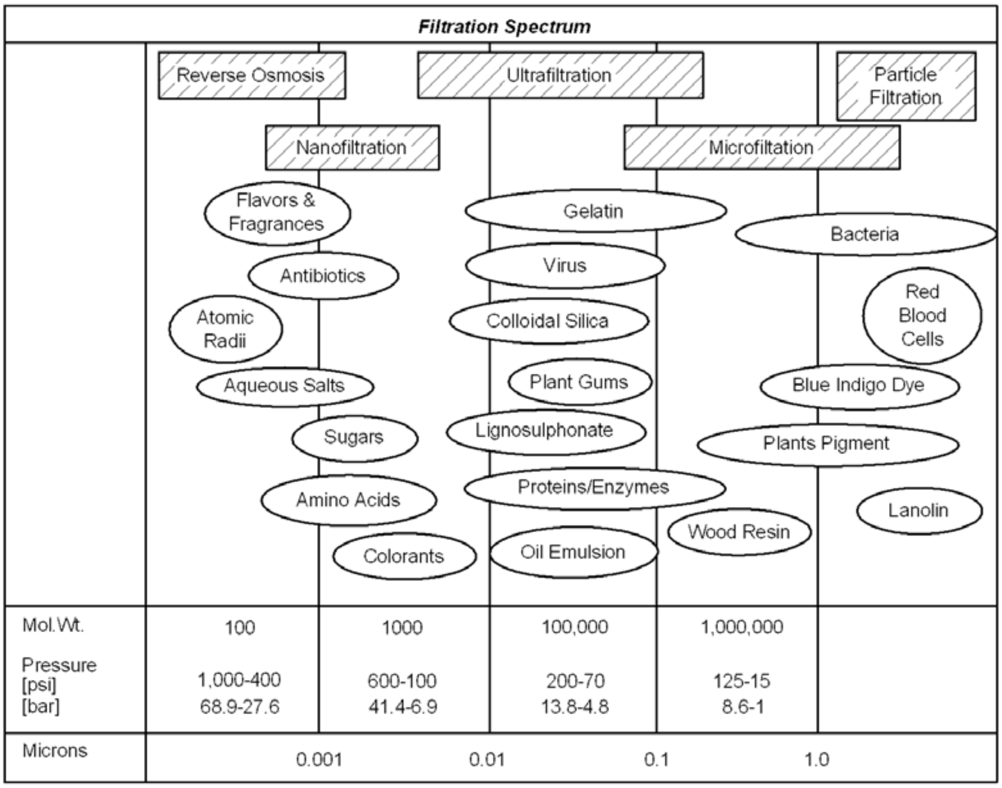


Figure 4.25 Filtration spectrum

c. Pre-filtration

Pre-filtration, including screening or coarse filtration, is a common means of pre-treatment for membrane filtration systems that are designed to remove large particles and debris. Pre-filtration can either be applied to the membrane filtration system as a whole or to each membrane unit separately. The particular pore size associated with the pre-filtration process (where applicable) varies depending on the type of membrane filtration system and the feed water quality. For example, although hollow-fibre microfiltration (MF) and ultra filtration (UF) systems are designed specifically to remove suspended solids, large particulate matter can damage or plug the membrane's fibres.

Because nanofiltration (NF) and reverse osmosis (RO) utilize non-porous semi permeable membranes that cannot be backwashed and are almost exclusively designed in a spiral-wound configuration for municipal water treatment applications, these systems must utilize much finer pre-filtration in order to minimize exposure of the membranes to particulate matter of any size.

A summary of the typical pre-filtration requirements associated with the various types of membrane filtration is presented in Table 4.4.

d. Backwashing

The backwash process for membrane filtration systems is similar in principle to that for conventional media filters and is designed to remove contaminants accumulated on the membrane surface. Each membrane unit is backwashed separately and in a staggered pattern so as to minimize the number of units in simultaneous backwash at any given time. During a backwash cycle, the direction of flow is reversed for a period ranging from about 30 seconds to 3 minutes. The force and direction of the flow dislodge the contaminants at the membrane surface and wash accumulated solids out through the discharge line. Membrane filtration systems are generally backwashed more frequently than conventional media filters, with intervals of approximately 15 to 60 minutes between backwash events. Typically, the membrane backwash process reduces system productivity in the range of 5 to 10 percent due to the volume of filtrate used during the backwash operation.

Table 4.4 Typical membrane system pre-filtration requirements

Membrane System		Pre-filtration Requirements	
Classification	Configuration	Size (μm)	Type(s)
Membrane Cartridge Filtration (MCF)*	Cartridge	300 - 3,000	Strainers; Bag Filters
Microfiltration (MF) / Ultra filtration (UF)	Hollow-Fibre, Inside-Out	100 - 300	Strainers; Bag Filters
	Hollow-Fibre, Outside-In	300 - 3,000	Strainers; Bag Filters
Nanofiltration (NF) / Reverse Osmosis (RO)	Spiral-Wound	5 - 20	Cartridge Filters

* Pre-filtration is not necessarily required for MCF systems

Source: WEF, 2008

Backwashing is conducted periodically according to manufacturer's specifications and site-specific considerations. Although more frequent backwashing allows for higher fluxes, this benefit is counterbalanced by the decrease in system productivity. In general, a backwash cycle is triggered when a performance-based benchmark is exceeded, such as a threshold for operating time, volumetric throughput, increase in transmembrane pressure (TMP), and/or flux decline. Ideally, the backwash process restores the TMP to its baseline (i.e., clean) level; however, most membranes exhibit a gradual increase in the TMP that is observed after each backwash, indicating the accumulation of foulants that cannot be removed by the backwash process alone. These foulants are addressed through chemical cleaning.

Because the design of spiral-wound membranes generally does not permit reverse flow, NF and RO membrane systems are not backwashed. For these systems, membrane fouling is controlled primarily with chemical cleaning, as well as through flux control and cross flow velocity. The inability of spiral-wound membranes to be backwashed is one reason that NF and RO membranes are seldom applied to directly treat water with high turbidity and/or suspended solids.

e. Chemical Cleaning

Chemical cleaning is another means of controlling membrane fouling, particularly those foulants such as inorganic scaling and some forms of organic and biofouling that are not removed via the backwash process. As with backwashing, chemical cleaning is conducted for each membrane unit separately and is typically staggered to minimize the number of units undergoing cleaning at any time. While chemical cleaning is conducted on both MF/UF and NF/RO systems, because non-porous, semi-permeable membranes cannot be backwashed, chemical cleaning represents the primary means of removing foulants in NF/RO systems. Although cleaning intervals may vary widely on a system-by-system basis, the gradual accumulation of foulants makes eventual chemical cleaning virtually inevitable. Membrane cartridge filters are an exception, however, in that cartridge filters are usually designed to be disposable and thus are typically not subject to chemical cleaning. (Table 4.5)

Table 4.5 Chemical cleaning agents

Category	Chemicals Commonly Used	Typical Target Contaminant (s)
Acid	· Citric Acid ($C_6H_8O_7$) · Hydrochloric Acid (HCl)	Inorganic scale
Base	· Caustic (NaOH)	Organics
Oxidants / Disinfectants	· Sodium Hypochlorite (NaOCl) · Chlorine (Cl_2) Gas · Hydrogen Peroxide (H_2O_2)	Organics; Biofilms
Surfactants	· Various	Organics; Inert particles

Source: WEF, 2008

As with backwashing, the goal of chemical cleaning is to restore the TMP of the system to its baseline (i.e., clean) level. Any foulant that is removed by either the backwash or chemical cleaning process is known as reversible fouling. Over time, membrane processes will also typically experience some degree of irreversible fouling which cannot be removed through either chemical cleaning or backwashing. Irreversible fouling occurs in all virtually membrane systems, albeit over a wide range of rates, and eventually necessitates membrane replacement.

4.17.5 Integrated Nutrient Removal

4.17.5.1 Nutrient Removal

Sewage may contain high levels of the nutrients nitrogen and phosphorus. Excessive release of these nutrients to the environment can lead to a buildup of nutrients, called eutrophication, which can in turn encourage the overgrowth of weeds, algae, and cyanobacteria (blue-green algae). This may cause an algal bloom, a rapid growth in the population of algae. The algae numbers are unsustainable and eventually most of them die. The decomposition of the algae by bacteria uses up so much of oxygen in the water that most or all of the animals die, which creates more organic matter for the bacteria to decompose. In addition to causing deoxygenation, some algal species produce toxins that contaminate drinking water supplies. Different treatment processes are required to remove nitrogen and phosphorus.

4.17.5.2 Nitrogen Removal

Nitrogen is removed through the biological oxidation of nitrogen from ammonia to nitrate (nitrification), followed by denitrification, i.e., the reduction of nitrate to nitrogen gas. (Figure 4.26)

Nitrogen gas is released into the atmosphere and thus removed from the water. Nitrification itself is a two-step aerobic process, each step facilitated by a different type of bacteria. The oxidation of ammonia (NH_3) to nitrite (NO_2^-) is most often facilitated by Nitrosomonas spp. (nitroso referring to the formation of a nitroso functional group). Nitrite oxidation to nitrate (NO_3^-), though traditionally believed to be facilitated by Nitrobacter spp. (nitro referring the formation of a nitro functional group), is now known to be facilitated in the environment almost exclusively by Nitrospira spp.

Denitrification requires anoxic conditions to encourage the appropriate biological communities to form. It is facilitated by a wide diversity of bacteria. Sand filters, lagoons and reed beds can all be used to reduce nitrogen, but the activated sludge process (if designed well) can do the job the most easily. Since denitrification is the reduction of nitrate to nitrogen gas, an electron donor is needed.

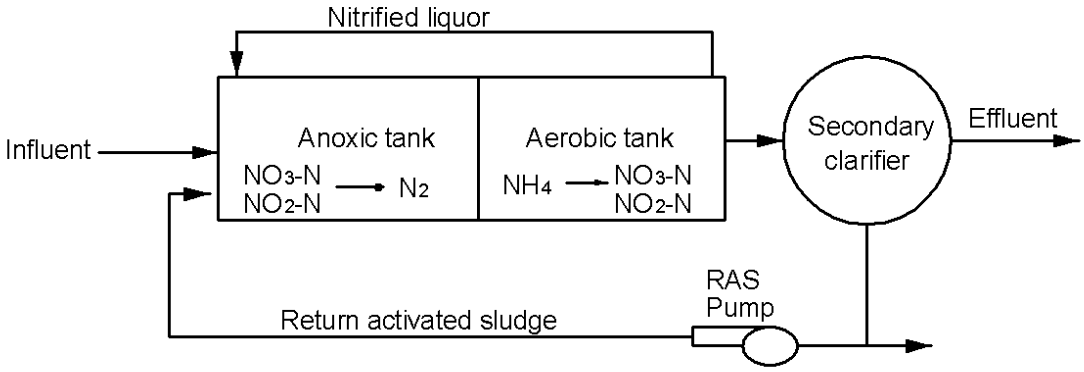


Figure 4.26 Configuration of recycled nitrification/denitrification process

This can be, depending on the sewage, organic matter (from faeces), sulphide, or an added donor like methanol. Sometimes the conversion of toxic ammonia to nitrate alone is referred to as tertiary treatment. Many sewage treatment plants use axial flow pumps to transfer the nitrified mixed liquor from the aeration zone to the anoxic zone for denitrification. These pumps are often referred to as Internal Mixed Liquor Recycle (IMLR) pumps.

4.17.5.2.1 Process Control

Operators of biological nitrogen removal (BNR) facilities need more process-control knowledge than those of conventional treatment facilities to keep them operating smoothly. The key operating parameters for a BNR facility typically include:

a. SRT

SRT is the key to understanding whether the BNR process has enough time to function effectively. When evaluating SRT, operators should answer such questions as:

- Is the SRT long enough to establish nitrification?
- How much sludge should be wasted to maintain a desired SRT?
- Can the SRT be increased by maintaining a higher MLSS?

b. F/M Ratio

The F/M ratio is a good indicator of how well selector reactors will promote the growth of floc-forming bacteria. When the F/M ratio is high, floc-forming bacteria have a competitive advantage over filamentous bacteria. Selector loading also helps ensure that nuisance bacteria will not cause operating problems. The selector cells should be arranged so BOD is taken up rapidly.

c. HRT (Hydraulic Retention Time)

Although not used in daily BNR operations, HRT indicates whether the plant is operating within a normal contact time. Nitrifying facilities, such as conventional activated sludge and A2O (Anaerobic, Anoxic, and Oxic process), typically have an HRT between 5 and 15 hours.

d. Oxygen Levels

When a conventional activated sludge system is converted into a BNR facility, its dissolved oxygen requirements typically increase, requiring changes in the aeration equipment or diffuser layout.

e. Alkalinity and pH Control

Every time 1 mg of ammonia-nitrogen is oxidized to nitrate, 7.14 mg of alkalinity is consumed. Likewise, every time 1 mg of nitrate is converted to nitrogen gas, 3.57 mg of alkalinity is recovered.

f. ORP (Oxidation–Reduction Potential).

Automated control systems for the internal anoxic mixing process measure the ORP so they can detect nitrate depletion in the mixed liquor. This variable indirectly measures nitrate availability in an aqueous media, although there is no direct correlation between any specific ORP value and nitrate concentration.

Oxidation–reduction potential measures the net electron activity of all oxidation–reduction reactions occurring in sewage. It is affected by temperature, pH, biological activity, and the system's chemical constituents, but its response pattern to changes in a solution's oxidative state is reproducible in a specific system. In continuous-flow suspended-growth systems, the control system's ORP breakpoints must be constantly reviewed and revised. In batch systems (e.g., SBR or cyclic aeration systems), however, a characteristic "knee" (change in ORP values) indicates when the system is changing from an oxidized state to a reduced one.

g. Recycle Flows

For sewage facilities with either ammonia and/or nitrate limitations, it will be necessary to adjust recycle flows (typically RAS flow) to achieve operational goals.

h. Secondary Clarification

It is essential that the secondary clarifier be able to both separate biological solids from the treated effluent and also concentrate the solids without a build-up of sludge within the clarifier. Parameters of concern with clarification are the hydraulic loading rate (HLR) and the solids loading rate (SLR).

4.17.5.3 Phosphorus Removal

Phosphorus removal is important as it is a limiting nutrient for algae growth in many fresh water systems. It is also particularly essential for water reuse systems where high phosphorus concentrations may lead to fouling of downstream equipment such as reverse osmosis.

Phosphorus removal in excess of metabolic requirements can be achieved by using enhanced biological phosphorus removal (EBPR) or chemical addition.

Phosphorus can be removed biologically in a process called enhanced biological phosphorus removal In this process, specific bacteria, called Polyphosphate Accumulating Organisms (PAOs), are selectively enriched and accumulate large quantities of phosphorus within their cells (up to 20 percent of their mass). When the biomass enriched in these bacteria is separated from the treated water, these biosolids (sludge) have a high fertilizer value.

The EBPR process consists of anaerobic and aerobic zones. By definition, an anaerobic zone contains no usable dissolved oxygen or nitrate. In this zone, PAOs do not grow, but consume and convert readily available organic material (i.e. VFAs) to energy-rich carbon polymers called poly-hydroxyalkanoates (PHA). The energy required for this reaction is generated through breakdown of the stored polyphosphate (poly-P) molecules, which results in phosphorus release and an increase in the bulk liquid soluble phosphorus concentration in the anaerobic stage. Magnesium and potassium ions are concurrently released to the anaerobic medium with phosphate. In addition, for a substantial amount of reducing power is required PAOs to produce PHA. The breakdown of glycogen, another form of internal carbon storage, generates the reducing power.

Phosphorus removal can also be achieved by chemical precipitation, usually with salts of iron (e.g. ferric chloride), aluminium (e.g. alum), or lime. This may lead to excessive sludge production as hydroxides precipitate and the added chemicals can be expensive. Chemical phosphorus removal requires significantly smaller equipment footprint than biological removal, is easier to operate and is often more reliable than biological phosphorus removal. Another method for phosphorus removal is the use of granular laterite. Once removed, phosphorus, in the form of a phosphate-rich sludge, may be stored in a land fill or resold for use in fertilizers.

4.18 DISINFECTION FACILITY

Disinfection of effluent from water reclamation facilities (WRFs) is required to decrease the disease risks associated with the discharge of sewage containing human pathogens (disease causing organisms) into receiving waters. These microorganisms are present in large numbers in sewage effluents.

The chlorine gas is controlled, metered, introduced into a stream of injector water and then conducted as a solution to the point of application.

The primary advantage of vacuum operation is safety. If a failure or breakage occurs in the vacuum system, the chlorinator either stops the flow of chlorine into the equipment or allows air to enter the vacuum system rather than allowing chlorine to escape into the surrounding atmosphere. In case the chlorine inlet shutoff fails, a vent valve discharges the incoming gas to the outside of the chlorinator building.

The operating vacuum is provided by a hydraulic injector. The injector operating water absorbs the chlorine gas and the resultant chlorine solution is conveyed to a chlorine diffuser through corrosion resistant conduit. A vacuum chlorinator also includes a vacuum regulating valve to dampen fluctuations and allow smooth operation. Vacuum relief prevents excessive vacuum within the equipment.

Chlorine gas flows from the chlorine container to the gas inlet. After entering the chlorinator, the gas passes through spring-loaded pressure regulating valve which maintains the proper operating pressure. A rotameter is used to indicate the rate of gas flow. The rate is controlled by V-notch variable orifice. The gas then moves to the injector where it dissolved in water and leaves the chlorinator as a chlorine solution (HOCl) ready for application.

4.18.1 Operational Variables

The process-control variables associated with chlorination systems are:

a. Detention (Contact) Time

The chlorine solution is best injected into the effluent via a diffuser or, preferably, a flash mixer. Otherwise, some of the chlorine gas could come out of solution undissolved (stratification). This would impair the efficiency of disinfection and increase its costs.

Typically, depending on the STP’s (sewage treatment plant’s) permit requirements or the state or regional regulatory requirements, chlorine detention time should range from 30 to 60 minutes at the average daily flow (ADF) and should equal or exceed 15 minutes at peak flows. Such detention times allow a safety factor for possible hydraulic inefficiency of the contact chamber, thus maximizing pathogen inactivation.

b. Chlorine Residual

Depending on the effluent-disposal method (receiving-water discharge or reclaimed-water reuse) the permit may require a chlorine residual in the contact chamber effluent. The three types of chlorine residuals are combined, free, and total. Free and total residuals are typically monitored.

The combined residual consists of chloramines and chloro-organic compounds that are formed by the reaction of chlorine with ammonia and organic compounds in the secondary or tertiary effluent. Each milligram per litre of ammonia consumes 10 mg/L of chlorine. The chlorine dose that satisfies the ammonia's chlorine demand is called the breakpoint. Note that the combined residual decreases slightly as the chloramines and chloro-organic compounds are oxidized at a narrow range of chlorine doses less than the breakpoint (Figure 4.27)

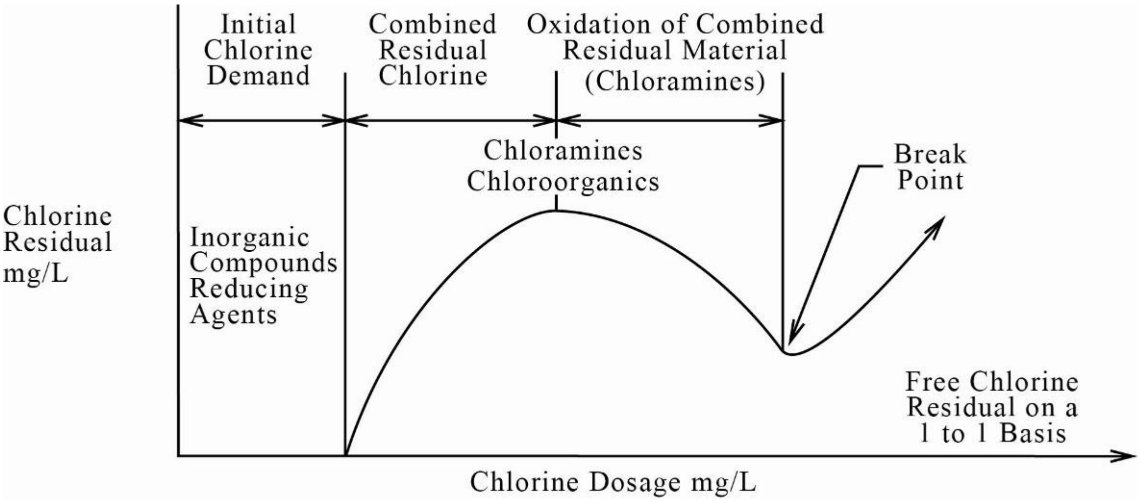


Figure 4.27 Breakpoint chlorination curve

c. Indicator Bacteria Results

Regardless of the chlorine residual method employed enough chlorine solution must be injected into the effluent to sufficiently destroy or inactivate the indicator bacteria that signal the likely presence of pathogens. The primary objective of chlorination is to destroy pathogenic organisms; however, the coliform bacteria often used as indicators are not pathogenic. The indicator bacteria inactivation concept works because coliform and other indicator bacteria are much easier to detect than pathogens and more difficult to destroy than most pathogens, except possibly viruses.

Testing directly for pathogens is complex and costly. If the coliform count has been sufficiently reduced through disinfection, a corresponding proportion of pathogens has probably been inactivated.

4.18.2 Operational Hazards

a. Chlorine Hazards

Chlorine is a gas, 2.5 times heavier than air, extremely toxic, and corrosive in moist atmospheres. Dry chlorine gas can be safely handled in steel containers and piping, but with moisture it must be handled in corrosion-resisting materials such as silver, glass, Teflon, and certain other plastics. Chlorine gas at container pressure should never be piped in silver, glass, Teflon, or any other plastic material. Even in dry atmospheres, the gas is very irritating to the mucous membranes of the nose, to the throat, and to the lungs; a very small percentage in the air causes severe coughing. Heavy exposure can be fatal.

b. Warning

When entering a room that may contain chlorine gas, open the door slightly and check for the smell of chlorine. Never go into a room containing chlorine gas with harmful concentrations in the air without a self-contained air supply, protective clothing, and help standing by. Help may be obtained from your chlorine supplier and your local fire department.

4.18.3 Maintenance

Routine operations and troubleshooting

Table 4.6 lists routine operational checks of chlorination equipment and remedies if these checks indicate potential problems.

Table 4.6 Routine operational checklist and troubleshooting guide for chlorination system

Items	What to check	Potential problems	Corrective actions
Record scale reading	Usage	Degrading effluent increases chlorine demand (nitrite demand increases use)	Monitor dose and demand. Adjust process to improve effluent quality.
		Low scale weight, chlorine about to run out	Replace container or cylinder before scale reaches zero to prevent sediment from entering system.*
Chlorine lines, valves, and Unions	Erratic reading	Scale not tared out properly	If necessary, retare or calibrate scale.
	Presence of chlorine leaks	Personal injury (potential death), evacuation logistics, and corrosion of nearby equipment and electronics	Work with a trained assistant, wear SCBAs (Self-Contained Breathing Apparatus), and follow all appropriate safety procedures when closing container or cylinder main valve and evacuating chlorination pipe network. Repair all leaks immediately; they will only get worse. Notify emergency response teams if required.
	Iced container or cylinder	Chlorination rate too high	Reduce chlorination rate, or manifold containers or cylinders together. If an evaporator is being used, be certain liquid chlorine is being withdrawn from the container's bottom valve.
Solution lines	Leaks	Chlorine evaporating	Repair all leaks immediately. Evacuate chlorine network and repair PVC pipes. Follow all appropriate safety procedures when working with any chlorine leak.
System gauges	Gauges	Chlorination system downtime	Correct all potential problems immediately.
	Main manifold pressure	Could break rupture disk?	If necessary, evacuate network and replace rupture disk. Check all network valves for correct positioning.

*This will prevent sediment in the container from entering the chlorination network and possibly damaging the process equipment.

Source: WEF, 2008

4.19 OPERATION & MAINTENANCE OF DEWATS AND JOHKASOU

The package treatment plants like Johkasou and also DEWATS have to be maintained as per the vendors of these systems.

4.20 PREVENTIVE MAINTENANCE

Preventive Maintenance addresses the civil, mechanical, electrical, instrumentation and automation aspects.

In respect of civil works, follow the local rules, regulations and guidelines of the local Public Works Department (PWD). These procedures are mostly annual. It will be better to hand over such maintenance to the PWD and remit the costs to that department.

In respect of mechanical equipment, it is better to enter into a contract with the contractor who has built the STP to do this as per the directions of the equipment suppliers and retain the equipment supplier to check and certify the work.

In respect of the electrical installations, it is better to entrust this work to the local Electricity Department, similar to civil works.

In respect of instrumentation and automation, similarly, entrust the work to the contractor who supplied and erected these and retain a third party agency to certify the proper completion of the work.

The following checklist (Table 4.7) is an example of a preventive maintenance program for activated-sludge facilities. When developing a site-specific schedule consult the service manuals that were provided with each piece of equipment.

Table 4.7 An example of a preventive maintenance program for activated-sludge facilities checklist

Activated-sludge system preventive maintenance (typical)	Daily	Weekly	Monthly	Quarterly	Biannual	Annual	Comments
Aeration blower							
Maintain proper motor lubricant level		●					
Lubricate motor roller bearings							1.5 months
Check for abnormal noises and vibration				●			
Check that air filters are in place and not clogged				●			
Check motor bearing rise temperature				●			
Check motor for voltage and frequency variations				●			
Check that all covers are in place and secure				●			
Rotate blower operation				●			
Lubricate motor ball bearings				●			
Check that electrical connections are tight				●			
Check wiring integrity				●			
Lubricate motor sleeve bearing					●		or 2000 hours
Inspect and clean rotor ends, windings, and blades					●		
Check that electrical connections are tight and corrosion is absent					●		
Change blower bearing oil						●	
Re-lubricate after checking flexible couplings							As needed
Oxygen dissolution system							
Lubricate motor					●		
Change gear drive oil					●		
Lubricate flex coupling						●	or 2500 hours
Inspect gear tooth pattern wear, shaft and bearing end play alignment, bolting, and seal condition						●	
Fine bubble diffusers							
Check biological reactor surface pattern	●						
Check air mains for leaks	●						
Check and record operating pressure and airflow	●						
Purge water moisture from distribution piping			●				

Activated-sludge system preventive maintenance (typical)	Daily	Weekly	Monthly	Quarterly	Biannual	Annual	Comments
Bump diffuser system			●				
Drain biological reactor						●	
Remove excess solids that may accumulate						●	
Clean diffusers						●	
Check that retaining rings are in place and tight						●	
Check that fixed and expansion joint retaining rings are tight						●	
Secondary clarifier							
Remove trash and debris	●						
Test torque-control line switches		●					
Test torque overload alarm		●					
Verify torque scale pointer moves		●					
Check drive unit for accumulated condensation		●					
Check drive oil level and quality		●					
Check drive overload response controls						●	
Inspect entire mechanism above and below water line						●	
Inspect and tighten all nuts and bolts							Regular interval
Inspect lubrication for torque-overload protection device, per manufacturer's instructions							e.g., 18 months or 500 cycles
Return activated sludge pumps (centrifugal)							
Lubricate pump bearings							or 2000 hours
Lubricate motor bearings				●			
Waste activated sludge pumps (centrifugal)							
Lubricate pump bearings							or 2000 hours
Lubricate motor bearings				●			

Source: WEF, 2008

4.21 TROUBLESHOOTING

Refer to Appendix 4.1.

4.22 RECORD KEEPING

The importance of maintaining adequate O&M records cannot be overemphasized. The purpose of recording data is to track operational information that will identify and duplicate optimum operating conditions. Records of the volume and concentration of waste sludge fed to the digester and volume and concentration of digested solids removed from the digester should be kept. Additional information that needs to be maintained, include DO concentration and pH. Keep a monthly report form. In plants where the aeration system capacity is marginally adequate in providing desirable DO concentration in the digester, record DO concentration data on a trend chart. If chemicals are added to the digester for pH or odour control, record the type and amount of chemicals added. If mechanical aerators are used, record the power usage. In the case of diffused-air systems, air flow records may be of interest. If airflow meters are not available, records of power consumption may be useful. Experimenting with the aeration system often leads to significant savings in power costs.

A record of instrument performance and repairs allow operations or maintenance personnel to properly evaluate an instrument's effectiveness and determine if the instrument meets the objectives used to justify its purchase and installation. As a minimum, the following basic information should be maintained for each instrument in the sewage treatment plant:

- Plant equipment identification number
- Model number and serial number
- Type
- Dates placed into and removed from service
- Reasons for removal
- Location when installed
- Calibration data and procedures
- Hours required to perform maintenance
- Cost of replacement parts
- Operations and maintenance manual references and their locations
- Apparatus failure history

4.23 SUMMARY

Appendices to this manual provide troubleshooting lists for possible problems in STPs. Operators should check their operational problems in the troubleshooting lists so that they can take prompt measures to solve the problem on their own.

CHAPTER 5 SLUDGE TREATMENT FACILITIES

5.1 INTRODUCTION

Sludge treatment processes are often the most difficult and costliest part of sewage treatment. Untreated sludge is odorous and contains pathogens. Sludge stabilization processes reduce odours, pathogens, and biodegradable toxins, as well as bind heavy metals to inert solids, such as lime that will not leach into the groundwater. The resulting biosolids can be used or disposed of safely.

Sewage residuals include primary, secondary, mixed, and chemical sludge, as well as screenings, grit, scum, and ash. The concentration and characteristics of chemical sludge depend on the treatment chemicals (alum, ferric salts, or lime) used. It typically is found at treatment plants that have tertiary treatment, such as phosphorus removal. The use or disposal method for residuals depends on how much treatment they have received. Biosolids are residuals that have been stabilized so they can be beneficially used as a soil amendment. Combustible residuals, such as screenings, may be incinerated or landfilled. Non-combustible residuals, such as grit, may be landfilled.

5.2 SLUDGE THICKENING

The role of sludge thickening is to thicken the sludge of low concentration generated in sewage treatment facilities, and to make subsequent processes such as sludge digestion and sludge dewatering more effective. Thickened sludge may be of two kinds: primary settling tank sludge generated in the primary settling tank and excess sludge generated in the secondary settling tank.

Sludge thickening may be broadly classified into four types by thickening method: gravity thickening, centrifugal thickening, floatation thickening and belt type thickening.

When the thickening of sludge is inadequate, not only will the efficiency of subsequent sludge treatment reduce, but also centrate containing large amount of suspended solids will return to the sewage treatment facilities and degrade the water quality of treated water.

For this reason, excess sludge for which gravity thickening is difficult is increasingly being mechanically thickened using centrifugal thickening machines or floatation thickeners. When the water content of thickened sludge is 98% or more especially, separation and thickening should be considered.

5.2.1 Gravity Thickening

Gravity thickening is the most common practice for concentration of sludge (Figure 5.1). Gravity thickening concentrates sludge through sedimentation. The normal acceleration of gravity provides the driving force for the separation.

This is adopted for primary sludge or combined primary and activated sludge but is not successful in dealing with activated sludge independently. Gravity thickening of combined sludge is not effective when activated sludge exceeds 40% of the total sludge weight, and other methods of thickening of activated sludge have to be considered.

Continuous flow tanks are deep circular tanks with central feed and overflow at the periphery.

Better efficiencies can be obtained by providing slow revolving stirrers, particularly with gassy Sludge.

It is necessary to ensure provisions for:

- Regulating the quantity of dilution water needed

- Adequate sludge pumping capacity to maintain any desired solids concentration, continuous feed and underflow pumping
- Protection against torque overload
- Sludge blanket detection

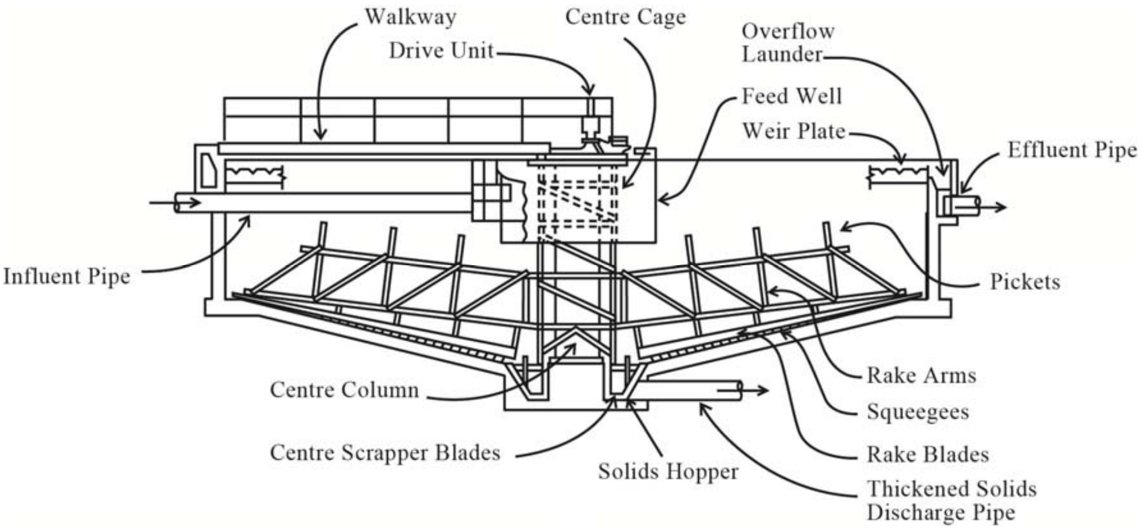


Figure 5.1 Example of a gravity thickener.

- Variable-speed drives may be used to increase rake speed to agitate the sludge blanket and release trapped gas bubbles, and to prevent rat-holing or coning. Prolonged operation at high speeds will reduce the ultimate solids concentration and reduce the life of the thickener drive mechanism.
- Scum removal equipment may include a skimmer and scum box. The ancillary equipment should include positive-displacement pumps (plunger, rotary lobe, diaphragm, or progressing cavity pumps). Process control equipment includes sludge blanket indicators (light path, sonic, or variable-height taps), online process monitors on the feed or underflow, torque readouts on the rake drive, and timers to vary the pump on-off (or speed) sequences. In cold weather areas or areas where odours are a problem, thickeners are typically covered.

Gravity thickeners are either continuous flow or fill and draw type, with or without addition of chemicals. Use of slowly revolving stirrers improves the efficiency. Continuous flow tanks are deep circular tanks with central feed and overflow at the periphery.

5.2.1.1 Process Control

Greater attention to the thickener is required when thickening waste activated sludge because it has a large surface area per unit mass, resulting in low settling rates and resistance to being compacted. Sludge tends to stratify in the gravity thickener while continuing biological activity, which includes the production of gases that can cause accumulated sludge to float.

Gravity thickener operation responds to changes in process temperatures; therefore, loading rates should be reduced to values at the lower end of the range when temperatures exceed 15 to 20°C, depending on the ratio of primary to secondary sludges. Higher temperatures will require additional dilution.

The following should be checked before or during operation:

- Avoid starting a thickener that contains accumulated sludge. To avoid overload, the sludge should be disposed of before starting the mechanism.

- Check and adjust the skimming mechanism to increase the amount of scum drawn into the scum box and to reduce the amount of supernatant carried with the skimming.

5.2.1.2 Maintenance

- Check all condensate drains and remove any accumulated moisture.
- Visually examine the skimmer to ensure that it properly comes into contact with the scum baffle and scum box.
- Inspect skimmer wipers for wear.
- Install kick plates on the gravity thickener bridge to prevent objects from falling into the tank.
- An object lodging in the underflow discharge pipe or under the mechanism will quickly halt operation of the thickener. If an object falls into the tank, immediately halt thickener operation to prevent torque overload.
- During plant rounds, regularly observe and record the drive torque indicator, which is the best indicator of mechanical problems.
- Regularly check the underflow pump capacity because pumps wear rapidly in a thickened sludge operation.
- Follow the manufacturer’s recommended lubrication schedule and use recommended lubricant types. Oil should typically be changed after the first 250 hours of operation and every 6 months thereafter.

5.2.2 Centrifugal Thickening

Thickening by centrifugation is chosen only when space limitations or sludge characteristics will not permit the adoption of other methods. This method involves high maintenance and power costs.

5.2.2.1 Configuration

Decanter centrifuges are centrifuges that have a screw conveyor inside that transports the settled sludge along the bowl and out of the centrifuge. They thicken and dewater the sludge simultaneously.

In the centrifuge, the process is the same, varying only in degree. Centrifuges use the principle of sedimentation to separate liquids from solids based on the same principle as the clarifiers and thickeners in the wet end of the plant. In case of sedimentation, it is the difference in density between the solids and the surrounding liquid that drives separation.

5.2.2.2 Operation and Maintenance

All process devices benefit from a constant feed quality, and centrifuges are no exception. Common problems are varying ratios of primary to secondary sludges or feed material that has become septic. For very complicated reasons, septic sludge is more difficult to thicken than fresh sludge. Holding feed material in storage tanks under uncontrolled conditions is poor practice. When in doubt, measure the pH drop through the tankage.

The manufacturer generally sets the bowl speed and it is rarely changed thereafter. Assuming the present speed was the correct speed several years ago is not proof that it is the best speed now. The plant engineer should adjust the speed periodically, to confirm that it is correct and to remind operators that it is a variable. It is good policy to consult the manufacturer before changing the bowl speed.

a. Start-up

Most modern centrifuges have a one-button start. Manual systems take a few minutes, but are not onerous. When the centrifuge is up to speed, the controls unlock the feed and polymer pumps, and the operator begins to put the centrifuge online. The start-up sequence is as follows:

- Turn on the feed and polymer to about one-third of the normal rate.
- Reduce the differential revolutions per minute and/or pond to minimum.
- When the cake thickness reaches the normal value, begin increasing the differential and the polymer feed rate. Some plants can jump directly to the normal operating conditions as soon as the cake is sealed, while others have to ramp up more slowly.

b. Shutdown

Again, modern centrifuges have a one-button stop. The shutdown sequence is as follows:

- Shut off the feed and polymer and turn the flushing water on.
- When clear water exits both ends of the centrifuge, push the centrifuge stop button.
- At some point, as the centrifuge slows down, flush water will come around the feed tube or around the casing seals. Note how long it took between engaging the stop button and the water gushing out. Next time, shut the water off a minute or two sooner.
- With the flush water off, the centrifuge can usually coast to a stop without operator intervention.

c. Sampling and Testing

Sampling and testing should include TSS and/or total solids for the feed, total solids for thickened sludge, and TSS, ammonia, and/or phosphorus (under some conditions) for centrate.

5.2.3 Air Floatation Thickening

Air floatation units employ floatation of sludge by air under pressure or vacuum and are normally used for thickening the waste activated sludge. These units involve additional equipment, higher operating costs, higher power requirements, and more skilled maintenance and operation. However, removal of grease and oil, solids, grit and other material as also odour control are distinct advantages.

In the pressure type floatation units, a portion of the subnatant is pressurised from 0.3 to 0.5 MPa and then saturated with air in the pressure tank. The effluent from the pressure tank is mixed with influent sludge immediately before it is released into the flotation tank. Excess dissolved air then rises up in the form of bubbles at atmospheric pressure attaching themselves to particles which form the sludge blanket. Thickened blanket is skimmed off while the unrecycled subnatant is returned to the plant.

5.2.3.1 Configuration

Flotation thickeners are equipped with both surface skimmers and floor rakes. The surface skimmers remove floating material from the thickening tank to maintain a constant average float blanket depth. Floor rakes are essential for removing the non-floatable heavier solids that settle to the bottom of the flotation thickener. Most units are baffled and equipped with an overflow weir. Clarified effluent passes under an end baffle (rectangular units) or peripheral baffle (circular units) and then flows over the weir to an effluent launder. The weir controls the liquid level within the flotation tank with respect to the float collection box and helps regulate the capacity and performance of the flotation unit.

The saturation system typically includes a recycle pressurization pump, an air compressor, an air saturation tank, and a pressure release valve. Although the flow through the pressurization pump typically is recycle-flow, it can be makeup water. The pressure release valve controls pressure loss and distributes the gas-saturated pressurized flow into the feed sludge as dissolved air emerges from solution. The rapid reduction in pressure causes dissolved air (under pressure) to emerge from solution or “effervesce” into minute bubbles.

Other important equipment that forms part of an air floatation thickening system is the float handling and pumping system. After removal of the float from the air floatation thickening unit, float solids are deposited in a hopper and then pumped for further processing. This aspect of the operation requires special considerations because of the following characteristics of float solids:

The parameter that is manipulated by the operator to control the performance of a thickener is the effective drainage time. This parameter is controlled by:

- Adjustment of skimmer on-time,
- Adjustment of skimmer off-time, and
- Adjustment of skimmer speed.

5.2.3.2 Operation

A float total solid content of 4% represents a typical minimum for flotation thickeners handling solids without primary sludge. Under optimum conditions, however, 5 to 6% solids content can be expected.

Proper operation requires reducing variations of the feed rate and concentration. A feed sludge holding and mixing tank helps with intermittent operation. Most units are operated continuously. Some are operated with a short period shut-down during weekends, while others are operated only during certain hours of the day.

The speed and the on-off times of the float skimmers should be set to maximize the float solids concentration, but should not be set too slow to cause excessive float-depth accumulation.

Dilution reduces the effect of particle interference on the rate of separation. Concentration of the sludge increases and the concentration of effluent suspended solids decreases as the sludge blanket detention time increases.

a. Start-up

- Fill the tank with screened final effluent or plant non-potable water until overflowing.
- Continue plant non-potable water flow to the air floatation unit and engage the recycle system, including the compressor, if applicable. Adjust to proper pressures and flow. After proper functioning, proceed.
- Ensure that the float and underflow pumps are functional by pumping some water.
- Prepare the polymer, if applicable, and engage the polymer addition at proper flow or as jar tests have indicated if starting after prolonged shutdown, start-up, or process changes.

b. Shutdown

- Stop polymer flow, if applicable, and at the same time stop waste activated sludge feed.

- If only down for a short time (30 minutes or so), there is no need to shut down the recycle system, including the compressor. If down for longer than this period, shut down the recycle system.
- The float rake timer can be left on until most of the float is removed into the hopper and pumped for further processing.
- If the unit is going to be down for more than 24 hours, displace the tank contents with non-potable water or drain and clean the tank, all troughs, and pipelines.
- In a typical operation, only the recirculation pump and retention tank discharge valves are closed when stopping a unit's operation. All other valves remain open, with the exception of valves on drain lines.

5.2.3.3 Maintenance

- Checking all oil levels and ensuring that the oil fill cap vent is open;
- Checking all condensation drains and removing any accumulated moisture;
- Examining drive control limit switches;
- Visually examining the skimmer to ensure that it is in proper contact with the scum baffle and scum box;
- Inspecting skimmer wipers for wear;
- Adjusting drive chains or belts;
- Semi-annual inspections of major elements for wear, corrosion, and proper adjustment include:
  - Saturation systems - eductors (if used) or nozzles should be inspected for wear or cleaned whenever the efficiency begins to decline, or on a semi-annual basis;
  - Mechanical systems, including shaft bearings and bores, bearing brackets, baffle boards, flights and skimming units, suction lines and sumps, and sludge pumps.

5.2.4 Belt Type Thickening

Gravity belt thickeners (Figure 5.2) work by filtering free water from conditioned sludge by gravity drainage through a porous belt. The gravity drainage area is usually horizontal but may be inclined under some circumstances. Chemical conditioning is generally required to flocculate the sludge and separate the solids from the free water. Chemical conditioning may be accomplished by injecting the chemical through an injection ring and mixing it with the sludge. After chemical injection, the sludge velocity is reduced in a retention tank and the sludge is allowed to fully flocculate before overflowing by gravity onto the moving belt.

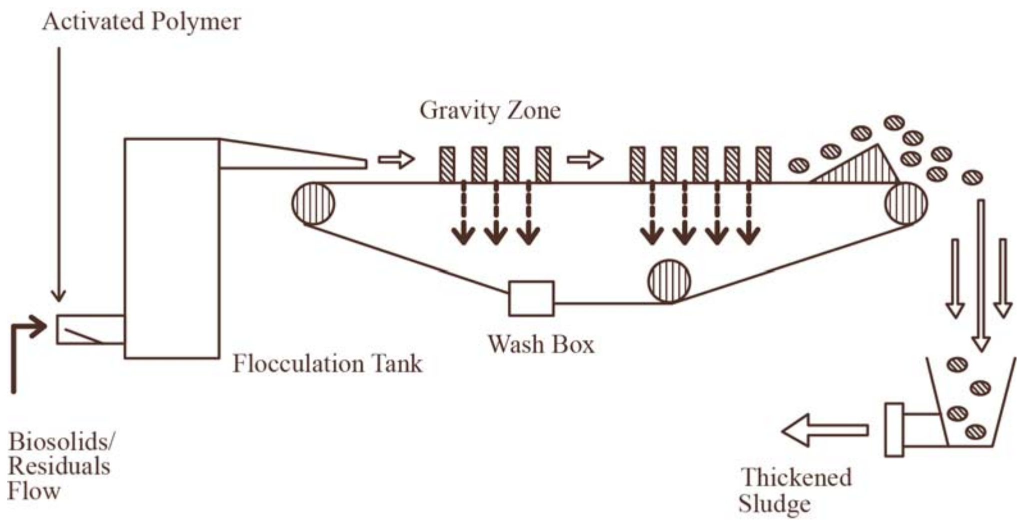


Figure 5.2 Gravity belt thickener process

As the moving belt carries the sludge, plows clear portions of the belt for the filtrate to drain through and gently turn over the solids, thereby exposing more free water. Prior to the discharge, most gravity belt thickeners have some type of dam or an adjustable ramp.

The hydraulic capacity of the equipment is determined by multiple factors including sludge type, sludge concentration, polymer type and polymer dosage, belt speed, belt type, as well as the obvious machine width and length.

5.2.4.1 Configuration

a. Polymer Addition

Polymer addition usually occurs by injection through a multiport injection ring; it is mixed with the sludge as it flows through an inline mixing device. In some cases, the polymer may be mixed mechanically in the retention tank. However, this generally results in higher polymer consumption.

b. Flocculation Tank

The flocculation tank allows the incoming sludge velocity to be reduced so that flocculation can fully occur before the sludge overflows onto the moving belt. Design of the tank is critical to prevent short-circuiting within the tank.

c. Belt and Supports

Belts are typically woven from polyester fibre. High pH and other unusual conditions may require special materials. The belt is supported on grid strips that also serve as wipers on the bottom of the belt. This wiping action increases the drainage capacity of the belt.

d. Belt Tensioning

Unlike a belt press, the performance of the belt thickener is not dependent on belt tension. Once the dewatering belt on a thickener is tight enough to prevent slippage on the drive roller, additional tension is unnecessary. Additionally, the belt tension on a thickener is not dependent on the type or amount of sludge loading. As such, the requirements for belt tension are much lower on a gravity belt thickener compared to a belt filter press.

Belt tension is a result of moving one roller closer to or further away from the other roller(s). This displacement may be through hydraulic, pneumatic, or mechanical actions. Once the belt is tensioned, it is not necessary to relax the tension until the belt is replaced.

e. Belt Drive

All belt thickeners have a variable-speed belt drive with a typical speed range of 8 to 40 m/min. The belt speed may be either mechanically or electrically varied with speed controls at the local control panel. Typically, the belt drive is attached to a rubber-coated drive roller.

f. Belt Tracking

During operation of a belt thickener, the belt should more or less remain centered and not move laterally on the machine. Although the belt should not move, some type of belt tracking device is included on most machines. Comparatively, the belt on a belt thickener is similar to a conveyor belt; all tracking devices have some roots in the conveyor or papermaking industry.

5.2.4.2 Operation and Maintenance

a. Start-up

- Start the hydraulic unit (or air compressor) and allow tension to develop in the belt.
- Start the belt drive and use an initial setting of approximately 20 m/min belt speed.
- Start the wash water pump and allow the belt to pre-wet.
- Start the polymer pump and allow the fresh polymer to reach the polymer injection point.
- After thickened sludge is available, start the thickened sludge pump (or thickened sludge conveyor).
- After the system is running, begin fine-tuning the process by adjusting the sludge flow, polymer dose, mixing energy, belt speed, and so on until the results are within the desired process parameters. It is important to only adjust one item at a time and to allow time for the adjustment to take effect before making another change.

b. Shutdown

- Shut down sludge feed pump.
- Shut down polymer feed pump.
- As the thickened sludge hopper empties, shut down the thickened sludge pump (or thickened sludge conveyor).
- Drain the flocculation tank.
- Wash the machine down from top to bottom.
- Allow the belts to be completely washed (this could take 15 to 45 minutes) without sludge or polymer.
- Shut down the wash water pump.
- Shut down the belt drive.
- Shut down the hydraulic unit/air compressor.

c. Sampling and Testing

At a minimum, gravity belt thickeners should be sampled and analyzed as follows:

- Sample influent feed for total solids, TSS, total volatile solids, pH, and flow.

- Sample wash water for TSS and flow.
- Sample thickened sludge for total solids and flow.
- Sample filtrate for TSS and flow.
- Measure flow and quantity of polymer used.
- Measure any dilution water used to make up polymer.

d. Process Control

Numerous variables affect the overall thickening process. Listed below are most of these variables.

- Sludge feed, polymer, polymer dosage, mixing energy, retention time
- Belt speed, belt tension, belt type, ramp angle
- Upstream variables, slurry pump selection, solids concentration
- Biological sludge content, sludge storage time, wash water characteristics

5.3 ANAEROBIC DIGESTION

In anaerobic digestion, anaerobic bacteria thrive in an environment without dissolved oxygen by using the oxygen that is chemically combined with their food supply.

Two major types of bacteria are present in the digester. The first group starts eating the organic portion of the sludge to form organic acids and carbon dioxide gas. These bacteria are called acid formers. The second group breaks down the organic acids to simpler compounds and forms methane and carbon dioxide gas. These bacteria are called gas formers. The methane gas is usually used to heat the digester or to run engines in the plant. The production of gas indicates that organic material is being eaten by the bacteria. Sludge is usually considered properly digested when 50% of the organic matter has been destroyed and converted to gas. This normally takes approximately 30 days if the temperature is kept at about 35°C.

Most digestion tanks are mixed continuously to bring the food to the organisms, to provide a uniform temperature, and to avoid the formation of thick scum blankets. When a digester is not being mixed, the solids usually settle to the bottom, leaving a liquid known as supernatant above the sludge. In many plants, however, there is no separation of solids and liquids after two days of sitting without mixing due to the type of sludge. The supernatant is displaced from the tank each time a fresh charge of raw sludge is pumped from the primary clarifier. The displaced supernatant usually is returned from the digester back to the plant head-works and mixed with incoming raw wastes. Supernatant return should be slow to prevent over-loading or shock loading of the plant.

In most new plants, sludge digestion takes place in two tanks. The first or primary digester is usually heated and mixed. Rapid digestion takes place along with most of the gas production. In the secondary tank, the digested sludge and supernatant are allowed to separate, thus producing a clearer supernatant and better-digested sludge.

Digester sludge from the bottom of the tank is periodically removed for dewatering.

5.3.1 Digestion Types

Two different types in anaerobic sludge digestion process namely, Low rate and High rate, are used in practice. The basic features of these processes are shown in Figure 5.3.

5.3.1.1 Low Rate Digestion

Low rate digestion is the simplest and the oldest process; essentially a low rate digester is a large storage tank, occasionally, with some heating facility. The basic features of this process are shown in Figure 5.3.

Raw sludge is fed into the digester intermittently. Bubbles of sewage gas are generated and their rise to the surface provides some mixing. In the case of few old digesters, screw pumps have been installed to provide additional intermittent mixing of the contents, say once in 8 hours for about an hour. As a result, the digester contents are allowed to stratify, thereby forming four distinct layers: a floating layer of scum, layer of supernatant, layer of actively digesting sludge and a bottom layer of digested sludge; essentially the decomposition is restricted to the middle and bottom layers. Stabilized sludge which accumulates and thickens at the bottom of the tank is periodically drawn off from the centre of the floor. Supernatant is removed from the side of the digester and returned back to the treatment plant.

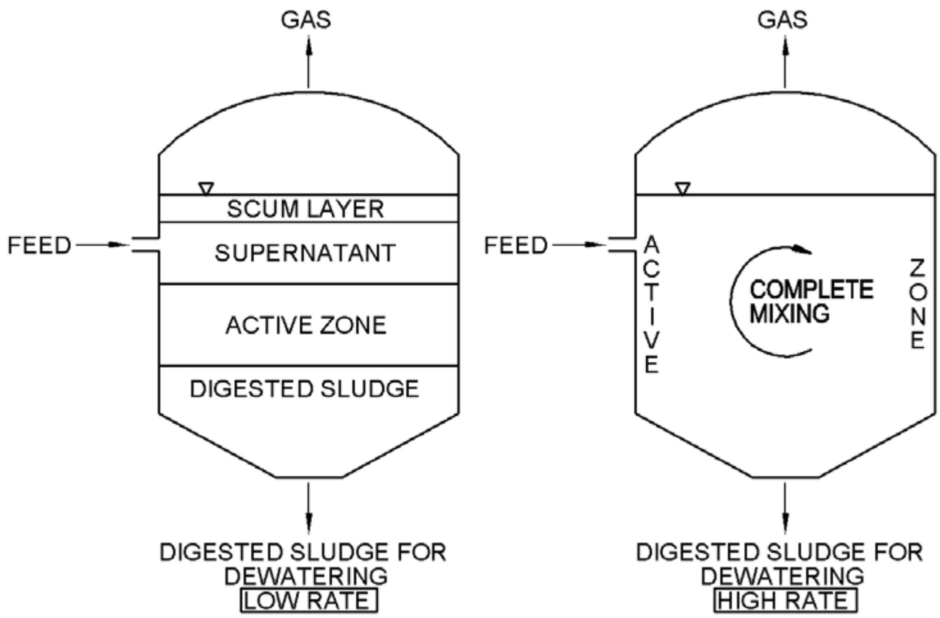


Figure 5.3 Sludge digestion system

5.3.1.2 High Rate Digestion

The essential elements of high rate digestion are complete mixing and more or less uniform feeding of raw sludge. Pre-thickening of raw sludge and heating of the digester contents are optional features of a high rate digestion system. All these four features provide the best environmental conditions for the biological process and the net results are reduced digester volume requirement and increased process stability.

Complete mixing of sludge in high rate digesters creates a homogeneous environment throughout the digester. It also quickly brings the raw sludge into contact with microorganisms and evenly distributes toxic substances, if any, present in the raw sludge. Furthermore, when stratification is prevented because of mixing, the entire digester is available for active decomposition, thereby increasing the effective solids retention time.

5.3.2 Configuration

5.3.2.1 Anaerobic Digestion Tank

Anaerobic digestion tanks may be cylindrical or cubical in shape. Most tanks constructed today are cylindrical. The floor of the tank is sloped so that sand, grit, and heavy sludge will tend to be removed from the tank. Most digesters constructed today have either fixed or floating covers.

A fixed cover digester may develop an explosive mixture in the tank when sludge is withdrawn if proper precautions are not taken to prevent air from being drawn into the tank. Each time a new charge of raw sludge is added, an equal amount of supernatant is displaced because the tank is maintained at a fixed level

A floating cover moves up and down with the tank level and gas pressure. Normally, the vertical travel of the cover is about 2.5m, with stops (corbels) or landing edges for down (lowering) control and maximum water level for upward travel. Maximum water level is controlled by an overflow pipe that must be kept clear to prevent damage to the floating cover by overfilling. Gas pressure depends on the weight of the cover. The advantages of a floating cover include less danger of explosive mixtures forming in the digester, better control of supernatant withdrawal, and better control of scum blankets. Disadvantages include higher construction and maintenance costs.

5.3.2.2 Agitator

Maintenance requires that the condensate be drained from the lines at least twice a day, that the diffusers be cleaned to prevent high discharge pressures, and that the compressor unit be properly lubricated and cooled.

Propeller mixers are found mainly on fixed cover digesters. Normally, two or three of these units are supported from the roof of the tank with the propeller blades submerged 3 to 3.5 m in the sludge. An electric motor drives the propeller stirring the sludge. Digested sludge normally contains a great deal of grit and debris. This type unit usually has reversible motors so the propeller may rotate in either direction. In one direction the contents are pulled from the top of the digester and forced down the draft tube to be discharged at the bottom. By operating the motor in the opposite direction, the digested sludge is pulled from the bottom of the tank and discharged over the top of the draft tube to the surface. Reversible motors also assist in minimizing accumulations of rags on the propeller.

If two units are installed in the same tank, an effective way to break up a scum blanket is operating one unit in one direction and the other unit in the opposite direction, thereby creating a push-pull effect. The direction of flow in the tubes should be reversed every day.

A limitation of draft tube-type mixers is the potential formation of a scum blanket. If the water level is maintained at a constant elevation, a scum blanket forms on the surface. The scum blanket may be a thick layer and the draft will only pull liquid sludge from under the blanket, not disturbing it, Lowering the level of the digester to just 7 to 10 cm over the top of the drain tube forces the scum to move over and down the draft tube. This applies mainly to single-direction mixers.

Pumps are sometimes used to mix digesters. This method is common in smaller tanks. The tank may or may not be equipped with a draft tube positioned in such a way that the pump suction may be from the top or valved from the bottom of the digester. Control of scum blankets with this method of mixing depends on how the operator maintains the sludge level and where the pump is pulling from and discharging to the digester.

Pressure gauges should be installed on the pump suction and discharge pipes. A change in pressure could indicate that the pump is not functioning properly and the desired mixing may not be taking place in the digester.

5.3.2.3 Digester Gas Equipment

a. Gas Tank

Several types of gas storage are available. The most common means of low-pressure gas storage is the floating gas-holder cover. Membrane storage can be installed either on the digester, to serve both as cover and storage space, or on the ground as a standalone structure.

b. Flow Meter

Gas production is a measure of digester performance. Reliable monitoring equipment alerts plant operators to process malfunctions and gas leaks. The flow meters used for gas monitoring can be broadly classified as positive-displacement, thermal-dispersion, and differential pressure flow meters (Table 5.1).

Separate flow meters are recommended for each digester because digester gas-production rates vary. Separate flow meters are also recommended to monitor gas use by the utilization equipment. The gas may contain moisture and impurities, which may cause maintenance problems for the metering devices.

Table 5.1 Gas-flow indication and metering

Type	Application	Operation and maintenance
Positive displacement	Used in many plants. Large devices that require bypasses when servicing. Accurate gas measurement unless dirty. Does not require upstream and downstream straight-pipe sections for accuracy.	Somewhat tolerant of dirty gas. Requires periodic cleaning and rebuilding.
Thermal dispersion insert	Increasingly used technology because of tolerance to dirty gas and simple installation. Accurate for low flows. Some accuracy problems with zero flow, such as for flares. Requires some upstream and downstream straight-pipe distances for accuracy. Can be inserted and removed through ball valve.	Smaller than most metering devices. Requires periodic cleaning of probe. Must not have liquid impinging on probe. No bypass needed, reducing need for piping and isolation valves to service.
Pressure differentia orifices and Venturis	Commonly used in older plants. Upstream and downstream straight piping sections needed.	Requires frequent cleaning when used for dirty gas. Accuracy depends on instrument cleanliness. Can significantly constrict gas flow when fouled.

Source: WEF, 2008

c. Gas system safety and control devices (Table 5.2)

Table 5.2 Gas system safety and control devices

Type	Application	Operation and maintenance
Flame traps (large pipe) and flame check valves (small piping)	Used to stop flame propagation in a pipe. Flame traps are installed with thermal shutoff valves as noted below. Installed on gas supplies to engines, compressors, boilers, flares, or other sources of ignition. Also used on digester covers with pressure- and vacuum-relief valves.	Require periodic cleaning, typically monthly. May require insulation and heating in cold climates to prevent ice formation. Foam will blind the devices, rendering other devices, particularly relief valves, ineffective.
Thermal shutoff valves	Spring-loaded or pressure-operated isolation valves that trip and shut off at flame temperatures. Must be installed between flame trap and	Replace element periodically or when tripped. Usually includes an indicator to show that the valve has tripped. May require

Type	Application	Operation and maintenance
	source of ignition.	insulation and heating in cold climates to prevent ice formation.
Pressure- and vacuum relief valves	Provided for all digester covers to prevent over pressurization or vacuum conditions in the digester. Typically adjustable, weighted valves, built as common unit. Should be set below design limits of cover. Typically two sets provided for each cover to allow servicing of one set while keeping digester in service. Typically discharge to area around valves. Available with pipe to allow discharge away from valves.	Check seals periodically; replace if leaks develop. May require insulation and heating in cold climates to prevent ice formation. Relief valves are last safety measure for digester covers to prevent over pressure or vacuum. These valves do not provide liquid relief.
Back pressure valves	Typically provided with waste gas flares. Maintain pressure upstream by relieving overpressure to flare. Usually uses weights to set relief pressure; however, some use springs. Upstream sensing line should ideally be in gas collection piping header, away from the valve and large enough to reduce the potential for clogging.	Frequent maintenance required to prevent sticking (open or closed). These valves regulate pressure in the gas-collection piping system and are the first level of protection for over pressurization of the digester cover.
Low-pressure check valves	Used to prevent backflow of gas. Typically constructed with leather or flexible flap to ensure operation at low pressure. Not commonly used.	Check flap and replace if not functioning.
Waste gas flare or burners	Provided to dispose of surplus gas. Usually provided with standing pilot or electronic ignition.	Provided for all plants to serve as a means of suitable disposal of gas. Untreated gas should not be freely released.
Open pipe or "candle flare"	Used for smaller plants and where stringent air-emissions control is not needed. Generally visible flame, gas disposal device.	Good pilot-gas supply is needed (may require natural gas or propane supply). Heat and corrosion make periodic replacement necessary. Pilot system requires frequent servicing.
Controlled combustion flare, ground flare, or emissions controlled flare	Used at plants where stringent air emissions are required and visible flame is not desired. Control air supply to maintain sufficient temperature to completely burn gas. These flares must be operated at a specific temperature to achieve emission limits. If oversized, auxiliary fuel may be required; this increases operating costs.	Require periodic system maintenance for controls and air blowers.
Pressure indication	Manometers used for low pressure. Gauges used for higher pressures, particularly for gas utilization lines.	Periodically clean manometers, replace fluid, and calibrate gauges. Pressure gauges should be provided with an isolating diaphragm to prevent gas contaminants from fouling the mechanism.

Source: WEF, 2008

5.3.2.4 Gas Scrubbers

a. Foam and Sediment Removal

Many systems are equipped with sediment traps and foam separators for cleaning digester gas. These devices provide a "wide spot" in the gas piping system for slowing velocities, collecting foam and particulates entrained in the gas, and removing collected condensate. The foam separator is a large vessel with an internal plate fitted with water nozzles that provide a continuous spray. The foam- and sediment-laden gas enters the vessel near the top and travels down through the spray wash under the baffle wall and up through a second spray wash, exiting the vessel through an elevated discharge nozzle. The spray wash and the internal plate reduce foam in the gas to prevent carryover to gas utilization equipment.

b. Hydrogen Sulphide Removal

The generation of hydrogen sulphide can also be inhibited by using ferric chloride injection into the digester. But this is usually very difficult as handling ferric chloride is not easy because it is very acidic and reactions with skin can be troublesome. Injection of ferric chloride can however be used as a temporary measure when sulphates in raw sewage become very high in drought situations when the population may use a lot of hard water for many purposes other than drinking, and which may increase the sulphate in raw sewage. Iron salts can be added at the following locations in the treatment process:

- The primary clarifier (helps settling and improves overall facility odour control)
- The suction side of the digester sludge-recirculation pump
- The suction side of a mechanical mixer

Iron salts should not be added directly upstream from the heat exchangers because this can result in deposits of vivianite on heat exchanger surfaces.

Refer to section 6.5.15.3 of the Part-A manual for the methods in use in India for removing hydrogen sulphide from digester gas.

c. Moisture Reduction

Moisture is condensed from digester gas as it cools. Gas piping should have a slope of at least 1% toward the condensate collection point. To effectively remove the moisture, the gas flow should not exceed 3.7 m/s countercurrent to condensate flow.

The condensate is collected in traps that should be located at low points in long pipe runs and wherever gas is cooled. Drip taps, which can be controlled manually or automatically, provide a convenient and safe means for removal of accumulated condensate. Manually operated drip taps are recommended for indoor applications. Float-controlled, automatic drip taps are also available, but these require frequent maintenance to keep the valves operating. Should the float stick, gas can escape to the surrounding atmosphere, which limits their use to outdoor installations (where permitted by local codes and safety considerations).

d. Carbon Dioxide Removal

Carbon dioxide can be removed from the digester gas by water or chemical scrubbing, carbon sieves, or membrane permeation; however, all of these technologies are expensive and their use may be cost-effective only if the gas is to be upgraded to natural gas quality and sold.

e. Siloxane Removal

Siloxanes are components of toiletries and personal care cosmetics such as sprays, deodorants, lipsticks, gels, lotions, shaving creams, cleaning fluids, and so on. Their use is growing every year. Not much data is available on their removal in STPs. It has been reported that siloxanes find their way in digester gas. The concern is in cold climates, if digesters are to be heated to maintain temperature of about 35°C, silicon dioxide deposits on the heat exchanger tubes, which reduces heat transmission. A typical photograph is shown in Figure 5.4.

Figure 5.4 Silicon dioxide deposits on boiler tubes

Hence it becomes necessary to protect equipment from siloxanes. This problem can occur also when digester gas is burned in gas engines. However, this has not been reported as a serious problem in digester gas usage in India.

f. Activated Carbon Scrubbers

Activated carbon scrubbers used to remove siloxanes from digester gas operate according to the same principles as the carbon scrubbers used for odour control in sewage treatment plants. The digester gas is passed through a vessel filled with activated carbon, which captures the organics, including siloxanes, hydrogen sulphide, and several other compounds in digester gas. With proper maintenance and replacement of the carbon, the siloxanes in the digester gas can be removed to below detection limits. However, activated carbon is not selective with regard to siloxanes and will remove other compounds as well. Consequently, if the digester gas contains other organics, the carbon will require frequent replacement. In India, the cocoanut shell activated carbon is locally available and is economical. Removal of hydrogen sulphide before it passes through the carbon scrubbers will provide better siloxane removal and extend the life of the carbon bed.

5.3.2.5 Gas Power Generator

Refer to Sec.6.4.2 “Gas Engines”.

5.3.3 Operation and Maintenance

5.3.3.1 Feeding Schedule

Uniformity and consistency are keys to digester operation. Sudden changes in feed solids volume or concentration, temperature, composition, or withdrawal rates will inhibit digester performance and may lead to foaming. The ideal feeding procedure is a continuous, 24-hour-per-day addition of a blend of different types of feed solids (primary and WAS). Where continuous feeding is impossible, a 5- to 10-min/h feed cycle is used. Smaller STPs that operate a single 8-hour shift use a schedule of at least three feedings: at the beginning, middle, and end of the shift. And typical causes of organic overloads include the following:

- Starting the digester too rapidly,
- Excessive volatile solids loading as a result of erratic feeding or a change in feed

solids composition,

- Volatile solids loadings exceeding the daily limits by more than 10%,
- Loss of active digester volume because of grit accumulation, and
- Inadequate mixing.

5.3.3.2 Withdrawal Schedule

Solids should be withdrawn from the primary digester immediately prior to feeding raw sludge to prevent short-circuiting. In digesters with surface overflow, the timing and rate of solids withdrawal and feed are coordinated to occur concurrently. Solids should be withdrawn at least daily to avoid a sudden drop in the active microorganism population. The primary digester may be regulated to simply overflow to the secondary digester or to the digested sludge storage tank as raw sludge is added. Solids may be withdrawn from the following locations:

- The bottom of the digester,
- The overflow structure, and
- Any point within a well-mixed digester.

A benefit of removing solids from the bottom of the digester is that it may also remove the grit that accumulates on the bottom of the digester. If possible, solids removal should be performed periodically.

It is important to recognize that because digestion destroys volatile solids, the concentration of the biosolids removed from the digester will be lower than the feed concentration unless the digester is decanted.

5.3.3.3 Scum Control

Scum accumulation in digesters is common. Scum is a combination of undigested grease and oil and often contains buoyant materials, such as plastics that are not removed at the plant’s headworks. Scum floats on the digester liquid surface and can accumulate, forming a dense mat. Properly designed and operated digester mixing systems can typically blend the scum into the tank contents.

If the digester operates without mixing for longer than 8 hours, scum may rise and float on the liquid surface. After mixing is restarted, the scum is re-suspended within the liquid. The primary method of scum control is to keep the digester mixing system well-maintained during operation.

5.3.3.4 Precipitate Formation and Control

The digestion process can produce crystalline precipitates that affect both the digestion system and downstream solids-handling processes. The precipitates can accumulate on pipes and dewatering equipment, causing damage and blockages and requiring costly and time-consuming maintenance. Common precipitates include struvite, vivianite, and calcium carbonate. The constituents that form these precipitates are present in undigested sludges and are released during the digestion process and converted to soluble forms that can react and crystallize. Their formation varies from site to site, depending on the chemistry of the digested sludges and the treatment processes. Because precipitates preferentially form on rough or irregular surfaces, glass-lined sludge piping and long-radius elbows help minimize their accumulation.

5.3.3.5 Digester Upsets and Control Strategies

The four basic causes of digester upsets are hydraulic overload, organic overload, temperature stress, and toxic overload. Hydraulic and organic overloads occur when the design hydraulic or organic loading rates are exceeded by more than 10% per day. The overload conditions can be controlled by managing digester feeding, as well as ensuring that the effective digester volume is not diminished by grit accumulation or poor mixing. Digester feeding is controlled by proper operation of upstream headworks, clarifiers, and thickeners to ensure the feed sludge concentrations. In the event of a digester upset, an effective control strategy includes the following steps:

- Stop or reduce sludge feed.
- Determine the cause of the imbalance.
- Correct the cause of the imbalance.
- Provide pH control until treatment returns to normal.

If only one digester tank is affected, the loading on the remaining units can be carefully increased to allow the upset unit to recover. If overloading is affecting several units, reducing the feed will require a method of dealing with the excess sludge by hauling it to another facility, providing temporary storage onsite, or chemically stabilizing and disposing of the sludge.

5.3.3.6 Temperature

Temperature-related stress is caused by a change in digester temperature of more than 1 or 2°C in fewer than 10 days, which would reduce the biological activity of the methane-forming microorganisms. If the methane formers are not quickly revived, the acid formers, which are unaffected by the temperature change, continue to produce volatile acids, which will eventually consume the available alkalinity and cause the pH to decline.

The most typical causes of temperature stress are overloading sludge and exceeding the instantaneous capacity of the heating system. Most heating systems can eventually heat the digester contents to the operating temperature, but not a harmful temperature variation.

5.3.3.7 Toxicity Control

The anaerobic process is sensitive to certain compounds, such as sulphides, volatile acids, heavy metals, calcium, sodium, potassium, dissolved oxygen, ammonia, and chlorinated organic compounds. The inhibitory concentration of a substance depends on many variables, including pH, organic loading, temperature, hydraulic loading, the presence of other materials, and the ratio of the toxic substance concentration to the biomass concentration.

5.3.3.8 pH Control

The key to controlling the digester pH is to add bicarbonate alkalinity to react with acids and buffer the system pH to about 7.0. Bicarbonate can be added directly or indirectly as a base that reacts with dissolved carbon dioxide to produce bicarbonate. Chemicals used for pH adjustment include lime, sodium bicarbonate, sodium carbonate, sodium hydroxide, ammonium hydroxide, and gaseous ammonia. Lime addition can be messy and will produce $CaCO_3$. Although ammonia compounds can be used for pH adjustment, they may cause ammonia toxicity and increase the ammonia load on the liquid treatment processes through return streams. Consequently, their use is not recommended.

During a digester upset, volatile acid concentrations may begin to rise before bicarbonate alkalinity is consumed. Because pH depression does not occur until alkalinity is depleted, it may be observed only after the digester is well on its way to failure.

5.3.3.9 Digester Foaming

Digester foam consists of fine gas bubbles trapped in a semi-liquid matrix with a specific gravity of 0.7 to 0.95. The gas bubbles are generated below the sludge layer and are trapped as they form. While some foaming always occurs, it is considered excessive if it plugs piping or escapes from the digester. Excessive foaming can cause the loss of active digester volume, structural damage, spillage, and damage to the gas-handling system, as well as being malodorous and unsightly. The most common cause of digester foaming is organic overload, which results in the production of more VFAs (volatile fatty acids) than can be converted to methane. The acid formers (which release carbon dioxide) work much more quickly than the methane-forming microorganisms. The resulting increase in carbon dioxide typically increases foam formation. Factors that can contribute to organic overload include:

- Intermittent digester feeding;
- Separate feeding or inadequate blending of primary sludge and waste activated sludge;
- Insufficient or intermittent digester mixing; and
- Excessive amounts of grease or scum in digester feed (especially problematic if the digester is fed in batches).

Organic overload can be minimized by feeding the digesters continuously (or as often as possible), blending different feed sludges well before feeding, ensuring that the digester-mixing system is operable, and limiting the quantities of grease or scum in the digester feed.

5.4 SLUDGE DEWATERING

Most of the digested primary or mixed sludge can be compacted to a water content of about 90% in the digester itself by gravity but mechanical dewatering with or without coagulant aids or prolonged drying on open sludge drying beds (SDBs) may be required to reduce the water content further. The dewatering of digested sludge is usually accomplished on sludge drying beds which can reduce the moisture content to below 70%. But excess oil or grease in the sludge will interfere with the process. Where the required space for sludge drying beds is not available, sludge conditioning, followed by mechanical dewatering on centrifugation, belt press, filter presses, screw press, rotary press, and vacuum filters.

5.4.1 Chemical Dosing Equipment

5.4.1.1 Coagulant

Chemical conditioning is the process of adding certain chemicals to enable coalescence of sludge particles facilitating easy extraction of moisture. The chemicals used are ferric and aluminium salts and lime, the more common being ferric chloride with or without lime.

Digested sludge, because of its high alkalinity exerts a huge chemical demand and therefore the alkalinity has to be reduced to effect a saving on the chemicals. This can be accomplished by elutriation. Polyelectrolytes show promise for sludge with finely dispersed sludge. The choice of chemical depends on pH, ash content of sludge, temperature and other factors. Optimum pH values and chemical dosage for different kinds of sludge have to be based on standard laboratory tests. The dosage of ferric chloride and alum for elutriated digested sludge is of the order of 1.0 kg/m^3 of sludge. Alum when vigorously mixed with sludge, reacts with the carbonate salts and releases CO_2, which causes the sludge to separate and water drains out more easily. Hence for effective results, alum must be mixed quickly and thoroughly. The alum floc, however, is very fragile and its usefulness has to be evaluated as compared with ferric chloride before resorting to its application.

Feeding devices are necessary for applying chemicals; mixing of chemicals with sludge should be gentle but thorough, taking not more than 20 to 30 seconds. Mixing tanks are generally of the vertical type for small plants and of the horizontal type for large plants. They are provided with mechanical agitators rotated at 20 to 80 rpm.

a. Inorganic Chemicals

Inorganic chemical conditioning is associated principally with vacuum and pressure filtration dewatering. The chemicals typically are lime and ferric chloride. Ferrous sulphate, ferrous chloride, and aluminium sulphate are also used, although less commonly.

i. Ferric Chloride

Ferric chloride solutions typically are used at the concentration received from the supplier (30 to 40%); however, some STPs dilute the ferric chloride to approximately 10% to improve mixing and reduce the acidity and corrosivity of the material. This can be done in day tanks or inline. Dilution may lead to hydrolysis reactions and the precipitation of ferric chloride crystals.

An important consideration in the use of ferric chloride is its corrosive nature. It reacts with water to form hydrochloric acid, which attacks steel and stainless steel. When diluted with sludge, the acidity is neutralized by the alkalinity of the sludge and thoroughly diluted so that the end product is quite benign. Interlocks must be used to ensure that ferric chloride is always added to sludge in the proper ratio and is never pumped into sludge lines or process equipment by itself.

Special precautions must be taken when handling this chemical. The best materials are epoxy, rubber, ceramic, polyvinylchloride, and vinyl. Contact with the skin and eyes must be avoided. Rubber gloves, face shields, goggles, and rubber aprons must be used at all times. Ferric chloride can be stored indefinitely without deterioration. Customarily, it is stored in above-ground tanks constructed of resistant plastic and surrounded by a containment wall. Ferric chloride can crystallize at low temperatures, which means that the tanks must be kept indoors or heated.

ii. Lime

Vacuum filters and filter presses commonly use lime and ferric chloride to make the sludge easier to filter and improve the release of the sludge from the filter media. Lime is available in two dry forms–quicklime (calcium oxide) and hydrated lime [$Ca(OH)_2$]. When using quicklime, it is first slurried with water and converted to calcium hydroxide, which is then used for conditioning. Because this process (known as slaking) generates heat, special equipment is required.

Quicklime must be stored in a dry area, because it reacts with moisture in the air and can become unusable.

Hydrated lime is much easier to use than quicklime, because it does not require slaking, mixes easily with water with minimal heat generation, and does not require any special storage conditions.

Lime typically is used in conjunction with ferric salts. Although lime has some slight dehydration effects on colloids, odour reduction, and disinfection, it is used because it improves filtration and release of the cake from the filter media. The lime reacts with bicarbonate to form a precipitate of calcium carbonate, which provides a granular structure that increases porosity and reduces compressibility of the sludge.

b. Organic Flocculants

Organic flocculants are widely used in many industries and processes involving the separation of sludge from liquids. These liquid- sludge separation applications may involve processes related to the recovery of finished products, clarification or purification of liquids, and volume reduction of waste materials.

While organic polyelectrolytes are commonly used in applications involving liquid-sludge separation, the processes of sewage sludge thickening and dewatering are completely dependent on their use.

i. Polymer Characteristics

The product characteristics of these complex and proprietary polyacrylamide flocculants may vary according to the following:

- Electronic charge (anionic, nonionic, or cationic)
- Charge density
- Molecular weight (standard viscosity)
- Molecular structure

ii. Polymer Specifications and Quality Control

Along with the product identification and type and form of product, the following standard product specifications should be obtained to determine storage conditions, pumping requirements, and potential hazards:

- Total solids
- Specific gravity
- Bulk viscosity
- Flash point
- Freezing point

5.4.1.2 Equipment

a. Liquid Feeders

A typical solution-feed system consists of a bulk storage tank, transfer pump, day tank (sometimes used for dilution), and liquid feeder. Some liquid chemicals can be fed directly without dilution, and these may make the day tank unnecessary, unless required by a regulatory agency. Nonetheless, dilution water can be added to prevent plugging, reduce delivery time, and help mix the chemical with the sewage. However, sometimes, the dilution water can have adverse chemical effects. For instance, dilution water that has not been softened can potentially cause calcium carbonate scale to build up on the piping. Special consideration should be given to the final water chemistry of the solution before adding dilution water.

Liquid feeders are typically metering pumps. Metering pumps are generally of the positive-displacement type using either plungers or diaphragms.

Positive-displacement pumps can be set to feed over a wide range (10:1) by adjusting the pump stroke length.

The chemical addition rate can be set manually by adjusting a valve or the stroke/speed on a metering pump.

b. Dry Chemical Feeders

Lime and alum are typical of the kinds of chemicals used with a dry chemical-feed system. It consists of a feeder, a dissolver tank, and a storage bin or hopper. These systems are complex because of their many storage and handling requirements. The simplest method of feeding dry or solid chemicals is by hand. Solid chemicals may be pre-weighed and added or poured by the bagful into a dissolving tank. This method generally applies only to small plants where dry chemical-feed equipment is used.

Most dry feeders are of the belt, grooved-disk, screw, or oscillating-plate type. The feeding device (belt, screw, disk, etc.) is typically driven by an electric motor. Many belt feeders, particularly the gravimetric type, also contain a material flow-control device such as a movable gate or rotary inlet for metering or controlling flow of the chemical to the feed belt.

5.4.1.3 Operation

Many metering pump systems handle chemicals that coat or build a layer of residue or slurries that can settle out solids during operation. Strainers are helpful in removing large particulates, but the operator must keep these cleaned. Periodic flushing to remove residues and deposits is often required. Piping and valve arrangements should allow the system to be isolated so that a clear liquid, such as water, can be used to pressurize the system for flushing the residue or solid buildup. Such flushing systems can be operated manually using hand-operated valves or can be automatically operated using solenoid valves with a timer control system. Systems where the metering pumps and piping are periodically shut down will require flushing connections to remove solids.

Most feeders, regardless of type, discharge their material to a small dissolving tank equipped with a nozzle system or mechanical agitator, depending on the solubility of the chemical being fed. The surface of each particle needs to be completely wet before it enters the feed tank to ensure thorough dispersal and avoid clumping, settling, or floating. When feeding some chemicals, such as polymers, into dissolvers, care must be taken to keep moisture inside the dissolver from backing up into the feeder.

5.4.1.4 Maintenance

Systems where the metering pumps and piping are periodically shut down will require flushing connections to remove solids. In addition, an allowance for T- and Y-cleanouts should be included for the piping system where longer horizontal piping runs cannot be adequately flushed.

A metering pump will lose capacity and become erratic when the suction or discharge valves become worn or when poor hydraulic conditions exist. These conditions will be indicated by the cylinder test. Also, debris in the chemicals being fed may obstruct or block the check valves, thus impeding their operation and decreasing the pump’s performance.

- Check dust filters periodically.
- Periodically clean and calibrate level measurement and indication instrumentation in liquid and dry storage tanks.
- Check the level and condition of the oil in the gear reducer.
- Check the condition of all painted surfaces.
- Clean dirt, dust, or oil from equipment surfaces.
- Check all electrical connections.
- Stop and start equipment, checking for voltage and amp draw and any movement restrictions because of failed bearings, improper lubrication, or other causes.
- Check the drive motor for any unusual heat, noise, or vibration.
- Check the packing for leakage and wear.

5.4.2 Sludge Feed Pump

5.4.2.1 Operation

The following operations directly affect sludge pump performance.

Positive-displacement pumps need a drive system that can operate the pump at the speed needed to perform adequately under all operating conditions. Sometimes, this involves manually and automatically timed starts and stops, as well as variable pump discharge rates. This variable-speed arrangement can be provided via mechanical vari-drives; variable pitch pulleys; direct-current, variable-speed drives; alternating-current, variable-frequency drives; eddy-current magnetic clutches; or hydraulic speed-adjustment systems. Each has various advantages and disadvantages with respect to cost, amount and ease of maintenance required, efficiency, turndown ratio, and accuracy. Because positive-displacement pumps are constant torque machines, operators should ensure that the output torque of variable-speed drive exceeds the pump's torque requirement at all operating points. Although variable-speed drives are often either a necessity or an enhancement to proper plant operation, the challenge is providing the continued maintenance and servicing required.

Operators should check the following items:

- Inlet and outlet flow rate
- Noise or vibration
- Bearing housing temperature
- Running amperage
- Pump speed
- Pressure

5.4.2.2 Maintenance

Following is the maintenance checklist for sludge pumps:

- Check the level and condition of the oil in the gear reducer.
- Check the shaft alignment.
- Check the condition of all painted surfaces.
- Visually inspect mounting fasteners for tightness.
- Clean dirt, dust, or oil from equipment surfaces.
- Check all electrical connections.
- Stop and start equipment, checking for voltage and amp draw and any movement restrictions because of failed bearings, improper lubrication, or other causes.
- Check the drive motor for any unusual heat, noise, or vibration.
- Check mechanical seals and packing for leakage or wear.

5.4.3 Mechanical Dewatering

5.4.3.1 Centrifugal Dewatering

Centrifugation is the process of separating solids from liquids by the process of sedimentation, enhanced by centrifugal force.

5.4.3.1.1 Operation

A centrifuge can thicken or dewater the sludge with only a minor change in the weir setting (also called pond setting). Likewise, it can dewater sludge to a moderate consistence at low polymer dose or produce very dry solids using higher polymer dosages.

a. Sludge Type and Quality

The operation of the wet end of the plant determines the quality of the sludge, which, in turn, greatly affects the dry end.

b. Polymer Activity and Mixing with the Sludge

If the polymer does not react well with the sludge, performance suffers. Also, adding the polymer closer to or further from the centrifuge will affect performance.

c. Polymer Type and Dosage

Some polymers are designed to obtain drier cakes than others.

Likewise, the dosage will increase and decrease with cake dryness. Some polymers become less effective at higher dosages. This will be apparent from a quick jar test or observing that adding more polymer results in either poorer operation or the same operation.

– Hydraulic Loading

Centrifuges are less limited by the volume of water that passes through the centrifuge than filtration devices. As a result, thinner feed sludges will have less effect on performance than in filtration devices.

– Solids Loading

The solids residence time is important. If there is more sludge to dewater, there will be less solids residence time and therefore wetter solids, all else being equal.

– Capture

The solids capture is generally fixed by the plant management, and is not an operating variable.

d. Torque Control

In recent years, nearly all centrifuges have a controller that allows the operator to choose a scroll drive load or torque set point, and the controller then adjusts the differential speed to maintain that set point. In this manner, the torque and therefore the cake dryness is fixed.

One way of looking at the centrifuge is that it is a very expensive viscometer. The conveyor is turning at a controlled speed immersed in the sludge. The effort or torque needed to turn the conveyor is measured by the scroll drive device.

As the cake becomes drier, its viscosity increases, which, in turn, increases the torque or load on the scroll drive. When operating in load control, the controller automatically adjusts the differential revolutions per minute to maintain a constant torque level, and the operator’s only task is to observe the centrate quality from time to time and adjust the polymer rate to maintain the desired centrate quality.

This is a really simple control; one of its virtues is that the major operating cost - cake -dryness is fixed, and any operator error shows up in the centrate, which is easy to see and is not so costly if it is off slightly.

Consult the manufacturer of the centrifuge for a recommendation on operating speed changes.

e. Process Control

The following shutdown procedures are suggested:

– Stop sludge and polymer feed to the centrifuge.

– Add flush with water (effluent water is acceptable) until the centrate is clear and the torque level begins to drop.

– Turn the centrifuge off.

– Continue flushing at 25% of normal feed flow until the centrifuge reaches 7 to 800 r/min.

– Turn off the lubrication system and cooling water when the unit is completely stopped.

5.4.3.1.2 Maintenance

During operation, the operator should check for the following:

- The oil level and the flow of oil to the bearings in circulating oil systems
- Flow of cooling water and oil temperature, to ensure it is operating in the proper range
- Machine vibration
- Ammeter reading on the bowl motor
- Bearing temperatures, by touching them
- System for leaks
- Centrate quality
- Scroll drive torque

Because the centrifuge will shut itself down in the event of a fault, the operator typically only looks at the mechanical parameters once per shift.

5.4.3.2 Belt Filter Press Dewatering Equipment

The operation of a Belt Filter Press (BFP) is based on the principles of filtration and comprises the following zones (Figure 5.5):

- Gravity drainage zone, where the feed is thickened
- Pressure zone
- Shear zone

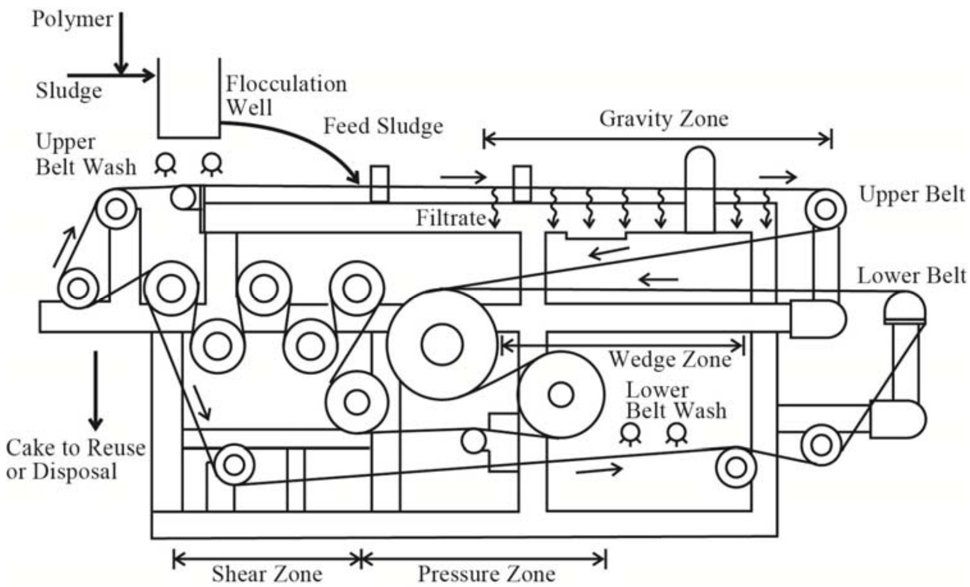


Figure 5.5 Belt filter press

5.4.3.2.1 Operation

a. Process Variables

There are several process variables that affect the performance of all dewatering systems. In general, dewatering devices must run at 95% capture or better, so capture really is not an operating variable. Of the remaining parameters - cake dryness, loading, and polymer dosage - within limits, the operator can take from one to give to another. For drier cake, one can reduce the loading and/or increase the polymer dosage.

– Cake Dryness

Increased cake dryness comes at the price of lower capacity and/or higher polymer dosage. The ability to obtain higher cake dryness is, to a great extent, a function of the design of the press. Presses with extended gravity zones to better pre-concentrate the feed and additional pressure rollers give longer sludge residence times and drier cake.

– Polymer Type and Dosage

Some polymers are designed to obtain drier cakes than others. Likewise, the dosage will increase and decrease with the cake dryness. Some polymers become less effective at higher dosages. This will be apparent from a quick jar test or observing that adding more polymer results in either poorer operation or same operation.

– Hydraulic Loading

Belt filter presses are limited by the volume of water that can go through the belts. As a result, thinner feed sludges will result in less quantity of dry solids produced, all else being equal.

– Solids Loading

Likewise, more solids will result in less solids residence time inside the press and therefore wetter sludge, all else being equal.

– Capture

The solids capture is typically fixed by the plant management and is not an operating variable.

– Belt composition and condition, speed, and tension

– Size and number of rollers

– Wash water flow, pressure, and suspended solids concentration

b. Sequence of Operation

The sequence of operation for a BFP typically is set up in the following order:

– Open wash water valve.

– Start wash water pump.

– Start pneumatic/hydraulic belt tension system.

– Start belt drive and dewatered cake conveyor.

– Start polymer solution feed pump.

– Start sludge feed pump.

Modern presses typically have a one-button start system, so the operator only has to manually start the feed and polymer pumps. In any event, one benefit of filling out the operating log is that the operating conditions the last operator used are known, as are the conditions of the previous week and month.

5.4.3.2.2 Maintenance

Rollers and bearings require frequent lubrication. Follow the manufacturer's operations and maintenance manual for lubrication schedule. This extends the life of the roller bearings and belt drive motor.

Replacement of filter belts is a common maintenance requirement.

The following procedures will extend the life of the BFP and reduce its operating cost:

- Wash down the BFP every day after finishing the dewatering shift. This prevents cake from drying and accumulating in different sections of the BFP.
- Confirm that all rollers are turning freely.
- Check the press weekly for damaged bearings.
- Check the grinder that prevents large particles from entering the press twice per year.
- Clean the wash water nozzles as frequently as necessary (this depends on the quality of the wash water). This ensures proper cleaning of the belts.
- Inspect and change sludge containment and washbox seals, as necessary.
- Inspect and clean doctor blades from any accumulated debris, hair, or any other foreign materials.
- Clean the chicanes (plows) in the gravity section after shutting down the press.
- For any other maintenance of complex mechanical parts of the BFP, contact the manufacturer for advice.

5.4.3.3 Filter Press

Filter presses for dewatering are generally either recessed plate filters or diaphragm filter presses. With the advent of better organic polymers, belt filters and centrifuges have largely displaced filter presses in the market. Filter presses can be attractive in unusual circumstances.

The fixed-volume recessed plate filter press consists of a series of plates, each with a recessed section that forms the volume into which the feed enters for dewatering. Filter media or cloth, placed against each plate wall, retains the cake solids while permitting passage of the filtrate. The plate surface under the filter media is specifically designed with grooves between raised bumps to facilitate passage of the filtrate while holding the filter cloth. Before pumping into the press, the feed must be chemically conditioned to flocculate the solids and release the water held within the solid mass. Most typical conditioning systems use inorganic chemicals and organic polymers.

High-pressure pumps force the feed into the space between the two plates. The filtrate passes through the cake and the filter media and out of the press through special ports drilled in the plate.

Pumping continues up to a given pressure and is stopped when solids and water fill the void volume between the filter cloths and filtrate flow slows to a minimal rate. The press then opens mechanically and the cake is removed, one chamber at a time.

5.4.3.3.1 Operation

a. Process Variables -Chemical Conditioning

Polymers have a narrow range of effective dosage. A dose that is too low or too high will result in a wet cake. Lime and ferric chloride have a broader range of effective dosage. While it is desirable for an operator to reduce the chemical usage to reduce costs, if erratic equipment operation or erratic feed qualities occur, a higher lime dose typically will protect against a wet cake. Polymer conditioning requires much less chemical per unit mass of solids dewatered, which results in more room in the press for organic sludges, and increased capacities.

- A torn cloth immediately results in a filtrate flow that is very dirty and heavy with solids.
- Feed sludge concentration. A very thin feed may blow out through the plate surfaces during the initial high-volume fill of the press because there would be too much filtrate flow for the drain capacity. A thin feed will at least require a longer filtration time and produce a wetter cake. A thick feed typically will produce a drier cake with a much shorter filtration time.

For a conventional filter press, the operator can control the following machine variables:

- Feed application rate by pacing the flow to the filter press.
- Overall filtration time, including such variables as the time at each pressure level in multiple pressure level operations.
- Use and amounts of pre-coat or body feed. Typically, pre-coat is unnecessary when inorganic chemicals, such as lime and ferric chloride, are applied. Pre-coat may be needed if particle sizes are extremely small, filterability varies considerably, or a substantial loss of fine solids to and through the filter media is anticipated.
- Conditioning chemicals, type, dosage, location, and mixing efficiency. Polymer addition versus lime and ferric chloride conditioning typically are not interchangeable, as each chemical requires special mixing and flocculation energies and reaction times. Polymers only need a quick mix before injection to the press. Modifications to the piping and mixing systems are typically needed if a change in the type of chemical for conditioning is desired.
- Flocculation efficiency and energy vary with the type of chemical being used. Polymer floc shears easily and remains stable for only a few minutes. Lime floc is more durable and remains stable for a few hours.
- Filter media. Filter cloth media vary widely, with different filament composition, weave pattern, and weave tightness.

b. Operational Considerations

- Many presses are very noisy when in operation. Hearing protection may be needed.
- Never insert objects between the press plates as they are being discharged without first shutting the unit down by tripping the light curtain or flipping the emergency shutdown switch.
- Lime treatment results in considerable ammonia fumes being released during cake discharge. Make sure that adequate ventilation pulls these fumes away from the operator, preferably with a high-capacity, down-draft blower system. If an adequate ventilation system is not operational, short term exposure may be allowed, if approved, and if an approved ammonia respirator is worn by all operators assisting with the cake discharge.
- Hydrochloric acid washing of the press releases volatile acid fumes, which should

not be inhaled or exposed to moist body tissues, such as eyes and lungs. A high-capacity ventilation system, as previously noted, is essential. If approved, short-term exposure may be allowed with an approved respirator and complete coverage of all exposed skin.

- Lime powder is very caustic when it comes into contact with moist body tissues. Therefore, an approved respirator and complete coverage of all exposed skin is necessary when working around lime.

5.4.3.3.2 Maintenance

Follow all equipment manufacturers' recommendations. Some typical areas that need special attention are as follows:

- The plate handles and the frame rails require frequent grease application to prevent binding and excessive wear.
- The plate shifter chain or other plate shifting devices require frequent lubrication.
- Even if a shredder is used before the conditioning step, rags will quickly accumulate on all mechanical mixer blades. These need to be removed frequently to prevent damaging the mixer gears and shaft bearings from operating out of balance.
- Lime systems scale up and plug over time and are unpleasant and potentially hazardous for operators to clean. When lime is used, cloth and plate washing may require both an acid and a water wash because lime causes scaling.
- Ferric chloride, hydrochloric acid, lime, and ammonia cause considerable corrosion to metal surfaces, such as the plate handles with their retaining bolts, the shifter chain, and even steel plates under a hard rubber cover. Frequent cleaning and lubrication are necessary to reduce corrosion. Powder-coated steel handles, polypropylene plates, and polytetrafluoroethylene-coated frame rails have been used by some facilities to reduce corrosion problems. Also, adding an inhibitor to hydrochloric acid will reduce its metal corrosion properties.
- From time to time, the cloths and gaskets should be removed, the plates should be pressure cleaned, and new cloths and gaskets cut and installed.

5.4.3.4 Screw Press

Screw presses dewater sludges first by gravity drainage at the inlet section of the screw and then by squeezing free water out of the sludges as they are conveyed to the discharge end of the screw under gradually increasing pressure and friction (Figure 5.6). The increased pressure to compress the sludges is generated by progressively reducing the available cross-sectional area for the sludges. The released water is allowed to escape through perforated screens surrounding the screw while the sludges are retained inside the press. The liquid forced out through the screens is collected and conveyed from the press, and the dewatered sludges are dropped through the screw's discharge outlet at the end of the press.

Screw speed and configuration, as well as screen size and orientation, can be tailored for each dewatering application.

Solids are combined with polymer and pumped into the flocculation vessel. After flocculation, sludges are transferred to the screw press. In the horizontal screw press configuration, sludges are fed by gravity from the flocculation tank into the screw press headbox. If a rotary screen thickener is used, sludges flow from the flocculation tank to the rotary screen thickener and then to the screw press headbox. Sludges then flow from the headbox into the inlet of the screw press.

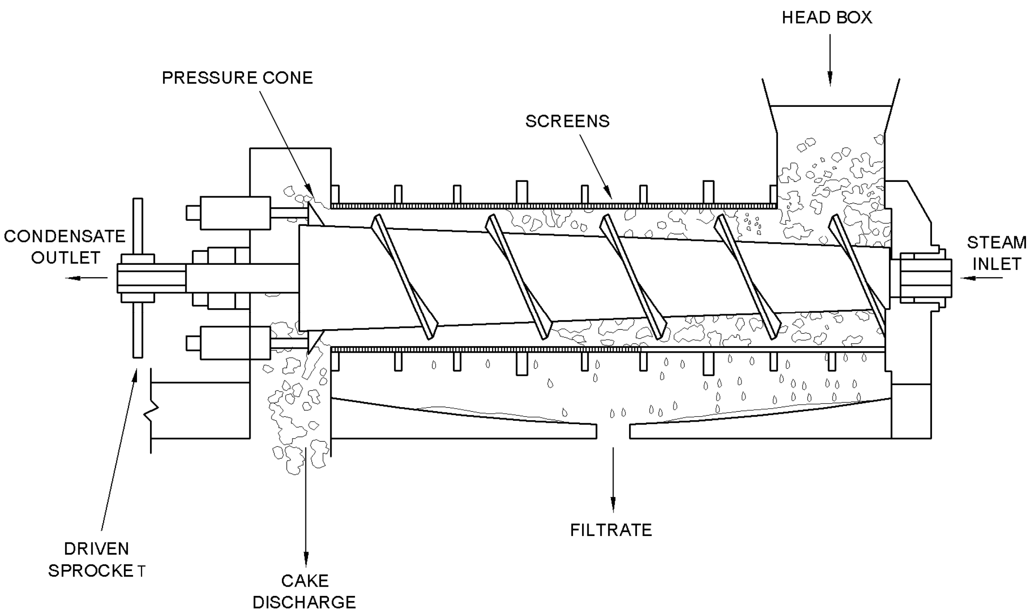


Figure 5.6 Screw press

5.4.3.4.1 Operation

Screw presses run continuously at low speeds and do not require close operator supervision; therefore, they are easy to maintain and have low power consumption. The manual cleaning schedule ranges from once per week to once every 30 days.

a. Chemical Conditioning

Polymer addition promotes particle flocculation and increases the dewatering and solids-capture rates. Jar testing and pilot testing can be used to estimate the type and quantity of polymer necessary for each application, because it may vary significantly depending on sludge characteristics. Polymer consumption is affected by multiple parameters (e.g., grit content of the sludge, the presence or absence of primary clarifiers, the type of biological treatment, and the type and duration of sludge digestion).

b. Cleaning System

Screw press systems have automatic cleaning systems which involve plant water and spray nozzles. During automated wash cycles, washwater from solenoid valves sprays onto the screw press screen to remove built-up sludge.

The brushes are made of nylon with stainless steel mounting hardware. This mainly cleans the screen to allow water to drain by gravity (especially in the lower part of the screen) and minimize resistance to water filtration. Clean screens require less dewatering pressure, which improves the solid capture rate.

The second cleaning process is an automatic spray wash system, which cleans the screen from the outside. It is comprised of a rotating spray-bar washing system and spray nozzles fed by solenoid valves.

c. Rotation Speed

Typical rotation speeds range from 0.1 to 2.0 rpm for horizontal screw presses and from 0.5 to 2.0 rpm for inclined screw presses. In general, an increase in screw rotation speed increases production capacity but decreases cake solids concentration. In a full-scale application, increasing rotational speed from 1 to 1.25 rpm reduced the cake concentration from 23 to 20%.

5.4.3.4.2 Maintenance

Maintenance checkpoints are as follows:

- Check the drive of the screw for abnormal sound and vibration during operation.
- Check the screen for any damage or clogging.
- Check the cleaning nozzle for clogging.
- Check the amount and the leakage of lubricating oil.
- Check the reading of the ammeter and indicator lamps.

5.4.3.5 Rotary Press

Rotary presses are a relatively new technology that can achieve cake solids and solid capture performance similar to belt presses and centrifuges. Rotary press and rotary fan press dewatering technology relies on gravity, friction, and pressure differential to dewater sludge.

The major elements of a rotary press are the polymer feed and mixing system, parallel filtering screens, a circular channel between the screens, the rotation shaft, and a pressure- controlled outlet (Figure 5.7).

The press screens of rotary fan consist of fabricated wedgewire with small openings and linear gaps. The rotary press drive configuration allows up to six rotary press channels to be operated on a single drive. Each channel has bearings, and the combined unit has an outboard bearing cantilevered on one end. The rotary fan press drive configuration uses a maximum of two rotary press channels on a single drive with isolated bearings in a sealed gearbox.

A key feature of both rotary press and rotary fan press dewatering technology is their slow rotational speed. Typical installations use speeds of 1 to 3 rpm. This provides low vibration, low shear, and low noise.

5.4.3.5.1 Operation

a. Operational Control

Operators can control the performance of the rotary press or rotary fan press by changing polymer type and dosage, feed rate, feed pressure, wheel speed, and outlet pressure.

Both types of rotary press require minimal supervision and can be unattended between startup and shutdown.

- Hydraulic Loading Rate

The hydraulic loading rate is a function of the equipment’s size and number of channels. The technology is modular, and the hydraulic loading rate of single-drive units ranges from 0.5 to 15 L/s, although a maximum hydraulic loading rate of 3 L/s per channel is typical. Rotary presses provide better performance on residuals with higher fiber content (e.g., primary sludges).

- Chemical Conditioning Requirements

Chemical conditioning is mandatory to attain design performance in rotary press or rotary fan press dewatering. Polymer feed systems can be supplied by the manufacturer or can be procured independently. In both cases, the feed systems typically include a polymer storage tank and metering pump, which feeds the polymer into the mixing or flocculation tank, where it is blended with the sludge. Dry or emulsion polymers can be used.

- Solids Loading Rate

Because solids capture is a function of the adjustable back pressure, the solids loading rate varies with the hydraulic loading rate. At higher solids concentrations, residuals will accumulate in the outlet zone, form cake, and extrude more quickly.

b. Cleaning System

Rotary presses and rotary fan presses include a self-cleaning system that must run for 5 minutes per day at the end of use to flush all lines and equipment. The system does not require high-pressure water for flushing. Typically, the normal in-plant water source has sufficient pressure, but in some cases, high-pressure booster pumps may be required.

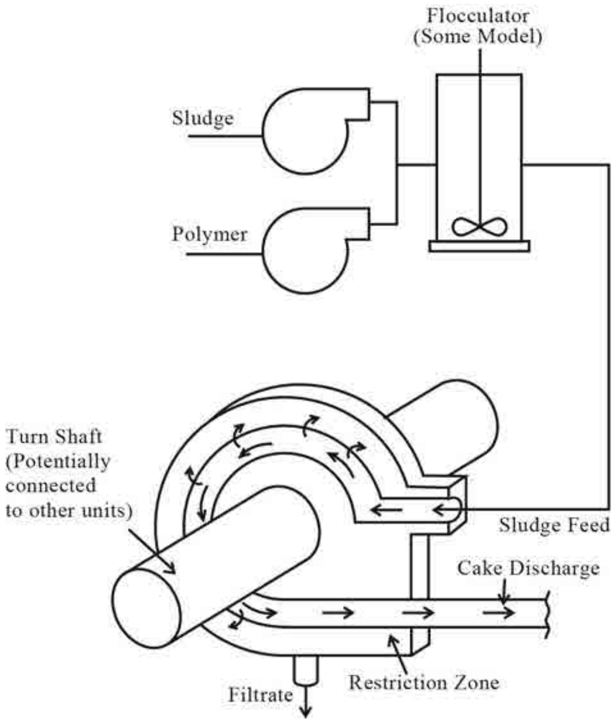


Figure 5.7 Schematic of a rotary press system

5.4.3.5.2 Maintenance

Maintenance checkpoints are as follows:

- Check the drive of the rotary for abnormal sound and vibration during operation.
- Check the rotary for any damage or clogging.
- Check the amount and the leakage of lubricating oil.
- Check the reading of the ammeter and indicator lamps.

5.4.3.6 Vacuum Filter

The vacuum filter consists of a cylindrical drum over which is laid a filtering medium of wool, cloth or felt, synthetic fibre or plastic or stainless steel mesh or coil springs.

The drum is suspended horizontally so that one quarter of its diameter is submerged in a tank containing sludge.

5.4.3.6.1 Operation

a. Process Variables

The principal variables that affect vacuum filter operation are as follows:

- Chemical conditioning

- Filter media type and condition
- Drum submergence
- Drum speed
- Vacuum level

Chemical conditioning most significantly influences dewaterability, because it changes the physical and chemical nature of the feed. Conditioning agents produce a feed that releases water more freely, thereby producing a drier cake. Conditioning agents also add to the sludges to be discarded.

b. Sludge Conditioning

Sludge conditioning is accomplished by the addition of various coagulants or flocculating agents such as ferric chloride, alum, lime, and polymers. The amount of chemical solution added to the conditioning tank is normally established by laboratory testing of sludge grab samples.

5.4.3.6.2 Maintenance

The installation of a blanket may require several days' work.

A blanket will usually last from 200 to 20,000 hours, but this depends greatly on the blanket material, conditioning chemical, backwash frequency, and acid bath frequency. An improper adjustment of the scraper blade, or accidental tear in the blanket, will usually require its replacement.

Both cloth blankets and coil springs filters require a high pressure wash after 12 to 24 hours of operation and, in some instances, an acid bath after 1,000 to 5,000 operating hours.

5.5 SLUDGE DRYING BED

These are the age old practices in India and are still preferred in arid parts where land is available and affords employment opportunities to unskilled labour. Other areas where rainfall is frequent are not suited for drying beds.

5.5.1 Applicability

This method can be used at all locations where adequate land is available and dried sludge can be used for soil conditioning. When digested sludge is deposited on well drained bed of sand and gravel, the dissolved gases tend to buoy up and float the solids leaving a clear liquid at the bottom which drains through the sand rapidly. The major portion of the liquid drains off in a few hours after which drying commences by evaporation. The sludge cake shrinks producing cracks which accelerates evaporation from the sludge surface. In areas having greater sunshine, lower rainfall and lesser relative humidity, the drying time may be about two weeks while in other areas, it could be four weeks or more. Covered beds are not generally necessary.

5.5.2 Unit Sizing

The sludge drying process is affected by weather, sludge characteristics, system design (including depth of bed) and length of time between scraping and lifting of sludge material. High temperature and high wind velocity improve drying while high relative humidity and precipitation retard drying.

5.5.3 Area of Beds

The area needed for dewatering and drying the sludge is dependent on the volume of the sludge, cycle time required to retain sludge for dewatering, drying and removal of sludge and making the sand bed ready for next cycle of application and depth of application of sludge on drying bed. The cycle time between two dryings of sludge on drying beds primarily depends on the characteristics of sludge including factors affecting its ability to allow drainage and evaporation of water, the climatic parameters that influence evaporation of water from sludges and the moisture content allowed in dried sludge. The cycle time may vary widely, lesser time required for aerobically stabilized sludges than for anaerobically digested sludge and for hot and dry weather conditions than for cold and/or wet weather conditions.

5.5.4 Percolation Type Bed Components

A sludge drying bed usually consists of a bottom layer of gravel of uniform size over which is laid a bed of clean sand. Open jointed tile under drains are laid in the gravel layer to provide positive drainage as the liquid passes through the sand and gravel.

5.5.5 Operation and Maintenance

Sludge that is drawn to the beds contains 4-10% solids depending upon the type of sludge. Wet sludge should be applied to the beds to a depth of 20 to 30 cm. After each layer of dried sludge has been removed, the bed should be raked and levelled. Sludge should never be discharged on a bed containing dried or partially dried sludge. It is preferable to apply the sludge at least a day or two after the sludge cakes are removed.

Removal of dried sludge from bed surfaces should be done with shovel, taking care that as little as possible of the sand is removed. When the sand layer is reduced to as low as 10 to 15 cm, it should be examined for clogging by organic matter and if found, the entire sand should be removed and the bed re-sanded to the original depth of 20 to 30 cm.

The dried sludge cakes may be sold as fertiliser. Some part of the sludge should be used in the plant itself for gardening, lawns, etc to demonstrate its fertiliser value and to develop a market value for the digested and dried sludge. Suitable storage facilities may be provided for the dried sludge.

Records of operation of sludge drying beds should show the time and quantity of sludge drawn to each bed, the depth of loading, the depth of sludge after drying time and the quantity of dried sludge removed. The solids content of wet digested sludge, its volatile portion and pH should be determined and recorded. Likewise, the moisture content and fertiliser value in terms of NPK of dried sludge should also be analysed and recorded. A typical operation sheet of sludge drying bed is as follows (Table 5.3).

Table 5.3 Typical operation sheet of sludge drying beds

Date and Time	Check List
	Cleaning of weeds
	Quantity of sludge to respective SDB
	Depth of the wet sludge
	Depth of dried sludge
	Quantity of sludge removed
	Cleaning and scrubbing of splash plate, pipes etc
	Volume of sand added
	Cleanup-washing scrubbing of filtrate sump

Source: JICA, 2011

5.6 PREVENTIVE MAINTENANCE

All preventive maintenance of equipment is to be done as per the equipment manufacturer only. Preventive maintenance of process control resides only in digestion process and has been discussed above.

5.7 TROUBLESHOOTING

Refer to Appendix 5.1.

5.8 RECORD KEEPING

There is no standard format for record keeping. Each STP has to have its own format. The crucial parameters to be recorded are the pH and temperature of the digesters on a daily basis. The gas analysis can be recorded once a week.

5.9 SUMMARY

Treatment of sludge, which is converted from removed organic matter in sewage, as well as quality and quantity of sewage inflow, and quality of treated water, are quite important in STPs.

Problems encountered in the course of operation are gathered in Appendices as troubleshooting. Operators can make use of the troubleshooting chart to take appropriate measures against each trouble.

CHAPTER 6 ELECTRICAL AND INSTRUMENTATION FACILITIES

6.1 INTRODUCTION

Electrical systems which are to supply electrical power for an entire STP consist of power receiving and transforming equipment, power distributing equipment, cables, drives and standby generators.

Instrumentation facilities are also installed for the purpose of measuring and collecting process data such as flow rate, pressure, water qualities, and so on, at all times. These are utilized to monitor and control treatment processes at optimal conditions for a stable treatment. The instrumentation facilities consist of sensors for processes, signal converters, operating devices (actuators), controllers (PLC: Programmable Logic Controller), monitoring devices (PC: personal computer), etc.

This chapter describes the following electrical and instrumentation facilities:

a. Power receiving and transforming equipment (Substation & transformers),

b. Standby power supply system (Generators, Engines, UPS: Uninterruptible Power Supply),

c. Prime movers and motor controllers (Motors, Starters, Cabling),

d. Instrumentation system, and

e. Supervisory control and data acquisition system (SCADA).

A typical single line diagram depicts the entire electrical power flow system of an STP. The single line diagram not only presents the type and number of equipment but also the electrical specifications. This is an important document for an O&M person who would like to refer it in case of any operational or maintenance need. Every STP should have:

- A single line diagram kept for record and displayed properly in the STP facility particularly near the electrical sub-station.
- Single line diagram periodically reviewed and updated suitably in case of any change.
- All people involved in the electrical and instrumentation work understand the single line diagram.

Typical electrical single line diagram is shown in Figure 6.1.

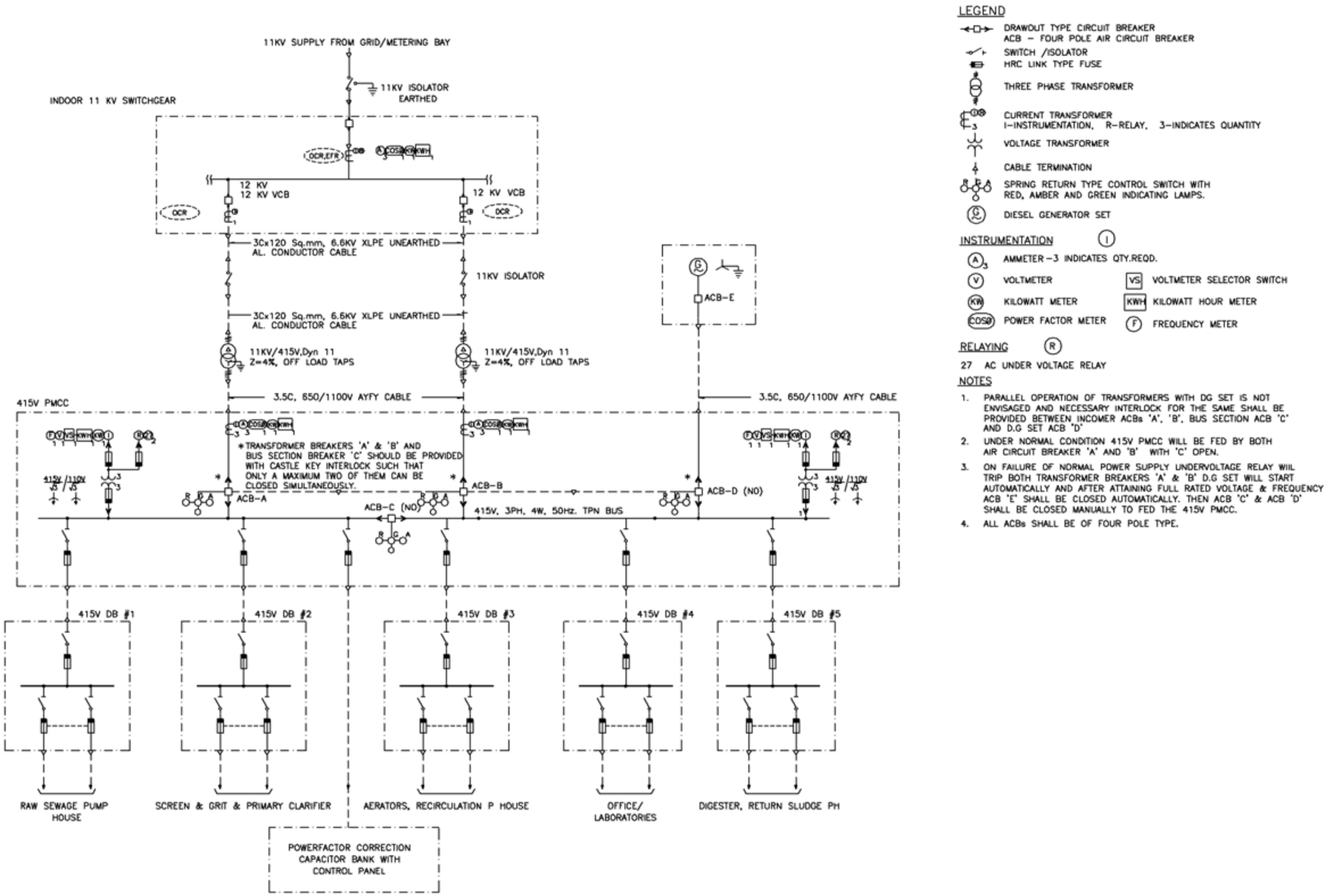


Figure 6.1 Electrical single line diagram

6.2 POWER SUPPLY SYSTEM

Power supply systems have the following three major functions:

- Transfer power from the transmission system to the distribution system;
- Reduce the voltage to the specified level (Typical voltage level is 415 volt for STPs) suitable for connection to local loads; and
- Protect the entire network by identifying and isolating electrical faults selectively.

6.2.1 Power Receiving and Transforming Equipment

If the STP facility receives the electrical supply at high voltage i.e. 11kV, 6.6 kV or 3.3 kV, it has to be reduced to the low voltage level. A substation which is used to step-down high voltage to low voltage, consists of the following equipment or devices:

6.2.1.1 High Tension (HT) Panel

The HT panel is composed of the following equipment and devices.

6.2.1.1.1 Disconnecting Switch

Disconnecting switches are devices to open/close a high voltage circuit when high-voltage equipment are inspected, measured, tested, or cleaned.

The devices are capable of safely breaking no load current but not load current.

For safe O&M work, be sure to open/close the disconnecting switch only after opening a circuit breaker which is located on the secondary side, just downstream of the disconnecting switch.

6.2.1.1.2 Circuit Breaker

Circuit breakers are switches that open/close electric circuits in normal and abnormal conditions (especially in short circuit). Therefore, the circuit breakers must be capable of tripping the circuits in conjunction with protective relays and by cutting off the short-circuit current definitely and safely, avoiding accidents due to high current.

Circuit breakers for high voltage are categorised into the following types according to their techniques of eliminating arcs:

a. Air Break Circuit Breakers (ACB)

b. Vacuum Circuit Breaker (VCB)

c. Inert Gas Method (SF6)

6.2.1.1.3 Power Fuses

The function of a power fuse is to sense and prevent flow of excess current in electrical devices and electrical wire from by melting the fuse element and thereby breaking the electric circuit when subjected to a short-circuit. Power fuses are typically used for smaller electrical systems because they have the capability and speed for breaking circuit as compared with circuit breakers.

A proper O&M, practice is that even if only one fuse melts due to an accident such as a short-circuit in a three phase switch, all power fuses including the melted one should be replaced.

6.2.1.1.4 Voltage Transformer (VT) or Potential Transformer (PT)

Voltage transformers are used mainly in high-voltage distribution equipment to step down voltage in measurement circuit for safe measurement. Single-phase and three-phase types are manufactured. The typical secondary voltage of the voltage transformer is 110 volt

(Phase-to-Phase). They are also applied to protective relays.

O&M issues to be observed in case of a PT are as follows:

- If once short circuit occurs on the secondary side of a VT, over current flows into the primary side and that may cause the fuse on the primary side to blow. The primary fuse has also to be checked when there is a fault trip or metering mismatch.

6.2.1.1.5 Current Transformer (CT)

Current transformers are used for stepping down current to be measured safely. It is also applied to protective relays. The typical secondary current of the current transformer is 5 Amp or 1 Amp.

O&M issues to be checked are as follows:

- If the secondary side of CT is open-circuited, all the current flowing to primary side is excited by magnetic saturation and causes damages to the CT by over-heating. Therefore the secondary side should never be left open-circuited. Even when the downstream instrument is removed for any repair, the secondary should be shorted.

6.2.1.1.6 Protective Relay

Protective relays should detect electrical faults promptly, isolate the faults from system, and activate alarms when there is a faulty condition sensed in the electrical supply to the circuits or electrical equipment (short circuit, earth fault, single-phase, reverse power flow etc.)

The protective relays should have the following three characteristics:

a. Certainty: The relay should always be sensing the parameters for action when there is a fault or specified abnormality.

b. Selectivity: The relay should be able to obey a selection of the limits beyond which a fault will be judged.

c. Promptness. The relay should sense and operate within the shortest possible time.

Categories according to protective functions are as follows:

a. Over current relay (OCR): Monitor and protect against over load and short-circuit;

b. Under voltage relay (UVR) and over voltage relay (OVR): Detect and protect under voltage (power failure) or over voltage; and

c. Earth fault relay: Protect by detecting current leakage to earth.

Protective relay is shown in Figure 6.2.

Figure 6.2 Protective relay

6.2.1.2 Transformer

A transformer is the most important component in substations. Transformers receive electrical power at high voltage and transform it to lower service voltage. They also provide isolation between high voltage and low voltage supply.

Cooling system for oil-immersed transformer: Oil serves as direct cooling medium to disperse the heat that is generated from windings and core. The oil is in turn cooled by indirect cooling medium such as air at the oil radiator.

Cooling system for dry transformer: Utilize surrounding air or SF6 as cooling medium.

Transformer Efficiency: The efficiency of a transformer varies between 96% and 99%. The efficiency of transformer not only depends on design, but also on operating load. The transformer losses are mainly attributed to:

- Constant Loss: This is also called iron loss or core loss, which mainly depends upon the material of the core and magnetic circuit of the flux path. Hysteresis and eddy current loss are two components of constant loss.
- Variable Loss: This is also called load loss or copper loss, which varies with the square of the load current.

The best efficiency of a transformer occurs at a load when constant loss and variable loss are equal. For distribution transformers, installed in an STP, the best efficiency would occur around 50% load.

O&M checks to be made are as follows:

- Check connections of cables for looseness and overheating.
- Check the transformer for abnormal vibration and noise.
- Check oil and winding temperature regularly with respect to manufacturer's manual.
- Check for moisture ingress by observing the colour of the silica gel.
- Check for level of oil in the conservator.

Transformer is shown Figure 6.3.

Figure 6.3 Transformer

6.2.1.3 Low Tension (LT) Panel

LT panels or LT switchboards are designed to distribute stepped-down voltage to power equipment and control panels. They typically consist of moulded case circuit breakers (MCCBs), power contactors (PCs), protective relays (PRs), meters, indication lamps, control switches, etc.

a. Moulded Case Circuit Breaker (MCCB)

An MCCB is designed to “open/close” low voltage feeder circuit or branch circuit at normal condition. It also breaks the circuit automatically in case of abnormal condition such as overload, short circuit, etc.

b. Power Contactor

A power contactor is typically used for “on / off” control of motors. A relay can be installed on the circuit for overload protection. Electromagnetic force works to “open /close” the contacts.

O&M checks to be made:

- Check for abnormal noise or overheating of exciting coils, abnormal noise and discolouration of contacts (carbonized or worn contact surfaces by arcing).
- Check for the proper working of all display indicators like voltmeters, ammeters, energy meters, indicator lamps.
- Check whether the name of the panel is written on it and it is correct as per the single line diagram.
- Check for the proper earthing of the panels.

6.2.1.4 Bus-bar

Bus-bars are conductors to carry power among the various components in the power circuit in an outdoor station or distribution board. They are to be rated to carry the maximum rated current continuously and also short-circuit current for a short time without damage.

O&M issues to be cared for:

- Check connections for looseness and overheating, and check the bus bar for discolouration.
- Check that the bus bars are properly colour coded (Red, Yellow or Blue) to represent the phases.
- Check that the bus bars are properly enclosed within panels.

6.2.2 Power Control

Correcting power factor is a typical power control technique. Power factor correction is described in this section.

6.2.2.1 Power Factor Correction

Active power, measured in kilowatt (kW), is the real power (shaft power, true power) used by a load to perform a certain task. However, there are certain loads like motors, which require another form of power called reactive power (kvar) to establish the magnetic field. Although reactive power is virtual, it actually determines the load (demand) on an electrical system. Electrical capacity required for some electrical equipment is referred to as “apparent power (kVA),” that is, the vector sum of “active power” and “reactive power (lagging/leading).”

Most of the power machineries in STPs are driven by three-phase induction motors, which are inductive loads. When an inductive load is driven, the sine wave of the load current flows at the same frequency as the sine wave of the voltage, but lags the voltage wave cycle slightly. When both current and voltage source waves cross zero and maximum value at the same time, the power factor is said to be unity, and the entire power can be utilised as real power. The ‘Apparent Power-kVA’ is equal to ‘the real Power-kW.’ When the current wave is slightly lagging the voltage wave the power factor is said to be lagging and is less than unity. The real power is less than the apparent power due to this lag. A lagging power factor is not beneficial to a power consumer as the billing is made based on the kVA used, while the actual utilisation is less. It is also not beneficial for the power supplier whose system power factor is also affected. Equipment used in most industries such as drives, controllers, etc., are inductive loads which lower the power factor.

The power factor is the ratio between active power (kW) and total power (kVA), or the cosine of the angle between active and total power (Figure 6.4). A high reactive power will increase this angle and as a result the power factor will be lower.

$$\text{Power Factor} = \frac{\text{Active power}}{\text{Total power}} = \frac{\text{kW}}{\text{kVA}} = \cos\varphi \tag{6.1}$$

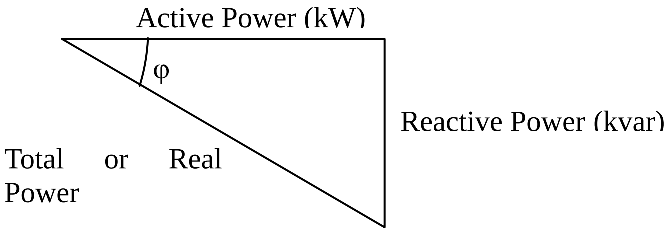


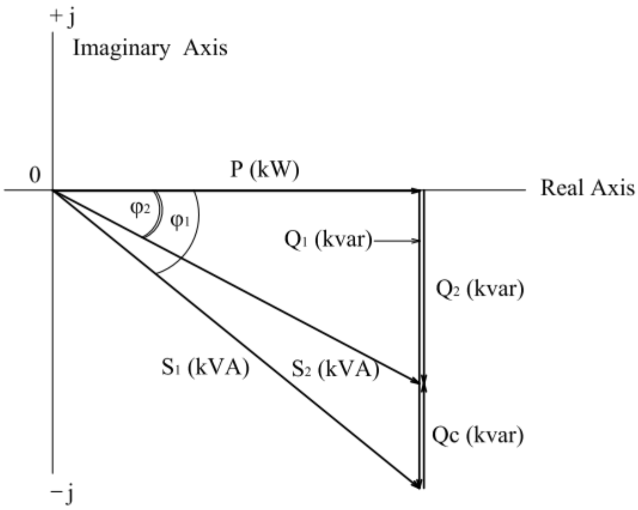
Figure 6.4 Vector diagram of power factor

In a typical STP since a large number of Induction Motors are used, the Power factor will be low and needs to be improved or corrected. The power factor can be improved by installing power factor correction capacitors to the plant's power distribution system. They act as reactive power generators and therefore reduce the amount of reactive power, and thus the total power, generated by the utilities. To improve or correct the power factor, apparent electrical capacity required for the electrical equipment should be decreased by cancelling the lagging reactive power by the use of leading reactive power unit. That can also reduce energy loss in cables, transformers, etc., before reaching to load equipment.

Rating of capacitor to be required for power factor correction (Figure 6.5) can be calculated by the following vector equation.

$$Qc = P \times (\tan\varphi_2 - \tan\varphi_1) = P \times \left\{ \frac{\sqrt{1-\cos^2\varphi_1}}{\cos\varphi_1} - \frac{\sqrt{1-\cos^2\varphi_2}}{\cos\varphi_2} \right\} (\text{kVA}) \tag{6.2}$$

Where, Qc: Capacitor rating in kvar



Where, S_1 :Apparent power (kVA) = P – jQ_1 (Before correction)

S_2 :Apparent power (kVA) = P – jQ_2 (After correction)

P :Active power (kW)

Q_1 :Lagging reactive power (kvar) (Before correction)

Q_2 :Lagging reactive power (kvar) (After correction)

Q_c :Capacity of condenser (Advancing reactive power) (kVA)

$\cos\varphi_1$:Power factor before correction

$\cos\varphi_2$:Power factor after correction

Figure 6.5 Vector diagram of power factor control

6.2.2.2 Capacitor Panel

Capacitor panels consist of some equipment such as condensers for power factor correction, series reactors meters, relays, etc.

6.2.2.2.1 Condenser (Capacitor)

Induction motors which are inductive loads generate lagged-phase reactive power. Phase-advanced condensers (capacitor) have the function of compensating the lagged-phase reactive power to improve power factor.

The effects gained from the condensers vary according to the points to be installed. For example, it is effective to install a condenser on the secondary side of a transformer if reduction in load and loss of the transformer is targeted.

With regard to operation and maintenance, the capacitor’s reactive power acts during light load (when power equipment has stopped), and when the current leads the voltage in the circuit so that leading power factor occurs, and the terminal voltage of the load increases causing adverse effects on the equipment. To prevent this phenomenon, the capacitor may need to be isolated, or an automatic power factor regulator may need to be installed.

Normally a capacitor unit comprises of individual capacitor elements arranged in parallel/ series connected groups within a steel enclosure. An internal discharge device is a resistor that reduces the unit residual voltage to 50V or less in 5 minutes. Capacitor units are available in a variety of voltage ratings from 240 V to 66,000 volts and sizes (2.5 kvar to about 1,000 kvar).

The capacitors can be with external fuses or internal fuses, or both. An internal fuse is a small fuse wire connected to each capacitor element, encapsulated in a wrapper. When a fault occurs in a particular element, the particular fuse melts, disconnecting the affected element only, and permitting the other elements to function without interruption. An external fuse unit typically protects each capacitor unit in a bank. In an oil-impregnated capacitor, the internal pressure may increase resulting in expansion due to excessive current because of the failure of internal elements. This leads to leakage of oil from the capacitor unit and failure of the capacitor. Care should be taken to select capacitors with sufficient cooling volume.

When a capacitor circuit is switched on, there is an inrush current which is likely to damage the capacitor. A choke or series reactor is used to control the inrush current.

6.2.2.2.2 Series Reactor

The major functions of a series reactor are to protect capacitor by means of the following:

- Limiting inrush current during switching
- Limiting resonance and protection of capacitor banks
- Harmonic filtration
- Lower loss and noise level

6.2.2.3 Power Factor Correction at Motor Panel

Power factor can be increased by installing low voltage capacitor in parallel with the motor. This enables the current to be reduced. Moreover, distortion waveform can also be stabilized by connecting a series reactor.

6.2.3 Supply and Interruption (Operation of Electrical Equipment)

Power interruption is classified into two types: a scheduled power interruption and an unscheduled power interruption.

The former requires specific operational procedure before interrupting the power supply, which is to “open” the switches from the load side (power distribution panel) to the power source (power receiving panel) sequentially. To restart power supply, “close” the switches from the power source (power receiving panel) to the load side (power distribution panel) one by one.

Make sure that the personnel in charge of the interruption/ restart operation know thoroughly the configuration of the machinery, the operational characteristics, the operational procedures, the place or position of switches installed, the electrical scheme diagram, and the load circuit diagram to avoid incorrect procedures.

During the work of starting, operating and stopping the load equipment, pay attention to meter readings, vibration, heat, and sound of equipment. If some abnormal state is found, report to the related person in charge immediately, investigate the causes and take appropriate measures.

In the latter case, investigate the cause of the power failure first of all. Power failures can be caused by the following: some failure attributed to the power company (outside power suppliers) and some local fault in the STP. To identify the causes, read indicated values or signs on the incoming supply voltmeter, under-voltage relay, earth fault relay, over current relay, etc.

Judgement by incoming supply voltmeter or under-voltage meter

- If the receiving voltmeter indicates “0” and the under voltage relay is “tripped,” it implies that power is interrupted on the power source side (attributed to power company). After confirming that the receiving circuit breaker is “opened,” the contact person or authority prescribed by the power company should be asked about the causes and the estimated recovery time. However, the related substation should try to restore power at the earliest.

– If the reading of the receiving voltmeter is within a specified range, the under voltage relay is "untripped" and the earth fault relay or the over current relay is "tripped," that implies some failure (overload, short, earth fault, etc, in equipment or lines) has occurred in the STP and the circuit breaker for receiving power is "opened." By studying the protective relay, circuit breakers, etc., which were tripped or opened, identify the line with fault and isolate the broken down point immediately before recovering from the failure.

6.2.4 Gas Engines

Generally, digester gas is used as fuel in boilers for heating sludge digestion tanks; surplus gas is incinerated in biogas combustion units and discharged to the atmosphere. (Figure 6.6)

A sewage gas generator uses the sewage gas as fuel to a gas engine and generates electricity, which is supplied to equipment within a STP.

The digester gas engine consumes gas as fuel and employs spark-ignition method, which is the same as one used in car engines.

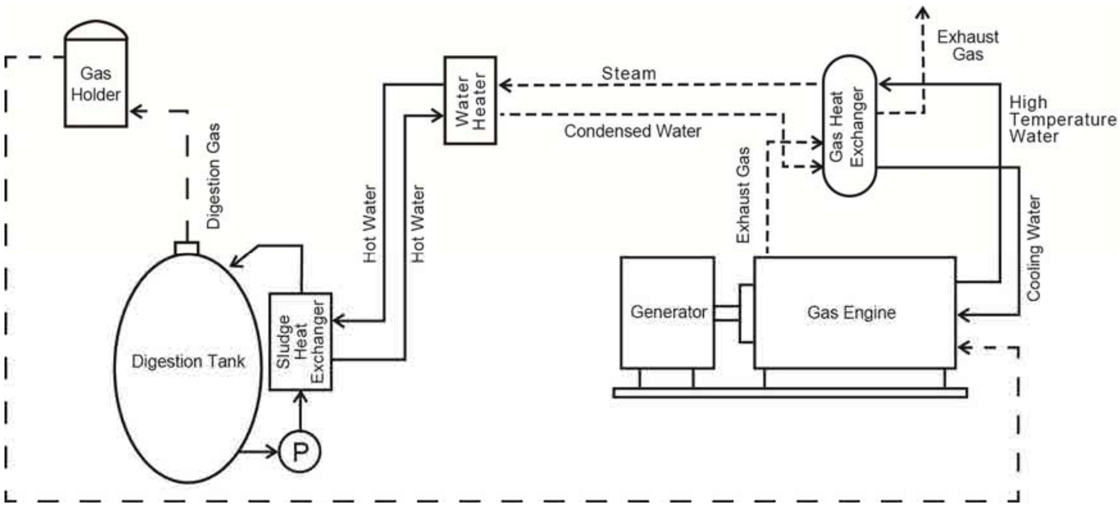


Figure 6.6 Example of flow of power generated from digester gas

O&M issues to be noted for are as follows:

- Typical concentration of NOx in exhausted gas from digestion gas engines is about 2,000 ppm. NOx should be reduced to prevent air pollution.
- Replace the ignition plugs in the spark-ignition system periodically.
- Periodic opening up, cleaning and inspection of a digestion gas engine is extremely important because siloxane compound gets deposited in the combustion chamber of such an engine, which causes faults in engine parts.

6.2.5 Dual Fuel Engine

Dual-fuel (gas-diesel) engines are compression-ignition, not spark-ignition engines. To ignite, they simultaneously burn gas and a small amount of diesel fuel as pilot fuel. Their controls also allow automatic switchover to 100% diesel fuel operation without changing load if the digestion gas supply is inadequate or is interrupted. This capability is a beneficial feature for standby units because they can start and operate even during power failures.

Dual-fuel engines typically use 1 to 5% diesel fuel oil, but many can, if necessary, operate on 1 to 100% diesel fuel. Such fuel flexibility is an excellent advantage, especially if the digestion gas supply is disrupted. This option includes storage and handling equipment for diesel fuel, along with gas compressors to supply digester gas to these engines.

The same O&M checks should be made for the diesel engine and the gas engine. Please refer to 6.3.2 and 6.2.4.

6.3 STANDBY POWER SUPPLY SYSTEM (GENERATOR)

Standby or emergency power can be supplied through AC(alternating current) generator and diesel engine.

Most generators of STPs are installed for the purpose of standby power supply. Therefore, they should be highly reliable because the STPs have to keep functioning without hindrance even in the event of unexpected power cut from the power company.

6.3.1 AC Generator

A generator is machinery that converts mechanical energy to electrical energy by electromagnetic action to generate electrical power.

Synchronous generator, the principle of which is reverse as that of an electric motor, is an AC generator which generates electric power synchronizing to rotating rate of magnetic field passing through armature windings.

Frequency of the synchronous generator is determined according to the rate of rotation, and accordingly, the frequency decreases as the rate of rotation becomes lower than the synchronous rate. Therefore, the rate of the engine for the synchronous generator should be regulated to maintain the level of synchronous rate.

O&M issues to be taken care of are as follows:

- Winding
  - Oil or dust on windings or air vent sleeves obstructs air ventilation and leads to overheating of the generator and deterioration of insulators which may cause short circuit and ground fault. The dust should be blown off by a compressed air and the oil and grease should be removed with cloth, cleansing oil, etc.
  - In the case of severe accumulation of oil and dust, it is recommended to have the winding cleaned and varnished with insulation paint after drying thoroughly, by a professional cleaning company.
  - Inspect insulation coating over terminals should be checked for overheat or discolouration due to cracks or slacks.
- Bearing
  - Pay full attention to any abnormal noise from bearings during running to detect any defect at early stage. It is the simplest way to check bearing conditions.
  - Grease should be supplied periodically while the generator is running through the openings for grease. If a drain valve is provided to the grease chamber, always open the valve during filling grease to purge out old grease.
- Brush (Static excitation system)
  - Worn brush reduces brush pressure and causes sparks that may make the surface of a slip ring rough. To prevent it, always check for abrasion, unsymmetrical wear or damage to brush, and pressure of the brush holder. The brush lifting device should be inspected to ensure that it works properly.
  - Brushes should be replaced with new ones when the wear level reaches the designated value. The newly installed brushes should preferably be of the same

material and shape as the currently used ones.

- Exciter (brushless)
  - Exciters hate moisture and dust. Dust should be blown off by low pressure compressor and wiped with dry cloth.
  - Check bolts and nuts on terminal area and terminal block for looseness, wires for discolouration, and conditions of earthing and installation.

6.3.2 Diesel Engine

Diesel engines are generally used as drives for back-up power generators.

The diesel engine works by the action of high-speed diesel combustion which pushes out pistons by the expansion based on self-ignition. The compressed air is hot enough to self ignite when diesel fuel is injected. Piston action caused by the energy is converted in the crank shaft to rotating energy, which drives the generator. High speed diesel is typically used as fuel.

O&M issues to be handled as follows:

- For details of maintenance and inspections, follow the manufacturer’s manual.
- Regularly check the fault alarm to ensure it works properly.
- During inspection and maintenance, take care not to allow dust contamination especially into fuel or lubrication system.
- Check wiring for loose connection and check piping for leakage.
- Do not place anything around an inlet port that obstructs suction.
- Pay attention to abnormal noise and overheat.
- Where it is necessary to store diesel for such engines, mandatory precautions regarding storage area fire protection, clearances, etc., should be followed. Appropriate clearance from the jurisdictional authorities on pollution control and inflammable fuel storage should be obtained.

6.3.3 UPS

UPS stands for Uninterruptible Power Supply and is a power supply device which works when the usual power source is interrupted. Typical UPS circuit is shown in Figure 6.7.

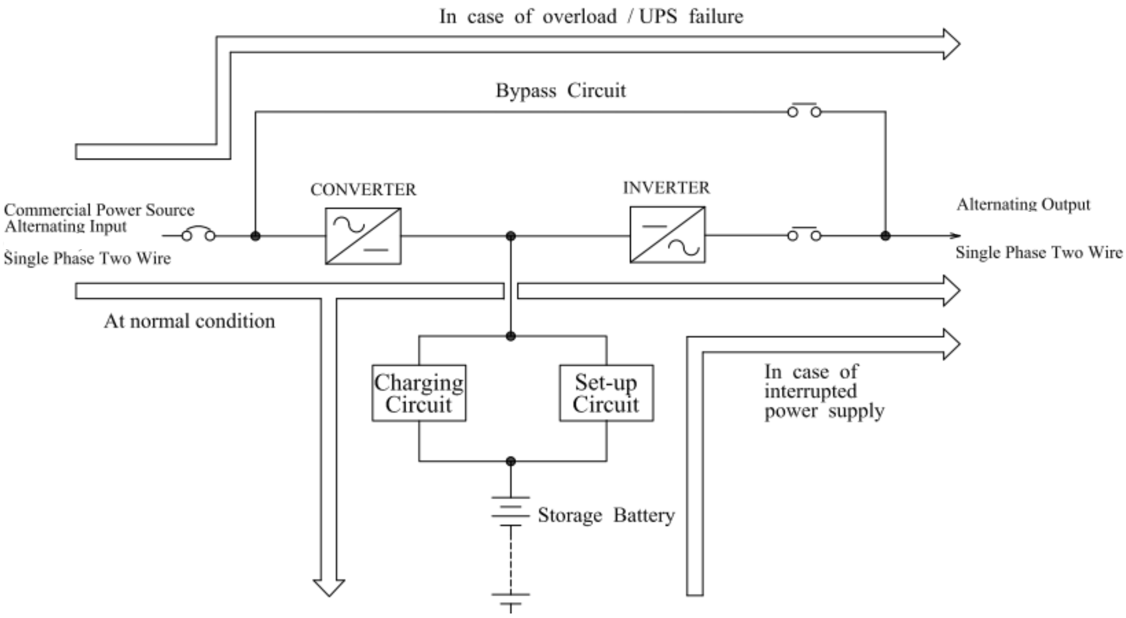


Figure 6.7 UPS circuit

In the normal condition, commercial AC (alternating current) power is sourced and converted to DC (direct current), which is then supplied to an inverter, and charges a battery.

When the commercial power source is interrupted, power charged in the battery is converted to AC and supplied to the load.

The UPS has a rectifier to convert AC supply to DC for charging the battery, a DC to AC inverter to convert the battery output to AC voltage, and a battery to act as a source of power during normal power interruption. Other components like protection, fuses, indication, surge controlling circuit etc., are also built into the unit.

The following points should be checked as maintenance tasks:

- Check for abnormal noise, smell, and heat in UPS.
- Check for looseness in each connection.
- Check appropriate time for battery replacement.
- Check for clogged ventilation opening.
- Ensure spare fuses are kept in stock.

6.4 PRIME MOVERS

6.4.1 Inductimon Motor

Three-phase induction motor is widely used as a general-purpose motor due to high reliability and low price among driving forces for general industrial machinery. Most prime movers used for pumps or blowers in STPs are three-phase induction motors.

A three-phase induction motor rotates the rotor by a rotating electromagnetic field, which is generated in the stator core by AC current flowing in the stator winding.

Rotating speed of the revolving magnetic field is referred to as “synchronous speed” and expressed as Ns (rpm). The speed of the rotor itself is slightly lower which is expressed as N (rpm). The ratio of Ns to the differential speed (Ns/N) is referred to “slip.”

$$N_s = 120f / p\,(\text{rpm})$$
$$N = (1 - s)N\,(\text{rpm}) \qquad (6.3)$$
$$s = (N_s - N) / N_s$$

Where, f : Frequency (Hz)

p : Number of magnetic poles

s : Slip

6.4.2 Starters

An extremely large current of about five to eight times the rated current flows when a motor is started. The power factor is at an extremely low value of about 0.2 at the start. The duration of the starting current is short, but the motor winding coil is subjected to thermal stress load as Joule heat. Voltage fluctuation occurs in the power system and its effect becomes more pronounced.

The starting method of three-phase induction motor includes a method of restricting current at start as mentioned above, and other methods described below.

a. Direct-on-line Starter

Power supply voltage is applied as-is, and a starting current which is several times the rated current flows. This starter is used in motors requiring comparatively small starting currents.

b. Star Delta Starter

$1/\sqrt{3}$ of power supply voltage is applied on the Y (star) connection winding at start, while Δ (delta) connection is used during operation. Compared to the full voltage starter, the starting current is one third and the starting torque is also one third.

c. Reactor Starter

The voltage to be applied to the motor at start is reduced by the reactor and full voltage is applied after the motor picks up speed, and is operated. The starting current can be restricted to a smaller value compared to the Y-Δ starting method.

Another starting method is to use a starting compensator.

Figure 6.8 shows the circuit diagram of some of the starting methods.

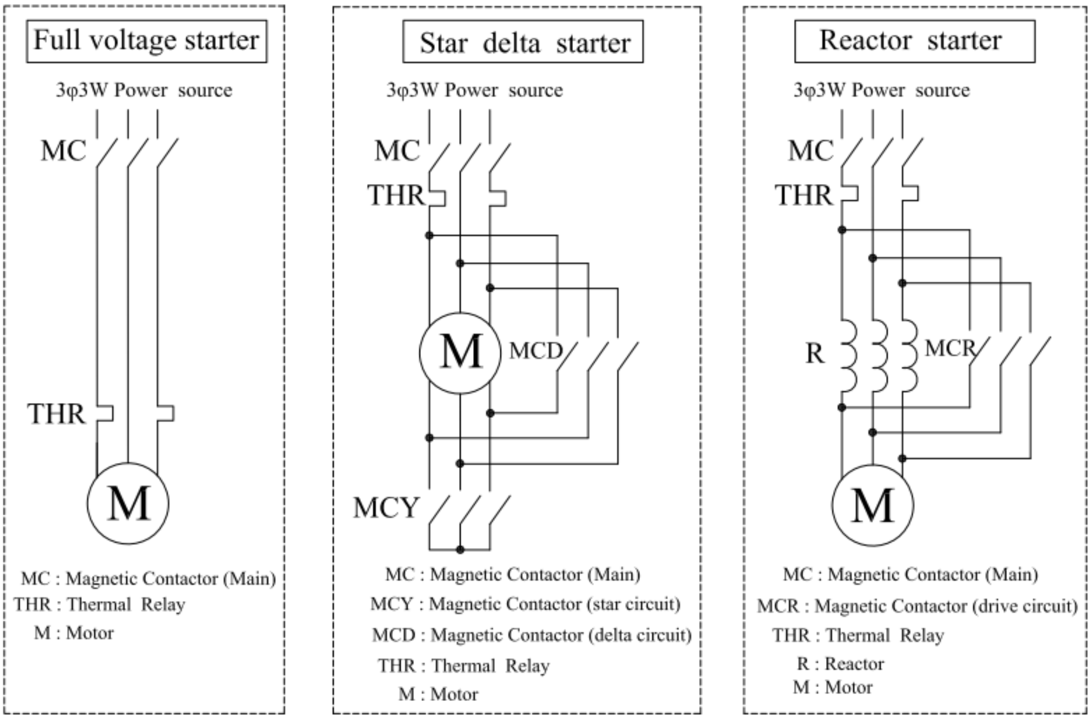


Figure 6.8 Starters

6.4.3 Characteristics of Induction Motor

Theoretical analysis should be carried out to study torque characteristics and overheating of three-phase induction motor due to fluctuation in frequency and variation in voltage of the motor.

Equation for induced electromotive force:

$$E = K \times n \times \varphi_m \times f \tag{6.4}$$

Where, E : Induced electromotive force (V)

n : Number of active coils

φ_m : Maximum magnetic flux (wb)

f : Frequency (Hz)

K : Factor of proportionality $(\sqrt{2} \times \pi \times 4.44)$

Torque equation:

$$T = K' \times V^2 / f \tag{6.5}$$

Where, T : Torque (N·m)

V : Voltage of power source (V)

f : Frequency (Hz)

K` : Factor of proportionality

a. When power supply voltage is greater than the rated voltage

According to the equation for induced electromotive force, the frequency is constant, therefore the maximum magnetic flux Φm increases, and the over-excitation phenomenon occurs. Heat is generated because of this excitation current. In a submersible pump, when a thermal protector is built-in in the internal coil for protection, it may activate.

b. When power supply voltage is smaller than the rated voltage

According to the torque equation, when the frequency is constant, the power supply voltage V reduces, so the torque reduces.

c. When the power supply voltage is unbalanced

When the power supply voltage is unbalanced, reverse phase current flows, and the temperature increases because of load loss in the coil resistance.

d. When the frequency f is higher than the rated frequency

According to the torque equation, when the power supply voltage is constant, the torque reduces.

e. When the frequency f is lower than the rated frequency

When the power supply voltage is constant, the maximum magnetic flux φ_m increases, and heat is generated because of the excitation current. According to the torque equation, when the power supply voltage is constant, the torque increases.

6.4.4 Performance Assessment of Motors

6.4.4.1 Efficiency of Motors

The efficiency of a motor is determined by intrinsic losses that can be reduced only by changes in motor design and operating condition. Losses can vary from approximately two percent to 20 percent. Table 6.1 shows the types of losses and their typical shares for an induction motor.

Table 6.1 Type of losses and shares for induction motors

Type of loss	Percentage of total loss (100%)
Fixed loss or core loss	25
Variable loss: stator I^2R loss	34
Variable loss: rotor I^2R loss	21
Friction & rewinding loss	15
Stray load loss	5

The efficiency of a motor can be defined as “the ratio of a motor’s useful power output to its total power output.” Factors that influence motor efficiency include:

- Age - New motors are more efficient
- Capacity - As with most equipment, motor efficiency increases with the rated capacity
- Speed - Higher speed motors are usually more efficient
- Type - For example, squirrel cage motors are normally more efficient than slip-ring motors
- Temperature - Totally-enclosed fan-cooled (TEFC) motors are more efficient than screen protected drip-proof (SPDP) motors
- Rewinding of motors can result in reduced efficiency
- Load, as described below

There is a clear link between the motor’s efficiency and the load. Manufacturers design motors to operate at a 50-100% load and to be most efficient at a 75% load. But once the load drops below 50% the efficiency decreases rapidly as shown in

Figure 6.9. Operating motors below 50% of rated loads has a similar, but less significant, impact on the power factor. High motor efficiencies and power factor close to 1 are desirable for efficient operation and for reducing costs down of the entire plant and not just the motor.

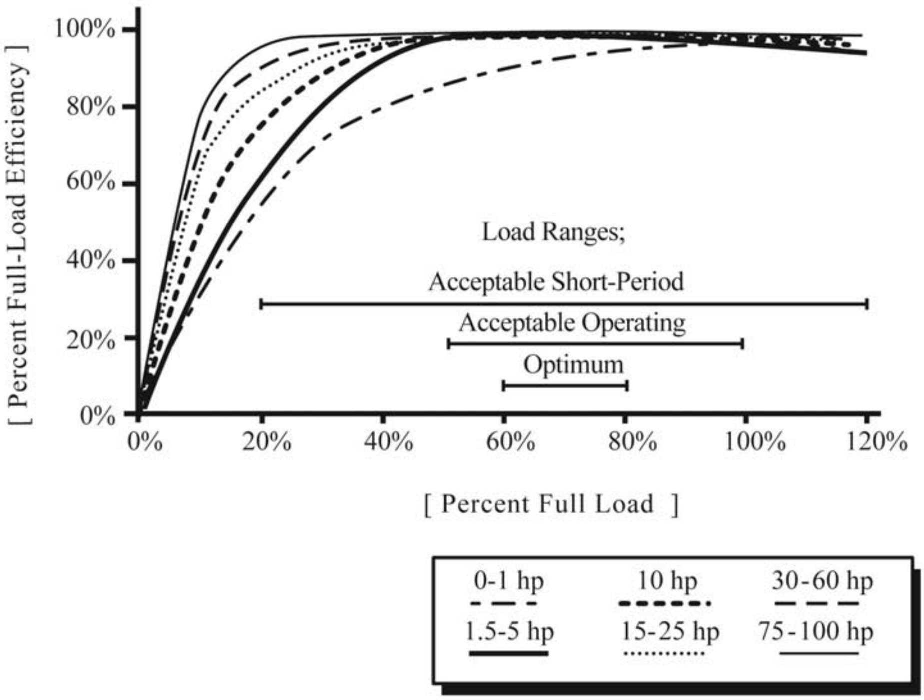


Figure 6.9 Motor part load efficiency

6.4.4.2 Motor Load

Because the efficiency of a motor is difficult to assess under normal operating conditions, the motor load can be measured as an indicator of the motor's efficiency. As loading increases, the power factor and the motor efficiency increase to an optimum value at around full load. It is necessary to see the %loading of the motor. If the motor runs at more than 70% load, then the power factor and efficiency will be good.

6.4.4.3 Energy Efficiency Opportunities

Apart from operational point of view, the motors should be seen from energy efficiency opportunities also. The following points may be considered :

a. Replace standard motors with energy efficient motors.

b. Reduce under-loading.

c. Avoid over-sized motors.

d. Improve power quality.

e. Don't go for multiple time rewinding.

f. Improving maintenance practices.

6.4.5 Condition Monitoring Techniques

6.4.5.1 Vibration Monitoring

Vibration in rotating machinery is caused by many reasons like unbalance, misalignment, loose foundation, mechanical looseness, bearing damage etc. Vibration monitoring is the most common, versatile and powerful condition monitoring technique adopted in rotating machinery to identify problem areas. The severity of the vibration is specified by IS 2372 which is measured with reference to class of machine. The criteria for class of machine are given in Table 6.2:

Table 6.2 Criteria for class of machine

Class- I	Individual parts of engines and machines integrally connected with the complete machine in its normal operating condition. (Electrical drives up to 15 kW are typical examples of machines in this category)
Class- II	Medium sized machines (typically electrical motors with 15 to 75 kW output) without special foundation, rigidly mounted engines or machines (up to 300 kW) on special foundations.
Class- III	Large prime movers and other large machines with rotating mass mounted on rigid and heavy foundations which are relatively stiff in the direction of vibration measurement.
Class- IV	Large prime movers and other large machines with rotating masses mounted on foundations which are relatively soft in the direction of vibration measurement (such as turbo-generator sets, especially those with light-weight structures)
Class- V	Machines and mechanical drive systems with un-balanceable inertia efforts (due to reciprocating parts), mounted on foundations which are relatively stiff in the direction of vibration measurement.

With above class of machine, the vibration severity can be judged by the guidelines shown in Table 6.3:

Table 6.3 Vibration severity chart for machine vibration limits

<table>
<tr><th colspan="2">Range for vibration severity in velocity (mm/sec)</th><th colspan="4">Example of Quality Judgment for Separate Classes of Machines</th></tr>
<tr><th>Peak</th><th>RMS</th><th>Class -I</th><th>Class -II</th><th>Class -III</th><th>Class -IV</th></tr>
<tr><td>0.40</td><td>0.28</td><td rowspan="2">Good</td><td rowspan="3">Good</td><td rowspan="4">Good</td><td rowspan="5">Good</td></tr>
<tr><td>0.64</td><td>0.45</td></tr>
<tr><td>1.0</td><td>0.71</td><td rowspan="3">Normal</td></tr>
<tr><td>1.58</td><td>1.12</td><td rowspan="3">Normal</td></tr>
<tr><td>2.5</td><td>1.8</td><td rowspan="3">Normal</td></tr>
<tr><td>4.0</td><td>2.8</td><td rowspan="2">Still Acceptable</td><td rowspan="3">Normal</td></tr>
<tr><td>6.4</td><td>4.5</td><td rowspan="2">Still Acceptable</td></tr>
<tr><td>10.0</td><td>7.1</td><td rowspan="5">Unacceptable</td><td rowspan="2">Still Acceptable</td></tr>
<tr><td>15.8</td><td>11.2</td><td rowspan="4">Unacceptable</td><td rowspan="2">Still Acceptable</td></tr>
<tr><td>25.0</td><td>18.0</td><td rowspan="3">Unacceptable</td></tr>
<tr><td>40.0</td><td>28.0</td><td rowspan="2">Unacceptable</td></tr>
<tr><td>64.0</td><td>45.0</td></tr>
</table>

6.4.5.2 Vibration Analysis

If the measured vibration level is more than the acceptable level, then it calls for vibration analysis which is a captured time waveform plotted as amplitude versus time, or data can be transformed using a fast Fourier transform (FFT) and expressed as amplitude versus frequency. Any random vibration signal can be represented by a series (a Fourier series) of individual sine and cosine functions that can be summed to yield an overall vibration level. The amplitude of this vibration signal defines the severity of the problem. Plotting the amplitude versus the frequency (the Fourier spectrum) allows for identification of discrete frequencies contributing most to the overall vibration signal, commonly referred to as a “signature analysis” or a “frequency spectrum.” Machine looseness, misalignment, imbalance, and soft foot conditions are all fairly easily identified in the frequency spectrum generated by an analyzer.

The guidelines for vibration frequency and its likely cause are shown in Table 6.4.

Table 6.4 Vibration frequencies and likely causes

Frequency in terms of RPM	Most Likely Causes	Other Possible Causes & Remarks
1xRPM	Unbalance	Misalignment (if high axial vibration) Bad belts if RPM of belt Resonance Reciprocating Forces Electrical Problem
2xRPM	Mechanical Looseness	Misalignment (if high axial vibration) Bad belts if 2 x RPM of belt Resonance Reciprocating Forces Electrical Problem
3xRPM	Misalignment	Usually a combination of misalignment and excessive axial clearance (Looseness)
Less Than	Oil Whirl (Less than ½ of RPM)	Bad drive belts Background vibration Sub-harmonic resonance
AC Line Freq.	Electrical Problem	Common Electrical Problems
Many Times RPM (Harmonically related)	Bad Gears Aerodynamic Forces Hydraulic Forces Mechanical Looseness Reciprocating Forces	Gear teeth times RPM of bad Gear No. of fan blades time RPM No. of impeller vane times RPM May occur at 2,3,4 and sometimes higher harmonics if severe looseness
High Frequency (Not Harmonically related)	Bad antifriction Bearings	Bearing vibration may be unsteady amplitude and frequency Cavitation, recirculation and flow turbulence cause random and high frequency vibration Rubbing

The vibration monitoring and analysis should be done periodically, typically once in 6 months for all rotating equipment.

6.4.5.3 Thermographic Analysis

Commonly identified with electrical equipment monitoring, thermography is also a useful tool for monitoring plant machinery. Thermography measures infrared radiation energy emissions (surface temperatures) to detect anomalies. Infrared cameras have resolution to within 0.1 °C and digitally store captured images. Both the absolute and relative temperatures can be obtained on virtually all types of electrical equipment, including switchgear, connections, distribution lines, transformers motors, generators, and buswork.

This technique is very popular because of the following reasons:

- It is a non-contact type technique.
- Fast, reliable & accurate output.
- A large surface area can be scanned in no time.
- It can be easily scanned from a distance up to 50 meter.
- Presented in visual & digital form.
- Software back-up for image processing and analysis.
- Requires very little skill for monitoring.

This technique can be very well used for seeing the loose contact, corrosive contact of all types of electrical joints, body temperature of motor and transformers, panels, etc. The criteria shown in Table 6.5 may be used to know the severity of the problem.

Table 6.5 Criteria for differential temperature of electrical equipment

SL	Criteria (Differential temperature above ambient)	Criticality Condition	Recommended Action
1	Up to 10 °C	Non-critical	No action is needed.
2	Between 10°C to 20°C	Less critical	Regular monitoring is needed.
3	Between 20°C to 40°C	Semi critical	Close monitoring needed. Should be attended in the next opportunity.
4	Above 40°C	Critical	Should be attended immediately as per the severity.

Few typical thermal images captured in thermography analysis (Figure 6.10):

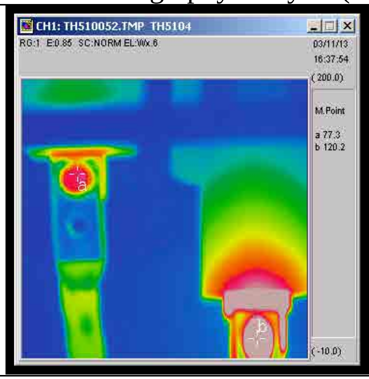
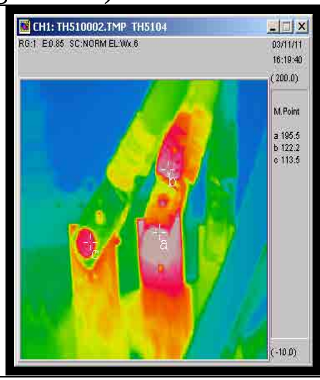
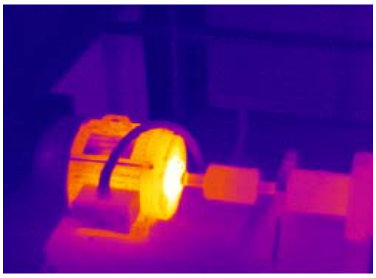
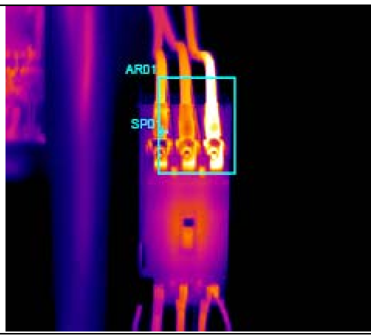
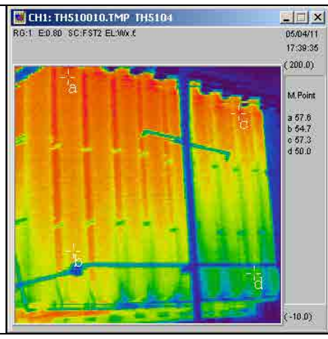
		
Hot-spot in a Transformer Bushing	Hot-spots in a 11kV cable terminal	Hot-spot in LT cable joints
		
Overheating of a Bearing	Loose Contact of a MCC Panel	Choked fins of a Transformer Radiator

Figure 6.10 Thermographic measurement

6.4.6 Speed Control Equipment

The following five types of ASDs (Adjustable Speed Device) are available.

- VFD: Electronic devices to control the speed of the motor by controlling the frequency of the voltage at the motor.
- Direct current ASDs: Electronic devices to control direct-current motors by changing the voltage applied to the motor.
- Eddy-current drives: Electrical devices that use an electro-magnetic coil on one side of coupling to induce a magnetic field across a gap, creating an adjustable coupling.
- Hydraulic Drives: Devices that operate much like an automotive hydraulic transmission.

- Mechanical speed-control products including gearing, mechanical transmissions, and belt drivers with variable-pitch pulleys can be used.

6.4.6.1 Variable Frequency Drive (VFD)

VFD varies the revolving speed of an induction motor freely by changing the power supply frequency and the power supply voltage. Although a power transistor is used for the main circuit and IC, and a microcomputer is for the control circuit of VFD, further advanced controlling technology has been applied due to improved semiconductor devices in recent years. Moreover, generally, VFD is also called inverter control equipment or variable voltage variable frequency (VVVF) equipment.

The fundamental configuration is shown in the following Figure 6.11.

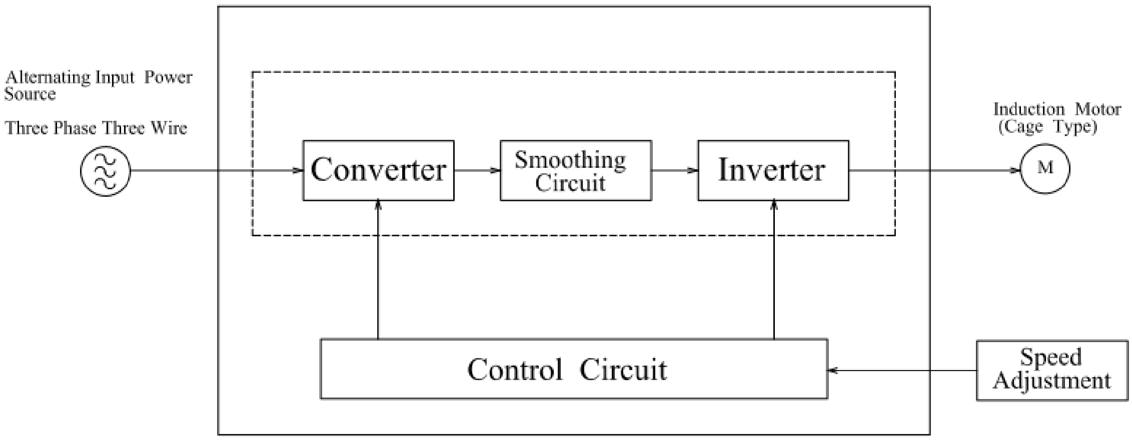


Figure 6.11 VFD

After changing an alternating power source into direct current in a converter part and making it smooth, transform the direct current inversely to variable frequency alternating current at an inverter part.

6.4.6.2 Advantages and Disadvantages of VFD

(Advantage)

- Variable speed continuous operation over a wide range is possible.
- Energy-saving possibility exists.
- Brush, slip ring and so on, used in induction motor are not required.
- Soft start and soft stop are enabled, extending the motor life.
- Settings for acceleration timing and deceleration timing can be adjusted.
- Starting current can be reduced.

(Disadvantage)

- Harmonic protection measures are necessary since high frequency current is generated.
- Generation of leakage current and noise due to high frequencies need to be restricted.
- Noise prevention for other equipment (especially measuring instruments) is necessary.

(Energy conservation effects)

One of the pump characteristics is that its load torque is proportional to the square of its revolving speed, and this torque is called square reduction torque load.

- Relationship between speed of revolution N (rpm) and flow rate Q (m^3/sec.)

  Flow rate is proportional to the speed of revolution. $Q \propto N$

- Relationship between speed of revolution N (rpm) and head H (m)

  Head is proportional to the square of speed of revolution. $H \propto N^2$

- Relationship between speed of revolution N (rpm) and power P (kW)

  Power is proportional to the cube of speed of revolution. $P \propto N^3$

- Relationship between speed of revolution N (rpm) and torque T (N-m)

  Torque is proportional to the square of speed of revolution. $T \propto N^2$

6.4.7 Motor Protection Equipment

Protection equipment for three-phase induction motors includes the following:

- Circuit breaker

  It has overload and short circuit protection functions. The former is a thermal function and has on-delay characteristics, while the latter is an electromagnetic function and has instantaneous characteristics.

- Thermal relay

  Changes bimetal with Joule heat of overload current, opens or closes the contact, and performs on-delay operation.

- Comprehensive motor protection relay

  This unit measures the current from all the three phases and checks for single –phase, unbalance, overload. The measurement and comparison of these three factors provide short circuit, single-phase, earth fault, phase sequence and thermal protection to the motors.

- Dry-run protection

  In addition dry-run protection is also provided by water level sensors in the sump which sense any low level of water and prevent dry running, thereby protecting the pump and motor.

6.5 INSTRUMENTATION FACILITIES

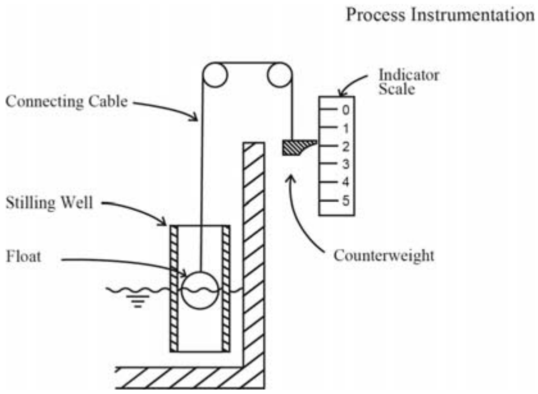
6.5.1 Flow Measuring Equipment

Please refer to Chapter 3 for “flow measuring equipment.”

6.5.2 Level Measuring Equipment

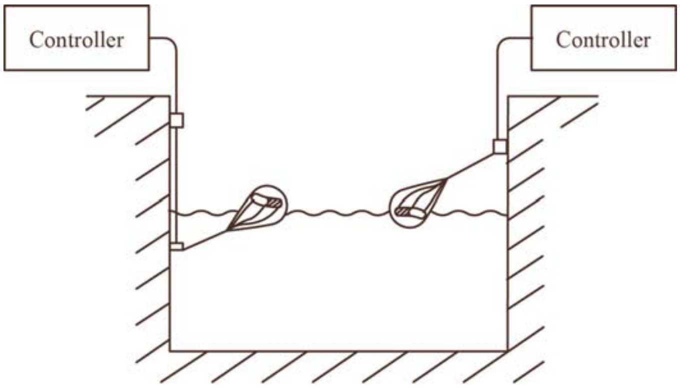
6.5.2.1 Float

A float device measures a liquid level from above. Floats, one of the oldest and simplest methods of level measurement, are used extensively in wet wells or sludge vaults that require a discrete high- or low-level indication. They are also used for local indication of level in tanks and open channels. (Figure 6.12 and Figure 6.13)



Source: WEF, 2008

Figure 6.12 Counterweighted float-level indicator



Source: WEF, 2008

Figure 6.13 Float switches

A float level meter shown in Figure 6.12 senses water level through a slide rheostat as resistance and converts the changed resistance into current. It transmits analog output signal (DC 4 mA to 20 mA) proportional to the water level and sends the signal representing the water level continuously to the monitoring room.

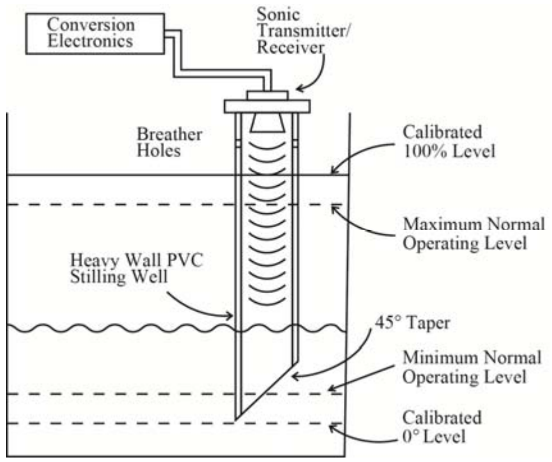
O&M issues to be cared for are as follows:

- Clean inside the stilling well regularly and keep it free from floating matter or scum to prevent malfunctions.
- Check moving parts such as a counter weight, pulley and wires for corrosion or damage.

A level switch shown in Figure 6.13 is used to control pump and to issue alarms according to water level. The signals from the level switch are "on/off" digital signals, which compromise a sequence circuit. Float switches should be located away from the tank walls to prevent the floats from banging against the concrete wall and internal contacts from failures.

6.5.2.2 Ultrasonic

Ultrasonic level measuring device installed above the liquid surface measures the level by generating a pulse of ultrasonic waves that bounce off the liquid surface. The instrument detects the echo, calculates the echo's travel time, and converts it to a level measurement (Figure 6.14).



Source: WEF, 2008

Figure 6.14 Acoustic level-sensor installation

Specifically, the relation between distance from sonic transmitter/ receiver to the liquid surface and the reaching time is expressed in the following formula:

$$H = \frac{1}{2} \times c \times t \qquad (6.6)$$

Where, H : Distance from transmitter/ receiver to liquid surface (m)

c : Sonic velocity in air= 331.5 + 0.61 × temperature in Celsius (m/s)

t : Time from transmission to receiving (sec)

O&M issues to be taken care of are as follows:

- Ultrasonic level meters require little daily maintenance because they have no moving parts and work without contacting measuring objects. However the junction boxes have to be regularly checked for any water ingress.
- Keep clear the area around transmitter / receiver.
- Keep liquid surface without scum, foam, wave, etc. Normally a perforated guard pipe protects the sensor from any turbulence and floating matter in the water. This may need to be checked regularly.

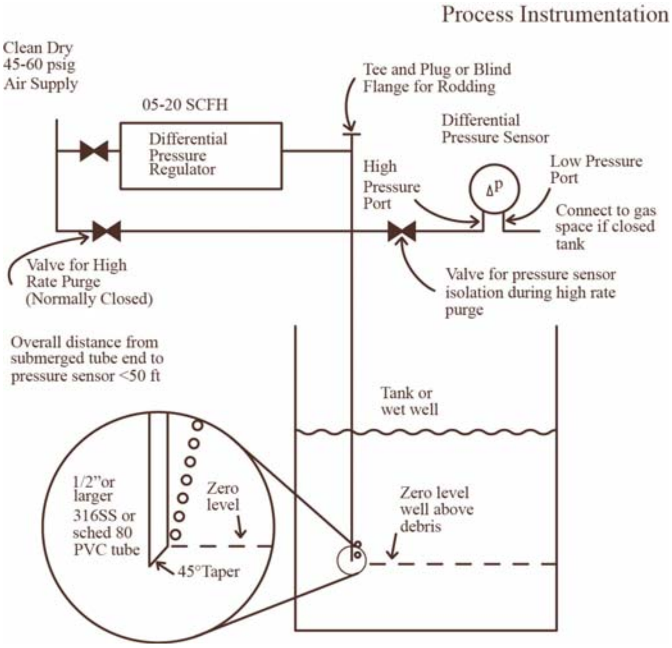
6.5.2.3 Head-Pressure

Head pressure level measuring devices, bubbler tubes and diaphragm bulbs measure the head pressure at the liquid level and are often used in open-channels or non-pressurized tank applications.

6.5.2.3.1 Bubbler Tube System

The bubbler tube system uses a small, regulated airflow that constantly bubbles into the liquid. Because the airflow is small, the system produces a back pressure equal to the static head of the liquid. A conventional pressure gauge or transmitter measures this back pressure as the height of an equivalent water column. (Figure 6.15)

Corrections are required when the liquid's specific gravity differs significantly from water. Because air is constantly bubbling out of the bubbler tube, the system is typically self-purging. Valves may be arranged to isolate the pressure-measuring device while providing high purge flow through the tube for preventive maintenance blow-down if fouling occurs. Stilling wells are often used to protect the bubbler tube from turbulence and damage. To protect pneumatic instruments and regulators, operators should clean the air supply of excessive moisture and oils.



Source: WEF, 2008

Figure 6.15 Schematic of bubbler-level system

When bubbles are discharged into the liquid from the front end of pipe, the pressure within the pipe becomes equal to the static pressure of liquid at the front end of the pipe. This pressure is proportional to the liquid height h. The calculation is expressed as given below.

$$h = P / \gamma (m) \qquad (6.7)$$

Where, h : Water level from tube end (m)

P : Internal pressure of tube (Pa)

γ : Specific gravity of liquid (kg/m^3)

Precautions for operation and maintenance are as given below.

The bubble type liquid level gauge does not have moving parts or mechanisms, so it has comparatively high accuracy. Moreover, it is suited to level gauges for corrosive liquids. However, daily maintenance of air sources such as compressor, purging set, and air piping is very important.

6.5.2.3.2 Diaphragm Bulb System

The diaphragm bulb system operates on the principle that air sealed between the dry side of the diaphragm (in the capillary tube) and the receiver compresses or expands with the movement of the diaphragm. A change in the static head of the liquid being measured moves the diaphragm, so the pressure of the trapped air is the same as the head pressure. Temperature changes because of sunlight or heat build-up, particularly along the capillary tube, can cause measurement errors as a result of expansion of the trapped air. To reduce the effect of temperature, the capillary can be filled with a fluid unaffected by operating temperature; however, this often affects the measurement response time.

The differential pressure from the diaphragm is detected by piezoelectric semiconductor element. The output signal (4 mA to 20 mA DC) generated by the converter is changed to analog data in the central monitor and transmitted.

The calculation equation for level is expressed as below.

$$H = \Delta P/\rho \tag{6.8}$$

Where, H : Distance from transmitter/ receiver to liquid surface (m)

ΔP : Differential pressure (Pa)

ρ : Density (kg/m^3)

The following precautions should be taken related to the use of differential pressure type level gauge:

- The installed position of differential pressure transmitter should be lower than the minimum liquid level.
- When the density of the liquid changes, correction is necessary. (Span adjustment on the converter side is required.)
- If the liquid has pulsing motion, the output of the differential pressure transmitter may become unstable.

6.5.3 pH and ORP Measuring Equipment

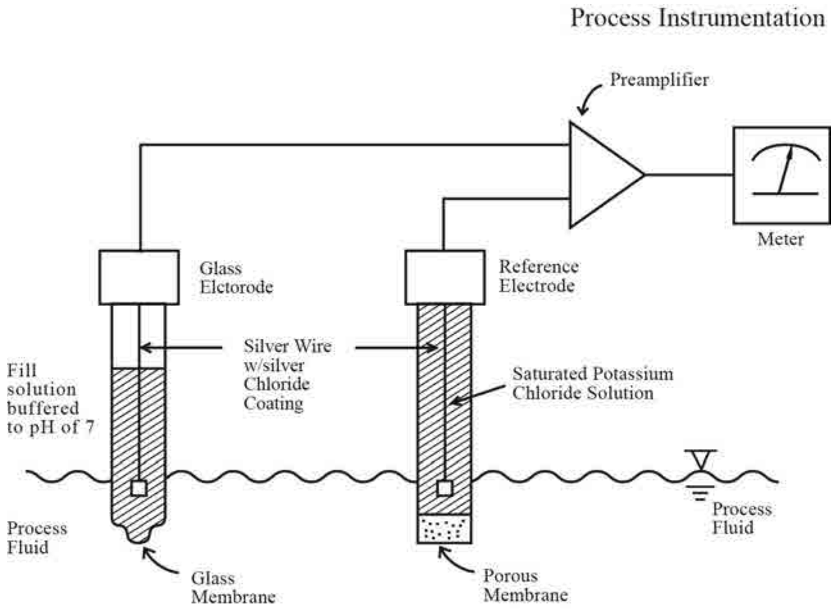
6.5.3.1 pH

pH is a measure of the acidity of a process liquid. Continuous measurements of pH of incoming sewage are frequently made, particularly in plants where drastic changes in pH (as a result of industrial discharges) cause treatment problems.

A glass electrode, which is sensitive to hydrogen ion activity, measures the pH of an aqueous solution (Figure 6.16). The electrode produces a voltage related to hydrogen ion activity and to pH. The pH is determined by measuring the voltage against a reference electrode. While it is generally assumed that no other ions seriously affect the pH electrode in an aqueous system, sodium ions can have an effect. Temperature corrections are also necessary but are typically done automatically by the meter.

Precautions for operation and maintenance are as given below.

- Dirt on the electrode surface should be periodically removed and the surface cleaned.
- Since the electrodes of the pH meter are made of glass, care is necessary to ensure that they do not break.
- Due to long period use of glass electrodes, dirt sticks on them gradually, the zero point changes, and the electromotive force by pH reduces, and it stops responding to changes in pH, making replacement necessary.
- Standard liquid should be used in the pH meter and it should be calibrated. Calibration should include zero adjustment (standard liquid with pH7) and span adjustment (standard liquid of pH4 or pH9).



Source: WEF, 2008

Figure 6.16 Typical pH sensor

6.5.3.2 ORP (Oxidation-Reduction Potential)

Oxidation-reduction potential is a measure of easily oxidizable or reducible substances in a sewage sample. An operator can control the process better by knowing if there is a large quantity of reducing substances (e.g., sulphide and sulphite) that may have an immediate, high oxygen demand and may result in an inadequate supply of oxygen for the microorganisms in the secondary process. Although not specific, the ORP measurement is instantaneous (an electrode is used) and can be used to help maintain dissolved oxygen in the aeration tank. Another application is to evaluate the progress of digestion and process stability in anaerobic digesters.

O&M issues to be cared for are as follows:

- Regular cleansing of electrode surface,
- Precautions against breaking an ORP electrode, which is made of glass and is fragile, and
- Replacement of the electrode if it is insensitive to changes of potential difference, because of stains accumulated over a long time usage.

6.5.3.3 DO (Dissolved Oxygen)

A dissolved oxygen meter is an electronic device that converts signals from a probe placed in the water into units of DO in milligrams per litre. Most meters and probes also measure temperature. The probe is filled with a salt solution and has a selectively permeable membrane that allows DO to pass from the stream water into the salt solution. The DO that has diffused into the salt solution changes the electric potential of the salt solution. T this change is sent by electric cable to the meter, which converts the signal to milligrams per litre on a scale that anyone can read.

If DO is a critical analytical parameter, it is recommended to calibrate at 100 percent saturated air, or use a known dissolved oxygen concentration (determined by the iodometric method) for the upper limit, and use a zero DO solution (even if it is not explicitly stated in a particular manufacturer’s manual) for the lower limit. If the DO meter does not allow for a second calibration point, the zero DO solution can be used as a check standard when the DO meter is set to the measurement mode. The DO meter should read less than 0.5 mg/L (or to the accuracy of the DO meter). If the DO meter does not read less than 0.5 mg/L, then there may be a problem with the DO membrane.

If it is determined that the DO membrane needs to be replaced, consult the manufacturer's manual on conditioning the new membrane before use. It is also possible that other maintenance may need to be performed on the DO meter or the zero DO solution may need to be replaced. Other factors that affect the accuracy of DO measurements include: improper calibration, not verifying calibration after use, not correcting for ambient barometric pressure/altitude, and instrument drift. (Figure 6.17)

Source: M/S YSI.

Figure 6.17 Hand held DO meter with probe for field use

O&M issues to be cared for are as follows:

- Regular cleaning of diaphragms,
- Zero calibration and span calibration,
- Regular replacement of internal electrode solution, and
- Regular cleaning of an electrode and replacement if broken.

6.5.3.4 Temperature

Even though most of the major sewage treatment processes are not temperature-controlled, many temperature measurements are required. Obvious applications for temperature measurement are anaerobic digesters, chlorine evaporators, incinerators, and equipment protection. Less obvious are temperature controls for analyzers and flow meters. Temperature measurement devices include liquid thermometers, bimetal thermometers, pressure on liquid or gas expansion bulbs, thermistors, resistance temperature detectors (RTDs), infrared detectors, and crystal window tapes. The RTD is typically used on lower, ambient-range temperatures, while thermocouples provide better reliability in higher ranges. Also, gas- and liquid-filled temperature sensors and thermistors are frequently used for equipment-protection and cooling systems.

For continued accurate service, operators should periodically calibrate the instruments using a standard temperature measurement device with high accuracy.

6.5.3.4.1 Thermocouple

The thermocouple operates on the principle that current flows in a circuit made of two different metals when the two electrical junctions between the metals are at different temperatures. The various combinations of metals used are tabulated in most engineering handbooks, and the selection of metals is based on the maximum temperature to be measured. Thermocouples measure as high as 980°C, with an accuracy of 1% of the full scale.

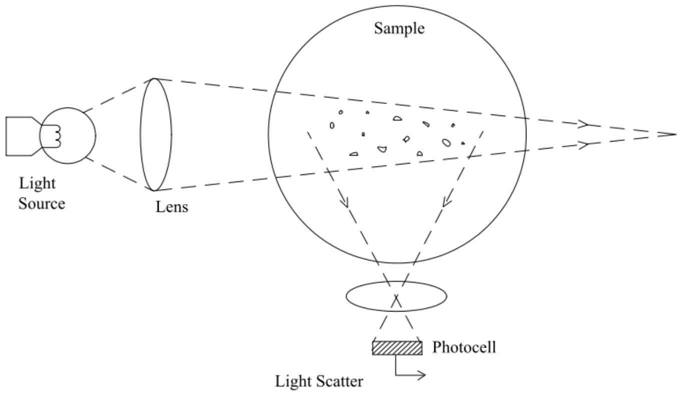
6.5.3.4.2 Resistance Temperature

A resistance temperature detector has a temperature-sensitive element in which electrical resistance increases repeatedly and predictably with increasing temperature. The sensing element is typically made of small-diameter platinum, nickel, or copper wire wound on a special bobbin or otherwise supported in a virtually strain-free configuration. The detector is typically selected for high accuracy and stability. A common RTD application is the measurement of bearing and winding temperatures in electrical machinery.

6.5.3.5 MLSS (Mixed Liquor Suspended Solid)

All solids concentration meters use indirect methods (such as optical, ultrasonic, and nuclear). Indirect methods correlate the solids concentration with a measurable factor. The limitation of not relating perfectly to the quantity of suspended matter does not seriously affect the analyzers' ability to produce a repeatable signal of great value in process control.

When a light beam is directed on to liquid containing suspended particulates, the suspended particulates scatter some of the light. The nephelometer helps observers measure the amount of light that the particulate matter scatters (Figure 6.18). The amount of scattered light relates approximately to the amount of particulate matter, particle size, and surface optical properties. The nephelometer is a photoelectric device that uses an incandescent light source (lamp), which produces light in wavelengths from blue to red. The light is directed to a liquid and if the liquid contains particles, some of the light strikes the particles and scatters. By placing a photocell or light detector at an angle to the light beam rather than directly in front of it, the detector receives only light scattered by the suspended particulate matter. Most nephelometers have the photo detector placed at a 90-degree angle to the incandescent light source.

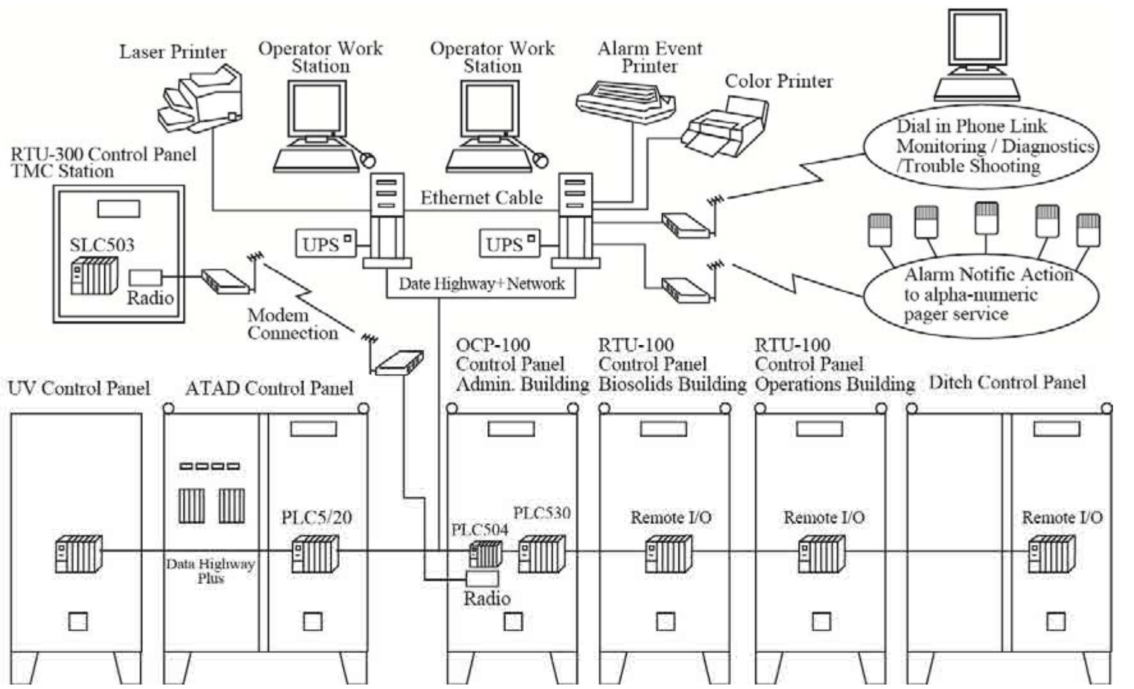


Source: WEF, 2008

Figure 6.18 Nephlometer

6.6 SCADA SYSTEM

SCADA is an acronym for Supervisory Control and Data Acquisition. This presents the data as a viewable and controllable system on the screen of a computer. The data thus collected can be stored and also analyzed for optimization of the process and for better real time process control. It assists plant operating personnel by monitoring and announcing abnormal conditions and failures of equipment. It allows the operators to perform calculations based on the sensor inputs. Daily, weekly, monthly reports can be prepared using the stored data. It also allows the operator to know the state of a process and an alarm associated with it. A typical SCADA communication overview is shown in Figure 6.19.



Source: Kruger

Figure 6.19 Typical SCADA communication overview

6.6.1 Monitoring and Control Equipment

For maximum use and effectiveness, signals generated by various sensors and instruments are transmitted from the sensor to a receiver installed at another location. Often, the sensor output is transmitted to a control panel or computer system, which allows operators to inspect many process variables simultaneously.

The three components of a signal-transmission system are the transmitter, receiver, and transmission medium (the connection between the transmitter and receiver). The transmitter converts a mechanical or electrical signal from the sensor into a form that the transmission medium can use. The transmission medium contains the signal and transfers it to the receiver. The receiver subsequently converts it into a form that the receiving system can use.

6.6.1.1 Signal

6.6.1.1.1 Analog Input Signal

“Analog input signal” means continuous signal such as process data which is transmitted from a local transmitter to a central control unit (CCU).

For instance, process variables expressed in physical amount such as opening degree of a sluice gate (0-100%), sewage flow rate (0- ***m^3/hr), and water level in tanks (0-***m) are converted into electrical quantities. The electrical signals are transmitted to CCU. Standard electronic transmission systems use 4 to 20 mA DC.

There are several transmission systems. One is to connect directly with the CCU I/O (Input/Output) device via shielded cables. Another is the so-called a link system with PLC, in which analog signal is converted to digital signal and is transmitted via coaxial cables or optical fibres.

6.6.1.1.2 Analog Output Signal

“Analog output signal” means signals continuously transmitted from CCU to local control panels or equipment to direct operational amount.

Electric operated valves and regulating valves for controlling pressure of pipe, and VFD for controlling frequency of aerators or pumps, etc., are typical examples which are controlled by analog output signals. More specifically, there are electromagnetic valves and regulating valves used to control pressure in the piping; there are also aeration blowers or VFD (inverter) equipment used to control pump rpm.

Standard electronic transmission systems use 4 to 20 mA DC. One of the transmission systems for analog output signal connects directly to the I/O device of CCU via shielded cables.

6.6.1.1.3 Digital Input Signal

“Digital input signal” refers to a contact output signal generated and transmitted from local equipment. For example, answerback signal to express equipment conditions, alarm signal for abnormal conditions and “remote / local” switch signal of local control panels are examples of digital input signal.

Contact signals are electronically converted to an appropriate series of zeros and ones. Link systems with PLC are widely used for transmitting the signal, with which analog signal is converted to digital signal and is transmitted via coaxial cables or optical fibres.

6.6.1.1.4 Digital Output Signal

Digital output signal means contact output signal expressed “1 / 0” transmitted from CCU to an auxiliary relay on the control centre panel. For example, “on/off” signal for equipment is regarded as digital output signal. Link systems with PLC are widely applied for transmitting the signal, with which analog signal is converted to digital signal and is transmitted via coaxial cables or optical fibres.

6.6.1.2 HMI (Human Machine Interface)

Basically the PLC is a blind device. It does not have any provision of displaying the plant status to the operator or to enter certain data like set points or manual mode operation. An additional device is needed for these provisions, to communicate with PLC, which will have a display to show the status and also the means to enter set points. Such a unit is called Human Machine Interface (HMI).

There are two basic types of HMI:

- Industrial panel mounted type HMI (Figure 6.20)
- PC based system in which the computer acts as HMI (Figure 6.21)

Source: JICA, 2011

Figure 6.20 Industrial panel-mounted type HMI

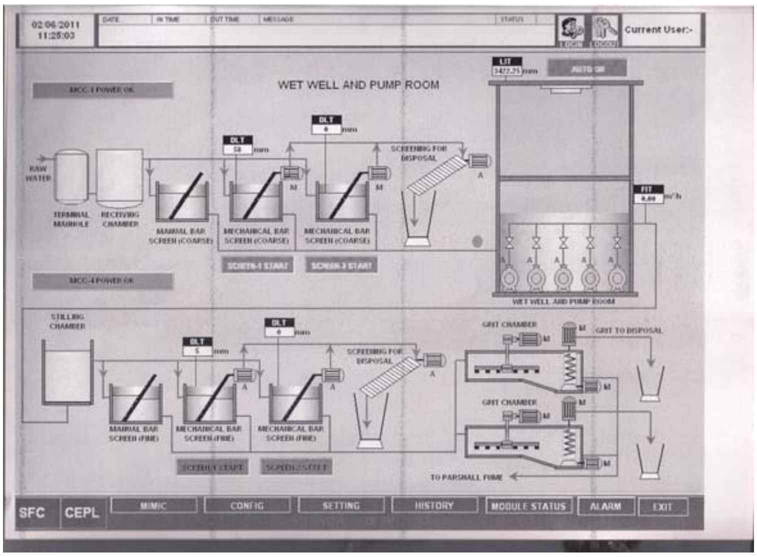


Figure 6.21 PC based system in which the computer acts as HMI

6.6.1.3 PLC (Programmable Logic Controller)

PLC is electronic equipment that senses inputs and takes the decision to change outputs according to the set rules stored in the memory.

It is primarily an electronic controller, housed in industrial housing, which has logic programming function and can be an interface to industrial devices.

6.6.2 Automatic Control

Automatic control systems can be categorized according to their control techniques as follows:

Figure 6.22 shows the control system.

Automatic control	Feedback control	Compare process variables with their set-points and repeat corrective actions until the variables becomes as desired.
	Feedforward control	By predicting influences caused by disturbances, take actions to reduce the effects. Always combine with feedback control.
	Sequence control	Control proceeds according to pre-programmed sequences.

Figure 6.22 Automatic control system

Instrumentation facilities are established mainly based on feedback control in combination with feed forward control in most STPs for controlling process variables such as temperature, water level, pressure, flow rate, etc.

6.7 CABLES

The flow of power from transformer to switchgear and from there to starter and to motor and other related equipment like capacitors are through power cables. Table 6.6 gives information on various types of cables.

Table 6.6 Types of cables for different voltages

No.	Range of voltage	Type of cable to be used	IS Ref.
1	1-230 V / 3-415 V	PVC insulated, PVC Sheathed	IS 1554
2	Up to 6.6 kV	PVC insulated, PVC Sheathed	IS 1554

No.	Range of voltage	Type of cable to be used	IS Ref.
		Paper insulated, lead Sheathed	IS 692
3	11kV	XLPE- Cross Linked, Polyethylene insulated, PVC sheathed	IS 7098
		Paper insulated, lead sheathed	IS 692

Source: CPHEEO, 1993

The size of the cable should be so selected that the total drop in voltage, when calculated as the product of current and the resistance of the cable should not exceed 3%. Values of the resistance of the cable are available from cable-manufacturers.

The following points should be considered when selecting the size of the cable:

- The current carrying capacity should be appropriate for the lowest voltage, the lowest power factor and the worst condition of installation, that is, duct-condition.
- The cable should also be suitable for carrying the short circuit current for the duration of the fault. The duration of the fault should preferably be restricted to 0.1 sec. by proper relay setting.
- Appropriate rating factors should be applied when cables are laid in group (parallel) and/or laid below ground.
- Suitable trenches or racks should be provided for laying cables.

The following O&M tasks should be implemented:

- Measure insulation resistance between cables and the earth.
- Visually observe deterioration, corrosion, and discolouration.

6.8 ENERGY AUDIT

Among all the power consuming components, pumping installations consume a large amount of energy in STPs. Need for conservation of energy, therefore cannot be over emphasized. All possible steps need to be identified and adopted to conserve energy and reduce energy cost so that sewage charges can be kept as low as possible and gap between high cost of sewage treatment and affordable charge to users can be reduced.

Some adverse scenarios in energy aspects given below are quite common in pumping installations:

- Energy consumption is higher than optimum value due to reduction in efficiency of pumps.
- Operating point of the pump is away from best efficiency point (b.e.p.).
- Energy is wasted due to increase in head loss in pumping system, for instance, clogging of strainer, encrustation in column pipes, and encrustation in pumping main.
- Selection of uneconomical diameter of sluice valve, butterfly valve, reflux valve, column pipe, and drop pipe, etc., in pumping installations.
- Energy wastage due to operation of electrical equipments at low voltage and/or low power factor.

Such inefficient operation and wastage of energy should be avoided to cut down energy cost. It is therefore, necessary to identify all such shortcomings and causes which can be achieved by conducting methodical energy audit.

Strategies as given below should be adopted for the management of energy.

- Conduct thorough and in-depth energy audit covering analysis and evaluation of all equipment, operations and system components which have bearing on energy consumption, and identify the scope for reduction in energy cost.
- Implement measures for conservation of energy. Energy audit as implied is auditing of billed energy consumption and how the energy is consumed by various units, and sub-units in the installation and whether there is any wastage due to poor efficiency, higher hydraulic or power losses etc., and identification of actions for remedy and correction.

6.8.1 Frequency of Energy Audit

Frequency of energy audit recommended is as follows.

- Large installations: Every year
- Medium installations: Every two years
- Small installations: Every three years

6.8.2 Scope of Energy Audit

Scope of energy audit and suggested methodology includes following actions, steps and processes:

a. Conducting in-depth energy audit by systematic process of accounting and reconciliation between the following:
   - Actual energy consumption, and
   - Calculated energy consumption taking into account rated efficiency and power losses in all energy utilising equipment and power transmission system, such as conductor, cable, panels, etc.

b. Conducting performance tests of pumps and electrical equipment if the difference between actual energy consumption and calculated energy consumption is significant and taking follow up action on conclusions drawn from the tests.

c. Taking up discharge test at rated head if test in b. above is not being taken.

d. Identifying the equipment, operational aspects and characteristics of power supply causing inefficient operation, wastage of energy, increase in hydraulic or power losses etc., and evaluating the increase in energy cost or wastage of energy.

e. Identifying solutions and actions necessary to correct shortcomings and lacunas in d. above and evaluating cost of the solutions.

f. Carrying out economic analysis of costs involved in d. and e. above and drawing conclusions on whether rectification is economical or otherwise.

g. Checking whether operating point is near the best efficiency point and whether any improvement is possible.

h. Verification of penalties if any, levied by power supply authorities, such as penalty for poor power factor, penalty for exceeding contract demand, and so on.

i. Broad review of the following points for future guidance or long term measure:
   - C-value or f-value of transmission main.
   - Diameter of transmission main provided
   - Specified duty point for pump and operating range

– Suitability of pump for the duty conditions and situation in general and specifically from efficiency aspects.

– Suitability of ratings and sizes of motor, cable, transformer and other electrical appliances for the load.

6.9 MANAGEMENT OF RECORDS

Records are the key to an effective maintenance program. Records can remind the operator when routine operation or maintenance is necessary. They help ensure that schedules are maintained and needed operation or maintenance are not overlooked or forgotten.

6.9.1 Record of Operation and Maintenance

Records must be permanent, complete, and accurate. Write entries clearly and neatly on data sheets in ink. A pencil should never be used because notations can smudge or they can be altered or erased.

Minimum recordkeeping that may be required for operations is listed below and shown in Appendix 6.1:

a. Operational record: Power receiving and transforming equipment

b. Monthly report: Electric power receiving

c. Ledger: Electrical equipment

6.9.2 Record of Operation and Maintenance and its Utilization

Records are utilized like the following:

Review of operating records can indicate the efficiency of the plant, performance of its treatment units, past problems, and potential problems.

Records can be used to determine the financial health of the utility, provide the basic data on the system’s property, and prepare monthly and annual reports.

6.10 PREVENTIVE MAINTENANCE

Generally, preventive maintenance can be described as maintenance of equipment or system before faults occurs. Preventive maintenance should be according to manufacturer’s manual in case of any problems.

It can be divided into two subgroups:

- Planned / Scheduled Maintenance (PM)

  Scheduled activities to ensure that an item of equipment is operating correctly and to therefore avoid any unscheduled breakdown and downtime.

- Condition Based Maintenance (CBM)

  Activities performed after one or more indicators show that equipment is going to fail or that equipment performance is deteriorating.

The vast majority of electrical maintenance should be predictive or preventive. This section focuses exclusively on these activities. There are four cardinal rules to follow in any maintenance program:

- Keep it clean

  Dirt build-up on moving parts will cause slow operation, arcing, and subsequent burning. Moreover, coils can short-circuit. Dirt will always impede airflow and result in elevated operating temperatures.

- Keep it dry

  Electrical equipment always operates best in a dry atmosphere, where corrosion is eliminated. Moisture-related grounds and short circuits are also eliminated

- Keep it tight

  Most electrical equipment operate at a high speed or is subjected to vibration.

- Keep it frictionless

  Any piece of equipment or machinery is designed to operate with minimum friction. Dirt, corrosion, or excessive torque will often cause excessive friction.

Of the four cardinal rules, none is essentially electrical in nature. The failure of a bearing in a motor can lead to an ultimate motor winding failure that is electrical, but the root cause of the failure could have been mechanical.

The goal of any electrical preventive maintenance program is to minimize electrical outages and ensure continuity of operation.

6.10.1 Types of Planned Maintenance

Maintenance works can be classified as follows according to their inspection intervals. The results of maintenance can be utilized for preventing possible faults or breakdowns of equipment in future.

- Routine maintenance

  Routine maintenance consists of observation for signs of overheating, dirt, loose parts, noise and any other signs of abnormalities. It will help grasping the state of electrical equipment.

- Periodic maintenance

  Regular maintenance includes inspections of electrical conditions such as electric current, voltage, insulation resistance, ground resistance, etc.

- Detailed examination

  Examinations should be preprogrammed according to manufacturer's recommendation or legislation. Recommended maintenance tasks for typical electrical equipment are listed in Table 6.7.

Table 6.7 Recommended maintenance on electrical equipment

Equipment	Frequency			
	Monthly	Quarterly	Semi-annual	Annual
Panel, Circuit-Breaker, Starter*	GI,CL	AJ		CB,GRT
Transformer Substation*	GI	GI,RE	TO,MR	GRT,CL
Motors*		GI,CL	AL,MR	PG
Standby power generator	GI			CL,AL
Gas engine	GI			CL,AL
Dual fuel engine	GI			CL,AL
UPS	GI			CL
Flow Measuring equipment				CB,MR
Level Measuring equipment			CL	CB,MR
Other Instrumentation	CL	CB	ADL	MR
Cables				MR

* Details of the maintenance tasks of the marked equipment above are given in Appendix 6.2.

(Legend)

CL	Clean	GRT	Ground resistance test
MR	Megger and record	TO	Test oil
PG	Pressure grease	GI	General inspection
SG	Surface grease	AL	Add lubricant
RC	Remove condensate	AJ	Adjustment
CB	Calibration	RE	Replenish / Replacement
ADL	Add liquid		

6.10.2 Inspection Tools

A wide variety of instruments are used to maintain electrical systems. These instruments measure current, voltage, and resistance. They are used not only for troubleshooting, but for preventive maintenance as well. These instruments may have either an analog readout, which uses a pointer and scale, or a digital readout, which gives a numerical reading of the measured value.

6.10.2.1 Multimeter

A multimeter is used to measure voltage and low levels of current in a live system and continuity in a switched-off system. There are several types available in the market. They are designed to be used on energized circuits and care must be exercised when testing. By holding one lead on ground and the other on a power lead, a user can determine if power is available, and also can tell if it is AC or DC, the intensity or voltage (1, 10, 220, 480, and so on) by testing the different leads. A clamp-on multimeter can measure larger current typical in a motor.

A digital multimeter and an analog multimeter are shown in Figure 6.23.

Source: HIOKI E.E. CORPORATION

Figure 6.23 Digital multimeter (left) and Analog multimeter (right)

- Only qualified and authorized persons should work on electric circuits.
- Use a multimeter or other circuit tester to determine if the circuit is energized, or if voltage is off. This should be done after the main switch is turned off to ensure that it is safe to work inside the electrical panel. Always be aware of the possibility that even if the unit the users are working on is off, the control circuit may still be energized if the circuit originates at a different distribution panel.
- Check with a multimeter before and during the time the main switch is turned off as a double check. This procedure ensures that the multimeter is working and that the users have good continuity to the tester.
- Use a circuit tester to measure voltage or current characteristics to a given piece of equipment for checking whether the circuit is “alive” or not. Switches can fail and

the only way to ensure that a circuit is dead is to test the circuit.

- In addition to checking for power, a multimeter can be used to test for open circuits, blown fuses, single phasing of motors, grounds, and has many other uses.

6.10.2.2 Clamp-on Meter

The clamp-on meter measures the current or amps in the circuit (Figure 6.24). It is used by clamping the meter over only one of the power leads to the motor or other apparatus and taking a direct reading. Therefore the measurement by the clamp-on meter is safe method in a high-current circuit.

Each lead in a three-phase motor must be checked.

Source: HIOKI E.E. CORPORATION

Figure 6.24 Clamp-on meter

6.10.2.3 Megger / Megohmmeter

A megger or megohmmeter is used for checking the insulation resistance of motors, generators, feeders, bus bar systems, grounds, and branch circuit wiring. This device actually applies a DC test voltage, which can be as high as 5,000 volts, depending on the megohmmeter selected.

The one shown in Figure 6.25 is a hand-held that applies 500 volts DC and is particularly useful for testing low-tension motor insulation. Battery-operated and instrument style meggers are also available in both analog and digital models.

Source: HIOKI E.E. CORPORATION

Figure 6.25 Hand-cranked megohmmeter

If a low reading is obtained, disconnect motor leads from power or line leads. A low reading in the megger for motor generally indicates that the motor winding insulation has broken down. If a good reading is obtained, meg the circuit or branch wiring. If this reading is low, the wiring to the motor is defective.

Motors and wiring should be subjected to megger test at least once a year, and if possible, twice a year. The readings taken should be recorded and plotted to determine the deterioration of insulation and predict its breakdown.

6.10.2.4 Ground Resistance Testers (Earth Meggers)

When electrical equipment is installed in housings, they may be charged against the ground. Therefore, they should be connected with earth (referred to as “earth”) to reduce the potential difference between the terminal and the earth to as low a value as possible (ideally 0 volt).

The purposes of the earth are as follows:

a. Prevent electric shock: Discharge any electricity charged in equipment housing due to electrical insulation failure or a transformer breakdown to prevent shock; and

b. Prevent breakdown of loaded equipment: Connect a neutral line on the load side of transformer with earth and prevent high voltage on the power source side from intruding into the load side in case of transformer fails so as to protect the loaded equipment.

Value of ground resistance is depends considerably on the soil to be earthed, and the smaller the resistance, the better.

Ground resistance testers are devices to measure the stated resistance when the circuit is earthed. Testers with measurable range from 0 to 1,000 ohms are widely used. (Figure 6.26)

Source: HIOKI E.E. CORPORATION

Figure 6.26 Ground resistance tester

6.10.3 General Precautions for Electrical Maintenance

The following should be ensured for safe electrical maintenance:

- Do not touch any energized parts directly.
- Fully understand configurations and operational characteristics of related electrical facilities and equipment.
- When operating electrical equipment, follow the operational procedures, confirm the purposes of the operation, and predict the result of the operation.
- When overheat, abnormal noise, or vibration, etc, is detected during inspection, report the condition to the person in charge of electrical work.
- When overheat, abnormal noise, or vibration, etc, is detected during inspection, stop the equipment and investigate the causes if necessary.
- Always keep the surrounding of electrical equipment tidy and clean. Never allow outsiders to enter the electrical equipment site.

6.10.4 Rehabilitation

If the equipment in the electrical facility is old, frequent outages and high maintenance and repair costs are likely to occur. If some of the equipment is beyond repair, breakdowns lead to long and extensive power outages in the STP.

To prevent such occurrences, functional degradation of electric equipment and causes for breakdown and stoppages should be tracked at an early stage and repaired. Causes of fault also follow a certain trend. Training should be imparted on predicting faults beforehand, so that measures and repairs can be implemented.

Spare parts and tools should be kept ready on site so that repairs can be carried out. Inventory of spare parts and tools should be confirmed, and the required number should be stored.

6.10.5 Planned Reconstruction

For reconstruction of electric facilities, plans should be formulated; therefore, scheduled O&M should have been implemented.

Items to be studied for planned reconstruction include:

- Find whether abnormalities exist from routine inspection records, data, periodic inspections and repair records, and judge the condition of equipment.
- Analyze collected and accumulated data, and understand the long-term deterioration trend of equipment.

6.11 TROUBLESHOOTING

Refer to Appendix 6.3.

6.12 SUMMARY

The primary function of electrical system in STP is to receive power from outside, transform it, and distribute it stably to each facility within the plant. Instrumentation system also plays an important role in indicating operating conditions.

For realizing these functions properly, the electrical system requires periodic inspection and maintenance for early detection of abnormal conditions. The instrumentation system should be inspected and adjusted regularly so that it can provide correct readings at all times.

CHAPTER 7 MONITORING OF WATER QUALITY

7.1 INTRODUCTION

Sampling and analysis is a tool to forewarn against possible and potential dangers in the areas bordering on human health and which can lead to water borne epidemics and endemics. It aims at a quick method of estimating the deterioration of the desired quality of the treated sewage not only at the outfall but also at each incremental stage of treatment so that the dysfunction of a particular unit operation can be detected and set right quickly before it has a cascading effect on downstream unit operations.

7.2 NEED FOR SAMPLING AND ANALYSIS

Effective operation and control of a sewage treatment plant requires that the operator possess thorough knowledge of the composition of the influent, effluent, and internal process streams. To acquire such knowledge, the sample should be collected and analysed representative samples of the raw sewage and streams throughout the plant and determines their characteristics.

7.3 SAMPLING

In general, the two major categories of sample collections are for (a) physical and chemical tests and (b) microbiological tests. In both cases, care should be taken to avoid entry of extraneous materials such as silt, scum and floating matters into sampling bottles.

7.3.1 Overview

Understanding the principles and practices of sampling to obtain a representative sample is important to get at a truly representative sample instead of randomly collection leading to misleading results. Laboratory analyses will have little value if representative sampling is not done. Sampling points must be located where homogeneity of the sewage or waste water with good mixing of the materials is available. Careless collections of samples give data which may lead to wrong conclusions.

7.3.2 Grab Sample

Grab samples are collected when frequent changes in character and concentrations are likely to occur and influence the treatment, undesirable constituents are suspected, the quality is not expected to vary or when samples require on the spot analysis for parameters such as DO, pH and residual chlorine. For example, the testing of the suspended solids in the clarifier overflow is an independent sample and it needs to be correlated to the time of sampling because the SS can vary between low flows, average flows and peak flows. Invariably the SS at peak flows of a few hours in the early forenoon may be higher. If the timing is not given, this will give the wrong impression that the entire performance over the 24 hours is having higher SS. Representative samples should be taken with good judgment and should be analyzed within 2 to 3 hours of sampling, A well washed clean PVC or plastic bucket connected to a sturdy long handle may be suitable for grab sampling.

7.3.3 Composite Sample

Since the sewage quality changes from moment to moment and hour to hour, the best results would be obtained by using some sort of continuous sampler-analyser. However, since operators are usually the sampler-analysers, continuous analysis would leave little time for anything but sampling and testing. Except for tests which cannot wait due to rapid chemical and biological change of the sample, such as tests for dissolved oxygen and sulphide, a fair compromise may be reached by taking samples throughout the day at hourly or two-hourly intervals.

When the samples are taken, they should be refrigerated immediately to preserve them from continued bacterial decomposition. When all the samples have been collected for a 24-hour period, the sample from specific location should be combined or composited together according to flow to form a single 24-hour composite sample.

To prepare a composite sample:

- The rate of sewage flow must be known, and
- Each grab sample must be taken and measured out in direct proportion to the volume of flow at that time.

Table 7.1 illustrates the hourly flow and sample volume to be measured for a 12-hour proportional composite sample. Large sewage solids should be excluded from a sample, particularly those greater than 6 mm diameter. A sample composited according to the following table would be total 1,140 ml.

Table 7.1 Hourly flow pattern during composite sampling

Time	Flow (MLd)	Factor	Sample Volume (ml)	Time	Flow (MLd)	Factor	Sample Volume (ml)
6 AM	0.2	100	20	12 N	1.5	100	150
7 AM	0.4	100	40	1 PM	1.2	100	120
8 AM	0.6	100	60	2 PM	1.0	100	100
9 AM	1.0	100	100	3 PM	1.0	100	100
10 AM	1.2	100	120	4 PM	1.0	100	100
11 AM	1.4	100	140	5 PM	0.9	100	90

Source: JICA, 2011

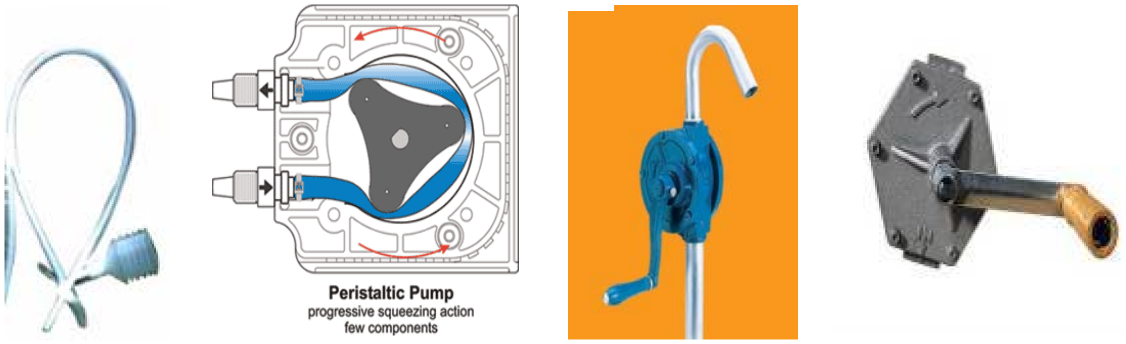
Points to be noted

During compositing and at the exact moment of testing, the samples must be vigorously remixed so that they are of the same composition and as well mixed as they were when originally sampled. Sometimes such remixing may become lax, so that all the solids are not uniformly suspended. Lack of mixing can cause low results in samples of solids that settle out rapidly, such as those in activated sludge or raw sewage. Samples must therefore be mixed thoroughly and poured quickly before settling occurs. If this is not done, errors of 25-50 per cent may easily occur. For example, on the same mixed liquor sample, one person may find 3,000 mg/L suspended solids while another may determine that there are only 2,000 mg/L due to poor mixing. When such a composite sample is tested, a reasonably accurate measurement of the quality of flow can be made.

7.3.4 Sampling Method and Precautions in Sampling

In all cases of sampling, procedures described in 'Standard Methods for the Examination of Water and Wastewater (APHA)' or 'Manual of Methods for the Examination of Water, Sewage and Industrial Wastes (ICMR)' or other standard manuals should be followed.

The sampling procedure is very important and is based on the purpose of sampling and tests to be performed. In general, sewage samples shall not be aerated during collection. Some of the manually operated sampling apparatuses are shown in Figure 7.1. Each has its preference, but the syphonic bellow at A is the easiest to use anywhere.



A B C D

Figure 7.1 Typical sampling apparatuses used in sampling of sewage in STPs

A-Syphonic tube with bellows; B- Electrically operated peristaltic pump, C- Hand operated rotary with positive displacement, D- Hand operated rotary with circular movement

The use of the syphonic bellows tube involves the dipping of the free end of the tube into the liquid surface and keeping the pump end below the liquid level outside the structure and pumping the bellow which sets off a siphon action. Initially some portion of the effluent is to be discharged freely. If the sample is meant for determining the dissolved oxygen, the free end after bellows shall be extended by rubber tubing with a standard laboratory pinch cock and the free end of the tubing dipped into the BOD bottle to effect a submerged discharge very slowly by using the pinch cock. A timing of 10 seconds to fill the BOD bottle is considered as optimum. The sample shall be allowed to overflow for 5 seconds before the tube is withdrawn and the bottle is corked with the ground glass cork. This is possible only in the case of tanks with water surfaces above ground level. If the water level is below ground level, a long handle connected scoop can be easily used. In this case, the scoop shall have a minimum of 1,000 ml volume and the above procedure can be done. The electrically operated peristaltic pumps (B) and other hand operated devices (C), (D) are fit only for the final treated sewage samples. In all cases, the discharge end shall be submerged in the sampling bottle and overflow of samples shall be allowed for about 5 seconds.

7.3.5 Sample Volumes, Quantity and Storage of Samples

1 to 2 litres of grab sample would be enough to perform all the tests and repeat some tests if required. For composite samples, a total quantity of 1 to 2 litres collected over a 24 hour period is adequate, Fractional sample at intervals of 1, 2 to 3 hours should be collected in suitable containers, each sample being well mixed and a measured portion proportional to the flow transferred by means of a pipette, measuring cylinder or flask and integrated to form a 1 to 2 litre sample. Hourly records of flow normally available with the Plant Superintendent would facilitate taking representative samples. All samples should be immediately transported to the laboratory for analysis. In case there is any delay in transportation, the preservation time is to be as short as possible and in any case not exceeding 24 hours and the ice shall not be found melted on receipt of the sample.

7.3.6 Selection of Sampling Location

Theoretically there is no end to the number of sampling stations that can be used in a STP. But then, it should be remembered that the best monitoring can be possible only when the barest minimum and objectively oriented sampling locations and tests are carried out instead of accumulating all and sundry data that will only confuse the situation. This is because the sewage passes through the STP on a time deferred scale and if samples are taken all at the same time from inlet to outfall, the chances are it is not representative of the true performance. A suggested set of sampling points is shown below.

a. Raw sewage samples should be collected after screens or grit chambers.

b. Samples of effluent from primary clarifier or secondary clarifier tanks should be taken from the effluent trough or pipe or ahead of discharge weirs.

c. Influent to top feed media units should be collected below the distribution arm and the effluent from the filter from the outlet chamber or at the inlet to secondary sedimentation tank.

d. A point where there is good mixing should be selected for sampling of mixed liquor in aeration tanks in the activated sludge process.

e. Influent samples of septic tanks, Imhoff tanks, and other sole treatment units such as waste stabilization ponds, oxidation ditches and aerated lagoons should he collected ahead of these tanks in their inlet chambers or channels leading to these units. Effluent samples should be collected outside the units in receiving weirs or channels or chambers.

f. Sampling within these tanks should be specified in terms of depth or distance or both.

g. Samples of raw sludge should be taken from sludge sumps or from the delivery side of the sludge pumps through sampling cocks.

h. Return sludge sample in activated sludge plant is collected at the point of discharge into primary units or aeration tank.

i. Samples from mixed primary and secondary sludge should be collected at the point of delivery to the digester.

j. Digested sludge samples may be drawn from the sampling points in the digester or from the discharge end of the delivery pipe leading to drying beds.

k. Digester supernatant may be drawn from sampling cocks provided for this purpose or through sampling wells on digester dome.

The flow chart indicating the various treatment units and the sampling points may be exhibited prominently in the laboratory. A list of tests to be carried out daily on the samples may also be displayed as a wall chart.

7.4 RELEVANCE OF PARAMETERS

In general, the parameters can be classified as broadly into statutory need and plant control need. The plant control needs are mainly to understand whether the STP is responding as per the design and to inform whether corrective measures are needed. Two separate records shall be kept; one for public consumption in respect of statutory discharge standards and the other for in-house plant control. These parameters are not for public consumption as they will be continually changing and the public may not be able to comprehend its nuances. For SBR MBBR, tests are Table 7.2,Table 7.3 and Table 7.4 apply.

7.5 ANALYSIS PARAMETERS AND FREQUENCY (LIQUID AND SLUDGE)

7.5.1 Items and Frequency for ASP

For day to day plant control, various sundry data need not be accumulated. Recommended tests to be carried out in typical STPs on a daily, weekly, and monthly to biannual basis are shown in Table 7.2, Table 7.3, and Table 7.4, respectively.

Table 7.2 Recommended plant control tests on a daily basis in a typical STP

No.	Tests	Raw sewage	Primary clarifier outlet	Aeration tank	Secondary clarifier outlet	Outfall	Primary sludge	Return sludge	Thickener underflow	Digested sludge	Sludge cake
1.	Temperature	●	●	●	●	●		●		●	
2.	pH	●	●	●	●	●	●	●	●	●	
3.	Alkalinity	●	●		●			●		●	
4.	BOD (Total)	●	●		●	●					
5.	COD (Total)	●	●		●	●					
6.	TSS	●	●		●	●					
7.	VSS	●	●		●	●					
8.	Residual Chlorine					●					
9.	Moisture Content						●	●	●	●	●
10.	MLSS			●							
11.	MLVSS			●							
12.	DO			●	●						
13.	SV_{30}			●							
14.	SVI			●							
15.	Ammonia, Nessler	●		●		●					
16.	Ortho P, Nessler	●		●		●					
17.	Sulphide	●				●					

Table 7.3 Recommended plant control tests on a weekly basis in a typical STP

No.	Tests	Raw sewage	Primary clarifier outlet	Aeration tank	Secondary clarifier outlet	Outfall	Primary sludge	Return sludge	Thickener underflow	Digested sludge	Sludge cake
1.	BOD (Filtered)	●				●					
2.	COD (Filtered)	●				●					
3.	Microscopy*			●							
4.	Faecal Coliform					●					
5.	Total Coliform					●					
6.	Oil and grease	●				●					●
7.	Total residual chlorine					●					
8.	Ammonical Nitrogen	●				●					
9.	Total Kjeldahl Nitrogen	●				●					
10.	Nitrate Nitrogen	●				●					
11.	Free ammonia	●				●					
12.	Dissolved Phosphates (P)	●				●					
13.	Sulphate	●				●					
14.	Chloride	●				●					
15.	Silica	●				●					
16.	Ca	●				●					
17.	Mg	●				●					
18.	TDS	●				●					
19.	Conductivity	●				●					

*Identify the following by microscopy.

Rotifers, Crustaceans, Protozoa, Ciliates, Ciliates, Nocardia, Ceronthirix, Nematodes

Table 7.4 Recommended plant control tests on a monthly to biannual basis in a typical STP

No.	Tests	Raw sewage	Primary clarifier outlet	Aeration tank	Secondary clarifier outlet	Outfall	Primary sludge	Return sludge	Thickener underflow	Digested sludge	Sludge cake
1.	Mercury (Hg)	●				●					●
2.	Lead (Pb)	●				●					●
3.	Cadmium (Cd)	●				●					●
4.	Hexavalent Chromium (Cr+6)	●				●					●
5.	Total chromium (Cr)	●				●					●
6.	Copper (Cu)	●				●					●
7.	Zinc (Zn)	●				●					●
8.	Nickel (Ni)	●				●					●
9.	Manganese (Mn)	●				●					●
10.	Iron (Fe)	●				●					●
11.	Vanadium (V)	●				●					●
12.	Cyanide (CN)	●				●					●
13.	Fluoride (F)	●				●					●
14.	Phenolic compounds					●					●
15.	Arsenic (As)	●				●					●
16.	Selenium (Se)	●				●					●
17.	Ca					●					
18.	Mg					●					
19.	Na					●					
20.	K					●					
21.	Chloride					●					
22.	SO_4					●					
23.	Alkalinity					●					
24.	CO_2					●					
25.	HCO_3					●					
26.	Bio-assay test	●				●					●
27.	Radioactive materials:	●				●					●
	(a)Alpha emitter	●				●					●
	(b)Beta emitter	●				●					●

Above tables may undergo changes based on the properties of the treatment process used.

In respect of BOD test, a graph of BOD versus COD for the raw, primary treated, secondary treated and outfall sewage should be prepared every week and the daily COD readings used to interpret the BOD values.

7.5.2 Items and Frequency for WSP

In general parameters of testing for diurnal examinations arise only when the treatment process is dependent on solar energy like in the case of ponds. In such cases, the tests will be as follows.

Table 7.5 Recommended plant control tests on a monthly basis in a typical WSP

No.	Parameter	Sample Type [a]	Remarks
1.	Flow	-	Measure both raw sewage and final effluent flows
2.	BOD	C	Unfiltered samples [b]
3.	COD	C	Unfiltered samples [b]
4.	Suspended solids	C	
5.	Ammonia	C	
6.	pH	G	Take two samples, one at 8:00-10:00 h and the other at 14:00-16:00 h
7.	Temperature	G	
8.	Fecal coliforms	G	Take sample between 08:00 and 10:00 h
9.	Total nitrogen	C	Only when effluent being used (or being assessed for use) for crop irrigation. Ca, Mg and Na are required to calculate the sodium absorption ratio [d]
10.	Total phosphorus	C	
11.	Chloride	C	
12.	Electrical conductivity	C	
13.	Ca, Mg, Na	C	
14.	Boron	C	
15.	Helminth eggs [c]	C	
16.	Dissolved Oxygen	-	At dawn and dusk

[a] C=24-hour flow-weighted composite sample; G=grab sample.

[b] Also on filtered samples if the discharge requirements are so expressed.

[c] *Ascaris lumbricoides*, *Trichuris trichiura*, *Ancylostoma duodenale* and *Necator americanus*.

[d] $SAR=(0.044Na)/[0.5(0.050Ca+0.082Mg)]^{0.5}$ where Na, Ca and Mg are the concentrations in mg/L.

Source: Duncan Mara, 1997

Care, safety and wisdom are paramount in taking samples from ponds especially diurnal samples as chances of vermin and reptiles straying around in wet climates and high summer cannot be ruled out. Proper clothing, safety wear, etc., and the presence of a qualified ambulance person with tool kit is mandatory in the diurnal sampling. A better way of managing this will be to leave a floating or other pump set erected in the daytime and operate it by remote switch in the night and collect the sample from the outlet hose of the pump set sufficiently far away at a well lighted and safe and secure location.

7.6 MICROBIOLOGY SAMPLING AND TESTING OF TREATED SEWAGE

7.6.1 Need for Microbiological Testing

Many water borne pathogenic organisms which can cause diseases as in Table 7.6 and can even cause an epidemic, are transmitted through the water route when infected with sewage which is not fully treated. This is because these organisms enter the water from the faeces of individuals suffering from these diseases or carriers of these organisms even after they are supposed to be fully cured.

Table 7.6 Diseases attributable to sewage pollution of drinking water

No	Diseases	Causative Organism	Source of Organisms	Symptoms
1	Gastroenteritis	Salmonella	Animal or Human faeces	Diarrhoea, Vomiting
2	Typhoid	Salmonella typhosa	Human faeces	Inflamed Intestine, Enlarged Spleen, Step ladder temperature

No	Diseases	Causative Organism	Source of Organisms	Symptoms
3	Dysentery	Shigella species	Human faeces	Diarrhoea
4	Cholera	Vibrio cholera	Human faeces	Sever Diarrhoea, Dehydration
5	Infectious hepatitis	Virus	Human faeces, Shell fish	Yellowed Skin, Abdominal Pain
6	Amoebic dysentery	Entamoeba histolitca	Human faeces	Diarrhoea, Dysentery
7	Giardiasis	Giardia lambia	Animal or Human faeces	Diarrhoea, Cramps, Nausea, Weakness

It is both difficult and time consuming to check the treated sewage for each of these organisms. A sterile laboratory system is required, which is admittedly not easy in many parts of India especially outside the metro cuties. Extensive research has shown that if the coliform group of bacteria is present, there is a probability that one or more pathogens may also be present. Therefore, coliforms have been chosen to be the bacterial group routinely tested when there is need or assessing the bacteriological safety of water. Presence of any of the coliform group of bacteria (total coliforms) indicates general contamination, while the presence of faecal coliforms indicates contamination of human or animal origin. These can be differentiated from other coliforms by incubating on selective media at 44.5°C.

7.6.2 Testing Method

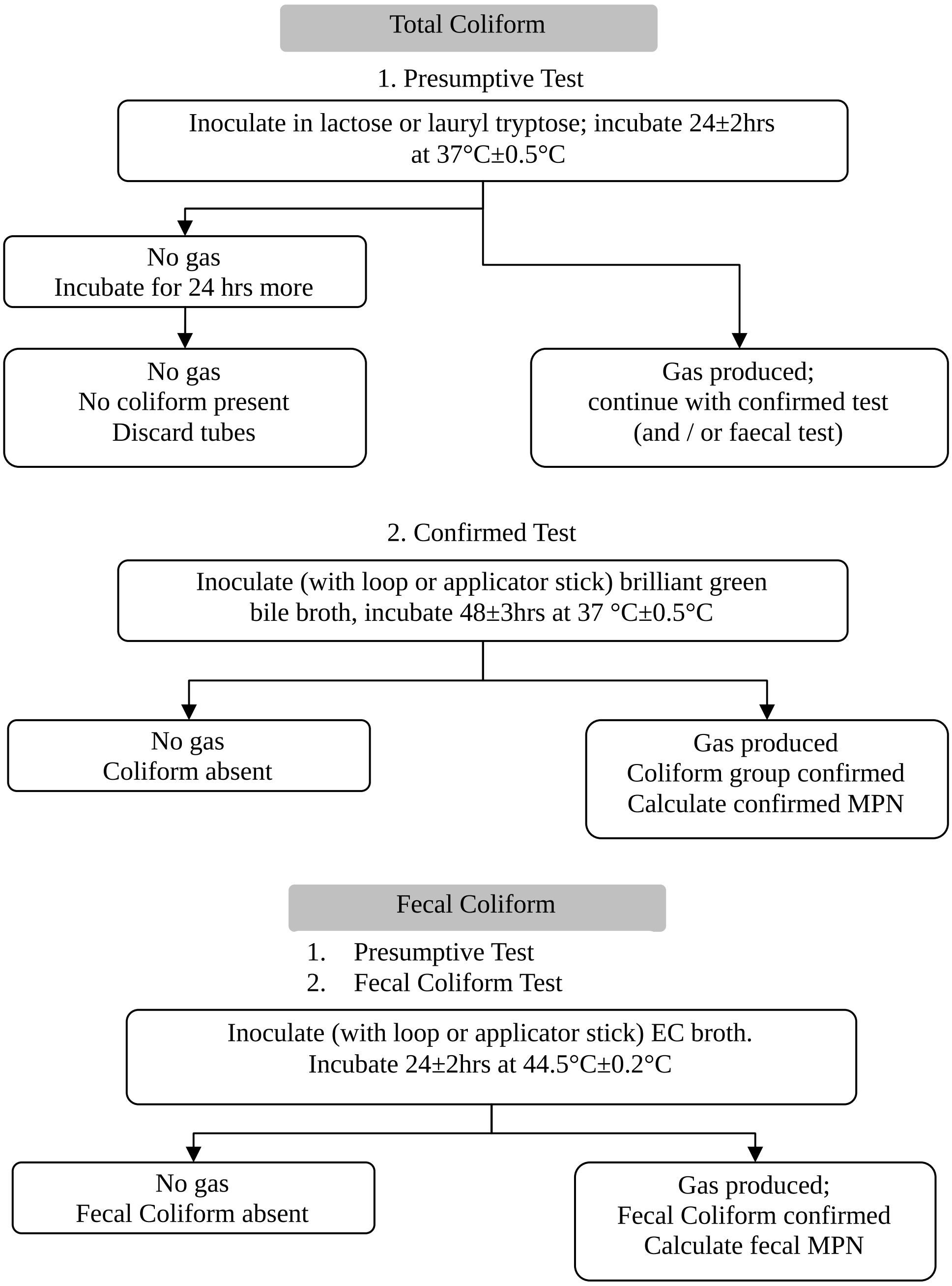
7.6.2.1 Multiple Tube Fermentation Method

7.6.2.1.1 Total Coliform Test

The oldest test is the multiple tube fermentation test. In this test, three sequential steps are performed as presumptive, confirmed and completed tests. A moderately selective lactose broth medium (Lactose Lauryl Tryptose Broth), containing a Durham tube is firstly used in the presumptive test to encourage the recovery and growth of potentially stressed coliforms in the sample. If harsher selective conditions are used, a deceptively low count may result. A tube containing both growth and gas is recorded as a positive result. It is possible for non-coliforms (Clostridium or Bacillus) to cause false positives in this medium, and therefore, all positive tubes are then inoculated into a more selective medium (Brilliant Green Lactose Broth or EC Broth) to begin the confirmed test. The confirmed test medium effectively eliminates all organisms except true coliforms or faecal coliforms, depending on the medium and incubation conditions. If a positive result is recorded in these tubes, the completed test is begun by first streaking a loopful of the highest dilution tube which gave a positive result onto highly selective Eosin Methylene Blue (EMB) agar. After incubation, subsequent colonies are evaluated for typical coliform reactions. A schematic illustration is presented in Figure 7.2. Sample of the tubes tested being either yielding gas or otherwise are shown in Figure 7.3.

7.6.2.1.2 Fecal Coliform Test

This test more reliably indicates the potential presence of pathogenic organisms than do tests for total coliform group of organisms. After presumptive test, which is the same as for the total coliform test, test the sample with water bath set at 44.5°C±0.2°C in EC broth media. A schematic illustration is presented in Figure 7.2.



Source: EPA, 2008

Figure 7.2 The Progress of the multiple tube testing for coliforms

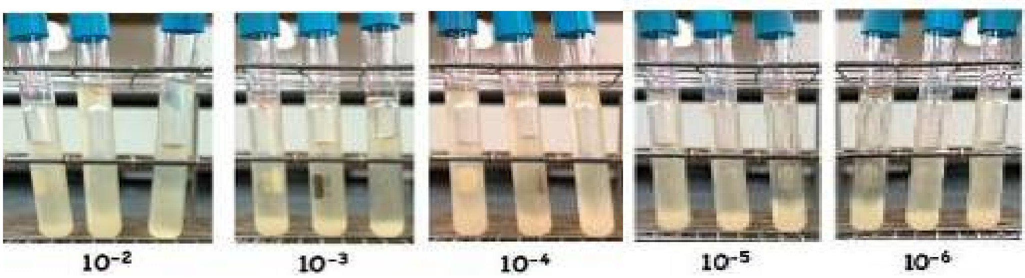
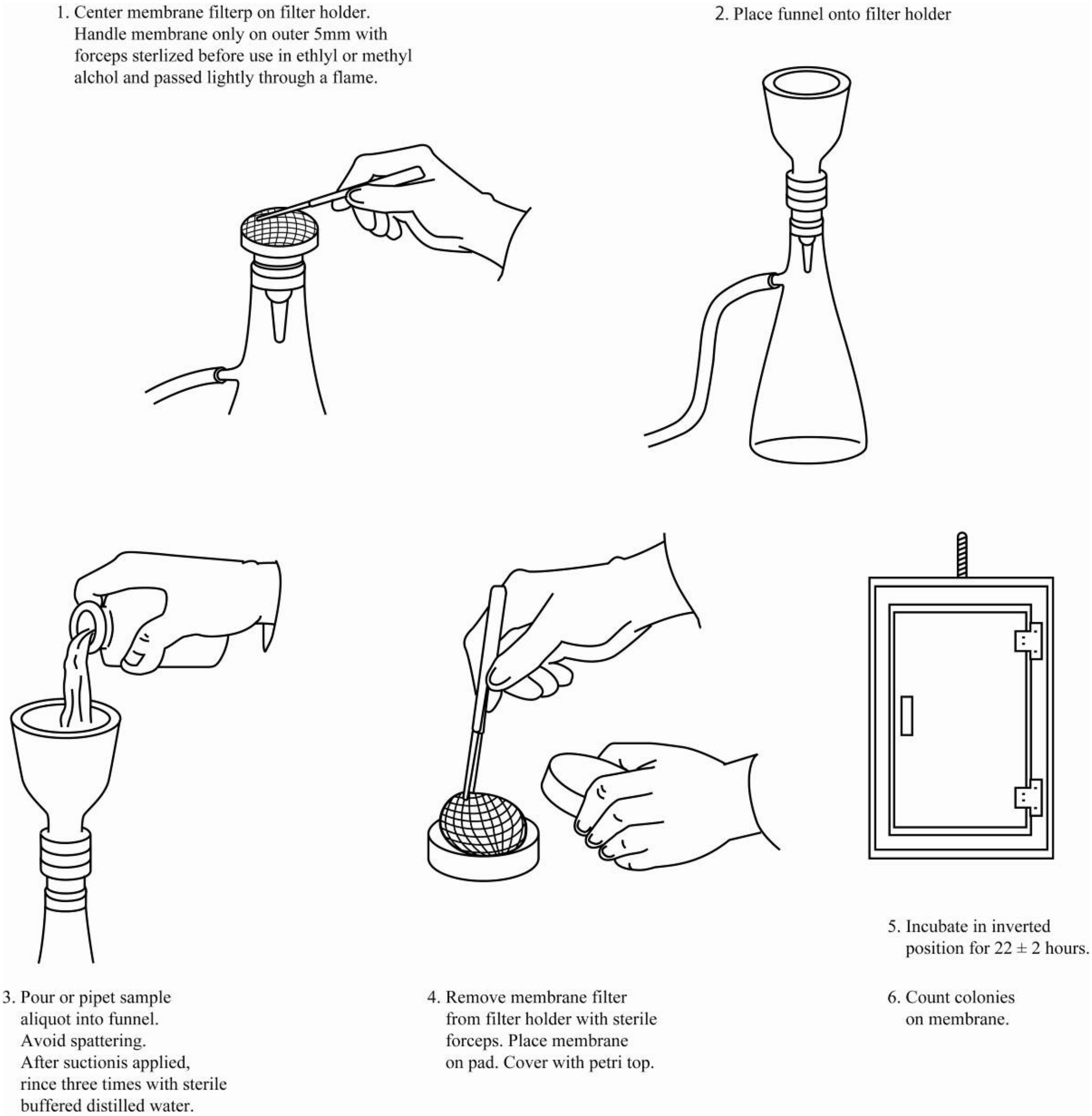


Figure 7.3 The fermentation as seen from the gas in the inverted vials inside the tubes

Based on the dilutions used, the number of tubes adopted and the identified number of tubes with gasification, a statistical formulation is made out called the Most Probable Number (MPN) in 100 ml of sample. It should be noted that a confirmed test may require anywhere up to 72 hours.

7.6.2.2 Membrane Filter Test

In this procedure, a given size sample, generally 100 millilitres, is filtered through a membrane, small-pore filter, which is then incubated in contact with a selective culture agar at 37°C. A coliform bacteria colony will develop at each point on the membrane where a viable coliform was left on the membrane during filtration. After the incubation period of 24 hours, the number of colonies per plate is counted. They represent the actual number of coliforms that were present in the volume of samples filtered. The procedure is illustrated in Figure 7.4. The incubated plates may appear as in Figure 7.5.



Source: EPA, 2008

Figure 7.4 The progress of the filter technique for coliforms

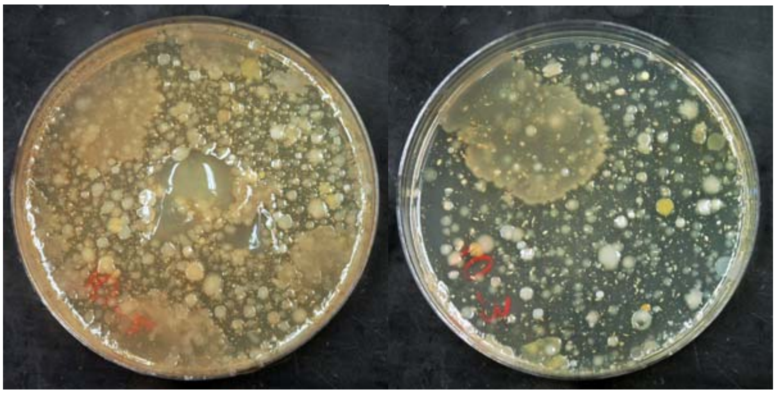


Figure 7.5 Illustrative appearance of cultured plates showing the growth of colonies

The number of colonies in a dish can be counted using a colony counter which can be manual or automatic counter or hand held digital type as shown in Figure 7.6.

Figure 7.6 Colony counters: automatic integrating pen type and grid plate for manual use

7.6.2.3 Colilert Test

Recently, it has been reported upon the Colilert technique which is relatively new and is a method has been accepted by the U.S. EPA for coliform testing. This is a presence/absence test and it does not indicate the extent of contamination. But it is reported as having been proven to be just as accurate as the membrane filtration method. In this method, the Colilert reagent contains a formulation of salts, nitrogen, and carbon sources that are specific to total coliform. It contains specific indicator nutrients that create a yellow colour when total coliforms are present and fluorescence when E. coil is present. The reagent is added to a 100-milliliter water sample in a sterile, non-fluorescent borosilicate glass container. The vessel is capped and shaken vigorously by repeated inversion to aid in mixing of the reagent. It is incubated at 35°C for 24 hours. After 24 hours, the technician compares the reaction vessels to the colour in a comparator supplied with the test kit. If the inoculated reagent has a yellow colour equal to or greater than the comparator, the presence of total coliform bacteria is confirmed. The sequence of testing is illustrated in Figure 7.7.

A rapid 7-hour faecal coliform (FC) test for the detection of FC in water has been developed. This membrane filter test utilizes a lightly buffered lactose-based medium (m-7-hour FC medium) combined with a sensitive pH indicator system. The 7-hour FC test was found to be suitable for the examination of surface waters and unchlorinated sewage and could serve as an emergency test for detection of sewage or faecal contamination of potable water. It is particularly useful for rapid detection of recreational water quality changes related to storm water runoff, sanitary waste spills or bypasses, and for effluent monitoring for treatment malfunction.

7.6.2.4 Recommended Testing for Treated Sewage

Whatever be the advancements occurring elsewhere in the world, while recommending a specific testing procedure for Indian situation, the following must be considered:

a. The fact that maintaining a sterile microbiological laboratory in a STP is still a far cry for many local urban bodies once it migrates outside the metropolitan cities.

b. The testing skills are specialty oriented and employing such microbiologists for full time by these local urban bodies will be impractical especially as such personnel will not have promotional avenues as compared to their employment in many R&D institutions.

c. These tests are not mandatory testing on a daily basis and can be carried out once a fortnight by the staff of the metropolitan laboratories by collecting and preserving the samples in suitable ice boxes for transiting overnight to their laboratories.

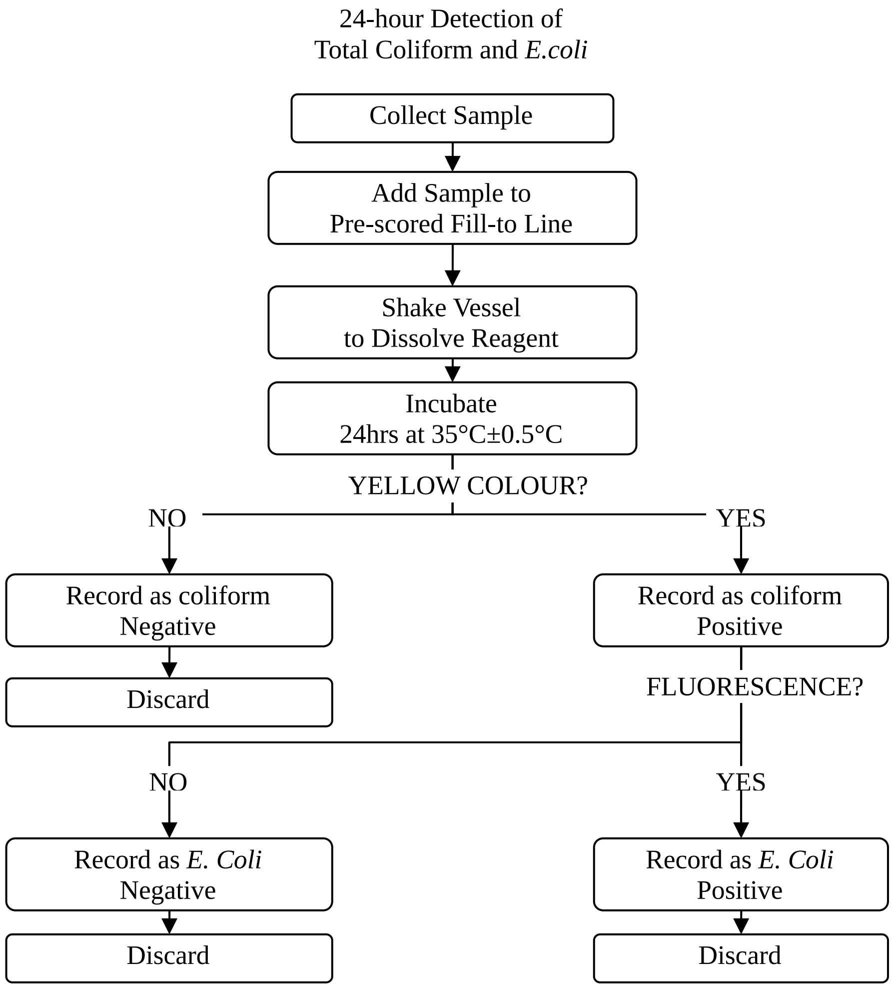


Figure 7.7 The progress of the Colilert technique for coliforms

Considering all the above points, the multiple tube method of MPN / 100 ml should be continued for some more time for total coliforms and faecal coliforms. The tests can be cross verified by plate count if felt necessary. The sampling procedures and analytical procedures shall be according to the Standard Methods (or) as in force by the concerned State Public Health Authority, as the case may be.

7.7 QUICK AND APPROXIMATE MEASUREMENT METHODS

7.7.1 Test Paper Method

Tests which can be done with this method are pH and sulphide. These are mainly qualitative and are of only incidental value.

7.7.2 Detector Tube Method (Transparency Tube, BOD Tube (UK))

Refer to Chapter 4 (4.7.4.1 “Process Control”, Figure 4.13).

7.7.3 Cylinder Test

(Including simplified colorimetric determination and simplified absorption spectrophotometry)

The colorimetric tests depend on the two hypotheses namely, the Beer’s law and Lambert’s law which in simple terms correlate the concentration of a solute in a solvent to the absorbance of monochromatic light when passed through the solution and the path length through which such a passage has taken place. This is the principle behind estimations using a calorimeter or spectrophotometer. There is also a possibility that these can be estimated by using Nessler tubes in the laboratory without depending on these electrically operated meters. Standard solutions are prepared with known concentrations of the solutes and these are stored in tightly corked Nessler tubes of 50 ml. When a new sample is to be tested, it is put through the sample preparation and thereafter is compared by looking down through a Nessler tube filled with the prepared sample and comparing with already prepared reference tubes. Thus, an idea of the concentration is obtained. This test is very useful on a day to day basis.

The presence of DO in aeration tank requires the elaborate procedure of using a meter operated electronically and keeping the probes well cleaned at all times. This is not always possible. Moreover, typical plant control requires an answer to the question of whether residual DO is present or absent in the secondary clarifier overflow. This can be easily carried out in the field as follows:

a. Take a 10 ml well washed test tube.

b. Hold it gently against the weir overflow sideways.

c. Allow the sewage to fill the tube and overflow for a few minutes.

d. Gently take the tube and pour out about 2 ml.

e. Add few drops of manganous sulphate solution.

f. Add a few drops of potassium iodide solution.

g. Close the top with the thumb and invert a few times.

h. Allow to stand for a few minutes.

i. If there is a yellow precipitate, DO is present.

j. If there is a white precipitate, there is no DO.

7.8 DATA ANALYSIS (ACCURACY AND PRECISION)

All analyses carried out should be properly recorded. Routine daily analysis, periodic analysis and special analysis should be recorded separately. Copies of these reports should be sent to the Plant Superintendent immediately after the analysis is done with explanatory notes to indicate any unsatisfactory conditions or abnormalities. The Superintendent should study the reports and direct the operating staff for proper corrective measures in the operation schedule. Such measures taken should be reported to the laboratory scientists who should check the efficiency of corrective measures by re-sampling and analysis. Corrective measures followed by sampling and analysis should be repeated till such time as satisfactory results are obtained.

Data collected over a period of time on various parameters of plant control should be analyzed and represented on charts and graphs and displayed in the laboratory for ready reference by the supervisory staff and visitors. These should be included in the weekly, monthly and annual reports of the laboratory.

7.8.1 Processing Water Quality Test Data

The analysis of results must be done judiciously. One should not jump to conclusions. Logic of the results should be first verified instead of blindly taking it for granted. Some of the fundamentals to be followed are listed below:

a. The outlet BOD of any unit cannot be higher than the outlet BOD of the upstream unit.

b. The ammonia of final treated sewage cannot be the same or higher than that in raw sewage.

c. The ortho P of final treated sewage cannot be the same or higher than that in raw sewage.

d. The SS of final treated sewage cannot be higher than that of raw sewage.

e. Rotifers, Crustaceans, Protozoans cannot be absent if BOD reduction is at least 75 %.

f. Follow the final BOD and SS on a graph which will show any sudden lapses.

g. Once a while refer the sample discretely to another lab to keep a check on the results.

h. Whenever visiting the STP, verify DO qualitatively by the Winkler method.

i. Whenever in the STP, take time to see through the oil immersion microscope for motility.

j. It is most important that you do not hold analysts alone responsible for plant failures.

7.8.2 Accuracy of Measured Values

a. If ammonia is reported as nitrified, bicarbonate alkalinity must be reduced 7 times.

b. If this is not the case, carry out a repeat test before deriving conclusions.

c. Make out an “audit” for BOD removed versus kWh spent on aeration system.

d. Hypothetical ionic equilibrium may not tally in all the lab results.

e. This may be a genuine case as precise chloride estimation is very difficult.

f. In such case, it is better to adjust the chloride value to bring the ionic equilibrium.

g. The COD reduction in treated sewage versus raw sewage cannot be less than BOD reduction.

h. If this is the case, the results are suspect.

With the availability of personal computers and software at reasonable cost, the advantages of electronic data processing for storage, retrieval and processing of laboratory test results are obvious. To start with, the analysis results may be entered from the daily records into computer storage. Simple programme can be written tot retrieval and presentation of data relating to any particular parameter. This can be in the form of display of data for a fixed period or weekly or monthly averages or the results of analysis carried out on samples collected at a particular time of the day for the period to be studied etc. A slightly more detailed programming can be prepared for the computer to go through the results of specified parameters entered daily and display or print out any figures which exceed a present value. This can be immediately passed onto the treatment plant staff for investigation and rectification. The computer can also be programmed to display and print out graphs showing the variation in any specified parameters over a period of time.

Analytical instruments are also available for carrying out tests automatically on a large number of samples simultaneously and electronically feed the data directly into the computer using a data logger module.

7.9 FREQUENCY MANAGEMENT

Laboratory results must stop at the Plant Incharge level and should not go all the way to the official in charge of the total O&M of the sewerage infrastructure in the head office on a daily basis . This will only set in motion a parallel organization in detecting reporting matters and replying to higher ups and the staff will lose interest. On the other hand, a fortnightly concise physical reporting illustrating any specific changes in raw sewage or treated sewage and suggesting ways and means and asking for specific funds / assistance alone should be sent to the official in charge of the total O&M of the sewerage infrastructure in the head office.

7.10 PLANNING OF LABORATORY FACILITIES

This is being explained in detail in Part A manual section 5.5.5 and also Appendix 5.9, 5.10 and 5.11.

7.11 UPKEEP OF PLANT LABORATORY

A well designed and adequately equipped laboratory under a competent analyst is essential in all sewage treatment plants. Very small size plants such as stabilization ponds need not have their own laboratories if the facilities of a nearby laboratory are available. The results of the laboratory analysis will aid in the characterization of any wastewater, pinpoint difficulties in the operation and indicate improvement measures, evaluate the composition of effluents and thus estimate the efficiency of operation and also measure the probable pollution effects of the discharge of such effluents on the receiving water bodies. The analytical data accumulated ever a period to time is an important document for safeguarding the treatment plant from allegations of faulty operation. The laboratory should also engage in research and special studies for evolving improvements and innovations in plant operation. The laboratory therefore must form an integral part of the treatment plant.

7.12 DISPOSAL OF LABORATORY WASTES

Any office or other place where a number of people work, requires a proper waste disposal system. In the case of a laboratory in a sewage treatment plant, special care has to be taken since the laboratory handles harmful chemicals and the samples themselves are capable for transmitting pathogens.

7.12.1 Solid Waste

Solid waste may include filter residues, used cotton plugs, etc. These should be collected and disposed scientifically in an eco-friendly way.

7.12.2 Liquid Wastes

Since the laboratory is attached to a sewage treatment plant, it will be possible in most cases to drain the laboratory wastes to the inlet chamber of the treatment plant, if necessary, by pumping.

However, since the laboratory wastes may also contain concentrated acids and alkalis, it may be necessary to provide a small holding tank where the concentrated chemicals will be diluted and neutralized to avoid the possibility of affecting the biological activity of the treatment plant.

7.12.3 Radioactive Wastes

If radioactive materials are suspected to be present in the waste samples, special precautions will have to be taken to protect the laboratory staff. Advice on this aspect may be obtained from the Atomic Energy Department.

7.13 PERSONNEL

Laboratories of large plants should be under the charge of a qualified and experienced analyst supported by junior technical staff having background in the field of chemistry, biology and bacteriology. The analyst should assimilate the details for functioning of the plants by experience and acquire the necessary preparedness for receiving further specialised training including performance interpretation and application of advanced techniques which enable the analyst to participate in the efficient operation of the treatment unit.

7.14 SUMMARY

Water quality analysis in STPs provides useful parameters for judging appropriateness of process control and quality of the treated water. Water quality analysts should have thorough understanding of analysis items and frequencies prescribed for their own STPs and provide the results of analysis to the O&M engineers.

CHAPTER 8 ENVIRONMENTAL CONSERVATION

8.1 INTRODUCTION

A sewerage system including both offsite and onsite treatment is an infrastructure which contributes to the improvement and conservation of the environment by reducing pollutants discharged to the water environment. A sewerage system is considered to have overall positive effects on environmental conservation. However, on the other hand, since the system handles insanitary objects, physical, mental and aesthetically negative impacts on the surrounding environment through both construction and operation stages are unavoidable.

Therefore, operational measures are required to minimize odour, epidemiological pollution, soil contamination, and water pollution. Plant beautification and landscaping would be also required to maximize the aesthetics.

In addition, since the sewerage system is an essential urban infrastructure which supports urban domestic, industrial and business activities, the operation of the sewerage system is also required to withstand disasters. The concept of the global warming gas regulations is also introduced in this chapter.

8.2 ODOUR

8.2.1 Odour from the Sewerage System

Odours from treatment plants are a complex combination of a wide variety of compounds; however, there are certain compounds and groups of compounds that contribute significantly to sewage odours and also significantly affect the selection of the control technology. These include the following:

- Hydrogen sulphide, and
- Ammonia.

8.2.2 Odour Control Methods and Technologies

8.2.2.1 Odour Control Procedure

Odour control is a complex and time-consuming challenge, often requiring a combination of methods for treating odorous gases and for removing or reducing the potential causes of the doors. If an odour problem is severe enough to affect the community, an emergency response and solution to the problems must be carried out quickly.

The approach for selecting an odour control method or technology includes the following steps:

a. Identify the odour source and characteristics through sampling and analysis.

b. List and assign priorities to controlling a specific odour problem, recognizing considerations such as cost, plant location, future upgrading of various sewage processes, severity of the odour problem, and the nature of the affected area.

c. Select one or more odour control method or technology for implementation to meet the objectives of steps “a” and “b”, taking into consideration the advantages and disadvantages of each.

d. Monitor odour emissions from the treated air for process adjustments and for feedback to evaluate the solution’s effectiveness.

8.2.2.2 Sampling Methods

Solving any odour problem begins with sampling and analyzing gases to identify and characterize the odours. The principal tools for diagnosing an odour problem are the techniques used for odour quantification and characterization. Chemical analysis of odour constituents could be performed. This is an indirect method, because the results of a chemical analysis still need to be related to odour concentration and intensity in some way.

8.2.2.3 Quantitative Testing-Analytical Methods

Gas chromatography can be used on many odorous organic compounds, but the analysis is complex and expensive. Portable gas-monitoring devices are described below;

The concentrations of individual compounds can be measured via standard analytical methods (Figure 8.1). For example, a simple apparatus consisting of a gas detector tube can be used in the field. Tubes are available for a number of compounds. For more accurate and complete results, samples should be collected in bags, stainless steel vacuum canisters, or tubes filled with adsorbent and analyzed by gas chromatography in a laboratory.


Figure 8.1 Gas sampling pump (left) and Detector tubes (right)

Gas detector tubes are sealed glass tubes filled with an appropriate indicator chemical which reacts with a particular gas and gives a colour reaction. To make a determination, the seals are broken at each end of the tube and a definite volume of the atmosphere for sampling is drawn through by a hand-operated or mechanical pump. The tubes are marked off in scale divisions and the concentration is determined according to the length of discolouration of the indicator for a given volume of atmosphere.

Detector tubes are simple, easy to use devices that can provide reasonably reliable, on-the-spot measurement of gas concentrations. Their accuracy may be in the range of 70 to 90% of the mean value if sampling is done carefully according to manufacturers' directions. For taking gas samples from difficult locations, extension tubes are available from manufacturers so that the detector tubes can be placed at the desired site.

In making use of detector tubes some precautions should be noted:

- Tubes will deteriorate with age - some types have a shelf life of two years when stored at room temperature; above 30°C, deterioration is more rapid.
- Direct sunlight can affect the properties of the tubes.
- At low temperatures, around freezing or below, tubes may not give reliable readings; they should be warmed to room temperature for best performance.
- Tubes may have cross-sensitivity to gases other than those for which they are designed. Information on cross-sensitivity should be obtained from the manufacturer.

8.2.3 Hydrogen Sulphide (H_2S)

Hydrogen sulphide (H_2S) is the most common odorous gas found in sewage collection and treatment systems. Its characteristic rotten-egg odour is well known. The gas is corrosive, toxic, and soluble in sewage. Hydrogen sulphide results from the reduction of sulphate by bacteria under anaerobic conditions.

8.2.3.1 Effects on Health

Hydrogen sulphide is considered a broad-spectrum poison, meaning it can poison several different systems in the body. Breathing very high levels of hydrogen sulphide can cause death within just a few breaths. Loss of consciousness can result after fewer than three breaths. Exposure to lower concentrations can result in eye irritation, a sore throat and cough, shortness of breath, and fluid in the lungs. These symptoms usually go away within a few weeks. Long-term, low-level exposure may result in fatigue, loss of appetite, headaches, irritability, poor memory, and dizziness. Refer also to 9.2.2.1.2 “Risk of Hydrogen Sulphide Poisoning in Confined Space” of Chapter 9.

8.2.3.2 Locations of Sources

a. Onsite

Septic tank, anaerobic filters, and mini-package treatment plant

b. Conveyance

Sewers, manholes, and closed drains (simplified sewers)

c. Pumping Station

Collection well

d. STP

Collection well, primary settling tank, sludge thickener, sludge digester, digested sludge sump, dewatering centrate/filtrate, sludge drying beds, UASB reactor, anaerobic lagoons, sludge lagoons, and septage treatment facility

8.2.3.3 Measurement

- Proper measurements should be performed in accordance with IS5182 Part 7.
- Short-term detector tubes, portable gas detector, etc., can be used for simplified measurements.
- When measuring concentration at a location where odour is generated (particularly when the concentration level is not known), take care to perform the work after wearing a gas protection mask. If the concentration is high, toxicity may be high; this is dangerous. Refer to Sec.9.3.1.1.1,a “Measurerement method.”

8.2.3.4 Preventive Measures

Hydrogen sulphide production can be controlled by maintaining conditions that prevent the build up of sulphides in the sewage. The presence of oxygen at concentrations of more than 1.0 mg/l in the sewage prevents sulphide build-up because sulphide produced by anaerobic bacteria is aerobically oxidized. Maintaining an aerobic environment also inhibits the anaerobic degradation process contributing to the generation of hydrogen sulphide. A checklist is given below:

- Prevent corrosion in the collection well of the facility by blowing air through the facility.
- Avoid storing screenings and grit generated in the grit chamber for a long time.

Dispose of screenings and grit at appropriate intervals.

- Retention time of sludge in the sludge treatment facilities should be appropriate. (Do not retain sludge for a long time)
- Maintain sewage at neutral pH range because most of the sulphide is present as odourless bisulphide ion at pH value of 7 to 8.

For septic tank

- Impossible to prevent because we cannot expect fine quality water to be used for ablution. Therefore, it is important to ventilate.

8.2.3.5 Control

The operator can

- Remove sand and grit deposited in house service connection or sewer immediately.
- Properly shut doors and windows of building where substances that become sources of foul odours are stored.
- Dispose of scum and sludge in the sedimentation basin at appropriate intervals and do not store them for a long period.
- Thoroughly clean each facility and the areas surrounding the facility.

Measures for septic tank are as follows:

- Open ventilating shaft at the cowl to the atmosphere and provide mosquito-proof netting. The height of the pipe should extend at least 2 m above the top of the highest building within a radius of 20 m. Refer to IS 2470 Part I and Part A 9.3.5 Conventional Septic Tank.

Operational precautions for deodorisation facilities are described below.

a. Soil (Bio) Deodorisation

This method makes use of oxidation and decomposition effects by micro-organisms to remove substances with foul odour. In actual practice in treatment plants, the ventilated air is led to the reactor or soil bed and the odour is removed.

In this method, substance with foul odour is delivered from the bottom part of the fertile soil bed in highly moist condition, and the substance with foul odour is removed because of the oxidative ability of mainly heterotrophic bacteria.

The following are examples of soil deodorisation (Figure 8.2).

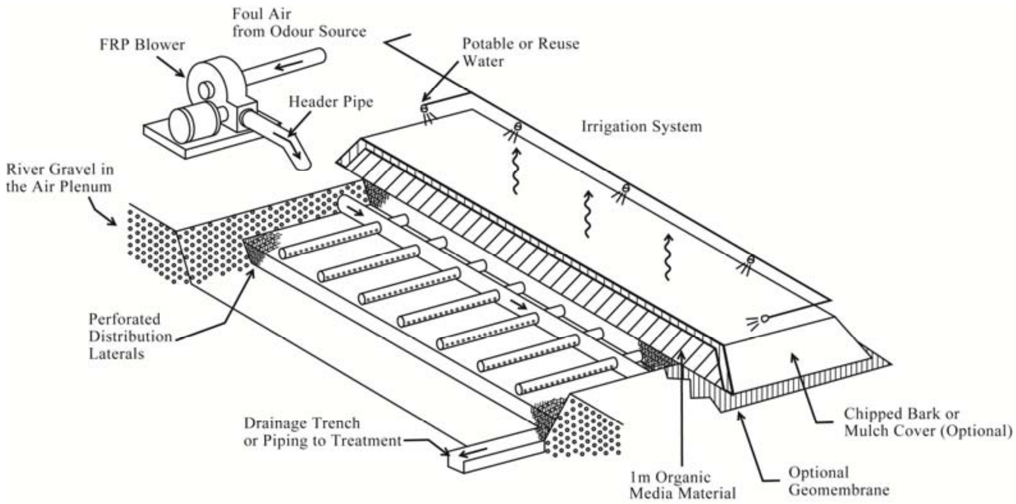


Figure 8.2 Soil (Bio) deodorisation configuration

Notes: Air for ventilation may concentrate in a certain part of the soil. In such cases, hole may have formed on the surface. Dig the soil so that air is vented uniformly.

b. ASP (Activated Sludge Process) - Deodorisation

This method makes use of decomposition effects by micro-organisms to remove substances with foul odour. In actual practice in treatment plants, the ventilated air is led to the reactor and the odour is removed.

Ventilated air is delivered to the inlet side of the blower. The substance with foul odour is oxidized and decomposed by aerobic micro-organisms in the reactor. The mechanism of ASP-deodorisation is illustrated in Figure 8.3.

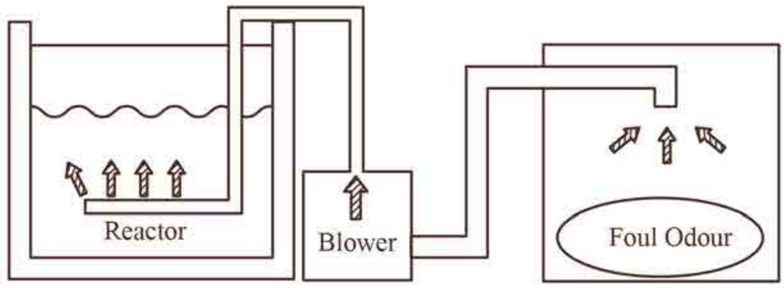


Figure 8.3 Mechanism of ASP-deodorization

Caution: Pipes used underwater are likely to clog easily; so periodically clean such pipes and remove the clogged material.

c. Activated Carbon Deodorisation

Foul odours are passed through the adsorption tower filled with activated carbon (charcoal or coconut shell charcoal) and removed by physical adsorption. (Figure 8.4) The effect is more pronounced when the substance with foul odour has large molecular weight. Odours are selective and the method is more effective in case of hydrogen sulphide and methyl mercaptan. However, it does not have any effect on ammonias and amines. It is suitable for faint odours, and is used as a finishing deodorising agent.

The normal activated carbons are acid, chlorine-based or halogen-attached activated carbons. These are effective in removing substances like hydrogen sulphide and ammonia.

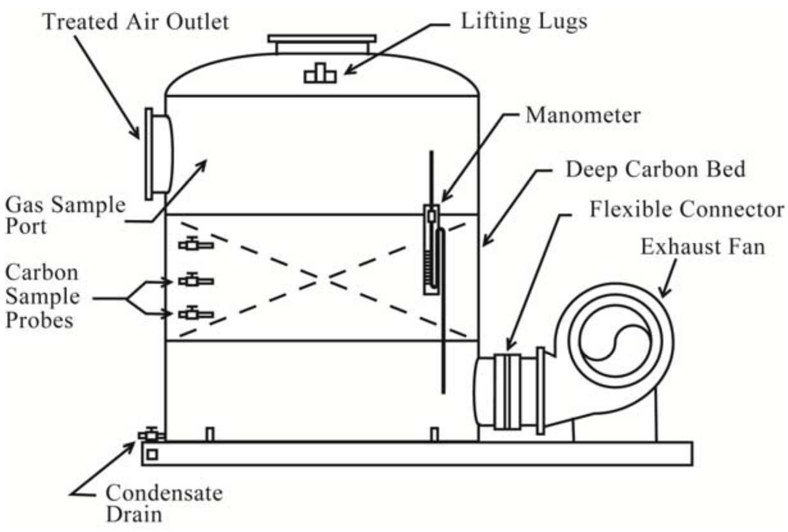


Figure 8.4 Activated-carbon deodorization

A differential pressure gauge is installed between the inlet and outlet of gas in this equipment. When the value indicated by this differential pressure gauge is large, clogging has probably occurred. This is a sign that the activated carbon is to be replaced or the pipe is to be cleaned.

Measure the concentration periodically near the outlet. When the value shows a sudden increase, it is time for replacement. (However, breakdown in the equipment may have occurred; confirm the equipment carefully and then perform work.)

8.2.4 Ammonia (NH_3)

Ammonia odour is most typically encountered at alkaline-stabilization facilities. Adding alkaline materials raises the pH, which causes the dissolved ammonia in dewatered cake to volatilize. Although the odours tend to dissipate quickly, the ammonia levels in mixing and drying areas can be high if the gas is not collected and treated.

8.2.4.1 Effects on Health

Ammonia is a colourless gas with specific irritant odour which when compressed liquefies at room temperature. Effects on the human body include irritation of the mucous membrane and breathing organs.

8.2.4.2 Locations of Sources

Ammonia typically appears in the dewatering processes and in the solids created from dewatering. This is especially true in digested solids. However, the small quantity of ammonia in sewage off gas at neutral pH contributes little to odour emissions, because the odours typically are dominated by sulphur compounds. Therefore, it rarely is necessary to provide an ammonia removal step in treating off gas from liquid sewage treatment processes, unless lime or other alkaline material is used in the process to elevate the pH.

8.2.4.3 Measurement

- Proper measurements should be performed in accordance with IS11255 Part 6.
- Short-term detector tubes, portable gas detector, etc., can be used for simplified measurement.

8.2.4.4 Preventive Measures

In the dewatering process, do not increase the pH.

8.2.4.5 Control

Generally, deodorisation equipment is effective in controlling ammonia, similar to H_2S. However, care is necessary since there is selectivity depending on the substance.

8.2.5 General Method of Prevention of Odour

Following is a short checklist of operational considerations for controlling odours of primary treatment facilities: (May also apply in other facilities)

- Remove scum routinely, with increased frequency during warm weather.
- Remove sludge before it can bubble or float.
- Wash weirs and other points where floatable and slime collect. Some facilities use submerged pipes with holes rather than effluent troughs. The submerged pipes do not splash the primary effluent, thereby reducing the release of hydrogen sulphide.
- Wash down all spills and grease coatings.
- When draining a tank, immediately flush it completely. If sludge does not drain quickly, spray lime, calcium hypochlorite, or potassium permanganate on the sludge surface to reduce odours. Because even a clean tank can produce odours, flushing the tank with a chlorine solution or keeping the tank floor covered with a low concentration of chlorine solution will reduce odours.
- If the sewage is septic, add chemicals in the collection system or at the plant, as appropriate, to reduce sulphides.
- If tanks are covered for odour control, keep plates and access hatches in place.
- Routinely check any odour scrubbers or deodorizers for plugging, adequate supply of chemicals, proper pressures for misting, and/or effectiveness of carbon.
- The splashing of primary effluent into weir troughs and effluent channels can result in the release of hydrogen sulphide. If possible, try to minimize the splashing of primary effluent into the channel or weirs. If it cannot be accomplished operationally, then installing submerged effluent pipes may be necessary. This will require tank modifications to verify the plant hydraulics and provide proper control to avoid fluctuations in the tank levels.
- Minimize the stripping of hydrogen sulphide from the sewage when using channel air diffuser systems.

Adoption of the following regular practices will not only increase removal efficiency, but will provide better working conditions for the operator:

- Regularly remove accumulations from the inlet baffles and effluent weirs with a hose or a broom with stiff bristles. Only experience will determine the necessary frequency.
- Clean scum removal equipment regularly; otherwise obnoxious odours and an unsightly appearance will result.
- Keep cover plates in place except when operations or maintenance require their removal.
- Immediately flush and remove all sewage and sludge spills. Avoid hosing down motors and enclosed control devices.
- Establish a housekeeping schedule for the primary treatment area, including galleries, stairwells, control rooms, and related buildings, and assign responsibility

for each item to a specific employee.

- Repaint surfaces as necessary for surface protection and appearance.

8.2.6 Chemical Addition

Chemical addition can control odours in sewage treatment plant by preventing anaerobic conditions or controlling the release of odorous substances. These chemicals fall into four basic groups based on their mechanisms for odour control, shown in

Table 8.1 to

Table 8.4.

The effectiveness of chemical addition as an odour control technology depends on such variables as cost, dosage, presence of odour-causing compounds, effects of chemical accumulations in sludge and process waters, equipment maintenance, space limitations, and safety or toxic substance concerns. Typical odour-control applications include collection systems, headworks, primary clarifiers, process sidestreams, aeration tanks, solids-handling applications, and storage lagoons. In general, it is more cost-effective to treat odours in the liquid phase than in the vapour phase. Common chemical agents used to control odours include iron salts, hydrogen peroxide, sodium hypochlorite (chlorine), potassium permanganate, nitrates, and ozone.

Table 8.1 Chemicals used for liquid-phase odour control

Chemical	Effective against
Oxidizers	
Ozone	Atmospheric hydrogen sulphide only
Hydrogen peroxide	Hydrogen sulphide, also acts as an oxygen source
Chlorine	Hydrogen sulphide and other reduced sulphur compounds
Sodium and calcium hypochlorite	Hydrogen sulphide and other reduced sulphur compounds
Potassium permanganate	Hydrogen sulphide and other reduced sulphur compounds
Raising the oxidation–reduction potential	
Oxygen	Higher temperatures increase microbial action of anaerobic bacteria and increase the release of volatile organic compounds from the liquid to the gaseous phase.
Nitrate	
Hydrogen peroxide	
Chlorine	
Bactericides	
Chlorine	Kill or inactivate anaerobic bacteria
Hydrogen peroxide	
Potassium permanganate	
Chlorine dioxide	
Sodium hypochlorite	
Oxygen	
pH modifiers	
Lime	Prevent offgassing of hydrogen sulphide; at a very high
Sodium hydroxide	pH acts as a bactericide on sewer wall slimes

Source: WEF, 2008

Table 8.2 Liquid process operational emissions control

Process	Problems	Control measures
Preliminary treatment		
Coarse bar screens	Influent sulphide are stripped by turbulence inherent to these processes.	Upstream chemical addition. Recycle return activated sludge (RAS) to headworks. Containment and ventilation to a vapour-phase control system.
Fine bar screens		

Process	Problems	Control measures
Primary treatment		
Primary clarifiers	Sulphide formed in basins during holding. Sulphide and stripped at weirs. Sulphide forms in settled solids.	Remove unneeded basins from service. Raise water level in flume to decrease weir drop. Pump sludge more often. Avoid cosettling of sludge. Add iron salts directly or upstream. Containment and ventilation to a vapour-phase control system.
Flow equalization basins	Odour from residual solids in flow equalization basins.	Install collection and removal equipment and flush solids with high-pressure hoses after each basin dewatering.
Secondary treatment		
Trickling filters	Influent sulphides stripped at distributors. Sulphide formed when overloaded or oxygen deficient.	Add iron salts upstream. Limit loading. Provide power ventilation. Slow distributors or increase wetting rate to maintain a thin aerobic film.
Rotating biological contactors (RBCs)		
Aeration basins	Influent sulphide stripped at head of basin. Sulphides form when oxygen deficient.	Decrease aeration at head of basin. Fine-bubble diffusers cause less stripping than coarse bubble. Pure oxygen causes lowest odour emissions.

Source: WEF, 2008

Table 8.3 Solids process operational emissions control

Process	Problems	Control measures
Thickening		
Gravity thickeners	Co-thickening biological and primary sludge causes sulphide generation. Long detention under anaerobic conditions is problematic.	Avoid co-thickening, if multiple basins are available. Use direct chemical treatment to reduce sulphide formed during thickening. Provide containment and ventilation to a vapour-phase control system.
Dissolved air flotation	Aeration strips sulphide and odours from sludge.	Use chemical pretreatment to remove sulphide from sludge before processing. Provide containment and ventilation to a vapour-phase control system.
Dewatering		
Belt presses	Pressing strips sulphide from feed sludge into belt press room.	Potassium permanganate or hydrogen peroxide will treat sulphide and other odorous. Provide containment and ventilation to a vapour-phase control system.
Stabilization		
Anaerobic digesters	The H_2S formed in the process corrodes combustion equipment. Air quality is a concern, because H_2S is converted to sulphur dioxide during combustion.	Maintain proper temperature and pH in the process. Add iron salts directly to the digester, at headworks, or at primary clarifiers.
Aerobic digesters	Odorous compounds form when process is overloaded or oxygen-deficient	Provide adequate aeration and mixing to maintain aerobic conditions. Feed at uniform organic loadings.
Lime stabilization	Ammonia is released due to high pH.	Vent ammonia to outside unless concentrations are very high or the site is in a sensitive area.

Source: WEF, 2008

Table 8.4 Summary of odour control technology applications at sewage treatment facilities

Methods	Effects	Problems
Operating practices		
Industrial process changes		—
Lower waste temperature	Hydrogen sulphide evolution much retarded	
Pretreat to remove odorous organics		
Collection system		—
Mechanical cleaning	Hydrogen sulphide reduction	
Aeration		
Ventilation		
Grit chamber		—
Daily grit washing	General odour reduction	
Primary clarifiers		—
Increase frequency of solids and scum removal	General odour reduction	
Aeration tanks		—
Remove solids deposits	General odour reduction	
Increase aeration to maintain dissolved oxygen at 2 mg/L		
Trickling filters		—
Increase recirculation rate	General odour reduction	
Keep vents clear		
Check underdrains for clogging		
Anaerobic digesters		—
Check waste gas burner	General odour reduction	
Relief valves should close tightly		
Aerobic digesters		—
Maintain constant loading	General odour reduction	
Maintain adequate aeration		
Liquid-phase control alternatives—Chemical addition		
Ozone	Oxidizes water-insoluble odorants into water-soluble projects	Requires onsite regeneration
Iron	Controls slime growth; precipitates sulphide; enhances settling	Increases solids
Nitrates	Inhibits production of sulphides	Costly
pH adjustment		—
Alkali: NaOH	pH 8 hinders bacterial growth in sewers and retards evolution of hydrogen sulphide.	—
Acid: HCl or H_2SO_4	Acid combines with basic ammonia and amines	—
Chlorine (gas and hypochlorite)	Inhibits growth of sulphate-reducing bacteria in sewers; oxidizes hydrogen sulphide and ammonia	—
Potassium permanganate	Reacts with sulphide and other organics to reduce odour	—

Source: WEF, 2008

8.2.7 Monitoring

Regular monitoring of treatment processes can prevent many odour releases as well as provide valuable information on operating procedures.

8.3 EPIDEMIOLOGICAL POLLUTION

Potentially pathogenic aerosols are generated as a result of the physical processes of aeration, trickling, and spraying sewage and sludge.

The density of microorganisms in aerosols is a function of the density of a specific organism in the sewage, aeration basin, or sludge, the amount of material aerosolized, the effect of aerosol shock (impact), and, finally, biological decay of the organisms with distance in the downwind direction.

In a sewage treatment plant, there are commonly either stagnant anaerobic conditions or an aerated mass of heated microbial material. With the use of activated sludge as a standard treatment process, the operators walk above and around a cauldron of airborne aerosols. They are often exposed to low-level aerosolized versions of microbes, some of which may be infectious.

8.3.1 Effects on Health

These aerosols may contain bacterial and viral infectious agents, and infections may result from contact with these aerosol mists. It is impossible to eliminate all sources of aerosol contamination in a sewage treatment plant.

The immune systems of many operators build up antibodies to a variety of bacterial and viral infectious agents. They become what are nicknamed “universal carriers” because they are often in contact with low levels of infectious agents that will not make them ill, but that they can build immunity to, much like vaccination theory. However, if operators’ bodies do get run down or they come into contact with a significant infectious agent, they can easily become ill.(Refer to 9.2.1 Diseases)

8.3.2 Locations of Sources

Aeration tanks, Attached growth system (Figure 8.5)

Figure 8.5 Aeration tank (left) and Attached growth system (right)

8.3.3 Measurement

Perform sampling using filter paper. Then, the samples can be collected on a petridish, and grown in the laboratory. These samples can later be tested.

The following are the studies to be carried out in an STP:

The total microorganism content of air immediately over the aeration tank liquid surfaces:

a. Decreases exponentially with height at least within the first 100 cm above the aeration tank liquid surface;

b. Approaches background concentrations by extrapolation of current data within 2.5 to 4 m above the aeration tank liquid surface; and

c. Appears to be influenced by several factors, including the mixed liquor suspended solids concentration of the aeration tanks, bacterial die-off, fallback of larger particles, and dispersion by wind currents.

In view of the above, one should bear in mind that aerosol increases closer to aeration tanks and also increases as one goes downwind.

8.3.4 Preventive Measures

- Cover the aeration tanks and attached growth systems. (To prevent diffusion of aerosols)
- Plant tall trees around tanks to prevent diffusion of aerosols.
- Stop using surface aerators and use diffused aerators.

8.3.5 Control

Controlling epidemic microbes in sewage is difficult. The above mentioned preventive measures are desirable.

8.4 SOIL CONTAMINATION

Soil contamination has become an issue in recent years. A sewerage facility that plays an important role in conserving the environment cannot become a source of contamination itself. Sewage leaks sometimes become issues. To prevent leaks in an STP, the following are necessary:

a. Check for leaks in every facility. (High probability of leaks in pipe parts and connections between facilities.)

b. Even if there are no leaks in the facility, there may be fissures or cracks. If so, immediately repair the same on site. If this is not possible, discuss with the Plant Engineer and make arrangements to get the defects repaired.

c. Sometimes, sewage overflows. In such a case, check whether the flow rate to the facility is greater than the design flow rate.

d. If the flow rate is below the design flow rate, there is a possibility of clogging in the stage after the problem location. The cause of the clogging should be eliminated.

e. Since sludge is thicker than sewage, it is likely to cause clogging in the sludge treatment facilities. For this reason, care should be taken against leaks from the sewage treatment facilities. Efforts should be made to eliminate leaks.

f. If the leak is identified clearly, and soil contamination is likely to occur, discuss with the Plant Engineer to get accurate measurements to be made by an authorized laboratory of the Ministry of Environment and Forest.

g. It is good to maintain a record of the TDS of ground water in the well waters of households surrounding the STP so that questions of sewage seeping into ground water and polluting the well waters can be verified.

8.5 WATER POLLUTION

Surface water quality considerations include compliance with treated effluent standards at the discharge point with respect to parameters like BOD, suspended and floating solids, oil and grease, nutrients, coliforms, etc. Special consideration may be given to the presence of public bathing ghats and intake points for water supply downstream.

Another environmental consideration is the potential for ground water pollution presented by the treatment units proposed to be built.

Necessary precautions should be taken to prevent water supply contamination due to leakage from sewers. Appropriate distance between water supply pipes and sewer pipes shall be maintained. On the other hand, early detection of sewage leakage and the repair is indispensable by implementing sewer inspections described in 2.2 “Inspection and examination for sewer” of this manual.

8.6 SEWAGE TREATMENT PLANT BEAUTIFICATION AND LANDSCAPING

A sewage treatment plant is a facility that handles sewage. The working environment in such a plant is poor since foul odours are generated. It is therefore essential that a clean environment be maintained within the sewage treatment plant through daily cleaning of the plant. Within the boundaries of the premises, open areas should be planted with trees and foul odours should be dispersed.

Specific measures should preferably be adopted such as providing park-like spaces within the premises to offer residents a place for relaxation and rest. The treated effluent should be reused for watering plants and trees within the premises.

Examples of plant beautification are shown in the figures below. Landscape should be maintained in this way (Figure 8.6).

Source: BWSS Board

Figure 8.6 An example of plant beautification adopted in Bangalore

8.7 REGULATION OF GREENHOUSE GAS

8.7.1 Greenhouse Gas

Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and “greenhouse gases” such as Freon are released in large quantities to the atmosphere with the increasingly energetic activities of human beings, and the average temperature of the entire earth has increased. This phenomenon is known as global warming. Global warming of the earth has a serious impact on the global environment.

Carbon dioxide (CO_2) emissions and methane (CH_4) generated are issues in STP operation.

a. Carbon Dioxide (CO_2)

Carbon dioxide is formed from the complete combustion of any fuel that contains carbon (e.g., methane). Any boiler, flare, or power-generation technology that combusts methane, will produce a corresponding predictable amount of carbon dioxide.

b. Methane (CH_4)

Methane is the principal component of both digester gas and natural gas. It is a light gas with a specific gravity of less than 1.0. Methane is an exceptionally important greenhouse gas; its global warming potential is 21 to 23 times that of carbon dioxide. From a greenhouse gas perspective, it is vital to completely burn all methane without atmospheric release.

8.7.2 Control

a. Reduction in the use of fossil fuels (fossil fuels are used even for generating electric power; so use of power is linked to the use of fossil fuels)

Fuel for operating the sewerage facilities and reduced use of electricity are essential. (For instance, change from continuous operation to intermittent operation, if possible)

b. Measures against generation of CH_4 from the treatment plant (since generation of this gas cannot be inhibited, conversion of the generated gas may be considered)

Since the generation of CH_4 is linked to global warming, checks on the CH_4 collection facility and leaks in piping are very important.

If there is damage or signs of damage, repairs should be carried out quickly.

8.7.3 Effective Use of Biogas

Biogas includes organic matter made of carbon, hydrogen, sulphur, and so on, and is a potential energy source of high value.

Presently, the main uses are as follows.

- Used in dual fuel engines. A part of the power requirements of a sewage treatment plant can be satisfied by generating power using biogas explained in clause 6.5.15.3 and its sub clauses in Part A.

8.8 CARBON CREDIT RECORD

This is a term that qualifies the holder to emit one ton of carbon dioxide into the atmosphere and is awarded to institutions or countries that have reduced their greenhouse gases below their emission quota, which literally means emission standards. These carbon credits can be traded in the international market at their current market price.

For details, refer to Sec. 5.15 CARBON CREDIT of Part A (Manual).

In sewage treatment plants to meet the requirements, the following are to be mainly performed:

- An example of the Clean Development Mechanism (CDM) project in sewerage facilities is biomass power generation. This project focuses on CH_4 generated from the facilities.
- For the project, the baseline CO_2 emissions must be studied. Based on this study, the CO_2 emissions in the base year and the reduction in CO_2 emissions thereafter are considered for approval of carbon credits.
- Accurate data during operation is required for specifying the baseline.
- Data collection and retention of accuracy of measuring instruments are the necessary items on site.

- STP power and flow rate data are mainly collected through SCADA. (Refer to Sec.6.6 "SCADA system")
- Even after the project is approved, data collection and maintenance of measuring equipment will continue.

8.9 SUMMARY

STPs are intended primarily for improvement of water environment. They should be operated properly while preventing water pollution and odour problems. . In addition to prevention of air pollution and soil contamination, planting or landscaping is also required to improve surrounding environment.

CHAPTER 9 OCCUPATIONAL HEALTH HAZARDS AND SAFETY MEASURES

9.1 INTRODUCTION

The sanitation workers, who are engaged in operation and maintenance of sewerage system or septic tanks, are exposed to different types of occupational hazards like injuries caused by physical actions and chemicals contacts, infections caused by pathogenic organisms in sewage and dangers inherent with oxygen deficiency, hydrogen sulphide, and combustible gases.

The Parliament of India is considering "Sanitation Workers (Regulation of employment and conditions of service) Bill, 2012." This bill will be helpful in eliminating the risk to the health and safety of sanitation workers.

As defined in the said bill, employers are obligated to provide their employees with safety equipment or protective gears (See 9.3.1.2 for details) as well as cleaning devices and ensure observance of safety precautions appropriate for each hazardous condition to reduce the employees' risks to health and safety. Moreover to guard against human error and carelessness, proper safety training and adequate effective supervision by safety personnel are most essential.

Although the Government of India enacted the "Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act, 1993", which declared the employment of scavengers or the construction of dry latrines to be an offence, considering these, a new bill titled "The Prohibition of Employment as Manual Scavengers and their Rehabilitation Bill, 2012" was prepared and introduced in the Parliament in September 2012. The Bill aims to eliminate manual scavenging and insanitary latrine, and also provide for proper rehabilitation of manual scavengers in alternative occupations so that they are able to lead a life of dignity.

In addition to the Acts mentioned above, employees shall follow to "Contract Labour Regulation and Abolition Act, 1970" for secure operational health and safety at their sites.

Operation and maintenance of sewerage facilities, which should not be discontinued at any moment, requires health and safety consciousness equal to or greater than one that is needed for construction projects.

In India, "health and safety policy" is defined in construction project management by Bureau of Indian Standard (BIS) (Refer to Appendix 9.1).

Therefore, the same health and safety policy for construction projects may be also adopted for operation and maintenance of sewerage facilities.

STPs and PSs are subject to safety audits which confirm the status of safety and health organizational setup, education / training, provision / inspection of personal protection, and records of safety, to ensure occupational safety and health at the work sites. The plant engineer should rectify failures immediately, if any. The audit shall be implemented as per IS: 14489 (1998) "Code of Practice on Occupational Safety and Health Audit." Standard safety audit procedures of the inspectorate of factories shall be at a frequency of a month and compliance reported to that agency.

9.2 OCCUPATIONAL HAZARDS

Occupational hazards are classified into Diseases and Accidents and described below.

9.2.1 Diseases

Workers for sewerage systems and onsite systems face the risk of various health problems by virtue of their occupation since they are exposed to a wide variety of chemicals, micro-organisms and decaying organic matters that comprise sewage. Table 9.1 shows types of diseases and their causes.

Table 9.1 Types of diseases and their causes

Diseases	Causes
Infections - Leptospirosis - Hepatitis - Helicobacter pylori - Tetanus - Diphtheria	Pathogen present in sewers or sewage
Dermatitis	Chemicals, mineral oil and tar
Respiratory symptoms	Endotoxins, Bioaerosols

Source: IJOEM, 2008

9.2.2 Accidents

Workers for sewerage systems and onsite systems such as below are exposed to risk of accidents during work. This chapter deals with oxygen deficiency, hydrogen sulphide poisoning, and dangers of combustible gas as confined space hazards*.

* Confined spaces are locations in sewers, pumping stations and treatment plants where fatal accidents frequently occur. A confined space is defined as a space with: (1) Cramped entry and exit; (2) Absence of broad daylight and ventilation; (3) Access is meant for very limited persons such as one or two persons. Possible hazards such as below are considered to be common among onsite and sewerage works.

- Confined space hazards

  Oxygen deficiency / Hydrogen sulphide poisoning /Combustible gas
- Chlorine poisoning
- Fall
- Slip
- Electric shock
- Fire

In this subsection, workplaces are categorized into the following five locations:

- On-site
- Sewer system
- Pumping station
- Sewage treatment plant
- Water and wastewater quality test laboratory

Possible hazards are listed for each workplace with subdivided locations in Table 9.2 by locations.

Table 9.2 Possible hazards by locations

Hazards / Locations	Confined space			Chlorine gas poisoning	Fall	Slip	Electric Shock	Fire
	Oxygen Deficiency	Hydrogen sulphide poisoning	Combustible gas					
On-site								
Septic tanks	✓	✓						
Anaerobic filters	✓	✓						
Closed drains	✓	✓						
Sewers								
Sewers	✓	✓	✓			✓		
Manholes	✓	✓	✓		✓			
Closed drains	✓	✓	✓					
Pumping station and STP								
Wet / dry wells	✓	✓			✓	✓		
Settling tanks	✓	✓			✓	✓		
Biological reactor	✓	✓			✓	✓		
UASB reactors	✓	✓			✓	✓		
Anaerobic lagoons	✓	✓			✓	✓		
Sludge thickeners	✓	✓			✓	✓		
Sludge digesters	✓	✓	✓		✓	✓		✓
Sludge dewatering facility	✓	✓				✓		
Sludge drying beds	✓	✓				✓		
Disinfection devices				✓				
Electrical equipment							✓	✓
Electric room							✓	✓

Possible hazards at wastewater quality test laboratory include toxic substances, alkalis /acids and glass appliances.

Details of the said accidents are described below.

9.2.2.1 Confined Space Hazards

Possible hazards in confined space include oxygen deficiency, hydrogen sulphide poisoning, and danger of combustible gases.

9.2.2.1.1 Risk of Oxygen Deficiency

- When oxygen concentration (See 9.3.1.1 for details of measurement method) drops below 17%, shortness of breath may occur.
- If the concentration reduces further, consciousness may be lost.
- When the oxygen concentration drops below 10%, death may result.

Table 9.3 shows the change in symptoms of anoxia due to drop in oxygen concentration.

Table 9.3 Relationship between reduction in oxygen concentration and symptoms of anoxia

Oxygen Concentration (%)	Symptoms of anoxia
19.5	Human begin to suffer adverse health effects when the oxygen level of their breathing air drops below 19.5%.
16 to 19.5	Workers engaged in any form of exertion can rapidly become symptomatic as their tissues fail to obtain the oxygen necessary to function properly. Increased breathing rates, accelerated heartbeat, and impaired thinking or

Oxygen Concentration (%)	Symptoms of anoxia
	coordination occur more quickly in an oxygen-deficient environment. Even a momentary loss of coordination may be devastating to a worker if it occurs while the worker is performing a potentially dangerous activity, such as climbing a ladder.
12 to 16	Concentration of 12 to 16% oxygen causes increased breathing rate, accelerated heartbeat, and impaired attention, thinking and coordination, even in people who are resting.
10 to 14	At oxygen levels of 10 to 14 %, faulty judgement, intermittent respiration, and exhaustion can be expected even with minimal exertion.
6 to 10	Breathing air containing 6 to 10% oxygen results in nausea, vomiting, lethargic movements, and perhaps unconsciousness.
Below 6	Breathing air containing less than 6% oxygen produces convulsions, then cessation of breathing, followed by cardiac arrest. These symptoms occur immediately. Even if a worker survives the oxygen deficiency, organs may show evidence of oxygen-deficiency damage, which may be irreversible.

Source: OSHA

9.2.2.1.2 Risk of Hydrogen Sulphide Poisoning in Confined Space

Hydrogen sulphide is extremely toxic. Sometimes it may be generated in high concentration in a sewage treatment facility, which causes immediate death.

- Hydrogen sulphide enters the body through eyes or mucous membrane of breathing organs.
- Blood seeps out from the capillaries in cavities of the lungs, causes pulmonary oedema, leading to breathing difficulties and death by suffocation.
- In sewer facilities, it is generated in rising mains with no oxygen supply and in inverted siphons, etc., where sludge is likely to accumulate easily.
- It is generated in grit chamber, pumping well, sedimentation basin, and sludge thickening tank in sewage treatment plants.
- Hydrogen sulphide generated in sewage and deposited sludge is sealed within and in the static condition, so it does not disperse to the atmosphere easily. However, when agitated, it disperses all at once to the atmosphere.

The relationship between concentration of hydrogen sulphide gas and its toxic effect is shown in Table 9.4.

Table 9.4 Relationship between concentration of hydrogen sulphide and its toxic effects

Conc. (ppm)	Effects and reaction by organ		
	Sense of odour		
0.025	Sensitive persons can sense the odour (limit of sense of odour)		
0.3	Anybody can sense the odour		
3 to 5	Foul unpleasant odour of medium strength		
10		Permissible concentration (lower limit for irritation of the mucous membrane of the eye)	

Conc. (ppm)	Effects and reaction by organ		
20 to 30	Although bearable, after getting accustomed to the odour (olfactory fatigue), any higher concentration cannot be sensed.	Breathing organs Lowest limit for irritating the lungs	
50			Eyes Conjunctivitis, itchiness, pain in the eyes, feeling of sand in the eye, glare, bloodshot eyes and swelling, turbidity of cornea, corneal damage and separation, bending and haziness of field of vision, increase in pain due to light
100 to 300	Olfactory nerve paralysis for 2 to 15 minutes; feels like unpleasant odour has reduced.	If exposed continuously for 8 to 48 hours, bronchitis, pneumonia, and death by suffocation due to pulmonary oedema	
170 to 300		Scorching pain in the mucous membrane of respiratory tract; if exposure is less than 1 hour (limit), serious symptoms may not occur	
350 to 400		Exposure for 1 hour or more may lead to loss of life	
600		Exposure for 30 minutes hour may lead to loss of life	
700	Cerebral nerves After excessive respiration for a short period, respiratory paralysis occurs immediately thereafter		
800 to 900	Loss of consciousness, respiratory arrest, death		
1,000	Swoon, respiratory arrest, death		
5,000	Instantaneous death		

Source: JSWA, 2003

9.2.2.1.3 Risk of Combustible Gas in Confined Space

- Combustible gas includes methane, gasoline, thinner, and so on.
- These gases become a mix of explosive gases in locations such as sewers.
- The minimum limit of concentration for explosion to occur is 5% for methane and 1.3% for gasoline.
- Combustible gasoline, thinner and so on, float on the surface of water and volatilise at room temperature, so they are dangerous.
- If large quantity of gasoline flows into a sewer, there is a possibility of large explosion to occur.
- At locations where sewage is likely to accumulate such as in sewers, toxic or explosive gases or vapours may be generated.

9.2.2.2 Risk of Chlorine

- 30 ppm causes coughing; 40-60 ppm is dangerous in 30 minutes.
- 1,000 ppm is apt to be fatal in a few breaths.
- Chlorine gas has specific weight that is 2.49 times heavier than air, is a yellowish green gas and is a strong irritant.

- Although its disinfecting effect is high, its toxicity is also high.

9.2.2.3 Fall

- Accidents frequently occur while climbing/descending ladders.
- Accident often occurs while working at high places.

9.2.2.4 Slip

Slippery surfaces are often encountered when working in an STP and sewers.

9.2.2.5 Electrical Shock

Electric shocks occur because of the following:

- Exposure of live parts and defects such as damage to insulating sheath.
- Inappropriate work such as forgetting to use insulated protective gear, touching live parts by mistake, etc.

Table 9.5 shows the effects on the human body subjected to an electric shock, while Table 9.6 shows the relationship between magnitude of shock current and duration.

The electric shock level when a person suffers an electric shock may be quantified by the equation below.

Electric shock level = Shock current (mA) x duration (s)

Table 9.5 Effects on the human body when subjected to electric shock

S.No.	Effect
a	Mild sensation, but not painful
b	Painful shock but muscle still in control
c	Muscle control affected
d	Muscle contraction , breathing affected
e	Rapid, uncoordinated series of contractions of heart muscle causing irregular heart beat (fibrillation) and possible death
f	Severe burns, muscle contractions, stoppage of heart, death certain

Table 9.6 Relationship between shock current and duration

Magnitude of Current, 50 Hz rms value	Duration										
Below 10 mA	a	≤10s									
10 mA to 15 mA	b	<1s	c	1s-2s	d	2s-10s					
15 mA to 20 mA	b	<0.5s	c	0.5s-2.0s	d	2s-10s					
20 mA to 40mA	b	<0.15s	c	0.1s-2.0s	d	2s-10s					
40 mA to 80 mA	b	<0.05s	c	0.05s-0.06s	d	0.6s-1s	e	1s-3s	f	3s-	
Above 100 mA	b	<0.04s	c	0.04s-0.05s	d	0.5s-0.8s	e	0.8s-1.9s	f	1.9s-	

Source: Khanna Publishers

9.2.2.6 Fire

Burns can be very serious and can cause painful injuries. Structural damage from fires can be very costly.

The three essential ingredients of all ordinary fires are:

- Fuel - paper, wood, oil, solvents and gas.
- Heat - the degree necessary to vaporise fuel according to its nature.
- Oxygen - normally at least 15 percent of oxygen in the air is necessary to sustain a fire. The greater the concentration, the brighter the blaze and more rapid the

combustion.

9.2.2.7 Risks in a Wastewater Quality Test Laboratory

9.2.2.7.1 Toxic Substances

Persons working in the water quality test laboratory use various chemicals including toxic substances. Inhalation of excessive steam, gas or dust, etc., in the course of their work, is harmful to health so these persons should take adequate precautions.

Typical toxic substances used in a water quality test laboratory and their toxicity are given in Table 9.7.

Table 9.7 Toxicity of chemical used in water quality laboratory

Type	Symptoms and poisons
Chemical asphyxia	Hydrogen cyanide, cyanogen compounds • Inactivation of haemoglobin in blood and oxygen associated with breathing leads to asphyxia. • Likely to occur easily during a reaction; permissible quantity is very small so care is required.
Caustic action	Arsenic compounds • Irritates mucous membrane of breathing organs, and at high concentration, breathing is arrested.
Systemic poisoning	Arsenic • Absorbed from an alimentary canal, the skin, and respiratory organs • Diarrhoea, vomiting, and shock in 30 minutes in serious cases (Arsenious anhydride) Inorganic mercury • Sharp pain in the stomach or the abdominal region, vomiting, and bloody urine Metal mercury • Easily evaporated and inhaled. • Trembling of hand and foot, and consciousness disorder Organic phosphorus • Absorbed from the skin, alimentary canal, and respiratory organs • Diarrhoea, vomiting, spasm, and consciousness disorder.

Source: JSWA, 2003

9.2.2.7.2 Alkali / Acid

Acids and alkalis used in the water quality test laboratory include:

- Hydrochloric acid
- Sulphuric acid
- Nitric acid
- Sodium hydroxide, etc.

9.2.2.7.3 Glass Appliances

Glass appliances can be broken if they are not handled carefully, and may lead to an injury.

9.2.3 Instances of Accidents

An instance of accident related to anoxia (due to oxygen deficiency) is described below.

- Type of work: Sewerage work
- Number of casualties: 2 dead, 1 employee in serious condition

This casualty occurred when lifting the drain pump from the manhole during sewerage work.

On the day of the occurrence, storm water pipes were being replaced.

- Worker (A) and worker (B) opened the manhole cover to perform work in the manhole, and entered the manhole through the trap.
- After a while, when Worker (C) looked into the manhole, he found the workers (A) and (B) had collapsed.
- He notified the other workers. Worker (C) rushed into the manhole for rescue and called out but there was no response.
- Soon after, worker (C) also collapsed on the spot.
- Later, workers (A), (B) and (C) were rescued by the rescue team and taken to the hospital.
- Workers (A) and (B) lost their lives, while the rescued worker (C) was admitted to the hospital with hypoxic encephalopathy (brain damage from lack of oxygen).
- Workers (A) and (B) were diagnosed with anoxia.

The probable causes of the accident were as follows:

- Was not aware that the location had the risk of oxygen deficiency.
- Did not measure the oxygen concentration and did not ventilate the manhole before entering it.
- Did not impart education and implement rescue drills related to work at dangerous locations with oxygen deficiency.
- No safety guard was stationed.

9.3 SAFETY ASPECTS AND MEASURES

Measures to protect workers from accidents are mentioned in 9.3.1 Preventive measures are taken to prevent accidents, and 9.3.2 Corrective measures are adopted when accidents occur. Preventive measures and corrective measures against accidents are described below.

9.3.1 Preventive Measures

9.3.1.1 Hazard-specific Preventive Measures

9.3.1.1.1 Confined Space Hazards

The potential for build-up of toxic or combustible gas mixture and/or oxygen deficiency exists in all confined spaces. Characteristics of common gases causing hazards are shown in Appendix 9.2. Refer to Table 9.2 for possible confined spaces related to sewerage works.

Follow the "Confined space entry procedure" shown in Figure 9.1 and Appendix 9.3. Entry into confined space should not be permitted until the space is ensured to be safe as specified in Table 9.8.

Table 9.8 Acceptable entry condition

Substance	Concentration
Oxygen	19.5% and more
Hydrogen sulphide	Less than 10ppm
Combustible gases	Less than 10%

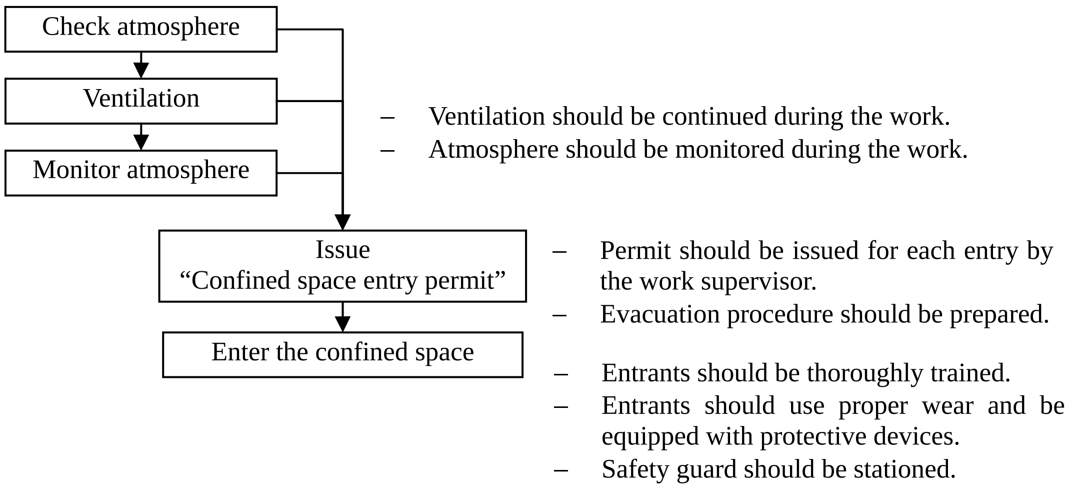
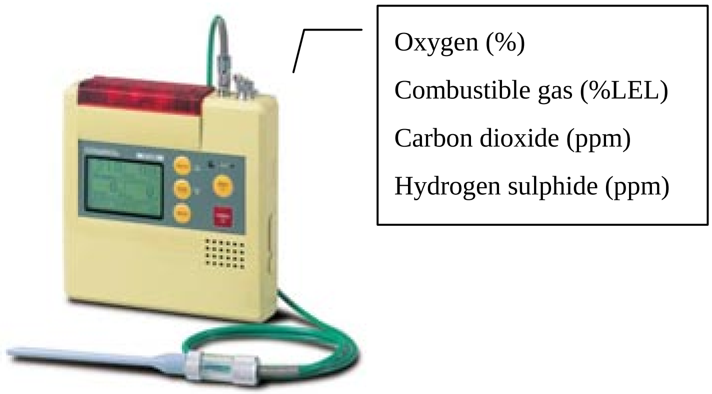


Figure 9.1 Confined space entry procedure

a. Measurement Method

An example of a portable toxic gas detector that can measure oxygen, combustible gas, carbon dioxide, and hydrogen sulphide simultaneously is shown in Figure 9.2 and is given here.

- Before measuring the confined space atmosphere, perform zero error correction of the instrument at a location where there is fresh air (no gas in the vicinity).
- Measure the atmosphere within the space to confirm if any hazard exists as given below.
  - Oxygen : Less than 19.5%
  - Hydrogen sulphide : 10 ppm or more
  - Combustible gases : 10% LEL (lower explosive limit) or more
- Measurement should be done at three locations – top, middle and bottom of the confined space – since the oxygen concentration differs according to the position.
- Record the measured results on "Confined space pre-entry checklist" (Appendix 9.4)



Source: PRISM GAS DETECTION PVT. LTD.

Figure 9.2 Portable toxic gas detector

b. Ventilation Method

If the measured results indicate one or more of the following hazards, be sure to ventilate the location before starting work.

- Oxygen : Less than 19.5%
- Hydrogen sulphide : 10 ppm or more
- Combustible gases : 10% LEL or more

To ensure the atmosphere is safe during the work, operate the ventilation equipment continuously.

Bring the blower outlet end close to the workplace and continue to blow air at the rate of 10 m^3/minute per person or greater.

c. Provisions for Evacuation

The work supervisor should make the following arrangements:

- Keep ready breathing apparatus, ladder, rope, safety belt and other equipment for use in evacuating or rescuing workers in the event of an emergency.
- Inspect protective gear before start of work and ensure that they are ready for use at all times. Repair or replace gear and equipment that are defective.
- Bear in mind that gas protection mask or dust protection mask is ineffective against anoxia.
- Non-spark tools should be used in confined spaces.

d. Stationing of Safety Guard

The work supervisor should station a safety guard to detect abnormality at an early stage and to take immediate and appropriate action.

- The safety guard should be stationed outside the opening if the situation inside the confined space can be monitored from the outside.
- The safety guard should check access to the workplace of the workers engaged in the work.

9.3.1.1.2 Chlorine Poisoning

- Store chlorine containers in a cool and dry place away from direct sunlight or from heating units.
- Wear a face shield when changing chlorine containers.
- As chlorine is approximately two and half times heavier than air, vents should be provided at floor level.

9.3.1.1.3 Fall

The work supervisor and worker should take the following precautions to prevent persons from falling into manholes, etc.:

- Ensure that nobody falls from ladders (including metal rungs) and that tools are not dropped from ground level.
- Wear uniform suitable for the work and wear the necessary protective gear.
- Check that the ladder to the manhole is not corroded or worn out.

9.3.1.1.4 Slip

- Special anti-skid shoes with metal cladding over the “fingers” portion should be provided by the employer for the workers. These shoes should be used by the workers only within the STP.

- Keep floor of workplaces dry and free from grease or oil.

9.3.1.1.5 Electric Shock

Electric shocks occur because of the following:

- Exposure of live parts and defects such as damage to insulating sheath
- Inappropriate work such as forgetting to use insulated protective gear, touching live parts by mistake, etc.

Measures to prevent electric shock are as follows:

- Methods for safe handling of electric equipment should be drilled into the workers and inspection and maintenance methods for electric equipment should be established.
- Special precautions should be taken to prevent electric shocks at locations where water is likely to accumulate (grit chamber, pumping room and in pipe gallery). Rubber-soled sports shoes may be used to prevent electric shocks.

a. Electric Room

Access to the electric room should be prohibited to all except authorized personnel. Signs should be put up indicating danger when current is flowing into the room.

The electric room should be managed by the procedure below:

- Do not place combustible items near exposed wiring and electric equipment.
- Install fire extinguishers at easily visible locations such that they can be used immediately in the event of a fire.
- If there is excessive lightning, do not approach equipment wiring and lightning arrester.
- Periodically inspect and store disconnecting switches, operating rods, insulating plates, etc., at their specified positions.
- Store electric torch at its specified position such that it can be used immediately during an emergency such as power failure.
- Place insulating mat on the floor in front of the MCC Panel to prevent electric shocks.

b. Equipment Repair

Before repairs of equipment or wiring, permission should be taken from the plant engineer (Refer to 9.5.2) and the work supervisor should hold a meeting and decide the work procedure. Repair work on electrical equipment should be prohibited to all except authorized personnel.

- Cut off circuits of equipment to be repaired before repairs.
- Put up sign indicating not to switch on power, assign a person to monitor the power switch, and strictly enforce power ON/OFF controls.
- Before starting the repair, always detect the voltage using a voltage detector or tester.
- Electric shock due to fault in cable run may also be considered; always ground the equipment before performing work.

- Operate switches such that you do not receive an electric shock.
- If a power capacitor exists, thoroughly discharge the remaining charge before starting work.
- If equipment breaks down at night, and if there is no emergency generator at the workplace, the worker should perform repairs during day time when there is daylight and not during night time.

9.3.1.1.6 Fire

Every facility should develop a fire prevention plan with input from the local fire marshal, fire chief, and/or insurance company. The plan may be very simple or very complex, depending on the specific facility needs. Some items which may be included in any plan are:

- Regulate the use, storage and disposal of all combustible materials/substances.
- Provide periodic clean-up of weeds or other vegetation in and around the plant.
- Develop written response procedures for reacting to a fire situation to include evacuation.
- Provide required service on all fire detection and response equipment (inspection, service, hydrostatic testing).
- Routinely inspect fire doors to ensure proper operation and unobstructed access.
- Immediately repair, remove or replace any defective wiring.
- Restrict the use of any equipment which may provide a source of ignition in areas where combustible gases may exist.
- Maintain clear access to fire prevention equipment at all times.

9.3.1.2 Personal Protection and Protective Devices

9.3.1.2.1 Head Protection

- All personnel working in any areas where there may be danger from falling, flying tools or other objects must wear approved hard hats. Such hats should be according to the relevant BIS. Specially insulated hard hats must be worn when working around high voltage to protect from electrical shock.
- It is advisable to have detachable cradle and sweat bands for two reasons (1) to permit easy replacement of cradles and sweat bands and (2) to make possible assignment of one helmet to several workers each with its own cradle and sweat band for sanitary reasons.
- Once broken, the crown of a hard hat cannot be effectively repaired. It must be replaced.

9.3.1.2.2 Face and Eye Protection

Impact Goggles must be worn to protect against flying objects. They can be spectacle or cup goggles.

Spectacle goggles must have rigid frame to hold lenses in proper position before the eyes. Frames must be corrosion resistant and simple in design for cleaning and disinfection.

Cup goggles should have cups large enough to protect the eye socket and to distribute impact over a wide area of facial bones.

- Chemical goggles and acid hoods should be used for protection against splashes of corrosive chemicals. A hood treated with chemical-resistance material having a glass or plastic window gives good protection. There should be a secure joint between the window and the hood material.

- Face shields can be used against light impact. Plastic shields should be non-inflammable, free from scratches or other flaws, which introduce distortions.
- Welding masks must be used for protection from splashes and radiation produced by welding.
- Protective creams are used to protect the skin from contamination and penetration by oils, greases, paints, dust etc.

9.3.1.2.3 Hands and Lower Arms

- Protective sleeves, gloves and finger pads are used for different types of hazards and jobs.
- Rubber and asbestos gloves should be long enough to come well above the wrist, leaving no gap between the glove and coat or shirt sleeve.
- Gloves or mittens having metal parts for reinforcements should never be used around electrical equipment.
- Linemen and electricians working on energized or high voltage electrical equipment require specially made and tested rubber gloves.

9.3.1.2.4 Body Protection

- A good quality diver suit should be provided to the diver whose services are very necessary while plugging the sewer line or removal of some hard blockage due to stone etc. at the mouth of the pipe in the manholes. Depending upon the site condition, suit should have provision to connect an air line with compressor or oxygen cylinder.
- Always use rubber aprons when working with chemicals.

9.3.1.2.5 Legs and Feet

- Leggings are provided where leg protection is necessary and are in the same category as coats, frocks and aprons. Kneepads made of cloth, padding, rubber, cork are used on jobs where kneeling is required.
- Ordinary work shoes are acceptable for many jobs. They should have non-skid soles to prevent slips.
- Safety shoes are required where there is danger of dropping tools or materials on the feet. Toe guards have been designed for the men to wear when operating machines as air hammers, concrete breakers etc.
- For working on electrical equipment suitable safety shoes must be used.

9.3.1.2.6 Mask

a. Gas Mask

General purpose gas masks are used for respiratory protection from low and moderately high concentrations of all types of toxic gases and vapours present in the atmosphere in which there is sufficient oxygen to support life (Figure 9.3). Masks afford necessary respiratory protection under many circumstances but it is most important to know the limitations of the various types available and to be familiar with their use. Even when masks are used properly, other precautions such as never using open flames or creating sparks in the presence of inflammable gases must be taken. The general purpose gas masks afford protection against organic vapours, acid gases, carbon monoxide up to 2 percent concentration, toxic dusts, fumes and smoke. The gas mask consists of a face piece, a canister containing purifying chemicals, a timer for showing duration of service and a harness for support. Protection against specific contaminants can be achieved by the selection of appropriate canisters.

Persons using gas masks should practice regularly with them in order to become proficient in putting them on quickly and breathing through them. Gas masks cannot be used in oxygen deficient atmospheres, in unventilated locations or areas where large concentrations of poisonous gases exist.

Source: JICA, 2011

Figure 9.3 Gas mask

f. Dust Protection Mask

This is a gas mask that takes air in which fine solid particles are suspended, removes the fine particles and detoxifies the air after passing it through the particle filter.

g. Respiratory Equipment

In all dusty areas, effective filter masks should be used to guard against specific hazards. Hose mask should be used by men entering tanks or pits where there may be dangerous concentrations of dust, vapour, gases or insufficient oxygen. Hose mask with blower and the airline respirator are used where the hazard is immediate, that is, hasty escape would be impossible or cannot be made without serious injury if there is failure of the equipment.

Oxygen or air breathing apparatus, that is, self-contained oxygen breathing equipment using cylinders or bottles of compressed oxygen or air is used where required. This is a must when the length of the hose pipe in on-line supply of oxygen exceeds more than 45 m.

Gas masks: Canisters consist of a face piece connected by a tube to a canister. Chemicals in the canister purify contaminated air. No single chemical has been found to remove all gaseous contaminants. It does not supply oxygen and can be used where there is sufficient oxygen.

Various types of respirators and their suitability are as follows:

– Self-contained breathing apparatus

This apparatus is equipped with a cylinder containing compressed oxygen or air which can be strapped on to the body of the user or with a canister which produces oxygen chemically when a reaction is triggered (Figure 9.4). This type of equipment is suitable for an oxygen deficient atmosphere. It is also suitable for high concentration of chlorine.

Source: Stylex Fire Protection Systems

Figure 9.4 Self breathing apparatus

– Air-line respirator: Air-line length 90 m (max.)

It is suitable in any atmosphere, regardless of the degree of contamination or oxygen deficiency, provided that clean, breathable air can be reached. This device is suitable for high concentrations of chlorine, provided conditions permit safe escape if air supply fails.

9.3.1.2.7 Ear Protection

Where noise levels are high and exceeds specified limits, effective ear-pads or earplugs must be used.

9.3.1.2.8 Safety Belt

When you work on ladders or scaffolding, use extreme caution to prevent falls. Safety belt should be used to prevent falls.

9.3.1.2.9 Portable Lighting Equipment

The equipment normally used is portable electric hand lamps of permissible types, electric cap lamps and explosion proof flash lights.

9.3.1.2.10 Portable Blowers / Ventilating Fan

Replace the air in oxygen deficient and hazardous spaces with fresh air using exhaust fan and exhaust ducts (Figure 9.5).Ventilation also includes the method of exhausting the air, but generally the method of blowing in air is more effective.

Source: GVT Engineering

Figure 9.5 Portable blower (ducting blower)

9.3.1.2.11 Safety Fences

Visitors including adults and children visit the STP as part of social studies. For this reason, the safety management officer should install fences in the facility and ensure a proper route for visitors so as to prevent any accident.

9.3.1.2.12 Safety Signs

To warn of danger to workers, visitors, and other construction workers in an STP, safety signs such as shown in Figure 9.6 should be displayed in the STP.

Source: http://www.safetysignindia.com

Figure 9.6 Safety signs

9.3.1.3 Workplace-specific Preventive Measures

Good design and the use of safety equipment will not prevent physical injuries in sewerage works unless safety practices are understood by the entire crew and are enforced. Safety preventive measures specific for the workplace are described here.

9.3.1.3.1 On-site

- Before entering the pit or tank, follow all of the procedures required for work in confined spaces defined in 9.3.1.1.1.
- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.
- Wear rubber gloves to prevent wounds from infection.

9.3.1.3.2 Sewer System

a. Traffic Hazards

- Before starting any job in a street or other traffic area, study the work area and plan your work.
- Traffic may be warned by high-level signs far ahead of the job site.
- Traffic cones, signs, or barricades arranged around the work, or a flagger are applicable to direct traffic.
- Whenever possible place your work vehicle between the working site and the

oncoming traffic.

- Use fluorescent jacket while working along roads (Figure 9.7).

Source: Vibgyor Industries

Figure 9.7 Fluorescent jacket

b. Manhole

- Before entering the manhole (Figure 9.8), follow safety entry procedure. (Refer to Sec. 2.11.1.2 “Safety measures to be taken before any manhole entry”)
- Before entering the manhole, follow all the procedures required for work in confined spaces defined in 9.3.1.1.1.

Source: JICA, 2011

Figure 9.8 Photo showing typical confined space entry

- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.
- Manhole work usually requires job site protection by barricades and warning devices.
- Never use your fingers or hands to remove a manhole lid. Always use a tool specifically designed for this purpose.
- Be alert for loose or corroded steps.
- Wear a properly fitted pair of rubber gloves and boots, or an approved substitute that will provide protection from infection.
- Tools and equipment should be lowered into a manhole by means of a bucket or a basket.

9.3.1.3.3 Pumping Station

- Before entering the well, follow all of the procedures required for work in confined spaces defined in 9.3.1.1.1.

- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.
- Do not work on electrical systems or controls unless you are qualified and authorized to do so.
- Guards over couplings and shafts should be provided and should be in place at all times.
- If stairs are installed in a pumping station, they should have hand rails and non-slip treads.
- Fire extinguishers should be provided in the station, properly located and maintained. The use of liquid-type fire extinguishers should be avoided. All-purpose A-B-C chemical-type fire extinguishers are recommended.
- Good housekeeping is a necessity in a pumping station to prevent slip and fall accidents.
- Properly secure and lock up an unattended pumping station when you leave so as to prevent injury to a neighbourhood child and possible vandalism to the station.

9.3.1.3.4 Sewage Treatment Plant

a. Head Works

- Bar screens or racks
  - Remove all slime, rags, grease, etc to prevent slip and fall accidents. Never leave rake or other tools on the floor.
  - Never lean against safety chains.
  - Always turn off, lock out and tag the main circuit breaker before you begin repairs.
  - The time and date the unit was turned off should be noted on the tag, as well as the reason it was turned off. No one should turn on the main breaker and start the unit until the tag and lock have been removed by the person who placed them.
- Pump rooms
  - If the room is below ground level and provided with only forced-air ventilation, be certain the fan is on before entering the area.
  - Guards should be installed around all rotating shaft couplings, belt drives, or other moving parts normally accessible.
  - Remove all oil and grease, and clean up spills immediately.
  - Be sure to provide barricades or posts with safety chains around the opening to prevent falls.
  - Until the area has been checked for an explosive atmosphere, no open flames (such as a welding torch), smoking or other sources of ignition should be allowed.
  - Do not work on electrical systems or controls unless you are qualified and authorized to do so.
- Wet pits or sumps

- Before entering the pits or sumps, follow all of the procedures required for work in confined spaces such as defined in 9.3.1.1.1.
- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.
- For access ladders to pit areas, the application of a non-slip coating on ladder rungs is helpful.
- Watch your footing on the floor of pits and sumps; the floor may be very slippery.
- Tools and equipment should be lowered into a manhole by means of a bucket or a basket.
- Only explosion-proof lights and equipment should be used in these areas.

• Grit channels

- Keep walking surfaces free of grit grease, oil, slime, or other material to prevent slip accidents.
- Before working on mechanical or electrical equipment, be certain that it is locked out and properly tagged.
- Install and maintain guards on gears, sprockets, chains, or other moving parts that are normally accessible.
- Before entering the channel, pit or tank, follow all of the procedures required for work in confined spaces such as defined in 9.3.1.1.1.
- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.
- Rubber boots with steel safety toes and a non-skid cleat-type sole should be worn.

b. Clarifiers or Sedimentation Basins

- Always turn off, lock out and tag the clarifier breaker before working on the drive unit.
- Maintain a good non-skid surface on all stairs, ladders, and catwalks to prevent slipping.
- When it is necessary to actually climb down into the launder, always wear a harness with a safety line to prevent a fall accident and have someone accompany you.
- Watch your footing on the floor of pits and sumps; the floor may be very slippery.
- Guards should be installed over or around all gears, chains, sprockets, belts, or other moving parts. Keep these in place whenever the unit is in operation.

c. Digesters and Digestion Equipment

- Methane gas produced by anaerobic conditions is explosive when mixed with the proper proportion of air.

- Smoking and open flames should not be allowed in the vicinity of digesters, in digestion control buildings, or in any other areas or structures used in the sludge digestion system.
- All these areas should be posted with signs in a conspicuous place which forbid smoking and open flames.
- All enclosed rooms or galleries in this system should be well ventilated with forced air ventilation. Never enter any enclosed area or pit which is not ventilated.
- Before entering the digester for cleaning or inspection, follow all of the procedures required for work in confined spaces such as defined in 9.3.1.1.1.
- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.
- Explosion-proof lights and non-sparking tools and shoes must always be used when working around, on top of, or in a digester.
- When working on equipment such as draft tube mixers, compressors and diffusers, ensure that equipment is properly valved out, locked out and appropriately tagged to prevent the gas from leaking.
- If a heated digester is installed, read and obey the manufacturer's instructions before working on the boiler or heat exchanger because there is a risk of explosion.
- Sludge pump rooms should be well ventilated to remove any gases that might accumulate from leakage, spillage or from a normal pump cleaning.
- Good maintenance of flame arresters will ensure that they will be able to perform their job of preventing a back flash of the flame.

d. Aerators

- An operator should never go into unguarded areas alone.
- Approved life buoys with permanently attached hand-lines should be accessible at strategic locations around the aerator.
- Operators should wear a safety harness with a life line when servicing aerator spray nozzles and other items around an aerator.
- Lower yourself into the aerator with a truck hoist if one is available.
- Be extremely careful when using fixed ladders as they become very slippery.
- Watch your footing on the floor of the aerators: the floor may be very slippery.

e. Sewage Ponds

- Never go out on the pond for sampling or other purposes alone. Someone should be standing by on the bank in case of trouble.
- Always wear an approved life jacket when working from a boat or raft on the surface of the pond.

f. Disinfection Device

- Do not accept containers that have not been pressure tested within five years of the delivery date.

- Do not accept containers not meeting the standards. (Refer to IS 10553 Part I “Requirement for chlorination equipment”)

The most common causes of accidents involving chlorine are leaking pipe connections and excessive dosage rates.

- Bottles or cylinders should be stored in a cool, dry place away from direct sunlight or from heating units.
- Bottles or cylinders should never be dropped or allowed to strike each other with any force. Cylinders should be stored in an upright position and secured by a chain, wire rope, or clamp.
- One of the tanks should be blocked so that they cannot roll.
- Always wear a face shield when changing chlorine containers.
- Connections to cylinders and tanks should be made only with approved clamp adaptors or unions. Always inspect all surfaces and threads of the connector before mixing connection. Check for leaks as soon as the connection is completed. Never wait until you smell chlorine or sulphur dioxide. If you discover even the slightest leak, correct it immediately.
- Like accidents, leaks generally are caused by faulty procedure or carelessness.
- Obtain from your supplier and post in a conspicuous place (outside the chlorination and sulphonation room) the name and telephone number of the nearest emergency service in case of severe leak.
- Cylinder storage and equipment rooms should be provided with some means of ventilating the room. As chlorine is approximately two and a half times heavier than air, vents should be provided at floor level.
- Normally ventilation from chlorine storage room is discharged to the atmosphere, but when a chlorine leak occurs, the ventilated air containing the chlorine should be routed to a treatment system to remove the chlorine. A caustic scrubbing system can be used to treat air containing chlorine from a leak.
- The IDLH (Immediately Dangerous to Life or Health) for chlorine is 30 ppm.
- Always enter enclosed cylinder storage or equipment rooms with caution. If you smell chlorine or sulphur dioxide when opening the door to the area, immediately close the door; leave ventilation on, and seek assistance.
- Never attempt to enter an atmosphere of chlorine when you are by yourself or without an approved air supply and protective clothing, which will allow a person to enter safely into an atmosphere of chlorine. Remember to use the "buddy system" (system in which two persons work as a single unit) when responding to a leak.

9.3.1.3.5 Water and Wastewater Quality Test Laboratory

a. Toxic substances should be handled with the following precautions:

- Store poisonous substances in containers with tight lids. Clearly indicate the contents of the containers; place them in a special cupboard for chemicals that can be locked, and record the quantities of the substances used.

- Some substances may decompose when exposed to light and explode; store such substances in cool, dark locations.
- Store gaseous substances in well-ventilated locations.
- Gaseous substances should generally be handled in well-ventilated locations. If this is not possible, safety masks should be worn, the location ventilated thoroughly, and after use, the persons handling the substances should gargle and wash their face.

b. Alkali / acid should be handled with the following precautions:

- Wear protective goggles, rubber gloves, and protective clothing, if necessary.
- Handling hydrochloric acid
  - Since this acid is highly corrosive, always wash your hands after handling it.
  - Sometimes pressure still remains in sealed bottles in which this acid is stored. When opening the bottle, take care because the acid within the bottle may gush out unexpectedly.
- Handling sulphuric acid
  - Since this acid is highly corrosive, always wash your hands after handling it.
  - Sulphuric acid generates heat after reacting with water. If a large amount of sulphuric acid falls on any part of the body, wipe it off first with cloth and then wash the affected part of the body with water (if you do not wash with water, symptoms may get worse due to generation of heat; so take precautions).
  - When diluting sulphuric acid, always dilute by pouring sulphuric acid into water and not vice versa.
- Handling nitric acid
  - Nitric acid vapours are strong respiratory toxins, so take care to ventilate the place thoroughly.
  - Take measures to not handle vapours.
  - When opening the container with nitric acid, ensure that the acid does not gush out when the container cap is removed.
- Handling sodium hydroxide
  - Take care that sodium hydroxide does not stick to the hand or other body parts because it has the action of decomposing proteins.
  - Locations should be available for properly washing parts of the body, preferably where sodium hydroxide is used.
  - When dissolved in water, intense heat is generated and the solution may spray out. Take care to dissolve little by little so as to avoid risks.

c. Glass appliances should be handled with the following precautions:

- Inspect thoroughly before use; do not use those with scratches or cracks.
- Handle beakers, flasks, test tubes which have small thickness very carefully since these objects have less mechanical strength.
- Containers with reasonable thickness if heated suddenly may break; so take precautions.

- Round off sharp corners of glass tubes before using them.
- Use appropriate supporting stands when you handle large flasks.
- When you insert a glass tube or a thermometer in a rubber stopper or cork stopper, do as carefully as it may break and lead to an injury.
- Take care not to touch heated glass with your bare hands.
- Insert solids in a beaker of flask while tilting the container and slide in the solid gently so as not to break the bottom.

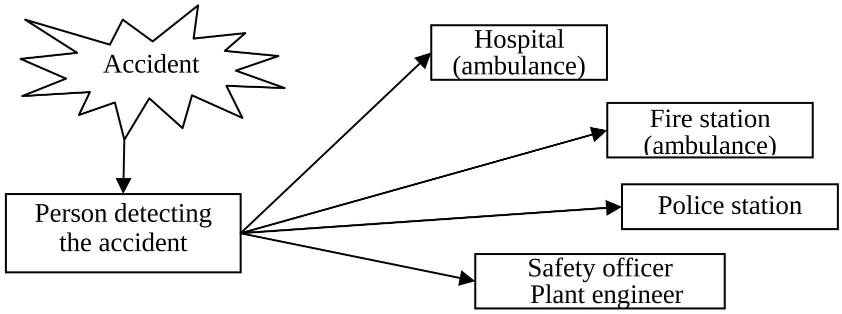
9.3.2 Corrective Measures

9.3.2.1 Emergency Contact

The plant engineer should set up an emergency contact system to prepare for emergencies, and appropriately fix the scope of contacts and the persons responsible for contacting relevant personnel.

The contact system should include records of medical organizations, and the names and telephone numbers of departments such as internal medicine, surgical department, ophthalmology or general hospital.

Figure 9.9 shows an example of emergency contacts.



Source: JSWA, 2003

Figure 9.9 Example of emergency contacts

9.3.2.2 Emergency Measures

Workers frequently perform dangerous work or handle dangerous chemicals while working in sewerage systems and on-site systems. For this reason, emergency measures need to be thoroughly understood beforehand. Workers need to adopt appropriate action if such an unexpected situation arises.

Information on emergency measures is given below.

- The supervisor of the safety personnel (organisation) should always inspect and maintain rescue appliances and clearly indicate their storage location.
- The supervisor of the safety personnel (organisation) should establish assistants for rescue action at each workplace and train them beforehand.
- Medical organisations to be contacted in an emergency should be decided beforehand (names and telephone numbers of hospitals with internal medicine, surgical department, ophthalmology or general hospital to be kept ready so they can be summoned immediately).
- Should be able to offer first aid immediately.

- Subsequently, the doctor, and if necessary, the rescue organisation where the patient is being given treatment, should be notified the type and seriousness of the accident, the first aid given, the rescue appliances in hand, etc.
- The patient should be put to bed in a relaxed manner.
- Although it is good to rest the head and the body in a horizontal condition on a bed, if the face is flushed, the head should be raised slightly.
- If the face is bluish in colour, the pillow should be removed and the head maintained at a low level.
- If the patient has vomiting sensation, the face should be kept sideways to allow the patient to vomit.
- The patient's body temperature should be checked, and the patient should be encouraged, but should not be indiscreetly moved.
- Attention should be paid so as not to overlook wound, burn, bone fracture, hip dislocation, and so on.
- The status of the patient, the condition of the surroundings, environment and work method should be studied closely, a sketch should be made and photos should be taken.
- Vomit, excrement and urine, bloodstain, etc., should be preserved as is, so that they can be analysed later.

Care and treatment for injured workers are described in Appendix 9.5 separately for each wound or injury.

9.3.2.2.1 First Aid Tools

The plant engineer should make arrangements for quickly offering first aid measures. The plant engineer should do the following to minimize injury during an accident or disaster:

- Provide necessary materials for offering first aid.
  - Artificial respirator
  - Stretcher (Figure 9.10)
  - First aid box (Figure 9.11)
- Should ensure that a responsible person always manages the first aid tools.
- Drugs and equipment set aside in a first aid box are as given below. Unnecessary items should not be placed in the first aid box.
  - Waterproof casts
  - Adhesive plasters of assorted sizes
  - Eye protection pads
  - Disinfectant lotions
  - Safety pins of assorted sizes
  - Unused sealed twin blade razor

Source: Hiren Industrial Corporation

Figure 9.10 Stretcher

Source: Hiren Industrial Corporation

Figure 9.11 First aid box

9.3.2.2.2 Extinguisher

Fires are classed as A-, B-, C-, or D-type fires, according to what is burning.

- Class A fires (general combustibles such as wood, cloth, paper, or rubbish) are usually controlled by cooling - as by use of water to cool the material.
- Class B fires (flammable liquids such as gasoline, oil, grease, or paint) are usually smothered by oxygen control - as by use of foam, carbon dioxide, or a dry chemical.
- Class C fires (electrical equipment) are usually smothered by oxygen control - use of carbon dioxide or dry chemical extinguishers - non-conductors of electricity.
- Class D fires occur in combustible metals, such as magnesium, lithium, or sodium, and require special extinguishers and techniques.

Use carbon dioxide or halon compressed gas extinguishers to control fires around electrical contacts. Do not use soda-acid type extinguishers because the electric motor will have to be rewound and you could be electrocuted attempting to put out the fire. Also remember that carbon dioxide can displace oxygen.

9.3.2.2.3 Emergency Lighting

Emergency lighting is required for illuminating critical control areas and for allowing fast exit from an area if the normal lights go out. An emergency generator that starts automatically with a power failure is wired separately to turn on emergency lights in critical areas. Instead of an emergency generator, battery packs are often used for evacuation. Please refer to clause 5.12.4 and 5.12.6 of Part A.

9.3.2.3 Searching out Hazards

The safety management officer should carry out the following safety examinations:

- Record the status of occurrence of accident (Appendix 9.6). Study the status of occurrence and causes of accidents, and based on the studies pick out the conditions for occurrence of industrial accidents (risk locations, risky work, risky actions, etc.).

- Examine which parts of the workers' bodies were affected by accidents from the records of accidents. Examine the necessity of protective gear.
- Check the status of work location, and study unsafe actions and inappropriate working methods of the workers.
- Study the status of use of workers' tools.

The safety officer should consider the results and report them to the plant engineer.

The safety officer should reflect the results of the examinations above in the education of workers.

9.4 HEALTH ASPECTS AND MEASURES

9.4.1 Preventive Measures

9.4.1.1 Personal Hygiene against Pathogen

The worker should take precautions because a large number of coliform groups, various kinds of micro-organisms, and egg parasites exist in sewage.

The workers should strive to maintain good health by taking care of the following points:

- Wear clean uniform, work boots, etc.
- After work and before having a meal, always wash hands and disinfect them.
- After work, take a shower if possible.
- Do not enter the offices and lounges wearing dirty clothes.
- If necessary, take vaccinations against tetanus, leptospirosis fever, and so on.

9.4.1.2 Maintaining Cleanliness

The worker should maintain each facility in a clean and neat condition.

- The floors of work rooms, stairs and corridors should be cleaned at the appropriate frequency to maintain them in a clean condition.
- Disinfection of relevant locations is to be carried out periodically.

9.4.1.3 Health Check

Workers should receive health check once a year so as to maintain their health, and prevent illnesses or detect them at an early stage. The results of the health check should be maintained as records.

Recommended items to be inspected during the health check are as given below.

- Examine medical history.
- Examine subjective symptoms and other objective symptoms.
- Check height, weight, vision and hearing ability.
- Chest X-ray examination.
- Blood pressure measurement.
- Check for anaemia.
- Check for liver functions.

- Check for lipids in blood.
- Check blood sugar level.
- Urine analysis.
- Electrocardiogram analysis.

9.4.2 Welfare Measures

The Draft Sanitation Workers (Regulation of Employment and Conditions of Service) Act 2012 proposes constitution of a Sanitation Workers State Welfare Board to exercise powers conferred on it and to perform welfare functions such as the following for sanitation workers:

- Provide immediate assistance to a beneficiary in case of an accident.
- Sanction of loan and advances.
- Medical expenses for treatment of major ailments.
- Financial assistance for education of children.
- Payment of maternity benefit.
- Make provision and improvement of such other welfare measures and facilities as may be prescribed.

9.4.3 Corrective Measures

When a worker has symptoms of an illness listed in Table 9.1, the plant engineer should ensure that the worker is checked up by a specialist doctor and receives proper treatment and care and should take the following actions considering the content of work done by the worker:

- Change the workplace if necessary.
- Change the content of the work.
- Shorten the working hours.
- Perform relevant measurements of the working environment.
- Maintain the facility or equipment.

9.5 SAFETY PERSONNEL (ORGANISATION)

The plant engineer is expected to establish an appropriate safety management organisation in order to avoid losses of workers, stoppage of operations, etc., due to industrial accidents.

9.5.1 Institutional Arrangement

The number of workers assigned for operation and maintenance of an STP varies according to the scale of the facility, the treatment process used, and equipment installed.

If the scale of the facility increases, the following will also increase:

- Equipment installed
- Workers
- Quantity of work
- Injuries and accidents

Accordingly, the number of safety and health supervisors will vary depending on the scale of the facility.

Figure 9.12 shows the safety management organisations for large STP, medium STP, and small STP, respectively.

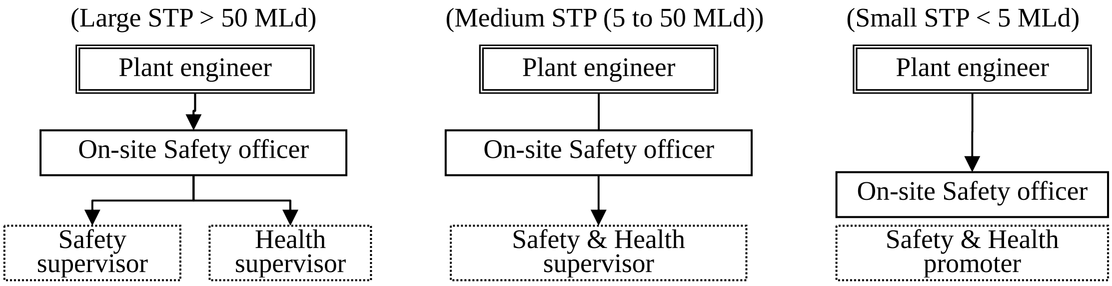


Figure 9.12 Safety management organisation

9.5.2 Human Resources

Safety officer is to be assigned, and safety management to suit the number of workers in the workplace is required to be implemented.

The plant engineer should select and assign safety officer to ensure the safety and health at the workplace. The plant engineer should give permission for any required repair works on equipment / facilities in the STP.

The safety officer should carry out the following duties as full time service:

- Prevent risks or personal injury to workers and promote health checks and other improvements to health of the workers.
- Select a safety supervisor to manage workers' safety, and select a health supervisor to manage workers' health.
- If an industrial accident occurs, investigate its causes and take measures to prevent its recurrence.
- Perform tasks necessary to prevent industrial accidents.

The safety supervisor is selected by the safety officer, and has the following duties:

- If there is a risk in the structure, equipment, work place or working method, adopt emergency measures or measures to prevent such risks.
- Periodically inspect equipment and tools such as safety equipment and protective gear, etc., to prevent risks.

The health supervisor is selected by the safety officer, and has the following duties:

- Study the working environment, working conditions, and equipment in relation to how they affect the health of the workers.
- Inspect and maintain first-aid tools.
- Provide health education and look after matters necessary for maintaining good health.

The plant engineer should nominate a safety and health promoter at a site where a safety supervisor or a health supervisor is not selected.

The safety and health promoter is selected by the plant engineer and has the following duties:

- The safety and health promoter should inspect the facility and equipment, check their usage stage, and based on the results of these checks, should adopt relevant measures.

- The safety and health promoter should make efforts to maintain the health of the workers through health checks and impart safety and health education to workers.
- The safety and health promoter should examine the causes of work accidents and measures to prevent recurrence of the same.
- The safety and health promoter should collect information on workers' safety and health, prepare and maintain statistics of work accidents, diseases, and absence from work.

Where no safety management officer, safety supervisor or health supervisor and safety and health promoter is selected, the plant engineer should manage all safety and health matters related to the facility.

9.6 AWARENESS AND TRAINING

Safety training should aim for improving awareness and techniques of persons engaged in work so that accidents during work are prevented. Safety training should consist of four courses to be imparted to Manager, Technical, Skilled and Unskilled grades of personnel.

- The Manager is a person who performs labour management and manages the work environment so as to ensure the safety of workers.
- A person in the Technical grade is an Assistant Engineer or Junior Engineer, who operates and repairs mechanical and electrical machinery and equipment by his own judgement.
- A person belonging to the Skilled grade is one who uses machines and equipment, and performs work following the instructions of the superior using the Work Manual.
- A person belonging to the Unskilled grade is one who performs manual work mainly in the plant obeying instructions of the superior.

Trainees should upgrade/acquire skills to perform their work safely through training. The overview of training for each grade of personnel is given below.

9.6.1 Manager

Managerial training should be given to managers once every five years on the topics mentioned below.

- Laws, regulations and latest information related to sewerage systems
- Labour and welfare matters related to workers
- Periodic performance assessment of subcontractors and vendors

9.6.2 Technical Staff

The plant engineer should ensure that training in their respective fields is imparted to the technical staff once every three years in the mechanical and electrical sections (Technical Grade).

9.6.2.1 Mechanical

- Operation and maintenance of mechanical machinery and equipment such as pumps and blowers
- Repairs to mechanical machinery and equipment such as pumps and blowers
- Methods of examining the causes of breakdown in mechanical machinery and equipment such as pumps and blowers

- Methods of operating machinery and equipment (welding equipment) used for repairs during breakdown of pumps, etc.
- Emergency response procedures

9.6.2.2 Electrical

- Operation and maintenance of electric equipment such as MCC
- Repairs to electric equipment such as MCC
- Methods for examining causes of breakdown in electric equipment
- Emergency response procedures

9.6.3 Skilled Staff

The plant engineer should ensure that training in their respective fields is imparted to the skilled staff once a year in the mechanical and electrical sections (Skilled Grade).

9.6.3.1 Mechanical

- Safe work
- Communication at the workplace including instructions from supervisors, communicating with subordinates, and communication during joint work
- Maintenance of mechanical machinery and equipment such as pumps and motors
- Repairs to mechanical machinery and equipment such as pumps and motors
- Hazardous work (oxygen deficiency, hydrogen sulphide poisoning)
- Measuring instrument (oxygen concentration meter, etc.)
- Method of usage of protective gear (safety belt, breathing apparatus)

9.6.3.2 Electrical

- Safe work
- Communication at the workplace including instructions from supervisors, communicating with subordinates, and communication during joint work
- Maintenance of electric equipment such as breakers and switches
- Repairs to electric equipment such as breakers and switches
- Electric shocks
- Hazardous work (oxygen deficiency, hydrogen sulphide poisoning)
- Method of usage of measuring instruments (oxygen concentration meter, rpm gauge, insulation tester, etc.)
- Method of usage of protective gear (safety belt, breathing apparatus)

9.6.4 Unskilled Staff

The plant engineer should give training to unskilled staff once a year.

- Safe work (what not to do)
- Communication at the workplace including instructions from supervisors, communicating with subordinates, and communication during joint work
- Matters related to keeping things tidy and in order, cleanliness and neatness

- Names of tools and their usage (pliers, screw drivers, etc.)
- Electric shocks
- Hazardous work (oxygen deficiency, hydrogen sulphide poisoning)
- Use of protective gear (gloves, protective goggles, etc.)

9.6.5 Training Assessment

Persons who have received safety training should be assessed on the lessons learnt. The results of the assessment should be recorded in the assessment table shown in Table 9.9. The plant engineer should warn the trainees on items assessed as unsatisfactory, and improve their awareness to such items.

Table 9.9 Record of training assessment

Job requirement	Trainee's current knowledge & skills				
	Excellent	Good	Fair	Poor	Nil
1					
2					
3					
4					
5					

Source: CPHEEO, 2005

The worker should receive safety training and should preferably not be transferred to a different workplace within one year. Otherwise this would result in lowering the quality of work at the workplace and may lead to a drop in work efficiency. For this reason, work status at the workplace, stationing of personnel and training assessment should be considered during transfers.

9.7 EMERGENCIES

9.7.1 What is an Emergency?

An emergency is a situation developing before our eyes with our full conscience and our realization that soon the situation will turn to adversity. We may not be equipped to deal with it. We cannot take control. This leaves us with no time to locate the source of help. We may not know where to get help for a given situation.

9.7.2 How to Think during Emergencies?

The foremost requirement is not to jump to conclusions. Always think of what is most important and imperative at that moment. Let us consider some situations that can arise

9.7.2.1 Situation 1

You notice a colleague during working hours trying to repair a floodlight during broad daylight at a height of some 6 m by standing on a permanent secure ladder but he is not wearing safety gloves. You grow cold at the thought that he may get electrocuted and nobody could reach him at that height soon enough. This is a simple emergency situation. For example, going back to the case of the colleague who was on top on a mast without safety gloves, you have the options of (a) calling him on the cell phone to alert him about his not wearing gloves, (b) going up the ladder personally with a spare set of gloves, (c) quietly switching off the electrical circuit to that mast and (d) quietly slipping out of the scene unnoticed. Each solution will merit itself under certain situations. Solution (a) is apt when the electrical circuit is already found switched off. Solution (b) is apt when the electrical circuit is switched off and the fuse is in your pocket. Solution (c) is apt when you find that the circuitry is energized. Solution (d) is apt when you find the circuitry is already switched off and your colleague has recorded in the works register that he is taking the fuse with him, so that nobody can energize the circuit until he returns.

9.7.2.2 Situation 2

A colleague is sitting on the walkway of a clarifier and is absorbed in collecting a sample of the treated sewage overflowing the weir. You notice that a snake is slowly making its way towards him. If you move in speedily, the snake may get hustled and move away from you faster and move closer to your colleague. This is a very serious emergency. Now then what will you are doing? The first thing to do will be to call out to the colleague on cell phone not to move and sit still as reptiles are alerted only when there is movement ahead of them. The next thing to do will be to ask your colleague to jump into the clarifier and swim to the safety of the channel and launder. Of course, this presumes he knows swimming. Suppose he does not know swimming, what will you do? Ask him to immediately stand upright so that if it bites, it may spare the body parts closer to the heart and he can still be saved by tying up the limb upside of the bite with a rope or at least torn piece of a shirt and simultaneously for you to follow the reptile and try to push it into the water surface with whatever piece of extended tool that you may have.

9.7.2.3 Situation 3

During a monsoon season, let us say there is a sudden cloudburst and torrential downpour and before the staff could realize what will happen, the entire site is flooded to about knee height and the sludge pits are marooned. Electrical connections get shorted somewhere and there is total darkness. The staff are scattered at different locations in the STP area of over 25 hectares. There was no way of setting foot forward, as they could not locate where the pump pit is. The fear of more floods is very much there. You can somehow make out the silhouette of the administrative building and slowly wade towards it by announcing yourself. When all the staff members reach the building, they could not hear voices of two persons in that shift. Panic grips them. But nothing could be done till next day morning when it is discovered that of the two missing persons, one was absent and the other has gone out on personal work without informing others. The lesson here is that in every shift, be punctual in reporting and ensure a mini assembly of handing over and taking over at the “meeting point.” This ensures mutual knowledge of presence or absence. Another lesson is to have solar powered lamp posts with self contained circuits insulated against rains and located adjacent to electrical lampposts so that when total electricity fails, these will come on at least for that interval of time.

9.7.2.4 Situation 4

When two operators are moving a portable diesel pump on a trolley over a gravel roadway, the road caves in suddenly and they are pulled into a huge pit, fortunately after the engine was pulled in. This is later on discovered as the plant bypass concrete pipeline crossing the road which has been corroded in the crown to such a degree that it could not take that load. There have been no signs on the site showing that the pipeline is crossing the road there. Just imagine if the operators had fallen first and the engine after them? The lessons are these - all pipe crossings of roads should be through culverts with sidewalls raised above ground. Bypass pipelines are flowing rarely and gases accumulate and would corrode the pipe easily. Always provide them in non-corrodible glass reinforced fibre pipe. Erect markers over the route of big buried pipes wherever these are not in the road alignment.

9.7.2.5 Situation 5

A primary settling tank sludge removal arm is not rotating for sometime but the settling tank continues to be operated. After certain time, it is noticed that the accumulated sludge is becoming visible through the sewage liquid when seen from the top. The settling tank is stopped from service and the sludge is allowed to dry up. Manual labourers are employed to walk into the settling tank and scoop out the sludge and transport it as head loads. Suddenly, two of labourers are found to be “sinking” into the sludge. Fortunately, the other labourers throw a rope and the two are able to grab it and are pulled out. The lessons are simple. Wet grit dumps can behave like quicksand in such locations. Suppose the two were not noticed sinking, they would have been located only after death while scooping the sludge. Removing such grit dumps should be as per regulations for confined spaces and all personnel should be watched and accounted for by a supervisor.

9.8 THE NEED TO RESIST

Sometimes, tasks required to be carried out by field staff may involve risks, ignoring safety and potential emergency. The employee must politely resist doing the same. If every staff member resists, only then the management will know and make amends.

9.9 SUMMARY

Sanitation workers or STP operators are often forced to work under poor working conditions with high risk of operational diseases or accidents.

Each operator or worker should ensure operational safety by wearing designated personal protection or by using designated protection devices. Above all, they should follow the working procedures thoroughly when working in confined spaces.

CHAPTER 10 ON-SITE SYSTEMS

10.1 INTRODUCTION

The on-site treatment is done individually in the premises (at the point of generation itself) as an interim measure. The on-site treatment ranges from a basic sanitary facility such as pit latrine (twin pit with water seal) to a simple type where anaerobic treatment and infiltration treatment are done by combining a septic tank and a soak pit and a sophisticated type where advanced sewage treatment is done. The sludge which is produced in each on-site facility is collected by an exclusive vehicle and then is treated collectively. The treatment systems of domestic wastewater in the on-site system and the off-site system are shown in Figure 10.1.

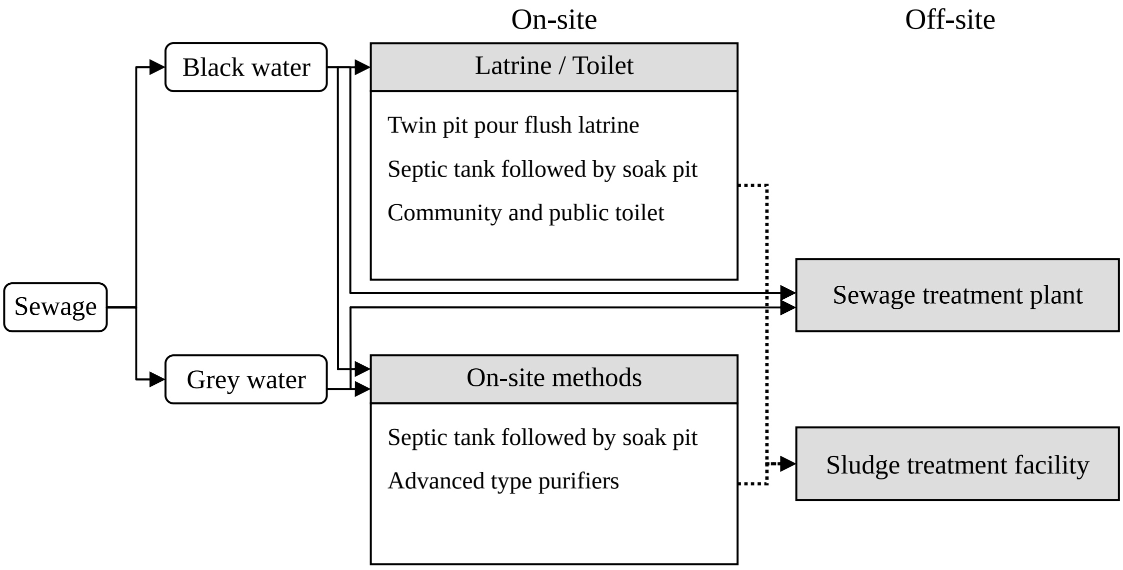


Figure 10.1 On-site sewage treatment system

Note: There can be cases where both black and gray can be treated together.

10.2 ON-SITE FACILITY MAINTENANCE SYSTEMS

A system for maintaining an on-site treatment facility varies depending on its scale and treatment method. If the scale is small, in many cases the installer or administrator controls the facility voluntarily. If the scale is medium or large, or if the facility employs an advanced method, in most cases a special vendor having engineers controls it. The different scales adopt different control types-staff members are resident in a large-scale facility such as a sewage treatment plant, whereas they make a regular travelling inspection in a small- or medium-scale facility.

Basic hygienic treatment facilities (e.g. pit latrines) and septic tanks require regular cleaning (sludge extraction) as the main maintenance work. Accordingly, the administrator (house owner) shall check daily how much sludge is accumulated in the facility and determine when it should be extracted. Meanwhile, the state and municipal governments shall prompt the residents and the persons concerned to raise awareness of the importance of the sludge control of their on-site facilities and to cooperate in it. More specifically, both state and municipal governments should draw up an action plan for extracting, treating, and disposing of the sludge generated in on-site facilities in accordance with the “Septage Management Guidelines” (MOUD, 2012), and prepare measures and budgets necessary for implementation of the plan.

Precautions to septage management planning are shown below.

- The state and municipal governments should establish an on-site sanitation system

(OSS) that conforms to relevant laws.

- Efficient management requires a database of hygienic facilities including septic tanks under control.
- Public and private providers in charge of sludge collection should establish a system to ensure that they offer services properly.
- Selecting a sludge treatment method requires a survey of land use requirements, travelling distance, pollution prevention, and facility construction and maintenance costs.
- It is necessary to disclose information about septage management to the residents and persons concerned, and to conduct necessary activities for receiving their cooperation.

10.3 MAINTAINING ON-SITE FACILITIES

An on-site facility is controlled by the installer, building owner, or community, but the administrator runs and maintains the facility by himself/herself or commits it to a special vendor, determined according to the scale and treatment method. This subsection summarizes general requirements for the latter case.

The vendor should be familiar with the facility plan, design statements (including the structure, facility capacity, and specifications for the components), relevant drawings, and maintenance records. In addition, the vendor should understand how to operate, maintain, inspect, repair, and adjust the equipment, as well as how to adopt measures against problems.

10.3.1 Inspecting and Maintaining the Treatment Unit

An advisory note on Septage management prepared by the Ministry of Urban development giving details about the Septage management plan which can be referred to regarding the inspection and maintenance of these on-site facilities.

a. Inspection

The purpose of inspection is to find an abnormal condition or failure at an early stage, find the cause, and take measures quickly by checking the equipment for operation and the whole treatment unit for operating status. How many times inspections are conducted and what is inspected vary according to the treatment capacity and method.

b. Maintenance and Repair

The purpose of maintenance is to ensure that the equipment displays its performance as defined in the specifications. If the inspection results show an abnormal condition, failure, or degradation in the performance defined in the specifications, repairs are made to recover the function. Such repairs are made by on-site staff or entrusted to a special vendor.

10.3.2 Cleaning

Cleaning the equipment and removing residue and sludge generated are necessary to maintain the performance of the facility. The vendor should keep a record of cleaning and reflect it in the maintenance work.

10.3.3 Water Quality Control

The means of checking whether the facility displays its performance as defined or whether it meets legal control values is to test the effluent water for quality. Some facilities may require evaluating the quality of not only the discharged water but also the water treated in each process because the latter gives control indices.

10.3.4 Hygienic Measures including Infection Prevention

Excreta and sludge include many infectious pathogens and parasites. Therefore, the illegal disposal of the sludge into the environment or its unsanitary treatment causes contagious diseases and pollutes groundwater or rivers with contaminants contained in the sludge. Table 10.1 shows key pathogens contained in excreta and sludge.

Table 10.1 Key pathogens contained in excreta and sludge

Bacteria	Cholera, dysentery, Salmonella typhi, paratyphoid, Vibrio parahaemolyticus, Enteropathogenic Escherichia coli, staphylococcus, streptococcus, and tubercle bacillus
Viruses	Polio, various enteroviruses, infectious diarrhoea, infectious hepatitis, and Izumi fever
Protozoans	Dysentery bacillus and amoeba
Parasites	Coprozoa, worm egg, roundworm, hookworm, whipworm, Trichostrongylus orientalis, pork tapeworm, and Taenia saginata

Source: Sudo.R , 1977

10.3.5 Measures against a Disaster or Accident

Unlike a large-scale sewage treatment plant, an on-site and small-scale treatment facility normally requires no resident engineer for operation control. Therefore, it is necessary to plan measures against emergency states in case no engineer is available. The administrator should:

- always take measures against any disaster or accident,
- when a disaster occurs, immediately perform patrols and inspections to check for abnormality,
- continuously monitor the storage states of materials for emergency recovery and reserve units, and place the latter in a standby state,
- draw up a mobilization plan and duty list against a disaster or accident, and inform the persons concerned thereof, and
- make plans for reporting, liaison, temporary action, and recovery work.

10.4 LATRINE/ TOILET

10.4.1 Pour Flush Water Seal Latrine

- The squatting pan should be sprinkled with a small volume of water and scrubbed daily with a long handle bamboo piece or strong wood gently crushed to the shape of a brush at one end. This shall be done preferably immediately after the morning usage is completed so that the pan is wet enough for the sticky organics to be scrubbed easily.
- After scrubbing, again a small volume of water should be poured and simultaneously the scrubbings can be pushed into the pit using the same make shift brush by the householder, or he can arrange to have it done.
- Ablution water shall be kept in a plastic container and covered with a lid and kept ready inside the latrine enclosure. The volume shall be not less than the needs of the number of persons in the household for a morning usage. For example, if a person can manage with 2 litters per usage and if there are four persons in a household, the water needed is 8 litres. It will be prudent to store 10 litters of water. The mug that is used for taking the water from the stored plastic container shall be hung from the wall on a strong nail and shall not be left inside the container because of growth of slime over such mugs when left immersed for long periods.

- Before using the latrine pan, pour about 500 ml of water along the surface of the pan starting from the uppermost side and guiding the mug to evenly wet the pan.
- Any other wastewater shall not be diverted into the pour flush latrine and particularly storm water should not be let into the pan.

The Technology Advisory Group and World Bank have stipulated the procedure for switching from one pit to another as under.

a. Only one of the two pits is to be used at a time. After about three years when the first leach pit is full (the indication being back flow when flushed), the discharge from the pan should be diverted to the second pit and the first pit should be allowed to rest. The diversion of discharge to the second pit can be undertaken by the householder or, if he wishes, he can make private arrangements for this to be done. After the pit is filled and the latrine is connected to the second pit, the pit cover should be removed and soil to a depth of 150 mm should be used to fill the first pit and the cover placed in position again. Where earth is not easily available, or there is difficulty in removal of the pit cover, the earth could be added later when emptying the pit contents, for ease of handling. When the first pit has been out of use for about two years, it can be emptied by the householder himself or by the local authority. This can be done manually by shovel or auger. The contents will then be safe for handling, dry and without any foul smell. In special cases such as flooded areas, etc., the sludge, after being taken out, should be spread out in a bed for sun drying during the non-rainy season and utilized as manure. It will be valuable humus with some fertilizer value. The humus can be utilized as manure in the kitchen garden or fields.' When the second pit is full, the first pit should be used by diverting the discharge from second to first pit. Thus, one of the two pits is to be used alternately. The householder should keep a record when each of the two pits is put to use, disconnected and emptied; a card supplied by the local authority should be used for this purpose. The local authority should provide emptying services to the householders free of cost on request through local contractors or through its own employees. The humus will become the property of the local authority. Marketing facilities should be developed for the sale and use of the humus as manure in the fields.

b. To foster confidence in the minds of the people about the suitability and performance of the pour-flush latrines, the local authority should provide free service to latrine adopters, and attend to their complaints regarding construction, operation and maintenance. Groups (each one consisting of a skilled and trained person, and a labourer, for about 2,000 latrines) should be maintained for this purpose. In small towns where the number of latrines is less than 1,500, only a trained labourer could be kept to work under the guidance of a technical employee of the local authority. However, in the beginning when the number of latrines is less than a thousand, the Junior Engineer or the Supervisor should attend to complaints

10.4.2 Public Toilet

Public toilets are installed in parks, along roads, and in public facilities. Some are independently arranged outdoors, and some are installed in buildings. The users of the former are unspecified, resulting in insanitation. Accordingly, the toilet administrator shall clean the toilets and maintain the hand-washing units regularly. If a public toilet has sewage treatment facilities, the administrator shall maintain them as well. It is recommended to clean the toilet at least once a day. There is an example of collecting fees from the users and spending them for cleaning the toilet smoothly.

In addition to playing a role as public sanitation, the public toilet works as a facility for local disasters, so it shall be maintained appropriately to allow anyone to use it at any time.

Improving the user’s manners requires school education and awareness-raising activities for residents.

Concerning community toilets, the users are limited, in many cases resulting in maintenance of good sanitation.

10.4.3 Mobile Toilet

Mobile toilets, which can be delivered by vehicle, are temporarily used for shelters and events. They have a storage tank in the lower part to store wastewater, which is extracted and disposed of at the appropriate time. Some mobile toilets are equipped with a cleaning water tank and manual pump to flush excreta with the water. The tank capacity is limited, so it is necessary to plan a system for extracting the stored wastewater and to maintain a disposal site.

The method of using common toilets applies to public and common toilets. The administrator should submit a request for regular cleaning and instruct the users not only to follow good toilet manners but also to cooperate in conserving water.

Mobile toilets need to be stockpiled for emergency use. Therefore, the state and municipal governments should establish a network with private sectors to construct a system for arranging such toilets when an emergency occurs.

10.5 ON-SITE METHODS

10.5.1 Conventional Septic Tank / Improved Septic Tank

The IS 2470 pertains to septic tanks.

To maintain the function of septic tanks, the user should:

- Not use, any chemicals (e.g. acid and alkaline agents) that have an adverse effect on the digesting function for cleaning the toilet,
- Keep the tank and its surrounding area neat so as not to block control,
- Not mix oil with discharged water because the digesting function degrades or offensive odour or scum is generated. If it is unavoidable, install an oil-water separator upstream of the septic tank, and
- Monitor the sludge accumulating status at the right time to prevent its overflow.

10.5.1.1 Purifying Wastewater and Accumulating Sludge

Organic and solid substances in wastewater are digested in the septic tank and converted to digester gases, scum, and settled sludge, which are gradually accumulated. Meanwhile, the wastewater is purified to change to intermediate water. If the settled sludge and scum in the septic tank accumulate excessively, they partially flow out with the intermediate water, resulting in degradation in the quality of treated water. If the degraded water flows into the soak pit, the penetration function degrades. Therefore, maintaining stable treatment requires the control and regular extraction of sludge in the septic tank.

The amount of sludge accumulated in the septic tank varies depending on the type, volume, and quality of wastewater, the tank capacity, the foreign matter mixing ratio, and the water temperature. The amount of sludge can be determined by inserting a transparent vinyl pipe to the bottom of the tank, blocking the pipe tip with a finger, and pulling it out. When the amount of sludge and scum reaches about one-half of the tank depth, it is the time to extract the sludge, so the administrator should arrange to do so. If the tank is large, it is recommended to perform sludge surface checks at multiple points and to find the average level. Accordingly, an inspection window should be arranged during the installation of the septic tank.

10.5.1.2 Mechanical Cleaning of Septic Tank

Please refer to Appendix 10.1 for the details on mechanical cleaning on septic tank.

10.5.1.3 Septage Management

In general, the administrator requests a cleaning vendor to extract sludge from the septic tank. If a regular extraction system is introduced, the vendor visits the facilities to conduct sludge extraction work regularly. Sludge extraction is classified into two types according to the sludge accumulation status: whole and partial. The former is employed typically in small-scale facilities. For this work, equipment like a vacuum tanker should be used rather than extracting sludge by hand from the sanitation point of view. The vendor should:

- Take care not to splash sludge on the surrounding area (e.g. the soil surface),
- Take hygienic measures if manual work is unavoidable,
- Extract sludge quickly, otherwise offensive odour will diffuse over the surrounding area, and
- Maintain a record of the work and the amount of sludge extracted.

The sludge extraction frequency is about once every two to three years, which varies depending on how the toilet is used and the tank capacity. As a rule, this work is conducted by a vacuum tanker.

10.5.2 Advanced Type Treatment Units

This sub-subsection describes the operation control of a relatively large-scale (medium or larger) plant-type treatment facility equipped with machines.

10.5.2.1 Pre-treatment Process

a. Screen Facilities

Inflow wastewater includes not only organic matter that can be treated biologically but also a variety of large and small foreign substances that cannot be treated biologically, such as cloth, paper, wooden pieces, soil, and sand. The screening process removes the latter before wastewater enters the following treatment unit. If screening fails for some reason, it clogs or damages the pipe, waterway, or other equipment.

i. Removing Caught Screened Materials

The amount of foreign matter to be captured by the screen varies depending on the foreign matter content of wastewater and the mesh size of the screen. If foreign matter is not removed from the screen at the right time, the captured amount increases gradually and the screen becomes clogged. In the extreme case, the wastewater may overflow the waterway. Moreover, clogging stops wastewater flow before the screen creating an anaerobic condition and offensive odour.

ii. Sanitary Disposal of Screened Materials

Foreign matter is removed and raked into the screen bucket, and then rinsed with water for sanitary disposal to a location where drainage equipment is installed. The area where the screen bucket is placed should be cleaned and disinfected.

b. Flow Equalization Facilities

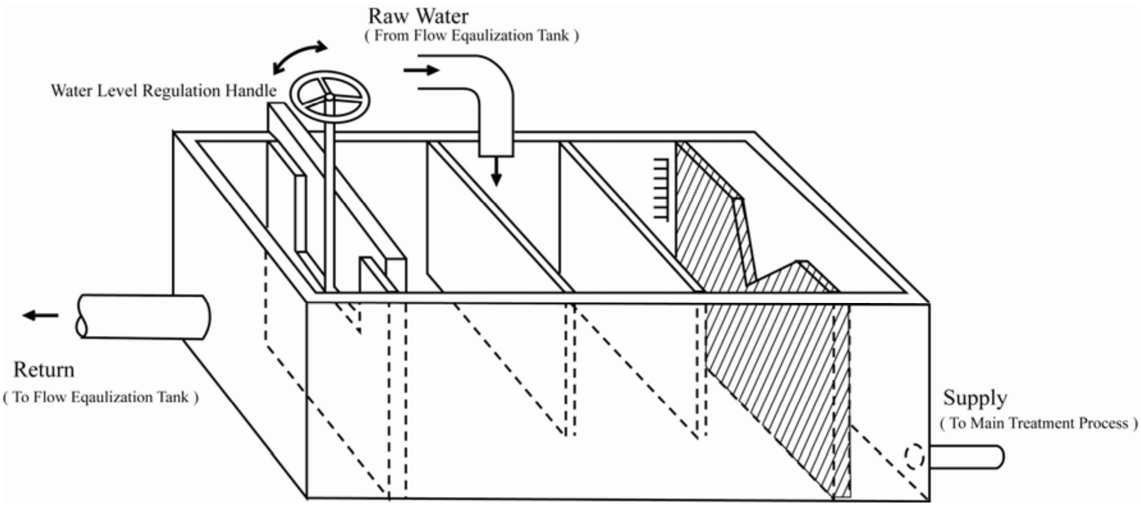
Stabilizing the function of the biological treatment process (main one) requires making the flow rate and quality of wastewater even, so the flow equalization facility adjusts the flow rate.

i. Control by Transfer Pump

In general, the transfer pump starts, stops, or issues an alert according to the water level of the flow equalization tank. The level at which the pump starts running varies depending on the variation in inflow wastewater and the margin of the flow equalization tank, but in many cases, it is set at 15 to 30 cm above the pump stop level (also known as the low water level (LWL)). Specifying such a control position is important for equalizing the water feed. This should be done carefully considering management of the subsequent metering unit. If garbage adheres to the level switch for pump control, it may not work; so regular inspection and cleaning are necessary.

ii. Controlling the Metering Unit

The metering unit (Figure 10.2) receives the wastewater lifted by the pump from the flow equalization tank, supplies a given amount of wastewater to the biological treatment process, and returns the remainder to the previous tank. The flow rate of the supplied water is adjusted by changing the height of the overflow weir. If sludge and sand accumulate in the unit or foreign matter is caught in the weir, the flow rate changes. Therefore, sludge and sand should be removed and the unit cleaned regularly.



Source: Jokasou Standard, 1980

Figure 10.2 Metering unit

iii. Stirring in the Flow Equalization Tank

The stable biological treatment function requires keeping the flow rate and properties of wastewater constant and uniform, so stirring is necessary in the flow equalization tank. The stirring method includes liquid circulation, mechanical stirring, and air stirring. It is essential to check whether the stirrer works correctly and whether the resulting stirring effect is good.

10.5.2.2 Main Treatment Process

a. Controlling the Aeration Tank

Refer to Chapter 4. (Sec.4.7 “Activated Sludge Process”).

b. Controlling the Sedimentation Method

The contact aeration method is based on treatment principles similar to those for the activated sludge method, but the former is more advantageous in flow rate and load changes and suitable for the treatment of wastewater with relatively low concentration. Accordingly, the contact aeration method is used in many on-site treatment facilities.

However, it has disadvantages: as the biological film thickness increases, the contact material becomes clogged. This result in degradation of the treatment function, and a fixed amount of microorganisms can respond to low load but cannot treat load beyond the design value. Accordingly, these advantages and disadvantages should be understood before using this method.

i. Controlling the Contact Aeration Tank

To improve the treatment efficiency of the contact aeration tank, the administrator should control it while paying attention to the following points:

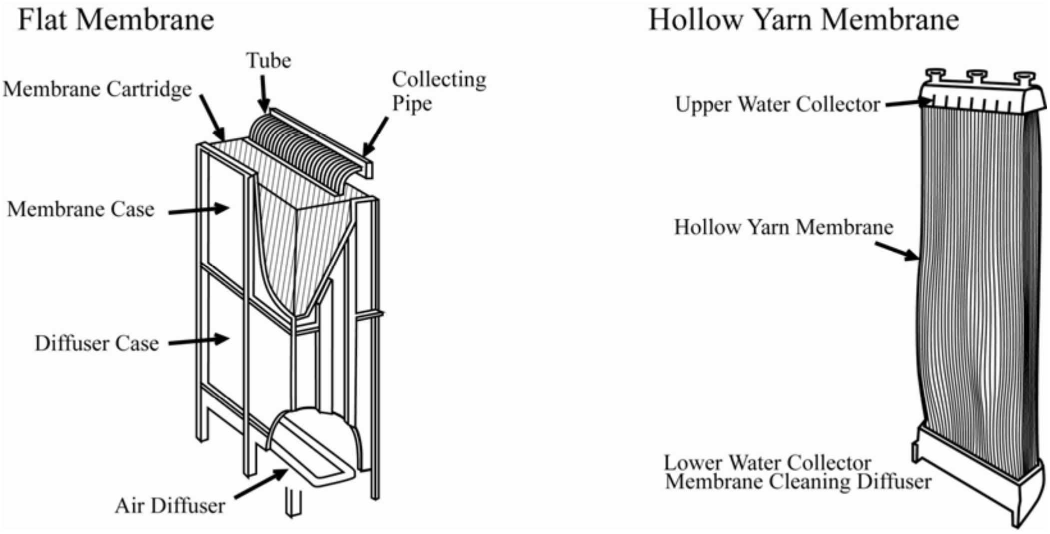
- Make efforts not to change the inflow rate by adjusting it,
- Keep BOD load in the proper range (overload should be avoided if no measures are taken),
- Form biofilm that consists of appropriate microorganisms,
- Confirm that aeration works well in the tank (the proper dissolved oxygen concentration is not less than 2 to 3 mg/L and it can be a little higher, but lower concentration degrades the treatment function),
- Pay attention to the thickness of biofilm and activate the back washing unit at the appropriate time to remove excess biofilm, and
- When the removed biofilm (sludge) increases excessively in the tank, temporarily stop aeration to settle and extract it with a pump (the sludge causes the contact material to be clogged).

ii. Controlling the Sedimentation Tank

In this treatment method, the amount of microorganisms that contribute to the treatment depends on the surface area of the contact material; therefore, it does not require adjustment of the sludge concentration in the aeration tank, as shown in the activated sludge method. Accordingly, all the sludge settled and separated in the sedimentation tank is not needed, so it should be extracted according to the accumulation status and fed to the sludge treatment process.

c. Controlling the Membrane Separation Method

This is the method of using a membrane separator to divide wastewater into solid and liquid instead of the conventional gravity settlement used in the activated sludge treatment system. The membrane separation method features sound solid-liquid separation, ease in keeping the MLSS concentration of the aeration tank high, and compact facility size. Many separators used in on-site facilities employ a membrane immersed in the aeration tank to obtain permeated liquid. The separator is classified into two types as shown in Figure 10.3: a “flat membrane” and a “hollow yarn membrane.”



Source: JEFMA

Figure 10.3 Membrane separators

i. Controlling the Aeration Tank

The control of the activated sludge method applies generally. One difference is that it is necessary to maintain a high MLSS concentration to enable proper functioning of the membrane separation method. The concentration should be 8,000 to 12,000 mg/L in many cases.

ii. Controlling the Membrane Separator

– Inspecting the treated water (which passes through the membrane)

While the membrane separator works correctly, the water that has penetrated the membrane should have a transparency of more than one meter. Therefore, if the results of inspecting the appearance of the permeated water show haze or SS, it is likely that the separator will not work. Possible causes include a break in the membrane or a certain connector, and the generation of slime in the membrane. In the former case, the broken part should be replaced or repaired. In the latter case, a chemical cleaner, is also used, as described hereunder.

– Differential pressure and water penetration rate

In the membrane separator, the differential pressure between the front and back of the membrane is the driving force to filter wastewater. Generally, the larger the differential pressure, the higher the water penetration rate. Continuous operation of the separator gradually forms sediment and deposit on the surface and in the micropores of the membrane causing clogging. Even if the separator runs at the same differential pressure, the filter resistance increases due to the clogged membrane and the water penetration rate reduces gradually. Conversely, to keep the rate constant, differential pressure should be increased in proportion to the amount of clogging.

However, there is a limit to increasing the differential pressure. Therefore, the membrane should be cleaned when the differential pressure reaches a certain level. The level varies depending on the facilities, so it is necessary to find a control value during trial operation. Generally the membrane needs to be cleaned when the pressure rise is 5 to 10 kPa for the flat type or 20 to 30 kPa for the hollow yarn type.

– Checking the aeration state

The tank in which the membrane separator is installed (immersed / kept out) should be aerated at a constant rate. Accordingly, it is necessary to check whether the aeration rate is appropriate and whether the whole membrane separator is uniformly and consistently aerated. The separation is by filtration through membranes.

– Cleaning the membrane

As mentioned earlier, continuous operation of the membrane separator gradually clogs the membrane and reduces filtering performance. Therefore, the membrane should be cleaned at the appropriate time.

– Rinsing with water

Activated sludge flocs, microorganism's metabolites, and other foreign matter that accumulate on the membrane surface should be removed by rinsing with water or by other physical means.

– Cleaning with chemical liquid

When the membrane pores are clogged with refractory organic substances in wastewater or with scale derived from inorganic substances in wastewater, it is not possible to remove them only by physical means. In this case, it is essential to use chemicals to decompose such adherents.

Sodium hypochlorite is used as a cleaner to decompose stains derived from organic substances. To decompose inorganic scale, organic acid such as oxalic or citric acid is used.

10.5.2.3 Advanced Treatment Process

a. Controlling the Flocculation Sedimentation Treatment

The control of sewage treatment facilities (Section 4.7 Activated Sludge Process of Part B) applies.

b. Controlling the Sand Filter

The control of sewage treatment facilities (Section 4.7.1 Sand Filtration of Part B) applies.

c. Controlling the Activated Carbon Adsorption Unit

The activated carbon adsorption unit has the objective of adsorbing soluble and difficult-to-biodegrade organic matter (COD) and inorganic matter included in sewage and removing them. Fixed bed activated carbon adsorption tower has practically the same construction as a sand filtration tower, and it requires periodic back washing, but it can also be automated. In the fixed bed tower, back washing may be performed at a frequency of once in one to two days. If the activated carbon layer gets deposited with suspended solids, combined washing using water and air is an effective method. The adsorbing performance of activated carbon degrades as water passes through; therefore, the activated carbon replacement period is decided taking COD as a control indicator.

10.5.2.4 Controlling the Disinfection Unit

There are some disinfection methods, such as chlorination, ultraviolet (UV) light treatment, and ozone treatment. This item describes the first one, the most popular method.

a. Coliform Bacilli as a Pollution Index

Escherichia coli that lives parasitically in the intestinal tract of men and animals is discharged with faeces outside and can be used as an index that shows the degree of pollution with excreta. Detecting coliform bacilli means that the bacteria in the digestive organ are discharged with faeces and that there is a possibility of pollution with dysenteric bacilli, bacteria that causes alimentary infectious diseases. The lifespan of such pathogenic bacteria in water varies depending on the living environment, including water temperature and pH. It is generally said that the lifespan of Salmonella typhi, Vibrio cholera, and dysenteric bacillus in a river are 10 to 30 days, 20 to 30 days, and 7 to 10 weeks, respectively.

b. Handling Disinfectants

Disinfectants frequently used include sodium and calcium hypochlorite. Handing these chemicals requires wearing protective equipment, such as goggles, rubber gloves, and a mask.

c. Controlling the Contact Tank

Adjusting the disinfectant injection rate requires measuring the residual chlorine concentration at the outlet of the contact tank. Too high a chlorine concentration is not good from the viewpoint of effect on the ecosystem in the effluent area. On the other hand, no residual chlorine indicates a possibility of insufficient disinfection. Therefore, the residual chlorine concentration at the outlet of the contact tank should be not too high or too low. In general, the control value is 0.1 to 0.3 mg/L.

10.6 SEPTAGE TREATMENT UNIT

The principles of Screen, Grit, Centrifuge, Activated sludge respectively shall apply here also.

10.6.1 Collecting and Delivering Sludge

Collecting and delivering sludge by vehicle corresponds to the transfer of wastewater through a sewer, and constitutes a network for sanitary treatment systems. The collection and delivery efficiency varies depending on the scale of the source, the distance between facilities or distance to treatment plants, and the truck size. In general, 4-ton trucks are used for a small-scale facility, and 6- to 10-ton trucks for medium- to large-scale facilities.

Manual sludge extraction causes problems, such as insanitary workers and pollution due to splashing during transportation. Accordingly, a mechanical method (e.g. a pump truck pump or vacuum tanker) should be used as a rule. When the tank truck extracts sludge, the suction unit emits offensive odour, which requires measures. For example, a deodourizer (e.g. an activated carbon adsorption unit) is sometimes attached to the outlet. The tank truck is likely to be insanitary, so it should be cleaned regularly. In addition, water used to clean the tank inside should be treated hygienically.

If the distance from the collection point to the vehicle is large or the difference in level between the two is large, it is necessary to install a suction pump on the way or to use a high-power vacuum tanker.

The vehicle carries highly corrosive matter. Therefore, it is essential to clean internal parts of the tank and change the lubricating oil.

10.6.2 Basics of Sludge Treatment

There are various sludge treatment methods, including treatment in a special facility, common treatment in a sewage treatment plant, and solar drying on a floor. It is necessary to select an optimal method considering the local conditions. The following summarizes common and basic points for planning sludge treatment and disposal:

- Sludge includes worm eggs and pathogenic bacteria, so a sanitary treatment method (not manual method) should be used.

- The organic concentration of sludge is more than 100 times higher than that of wastewater. Discharging it into the environment without treatment causes pollution, so proper treatment is necessary.
- Water accounts for a major part of sludge, so technology or operation for efficiently separating the water from the sludge is necessary.
- The operation and maintenance of a sludge treatment system require the development of human capabilities.
- It is necessary to introduce a resource recycling system; for example, to safely treat sludge for agricultural use.

10.6.3 Operation Control of Sludge Treatment

10.6.3.1 General

Like a sewage treatment plant, staff members reside in the sludge treatment facility, which in most cases is designed to receive collected sludge and run the main units including the solid-liquid separator in the daytime. A control system can be established in which no staff member works during night and on holidays.

The characteristics of sludge collected from septic tanks vary depending on the scale, extraction frequency, and load condition. Accordingly, the administrator of the treatment facility should hold prior discussion with the collecting vendor. The following shows key agenda items to be discussed:

- In a medium- or large-scale sewage treatment plant, a large amount of sludge is extracted at once. Therefore, the administrator should ask the vendor to distribute the work over several days to mitigate changes in the amount of sludge.
- The administrator should ask the vendor not to concentrate sludge delivery in a limited time slot.
- Sludge collected from restaurants may include a large amount of oil. Accordingly, the administrator should ask the vendor to adopt measures against this problem.
- Industrial sludge degrades the biological treatment function significantly, so the administrator should ask the vendor to adopt measures against this problem.

Figure 10.4 shows the configuration of a sludge treatment facility. The main process is solid-liquid separation. The maintenance of the facility requires expertise in the solid-liquid separation technology of sludge.

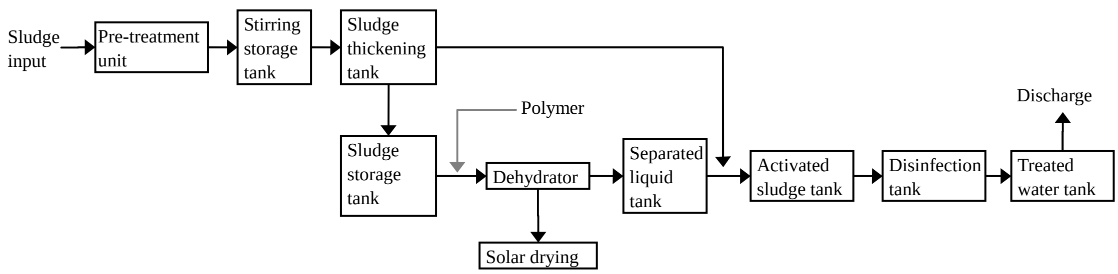


Figure 10.4 Flow chart of sludge treatment

10.6.3.2 Controlling the Pre-treatment Unit

a. Pre-treatment

Collected sludge includes foreign substances, such as cloth, paper, wooden pieces, soil, and sand, which should be removed, because they cause clogging of pipes or equipment failure.

The pre-treatment unit consists of a screen and sedimentation tank (Figure 10.5). Extracting the foreign matter including sand is insanitary work, so it is recommended that such work be automated.

The automatic raking screen rakes and places garbage into a bucket automatically, but it is necessary to clean the screen and extract the garbage.

Soil and sand accumulated at the bottom of the sedimentation tank should be discharged to the outside by a high-powered suction vehicle. There is a method of vacuuming the discharged sand.

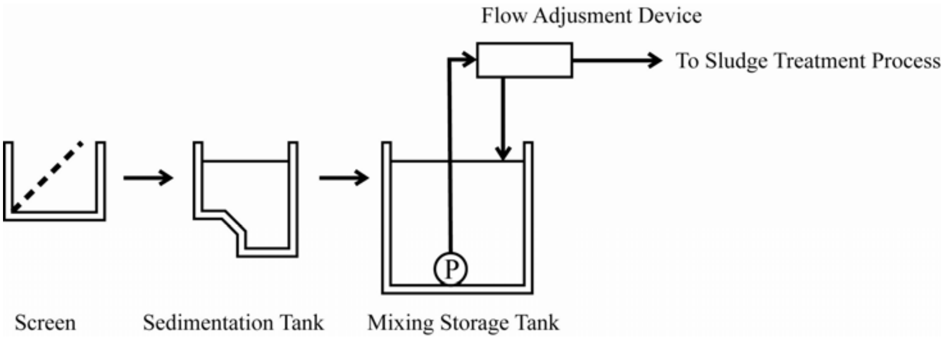


Figure 10.5 Flow chart of a pre-treatment unit

b. Stirring Storage Tank

The nature of collected sludge varies, so the stirring storage tank is used to make the quality and quantity of sludge uniform. The stirring method may be classified into aeration and pump circulation methods. The former is sounder and less troublesome. However, because of offensive odour, the installation environment may require the tank to be equipped with a lid to deodourize collecting odour. A given amount of the treated sludge moves from this tank to the sludge thickening tank via a transfer pump and a metering regulator. The operation control of mini package plants (Section 10.3.2.1) applies to each unit.

c. Controlling the Solid-liquid Separation Tank

i. Sludge Thickening Tank

An important point for running the sludge thickening tank is the adjustment of the extraction time according to the sludge accumulation status. Therefore, it is essential to observe the concentration of the extracted sludge. There are some sludge extraction methods, such as a manual pump and a combination of a timer and a pump. The daily control of the thickening tank includes removing scum on the surface and cleaning the area around the overflow weir.

ii. Sludge Storage Tank

This tank emits hydrogen sulphide and causes lack of oxygen because it keeps sludge in an anaerobic state. Accordingly, safety measures should be taken while cleaning the tank interior.

iii. Flocculant

The purpose of adding a flocculant is to change the nature of sludge particles to improve dewaterbility. The flocculant is classified into organic and inorganic (polymer) types, which are used independently or in combination. In many cases, the organic flocculant is powder, which is diluted to attain a specified concentration. The sludge thickening method is classified into two types: one uses a condensing tank with a stirrer, and the other employs a centrifugal separator in which a flocculant is injected directly into the sludge supply pipe. Selecting a proper flocculant basically requires a jar tester.

iv. Sludge Dehydrator

Refer to Chapter 5. (Sec.5.4 “Sludge Dewtering”).

d. Controlling the Activated Sludge Treatment Unit

Refer to Chapter 4. (Sec.4.7 “Activated Sludge Process”).

10.7 SUMMARY

On-site wastewater treatment has the following features; it is carried out near the source; its scale is mostly small because the treatment applies to individual houses; and a variety of technologies are adopted according to the surrounding conditions. Accordingly, there are cases where the administrator itself or a private special vendor conducts operation control of on-site facilities. In the operation control of a septic tank, a typical on-site facility, it is important to extract accumulated sludge properly in order to keep the function stable. Therefore, the state and municipal governments need to draw Septage management plan based on the “Advisory note on Septage Management Guidelines” (MOUD, 2012). The optimal Septage treatment technology is selected in consideration of the local conditions. It is necessary to conduct operation control according to the selected treatment technology.

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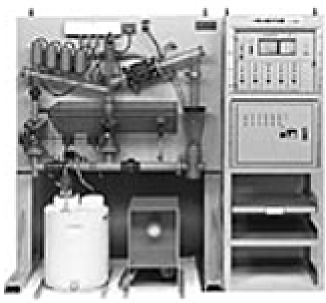
APPENDIX 1.1 MONITORING THROUGH INFORMATION CONTROL TECHNOLOGY

1.1.1 OUTLINE

Understanding the condition of sewage to be treated is very important for efficiently operating a sewage treatment plant. However, it is inefficient to receive data from site only at the time when such data is needed. That is why the condition of sewage to be treated can be grasped simultaneously by making use of systems for monitoring through information control technology. This can be done by centralized monitoring using systems such as SCADA (refer to Sec. 6.6 SCADA System, Part B), which helps to determine operating methods.

Items to be measured include DO, SS, pH, ORP, COD, influent flow rate, effluent flow rate, and return flow rate. Measuring equipment include equipment for measuring single items to those that can make several kinds of measurements simultaneously. Equipment that can make several measurements simultaneously, are described below.

1.1.2 EXAMPLES OF MEASURING EQUIPMENT



Source: DKK-TOA CORPORATION

Figure A1.1-1 Automatic water quality monitor

Features

- Monitors the environmental water quality of rivers, lakes, and other water bodies and the water quality of effluents, etc.
- Built-in automatic cleaning and calibration functions greatly reduce maintenance work.
- Integrated sensors are employed to reduce unit size and save space.

Measurement items

- Water temperature, pH, electrical conductivity, turbidity, dissolved oxygen

1.1.3 MONITORING EXAMPLE FROM JAPAN

1.1.3.1 Sewerage (Public Works Bureau) in the City of Osaka

- Operation and Maintenance (O&M) of Sewerage System

  It is important to properly operate and maintain facilities such as sewers, pumping stations and sewage treatment plants so that these facilities play their roles effectively.

- Operation and Maintenance (O&M) of Sewage Treatment Plants

  Sewage treatment plants are operated on a 24-hour basis in order to treat wastewater continually for ensuring effective operation of sewage treatment plants in response to varying inflow rates.

Various water quality examinations are conducted at plant laboratories to monitor the quality of the final effluent.

Figure A1.1-2 Water quality analysis

Figure A1.1-3 Central control room

1.1.3.2 Bureau of Sewerage Tokyo Metropolitan Government

Water Reclamation Centre

- Water reclamation centres must process wastewater as it flows in non-stop, 24-hours per day. If the centres should stop functioning properly, pollution would spread quickly to rivers and the sea.
- In order for microorganisms, which are the main players in the treatment process, to function properly and discharge wastewater debris as sludge, the water quality of influent and effluent is tested, and maintenance, inspection, and monitoring of equipment are performed constantly.

Figure A1.1-4 Main monitoring room in water reclamation centre

Note: Tokyo Metropolitan Government calls a "sewage treatment plant" a water reclamation centre.

APPENDIX 1.2 DATABASE FOR EFFECTIVE O&M

Effectively collecting, querying, analyzing, reporting, distributing, storing, and archiving data - whether electronic, paper, audio, image, or video—have become key to effective and efficient operations.

In recent years, raw data is being increasingly managed by computers.

A computerized maintenance management system (CMMS) {also called a computerized work management system (CWMS) or a work management system (WMS)} enables utilities to manage maintenance work and minimize equipment downtime cost-effectively. The system is designed to plan, schedule, and manage maintenance activities; control parts inventories; coordinate purchasing activities; and help prioritize long-term asset investment needs.

A CMMS typically consists of the following six components:

- Work management (corrective, preventive, and predictive maintenance scheduling, activities, and procedures);
- Equipment inventory (an inventory and description of equipment and support systems requiring maintenance, along with other technical or accounting information); Electrical equipment of ledger is shown in next page.
- Inventory control, tools, and materials management (materials, tools, and spare parts management, scheduling, and forecasting);
- Purchase or procurement (maintenance-related requisition, procurement, and accounting);
- Reporting and analysis (standard and ad hoc reports); and
- Personnel management (staff skills, wages, and availability).

If a database containing the items mentioned above can be used, costs can be easily managed, and the data can be used to prepare budgets.

Table A1.1-1 Ledger for electrical equipment

	Classification			File No.	

Name		Location		Related Ledgers	( )	( )
		Fixed asset No.			( )	( )

Items on name plate	Capacity					Rotor	Voltage	V	Others	Insulator type				
	Number of poles						Current	A		Insulation resistance allowance				
	Phase						Type			Rotating direction				
	Frequency	Hz				Rotation rate		rpm		Lead wire direction				
	Voltage	Primary	V	Secondary	V					Impedance voltage				
	Current		A		A	Specification			Test performance chart	Frequency				
	Mode1					Manufacturer				Voltage				
	Specification					Lot No.				Current				
						Date of mfg.				Loss				
	Mode1	( )		( )		Reducer	Reduction ratio			Measuring position	1) mm	2) mm		
Sleeve	Diameter	( )		( )			Mode 1				3) mm	4) mm		
	Length								Related charts	Name	Chart No.		Name	Chart No.
Coil	Wire	Type					Manufacturer							
		Thickness				Starting resistor	Voltage	V						
	No. of coils						Current	A	Special notes					
	Total weight						Resistance	Ω						
							Mode 1							
							Manufacturer							

Source: JICA, 2011

APPENDIX 1.3 CONCLUSIONS AND RECOMMENDATIONS

1. Mostly influent to the STP was found to contain lot of solid wastes including plastics,pouches etc. which may cause wear and tear of pumps & machinery and reducedefficiency of treatment, specially in case of UASB process where the feeding pipes and overflow weirs/V-notches in division boxes/effluent gutters, arechocked/obstructed, thus also resulting in reduced STP capacity. It is, generally,observed that mechanical screens installed in STPs/PSS are out of order, mainly because of the reason that these are not regularly sun and also clue to poor maintenance. Comprehensive scheme for providing solid waste management in all the towns including public awareness, institutional strengthening etc. need to be implemented. As an immediate solution to the problem, specially in UASB process, fine/mesh screens can be put in place of ordinary bar screens. Larger size of feeding pipes with more frequent cleaning can also solve this problem.

2. Staff/officers/engineers engaged for O&M at some STPs are not fully familiar and aware of the subject of sewage treatment. They are not trained in the O&M of the STPs. Proper training programme needs to planned & implemented for all the engineering level staff/officers who are deputed for O&M of STPs. This should be followed by training for operators as well as chemists who perform sampling/testing work.

3. At most of the STPs, either O&M manual is not prepared or it is not available/used, or it is not comprehensive enough to include various steps /procedures to be followed in day to day O&M of the plants as per design so as to have desired quality of treated effluent. O&M manual should spell out the procedure of reporting and recording of all the data/parameters including quality of waste water in various units of the plants.

4. Polishing ponds (in case of UASB process) and Waste Stabilization Ponds (WSPs) are mostly found accumulated with sludge resulting in reduced capacity/detention time in the tank. This also effects the quality of treated effluent due to sludge flowing out with it. Sludge levels should be checked regularly and the ponds should be cleaned off deposited sludge accordingly.

5. In case of polishing ponds or WSPs, it is found that single unit of these ponds have been provided in some STPs. In such cases, it is very difficult to clean off the accumulated sludge /silt without closing the STP. So it is important that at least two units of such ponds are provided at each STP. Also, in case of big ponds/channels wide and long partition/baffle wall need to be provided for easy access for inspection/repairs.

6. Sludge in UASB reactors are not withdrawn regularly based on its level and concentration in the reactors which results in sludge flowing with the effluent in polishing ponds and thus poor quality of treated effluent. Regular checking of sludge level and its concentration in the reactors is essential for proper sludge withdrawal.

7. Due to improper removal of filtrate from sludge drying beds, subsequent removal/withdrawal of sludge from sludge drawing beds/reactors is not possible in a desired manner, as the capacity of sludge drying beds is reduced. Hence, filtrate from the beds and sludge from the reactors/sludge drying beds need to be taken out regularly in a proper way.

8. It is important to prepare daily status report so as to record occurrence of problems in respect of running, functioning, repair, maintenance etc. of all the equipments, units, facilities etc. installed in each STP, so that the problems, if any, can be solved as and when applicable. This will also serve as feed back for future planning & execution as well as tool for monitoring the performance of STPs at a higher level.

9. Some of the STPs don’t have sufficient baffle walls and also, sufficient length of

overflow weirs at their final outlets in case of UASB polishing ponds and WSPs, resulting in poor effluent quality. Baffle walls should be constructed for whole length the pond width so that scum/sludge does not flow out with the effluent. Similarly, longer overflow weirs will ensure less approaching velocity of flow and subsequently, efficient solid liquid separation.

10. In view of frequent rusting/damage of iron/MS parts/accessories installed in STPs/PSs due to sulphur action, such items e.g. railings, screens, platforms etc., as far as possible, should be manufactured in stainless steel, as seen in case of STPs being constructed/renovated in TamilNadu, Maharashtra etc. Moreover, small electric installations such as motors, flow meters, starters, etc put up for operation of aerators, screens, grit removal mechanism, gates etc. should be covered with temporary sheds (PVC) to protect against rain water, dust etc.

11. It is observed that in most of the towns specially, in UP, Bihar and even Delhi, where there is acute shortage of power supply, standby arrangement during power cut/failure does not generally exists to meet the power requirement for running the plant. Frequent & long power cuts and subsequent sudden discharge into the STP also causes shock load to various units of STP, even in UASB and WSP processes, thus adversely effecting the efficiency of treatment. Hence, alternative standby arrangement in the form of generators along with sufficient funds for fuel need to be provided to ensure continuous operation of STPs. Intermittent operation of STPs will not help in achieving the desired quality of treated effluent and thus minimizing the river water pollution. In addition, unless continuous power supply is available effluent quality parameters specially, BOD etc can not be tested accurately.

12. Majority of State Govts./implementing agencies are not able to provide sufficient and regular funds for O&M of STPs resulting in their unsatisfactory performance. The annual const of O&M of sewerage system and STPs in a town varies from 5 to 10 %, depending on the quantum of pumping (stations) and type /size of STP. It is also observed that the revenue from STPs is negligible or far less than the expenditure required to be incurred for proper O&M of the STPs in all cases. In case of STPs constructed with central funding under NRCP by Ministry of Env. & Forests, O&M cost is to be borne by the State Govts. If the amount for O&M of STPs can not be provided on regular basis by the State Govts., the matter needs to be looked into at the highest level, whether further new works should be taken up under the programme.

13. Sometimes, the staff/engineers engaged in O&M of the STPs are frequently transferred so that their experience and know-how does not get transferred to their successors & is thus not available for O&M of the STP. So the O&M staff/engineers should be deputed at a plant for sufficient no. of years and their experience and knowhow transferred to their successors in a planned & systematic manner. In case O&M is being got done privately through an annual contract, the agreement should be such that the same contractor continues after initial period of one year, subject to its satisfactory performance. As a matter of fact, O&M of a STP should be included in the main construction contract for a period of at least 5 to 10 years. This arrangement is found to be giving good results in case of some of the STPs, namely at Channai, Panji, Nasik etc. where this practice has been adopted.

14. Mostly the result of tests for effluent quality being carried out by various independent agencies are not fed back to the staff managing the O&M of the STPs. As a matter of fact the results of the tests, especially, if they are adverse, should be informed to the operating staff as soon as possible so that corrective measures can be taken at site accordingly. Also, testing of effluent for fecal coliform is not being done in most of the plants which is one of the most important indicator in abatement of pollution of rivers.

15. In some of the states, specially in UP, O&M of the STPs in some towns is being done by local bodies which do not have qualified, experienced and knowledgeable staff who can supervise the O&M of the STPs. Local bodies have engaged private agencies on contract for O&M of these STPs but their performance is very much unsatisfactory. This arrangement of O&M of STPs by local bodies, where competent staff is not available, may not last long. In such cases, if it is essential for O&M to be done by local bodies only, staff/engineers with experience in O&M of STPs should be got transferred/appointed from the implementing agency, namely UPJN who have constructed the plant.

16. A holistic approach for abatement of pollution of rivers need to be adopted as on one hand population and other human activities are increasing & on the other hand the problem further gets compounded due to declining minimum flow, as a significant quantity of water is abstracted upstream of a town for irrigation/drinking purposes. This is specifically applicable in case of Yamuna in Delhi where all the water is withdrawn from the river upstream of Wazirabad barrage.

17. It is estimated that out of 3267 mld of sewage generated in Delhi, 2376 mld treatment capacity exists. But only 1530 mld of total sewage generated is treated at the STPs. Thus only 64.37% of treatment capacity of STPs is utilized. Under utilization of capacity of treatment is on account of (i) deficiency in sewerage not work (settlement/silting of trunk sewers) and (ii) improper O&M of conveyance system and pumping stations. Also, it is important to note that treated sewage is mostly discharged into storm water drains (17 nos.) which carry untreated sewage and join river Yamuna. Storm water drains carry sewage from unsewered areas, overflow from manholes/pumping stations and treated/untreated industrial wastewater. In order to have desired quality of river water in Yamuna at Delhi, the following immediate measures need to the taken :-

    a. Rehabilitation/desilting of trunk sewers.

    b. Provision of sewerage net work in unsewered areas.

    c. Augmentation of treatment capacity of STPs as per requirement.

    d. Use of treated effluent for irrigation & other purposes.

    e. Proper O&M of the sewerage system & STPs.

18. Sewage treatment with WSPs (anaerobic, facultative and maturation ponds) is most economical in terms of capital as well as O&M cost and is suitable for small towns where sufficient land is easily available. But certain basic precautions e. g. providing proper weir length and baffle wall(s) at the outlet of ponds during construction; and proper O&M in respect of cleaning of sludge deposited in ponds at suitable intervals (6 to 12 months) and arresting algal/hyacinth growth are minimum requirements which have to be kept in mind for achieving desired results.

19. Conventional treatment process, namely ASP/trickling filter is very much suitable in case of large towns, where land is scarce, provided there is no shortage of power and funds to meet capital and O&M costs. In some of the large towns UASB process has been provided under NRCP, as it is economical in respect of O&M as compared to ASP. But it is observed that in some cases desired results are not achieved as O&M agencies are not paying importance to the intricacies involved in the treatment process, namely uniform feeding to the plant/reactor, proper grit removal & withdrawal of sludge from UASB reactors, regular cleaning of accumulated sludge from polishing ponds etc. Improper O&M of these plants is giving a bad impression about UASB technology, which otherwise appears to be quite appropriate for sewage treatment for most of the

towns in our country.

20. In places, where land availability is very scarce, sewage treatment using FAB (Fluidized Aerobic Bed) reactor, in which biomass grows on small elements (media) that move along with the water in the fluidized bed state, can be the most appropriate choice. The movement is caused by bubbling air at the bottom of the reactor. The system has been provided in a few towns under NRCP but poor O&M might give a negative signal in adoption of this process of treatment.

21. Schemes for providing interceptors with nala-tapings and main/trunk sewers along with STPs (down stream works) are being implemented under NRCP by Ministry of Env. & Forests in various towns which are situated on the bank of different rivers and are polluting the river waters. Upstream works i.e. internal/branch sewers including house connections etc. for a town need to be taken up by the State Govts. Through their own resources so as to have a holistic approach in abatement of pollution of rivers. This will also help in solving the problem of weak sewage reaching the STPs for treatment. Besides, it is also observed that sewerage schemes in various towns are being sanctioned/implemented by different agencies/departments under different Central/State plans e.g. NRCP by Ministry of Env. & Forests, NURM by MOUD etc. Unless proper coordination exists between different agencies/departments, implementation of sewerage schemes may lead to defective planning/execution and duplication of works, without achieving the desired goal. Thus, as far as possible, all the sewerage schemes for a town should be sanctioned/implemented under a single funding agency/Ministry.

22. Out of 68 no. of STPs inspected for their performance evaluation, it is observed that O&M in case of 40 no. of STPs is found to be poor or very poor for various seasons. There is no mechanism for physical monitoring of the performance of STPs constructed and commissioned under NRCP by Ministry of Env. & Forests. These are seldom visited by higher officers of NRCD in Ministry of Env. & Forests for their inspection so as to get first hand information on the status of O&M of STPs by the State Govts./implementing agencies. Moreover, the scope of work of Project Management Consultants (PMC), appointed by the Ministry for implementation of YAP - II, includes monitoring of O&M all the STPs constructed in Delhi, UP & Haryana under YAP – I. But it is understood that no action has been taken by NRCD in this respect since the appointment PMC two years back. Regular monitoring of all the STPs for their performance evaluation at central level (CPCB) twice a year by having own independent sampling/testing of wastewater need to be carried out for bringing improvement in O&M of STPs and get the desired quality of treated effluent.

23. It is understood that projects based on generation of electric power from biogas, which is being produced as a result of digestion of sludge in STPs, are eligible for CDM (Clean Development Mechanism), as it will help in reducing and stabilizing the emissions due to methane which is a green house gas. Based on the potential of biogas/power generation from STPs, expenditure on O&M can be offset by earning ‘carbon credits’ on recurring basis. It is, therefore, recommended that a feasibility study should be got done for taking up a CDM project in case of any one of the STPs by DJB in Delhi as it can be a perennial source of revenue generation.

In view of importance of abatement of pollution and preservation of rivers and other water bodies, proper sewage treatment, its O&M and subsequently, optimum utilization of treated sewage for irrigation and other purposes needs to be given higher priority by Central/State Govts. urgently. Looking into the overall situation of O&M of the STPs, it can be concluded that sewerage and sewage treatment is generally not considered a priority item by the State Govts./local authorities/implementing agencies. So, unless importance/priority is given by them, the situation may become bad to worse.

APPENDIX 2.1 TROUBLESHOOTING IN SEWERS

Table A2.1-1 Troubleshooting in sewers

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	House sewer does not flow	Toilet floor below road elevation	Raise the toilet floor	Install small lifting arrangement
		House sewer pipe broken	Relay the sewer	Go for new connection
		Solids are choking the sewer	Use a kraite from the terminal chamber	Dig out the sewer and relay
		Connection is made to public sewer by Y or Tee junctions	Dig open the junction in road and rectify	Insert a manhole in public sewer
		House connection may be passing through bends	Dig it out and relay in straight alignment	Construct a new sewer in another alignment
		Roots of trees might have grown into the sewer	Expose the pipe and shear off the roots	Dig out and relay the sewer
2.	Septic tank emits foul smell	Organic matter has accumulated at the bottom and become concentrated	Raise the vent higher than the roof for free air passage	Take a sewer connection if available
3.	Septic tank effluent smells bad odour	This is always the case when discharged freely	Provide a leach pit and then let it out to road drain	Provide trees for evaporating the effluent
4.	Sewage overflows from manholes	The sewer to the next manhole is choked (or) some other downstream sewer is choked	Open out downstream manholes to find out where the sewage is not flowing	Use jet rodding machine at the downstream end and jet the sewer at the high end
		The sewer has collapsed in the next reach or somewhere else downstream	Use a bucket cleaning machine to establish the broken sewer or not	If established, dig out and provide new sewer pipe after temporary blocking upstream
5.	Sewage level does not go down at all in the sewage pumping station	The sewage pump sets are very old and worn out (or) ground water is infiltrating into the sewers	Check the TDS by a pocket meter every hour to find out abnormalities in nights. If TDS is much less in nights ground water is seeping through defective sewers or joints	Provide a bypass to nearby water course in the night hours and arrange for higher capacity pump sets to nearby STP or next higher pumping station. Launch a study to locate the infiltration

<table>
<tr><th>No.</th><th>Troubles / Problems</th><th>Likely causes</th><th>First stage remedies</th><th>Second stage remedies</th></tr>
<tr><td rowspan="2">6.</td><td rowspan="2">Sewer manhole keeps sinking into ground</td><td rowspan="2">The sub surface soil is defective (or) the foundation has given way</td><td>Insert new manholes on each side at a reasonable distance to be away</td><td>Interconnect by a CI or DI sewer pipe laid on proper venteak piles</td></tr>
<tr><td colspan="2">Use temporary bypass pumping of sewage from upstream manhole to downstream by diesel pump sets and flexible hose till the above remedy is completed. Connect the house service connections to the upstream manhole</td></tr>
<tr><td>7.</td><td>Public do not want ventilating columns near their property</td><td>The sewers are choked and anaerobic conditions have set in resulting in foul smelling Hydrogen Sulphide gas</td><td>Pull out the column and seal the connecting pipe to the public sewer</td><td>Try to ensure sewers flow freely and not over 80 % of its depth at all times</td></tr>
<tr><td>8.</td><td>Sewage pump sets require priming and take a long time</td><td>The pump is horizontal and its axis is higher than the sewage elevation in the well</td><td>Replace by wet submersible pumps</td><td>Redesign the pumping station fully</td></tr>
<tr><td>9.</td><td>Sewers do not let out sewage at downstream manhole</td><td>The sewer has collapsed in between and sewage is going into the ground</td><td colspan="2">Similar to the troubleshooting of item 1 above</td></tr>
<tr><td>10.</td><td>Road collapse occurs</td><td>The underground portion is hollowed because sand has been drawn into the pipe due to breakage or step displacement</td><td>safety equipments such as barricade, signs or security lights should be installed immediately around the collapsed road to prevent secondary disaster</td><td>Dig out the sewer and re-backfill or relay.
As other methods, soil stabilization is required</td></tr>
</table>

APPENDIX 2.2 T.V. INSPECTION REPORT

Table A2.2-1 T.V. inspection report

Book No.______________ Page No. ______________ Date:______________

Camera Direction M.H. No._________to M.H.No.____________________Viewer____________

District:	Pipe size & type:	Street	☐	Quadrant Code	4 1 / 3 2
		Easement	☐		
Distance:	Cleanliness of line:	M.H.Condition:		Grade of Line:	

Distance Reading	Quadrant				Photo No.	Remarks	Repairs	Root Rating
	1	2	3	4				

APPENDIX 3.1 DETAILED TROUBLESHOOTING FOR HORIZONTAL CENTRIFUGAL PUMP SETS

Table A3.1-1 Type of troubles

No	Type of Trouble	Probable causes as per conditions indexed in Table below
a.	Pump does not deliver water	1,2,3,5,6,7,9,10,15,18,21,23,26,28,29,30,31,33,40,41,42
b.	Insufficient discharge	2,3,4,5,6,7,8,9, 10,13,16,17,18, 20,21,23,24,27,28,29,30,31,33,39,40,41
c.	Insufficient pressure is developed	2,3,4,21,23,24,26,27,28,33, 39
d.	Pump loses prime after starting	22,25,28,33,37,38,49,53,54, 55,56,58
e.	Pump requires excessive power	22,25,28,33,37,38,49,53,54, 55,56,58
f.	Stuffing box leaks excessively	34,36,44,45,46,47,48,50,51, 52
g.	Gland packing has short life	11,12,34,36,44,45,47,48,49, 50, 52
h.	Bearing has short life	17,20,32,34,35,36,37,39,41, 44,48,51,54,55,56,57,58,59, 60,61,62,63
i.	Pump vibrates or is noisy at all flows	10,17,19,20,22,33,34,36,37, 38,40,41,43,45,46,47,48,51, 52,53,55,56,57,58,59,60,61,62, 63, 65
j.	Pump vibrates or is noisy at low flow	1,2,3,9,10,17,20,21,27,39
k.	Pump vibrates or is noisy at high flow	25,28
l.	Pump oscillates axially	38
m.	Coupling fails	34,36,38,60,62
n.	Pump overheats and /or seizes	1,2,3,11,12,17, 2 0,24,26,27, 31,34,36,37,38,44,45,47,48, 49,50,53,54,55,56,57,58
o.	Pump rotates in reverse direction on shutdown or after power failure or tripping	14,64

Table A3.1-2 Probable causes

No	Probable Causes
1.	Pump not fully primed
2.	Pressure at eye of impeller has fallen below vapour pressure, causing cavitation (check for clogging on suction side)
3.	Suction lift too high. (Reduce suction lift after calculating permissible suction lift from NPSHA and NPSHR)
4.	Excessive amount of air in liquid
5.	Air pocket in suction line (Check whether any point in suction line is above centre line of pump, and if so, lower the line)
6.	Air leaks into suction line
7.	Air leaks into pump through stuffing boxes or mechanical seal

No	Probable Causes
8.	Net opening area of foot valves is small
9.	Foot valve/strainer partially or fully clogged or silted up
10.	Suction bell mouth or foot valve insufficiently submerged
11.	Water-seal pipe clogged
12.	Seal cage improperly mounted in stuffing box, preventing sealing and allowing fluid to enter space to from the seal
13.	Circular motion in suspended suction pipe observed (The problem indicates occurrence of vortex)
14.	Foot valve leaks
15.	Flap of foot valve jammed
16.	Concentric taper in suction line causing air pocket (Replace with eccentric taper)
17.	Occurrence of vortex in intake, sump or well (Check whether all parameters for vortex-free operation are satisfied; take remedial measures)
18.	Casing not air-tight and therefore breathing in
19.	Short bend/elbow on suction side
20.	Inadequate clearance below suction bell mouth (Raise bell mouth to achieve recommended bottom clearance for vortex-free operation)
21.	Speed too low for pump driven by diesel engine
22.	Speed too high for pump driven by diesel engine
23.	Wrong direction of rotation
24.	Total head of system higher than design head of pump
25.	Total head of system lower than design head of pump
26.	Static head higher than shut off head of pump
27.	Pump characteristics unsuitable for parallel operation of pumps
28.	Burst or leakage in pumping main
29.	Pumping main partially or fully clogged
30.	Air trapped in pumping main
31.	Malfunctioning of line valve causing partial or full closure
32.	Capacity of thrust bearing inadequate
33.	Foreign matter in impeller
34.	Misalignment

No	Probable Causes
35.	Foundations not rigid, or broken/loose foundation bolts, or supporting structural member (RCC/ structural steel beams) not rigid (Dismantle existing foundation and cast new foundation. Strengthen supporting RCC/ structural steel beams)
36.	Pump (impeller) shaft bent
37.	Rotating part rubbing on stationary part
38.	Pump shaft bearing (bush bearing or anti-friction bearing) worn
39.	Wearing rings worn
40.	Impeller damaged
41.	Impeller locking pin loose
42.	Pump shaft or transmission shaft broken
43.	Transmission shaft bent
44.	Shaft or shaft sleeves worn or scored at the packing
45.	Gland packing improperly installed
46.	Incorrect type of gland packing for operating conditions
47.	Shaft running off centre because of worn bearing or misalignment
48.	Rotor out of balance, causing vibration
49.	Gland too tight, resulting in no flow of liquid to lubricate gland
50.	Failure to provide cooling liquid to water cooled stuffing boxes
51.	Excessive clearance at bottom of stuffing box between shaft and casing, causing interior packing to be forced into pump
52.	Dirt or grit in sealing liquid, leading to scouring of shaft or shaft sleeve
53.	Excessive thrust caused by mechanical failure inside the pump or by the failure of the hydraulic balancing device, if any
54.	Excessive grease or highly viscous oil in anti- friction bearing housing or lack of cooling, causing excessive bearing temperature
55.	Lack of lubrication causing overheating and abnormal friction in anti-friction bearing, bush bearing or transmission shaft bearing
56.	Improper installation of anti-friction ring (damage during assembly, incorrect assembly of stacked bearings, use of unmatched bearings as a pair, etc)
57.	Dirt in bearings
58.	Rusting of bearing from water in housing
59.	Mechanical seal worn out
60.	Coupling bushes or rubber spider worn out or wear of coupling
61.	Base plate or frame not properly levelled

No	Probable Causes
62.	Coupling unbalance
63.	Bearing loose on shaft or in housing
64.	Reflux valve (NRV) does not close tightly during shut down, after power failure or after tripping
65.	Critical speed close to normal speed of pump

Source: JICA, 2011

APPENDIX 3.2 POSSIBLE CAUSES AND CORRECTIVE ACTIONS TO CHECK FOR PUMPS

Table A3.2-1 Corrective actions

(1) Pump won't start or run	
Float switch is not being raised high enough	Check to see if float ball is stuck. If so, remove obstacle. If required, reposition pump or remount switch in new position so it does not get stuck. Fluid level might not be high enough to engage switch. Raise float manually or add water until float is at activation height to test switch
Pump is not receiving adequate power	Check outlet to ensure that it has power. If not, replace fuse or reset breaker in fuse/breaker box. Plug pump directly into an outlet without using an extension cord. If extension cord MUST be used, ensure that it is made of adequately heavy gauge wire to support the length of cord and horsepower of pump being used. Check that wire providing power to the outlet where pump is plugged in is adequate. Pump should be plugged into an outlet that is fed by its own circuit breaker (or fuse).If circuit breaker feeds power to other outlets or appliances, use an outlet that is fed by its own breaker
Impeller is jammed with debris	Remove screen from bottom of pump and make sure no obstruction is preventing the impeller from moving freely. Remove any obstructions
Float switch is defective	Bypass the float switch. Unplug pump cord from the piggyback plug of float switch. Plug the pump's plug directly into outlet to test. If pump runs, float switch is defective. Replace float switch. (Do not leave pump plugged in too long or it will burn out)
Pump is defective	If all items above check out OK, then pump is defective and needs to be replaced
(2) Motor hums but little or no fluid is ejected from pit	
Motor is just humming but does not run	Follow diagnostics above for "Pump won't start or run"
Pump is air-locked	Drill 1/16" to 1/8" anti-airlock hole in pipe just above pump's discharge and just below check valve

Check valve is stuck or closed, or installed incorrectly	Check valve usually has an arrow on it indicating water flow. Ensure it is pointing up towards the discharge, not towards pump. Inspect to see if check valve is stuck or closed.We recommend check valves be installed horizontally in sewage applications so solids cannot settle onto the flapper valve and hold it shut
Impeller is damaged	Inspect impeller for worn or missing blades. Replace impeller if needed
Discharge pipe is partially or fully blocked	Check for blockages at discharge of pipe. If in cold area, see if pipe is frozen closed. Discharge pipe has too many 90-degree elbows which restrict flow. Using more than 3 or 4 elbows can restrict flow considerably. Consider using 45° elbows instead of 90° elbows
Impeller is jammed	Inspect impeller area of pump for debris that has jammed the impeller. Remove as needed
Suction intake screen is partly or fully blocked	Inspect suction screen at bottom for debris blocking it. Remove debris
Volute (bottom of pump) is cracked allowing water to leak out	Inspect bottom section of pump for cracks or holes that would allow water to escape
Discharge pipe is leaking	Inspect discharge pipe and joints for any location where water can leave the pipe and return to the sump pit
(3) Pump runs for a short time and ejects some fluid but shuts off before pit is empty. (Bear in mind a few inches will remain at bottom of pit. This is normal)	
Pump is overheated and shut off by thermal overload	Be sure that pump is plugged directly into outlet. It is recommended that the outlet be fed by its own circuit breaker (or fuse). If the breaker (or fuse) sends power elsewhere, the pump may be short of voltage when it starts. Make sure proper pump has been chosen for your application. A sewage or effluent pump is designed to empty a sump, sewage or effluent pit. Using this pump where it can run for extended periods (waterfalls, pond circulation, etc.) can cause overheating
Float switch is out of adjustment	Check if pump shuts off before float ball is all the way down. If it shuts down too early, adjust float switch according to instructions in the owners' manual
Float switch is defective	If adjustment above did not resolve problem, or no adjustment is possible, replace the float switch
(4) Pump runs continuously	
Pump cord and float switch cord are plugged in separately	Plug pump cord into piggyback connector on back/side of float switch plug. Place the combination in a single receptacle of an outlet

Float switch is stuck	Inspect pit for debris that can cause the float ball to get stuck and not settle at its OFF position. Remove debris or relocate pump or switch to avoid it
Float switch is out of adjustment	For tethered style float ensure there is minimum of 5cm of cord between float ball and cord mounting bracket. Make sure cord is not so long that float can settle on floor of pit and not hang straight down
Fluid is not being discharged from pit	See item above labelled "Motor hums but little or no fluid is ejected from pit"
(5) Pump starts and stops too often	
Sewage pit or basin is very small	A very small pit or basin will simply not hold as much water. Enlarging the pit or basin (if possible) would be wise
Float switch is out of adjustment	For tethered style float ensure there is minimum of 5cm of cord between float ball and cord mounting bracket
Fluid is coming back into pit from discharge pipe	After pump has run, inspect to see if fluid is coming back into pit through the pump. If so, the check valve has failed. Replace the check valve
(6) Pump is noisy	
Discharge pipe is rattling or banging against wall and/or floor joists	Place insulating foam between pipe and wall and/or joists. Try hanging the pipe with an exhaust hanger from an auto parts store. Install a section of flexible rubber hose (like radiator hose) between the pump discharge and the discharge pipe for insulating vibrations
Check valve slams shut with a bang just after pump shuts off	Install a section of flexible rubber hose (like radiator hose) between the pump discharge and the discharge pipe for noise insulation. You may be using a pump that is higher in horsepower than you need. It may cause the water to move too fast in the pipe. After the pump shuts off, the fluid column keeps moving upward for a moment, then slams down
Pump is sucking air at end of its cycle	Adjust float switch according to the owners' manual so that it shuts off before it starts sucking air
Pump itself is vibrating	Inspect impeller for broken or missing blades, or debris stuck to blade. Clean / replace impeller or pump to rectify but also inspect sump pit to eliminate debris that could damage new impeller
(7) Fuse or circuit breaker feeding the outlet where pump is plugged in trips or blows when pump activates	
Water entered cord and/or float switch connector (especially possible if your breaker is a GFCI type breaker)	Separate pump plug from switch plug use hair dryer to dry them out. Remove cord connector from top of pump and dry out with cloth or hair dryer

Impeller is stuck or jammed with debris	Remove screen from bottom of pump and make sure nothing prevents the impeller from moving freely. Remove any obstructions
Using an extension cord or wiring to outlet which is of inadequate capacity	Check to make sure the wire supplying power to the pump is appropriate for the horsepower and amp draw of the pump in place
Shared circuit breaker (or fuse)	We recommend that the pump be plugged directly into an outlet and that the outlet is the only item being powered by the circuit breaker that feeds it. If the breaker is powering other items, the additional draw of the pump starting can pop the breaker (or blow the fuse)
Float switch is defective	Plug pump directly into outlet (without plugging into float's piggyback plug) to see if pump runs without popping breaker or fuse. If it does, but it pops fuse/breaker when plugged in through float switch, the float switch is defective. Replace float switch
Pump motor has a shorted winding	If all the items above check out OK, then the motor may be defective and it will be necessary to replace the pump

APPENDIX 3.3 TROUBLESHOOTING IN SEWAGE PUMP STATIONS

Table A3.3-1 Troubleshooting in sewage pump stations

<table>
<tr><th>No.</th><th>Troubles / Problems</th><th>Likely causes</th><th>First stage remedies</th><th>Second stage remedies</th></tr>
<tr><td rowspan="3">1.</td><td rowspan="3">Sewage pump set starts pumping and automatically trips after some time</td><td>The rated current has been exceeded because of worn out motor</td><td>Check the current drawn and compare value with that in the manual for pump set</td><td>If it exceeds rated current, stop the pump & report to competent officer</td></tr>
<tr><td>Cavitation has changed the dynamic balance of the impeller</td><td>Check for unusual gurgling sounds from the pump volute</td><td>If so, stop the pump &report to the competent officer</td></tr>
<tr><td>The pumping mains has been choked and there is back pressure</td><td>Verify the outlet end of the pumping main if it is a free discharge</td><td>If a pipe seems to be clogged, close the valve, remove a pipe length and check</td></tr>
<tr><td>2.</td><td>Sewage pump motor heats up beyond permissible limit</td><td>Use an appropriate flap type thermometer. Do not use bare hands</td><td>Verify with the manual of the pump set</td><td>If heating is excessive, stop the pump & report to competent officer</td></tr>
<tr><td>3.</td><td>Sewage pump set makes a lot of noise</td><td>Bearings have worn out or cavitation has loosened parts of impeller</td><td>Use a hand held decibel level meter and verify from 1-m distance</td><td>If noise level exceeds 80 dB, stop the pump and report to the competent officer</td></tr>
<tr><td>4.</td><td>Sewage pump has continuous gland leak</td><td>A constant and steady drip is beneficial in gland packing of horizontal foot mounted pump sets, but a steady flow is a source of trouble</td><td>Most probably, the packing rope has softened and has given way</td><td>Stop the pump and rectify the same from fresh supplies</td></tr>
<tr><td>5.</td><td>Sewage pump vibrates noticeably</td><td>Most probably the foundation bolts have given way or cavitation has occurred within</td><td>Install a new foundation outside the footprint of old foundation</td><td>Make an adaptor frame and remount the base plate</td></tr>
<tr><td rowspan="2">6.</td><td rowspan="2">Pump seems to be drawing current but flow meter does not record any flow</td><td rowspan="2">The non return valve may have tripped and discharge pressure is not able to open the flap of the non return valve. The same thing may occur with a gate valve also</td><td>The pump delivery head may be in the shutoff range. This should be verified from the pump curve and delivery pressure gauge</td><td>Remove the pressure gauge, fit a standby calibrated pressure gauge and reconfirm that the pump is at the shutoff range</td></tr>
<tr><td colspan="2">Immediately shut down the pump set and arrange for opening and inspection of the non return valve and gate valve, and rectify the same. Allow the raw sewage to go through emergency bypass to identified water course</td></tr>
</table>

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
7.	Pump makes a humming noise when switched on but there is no discharge	Pump may not be receiving the designated voltage	Check the voltmeter reading	If it is lower by 5% stop the pump and report to competent officer or switch over to genset if the timing is morning peak flow
		Pump delivery line may be having an air lock	Check the air valve position and release any trapped air by opening it	If the air valve is defective, replace the ball inside
		If the pump is submersible, the bottom casing may have cracked and sewage may be escaping there itself	The pump has to be switched off and physically raised above the water level and inspected	If crack is detected, take pump out of service and send it to the pump manufacturer
		The suction opening may be blocked by some sheets or rags	Stop the pump set. Use another pumpset if available	Allow the well to flood. Chances are the sheet or rag may float up and can be removed by a long pole and hook
8.	Circuit breaker for the pump trips when pump is switched on	Pump motor may have shorted winding	This is to be verified by a qualified operator. If true, take the pump out of service and do not install unless it comes back fully repaired and with all correct records	

APPENDIX 4.1 TROUBLESHOOTING IN STPS

Table A4.1-1 Manual bar screens

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Grit settles in screen chamber	Velocity of approach and velocity of exit are less than 0.6 m/s The flow is not entering the screen perpendicularly and forms a swirl before it	Take a branch air line and fix it to agitate the sewage at entry and exit. This will at least help in buoyancy	Reconstruct the approach and exit channels appropriately and maintain at least 4 times the width in each location
2.	Screen rods get clogged with plastic sachets, rags, sanitary napkins etc	Same causes as in 1 above	Place a flow deflector arrangement in water resistant ply upstream like the turnstile used in horse racing	
3.	Hand rake rod cannot be “ploughed” freely through the full length of the screen	The rods might have been welded to a cross rod before the sewage enters the screen	Fabricate a new screen set of rods which are individually fixed in the concrete floor and the walking platform	
4.	Operator feels insecure to stand and rake	The width of platform is too small and there is no handrail behind him	Add extra width of platform with handrail at the upstream end	
5.	Operator is uncomfortable in sun and rain	There is no roof	Provide a light roofing arched cover and fix appropriate light on the roof edges so that the operator is not subjected to glare	
6.	Operator is not able to carry the raking bar with him while climbing up	There is no arrangement to keep the raking bar near the platform	Make arrangement for hanging the rod on the outer air side of the sidewall at waist height while standing on the platform	
7.	Unusual or excessive screenings	Increase in sewage quantity or higher peak sewage flows or industrial effluents may occur	Verify flows and verify that bypass peak flows back to inlet chamber during peak hours of flow if gravity permits	If gravity does not permit and flows are very high, demand additional screen chambers

Table A4.1-2 Mechanical bar screens

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Same as items 1 and 2 above			
2.	Screenings drop back into the sewage channel	The flap plate at the top requires resetting	Should not be attended by the operator. Call the equipment supplier	

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
3.	The moving raker drops back with a loud noise	The mechanical arrangement is faulty		
4.	Motor is running but raker does not move	Shear pin may be broken, or rope over the pulley may be loose, or rack & pinion are not in mesh	Should not be attended by the operator. Call the equipment supplier	
5.	Marks of metal made on metal in screen rods	Alignment of stationary and moving parts are not in order and these parts have moved away		
6.	Screen starts moving and suddenly the motor trips	Motor torque power is not adequate		
7.	Sewage overflows screen chamber	The screen may be clogged (or) the hydraulics and channel dimensions are not matching	If choking is not the problem, refer to the design department	
8.	Unusual or excessive screenings	Increase in sewage quantity or higher peak sewage flows or industrial effluents may occur	Verify flows and bypass peak flows back to inlet chamber during peak hours of flow if gravity permits	If gravity does not permit and flows are very high, demand additional screen chambers

Table A4.1-3 Detritors

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Detritors and classifiers do not bring out any grit	Sewage is flowing too fast across the detritors	Try to reduce the flow through the detritors by opening the bypass valve? and watch for improvement	If this solves the problem construct additional detritors as needed
		Grit classifier is not meshing with the grit evacuation channel floor in the case of scrapers	Try to screed the inclined floor to match the rakes	Get the channel made in SS and fix correctly
		The screw is not meshing with the curved portion in which it is moving	Change the arrangement to raker type. This is economical considering overall aspects	
		The sewage may not have grit at all	Take a sample in a beaker, allow it to settle and watch for grit load in raw sewage. If there is no grit, bypass the grit chamber and remove the mechanical equipment to stores	
2.	The grit has foul smell	The grit washing mechanism is not working	Install organic return pump to lift the sewage to the top of the grit washer rake (or) screw and wash down the organics	

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
3.	Excessive grit	Road washings, ash, or material from building sites may be entering the collection system	Add extra classifiers to the existing ones by additional SS troughs and screws	Trace the locations in collection system and rectify the connections
			Increase speed of scrapper as well as frequency of removal of grit	
4.	Excessive organic matter in the grit	This can occur when the flow is small and velocity through detritors is less than design velocity	Install additional organic return pumps in classifiers	Try to recirculate outlet flows to attain the velocity
5.	For all other mechanized systems refer the problem to the equipment supplier. The operator should not attempt repairs			

Table A4.1-4 Velocity controlled grit removal channels

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Grit gets washed away in the channels	Velocity varies widely between average flow and peak flow conditions	Refer the problem to the design department	
2.	Grit removal facilities do not exist	Usually travelling platform with trip switches at end and vacuum pump set with hanging hoses are provided to discharge into dedicated channel along the length of grit chamber. This probably not provided or it is not working	Do not attempt any rectification	Never enter the grit channel. Demand a mechanized grit removal system
3.	The grit delivered by the grit removal vacuum system has foul smel	The system design does not permit rinsing of the grit	Construct a grit washing hydro cyclone facility	
4.	Excessive organic matter in the grit	This can occur when the flow is small and velocity through detritors is less than design velocity	Reduce the number of parallel grit channels in use	Install temporary pump sets to recycle outlet flow
			Insert planks or brickwork along the length to reduce the width of flow and increase the velocity	
5.	Carryover of grit	Velocity is too high and detention period is too short	Increase grit removal frequency	Add more channels or introduce equalization basin for raw sewage

Table A4.1-5 Oil & grease removal unit - gravity type

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Oil and grease floats on the surface before the downstream baffle and cannot be skimmed	The required facility of a slit pipe rotatable at the surface of the oil has not been provided	Do not try to skim by any other means. The layer is best left as it is	Arrange for spraying an insecticide mildly once a day on the scum
		The required operating platform with handrails is not provided	Demand the platform	
		The slit pipe is not rotating	Try to loosen it by blowing hot air around its housing at the ends. This can be done by using a hair drier. Stand on the outside on a ladder and not on the oil trap	If this does not work, call the equipment supplier
2.	In hot summer fumes are seen above the unit	The oily scum becomes hot and starts emitting fumes	Immediately place a non flammable light roof on the unit	Install a non flammable light roof with 4.5 m headroom

Table A4.1-6 Mechanized oil & grease removal unit

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	All problems	Whatever the reasons, the operator shall not attend to the problem and shall call the equipment supplier		

Table A4.1-7 Primary clarifiers circular mechanical sludge scraper type

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Scum flows over outlet weirs	Scum baffle is not provided	Use a long wire brush to scrape out the biological growths if there is a circular walkway with handrail. If there is no walkway, do nothing	Install a circular platform with handrails on the land side. The platform shall be preferably RCC supported independent of the clarifier foundation
				Demand installation of a scum baffle all round and a scum removal arm

<table>
<tr><th>No.</th><th>Troubles / Problems</th><th>Likely causes</th><th>First stage remedies</th><th>Second stage remedies</th></tr>
<tr><td rowspan="3">2.</td><td rowspan="3">Sludge solids start floating</td><td rowspan="2">Choked up sludge withdrawal pipeline</td><td>If discharge is by gravity, open the valve fully and watch for sludge.
If no sludge drains out, pump compressed air if a “Tee” flange joint is available. If there is no “Tee” joint, bring a sewer jet rodding machine and jet the line at mild pressure for not more than a minute and again after an hour</td><td rowspan="2">Even after these measures, if the sludge does not drain, divert the sewage from the clarifier, empty out by temporary diesel pump set. Then hose, inspect and rectify. Invariably, sludge pipelines are of CI or DI and they do not collapse. However, if it has collapsed, major repair is called for especially after ensuring that dewatering the groundwater is done to below the floor level of the clarifier</td></tr>
<tr><td>If it discharges by direct suction and if no sludge drains out, pump compressed air if a “Tee” flange joint is available. If there is no “Tee” joint, bring a sewer jet rodding machine and jet the line at mild pressure for not more than a minute and again after an hour</td></tr>
<tr><td>Higher HRT generates gas bubbles, which reduces density of sludge solids, leads to floating of sludge lumps</td><td colspan="2">1. Spray water on sludge lumps
2. Increase sludge removal frequency</td></tr>
<tr><td>3.</td><td>Sludge scraper arms do not rotate</td><td>Jamming of motor, gearbox unit (or) breakage of transmission mechanism</td><td>Check whether electrical supply is available at the motor terminals.
Check the local push button switch with megger</td><td>If both the connection and switch are in order, call the equipment manufacturer</td></tr>
<tr><td>4.</td><td>Scraper arms rotate but the sludge coming out is merely sewage and sludge is occasional</td><td>Scraper blades have lost the squeegees at the floor level. This means the sludge is not moving towards the centre for withdrawal</td><td colspan="2">Guide a remote operated video camera on the sides of the wall at three or four locations. Inspect the film footage and perform repairs</td></tr>
</table>

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
5.	Excess growth of bio mass on the V notches in weirs	Indicates aerobic organisms growing in the grooves	Same procedure as in item 1 above	
6.	Sludge pump runs for few minutes and stops suddenly	If it is a horizontal foot mounted centrifugal pump set, the gland packing may be too tight	Verify electrical connections, and switch off the motor. Remove the gland packing and re-fit it properly	Even after these measures, if pump does not work, call the pump set supplier
		If it is a positive displacement stator-rotor pump set, the stator and rotor might have jammed	Call the pump set supplier	
7.	Sludge does not drain easily by gravity in hopper bottom tanks	Grit has entered the tanks and has choked the drain pipe of the hopper tank	Install air lift pumps on the top of tanks and evacuate the grit content periodically	Try to increase the efficiency of grit removal equipment
8.	Surges occur in the settling tank overflows on the weirs	The incoming raw sewage is probably being pumped directly from the collection system	Usually settling tanks can absorb a peak flow of about 2.5 times during morning hours but if the raw sewage itself is pumped intermittently, then an equalization tank is needed	
9.	Settling tank effluent is darker than raw sewage	Typically, the thickener overflow may be darker than sewage and can cause this problem	There is nothing to be done; this can be allowed to go on and will automatically be rectified after aeration tank	
10.	Bubbles are noticed in the tanks and sludge spreads after the bubbles	Too much detention in the settling tank introduces septic conditions and anaerobic activity. This releases methane and hydrogen sulphide bubbles	Increase sludge removal frequency to contain the problem	Recirculate the outlet flow back to inlet to increase the flow and reduce detention

Table A4.1-8 Activated sludge plants

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Raw sewage flow is much less than design flow	This is a common problem, and it seriously affects the performance causing huge waste in the electrical energy for aeration	If the plant has been constructed in at least two parallel modules, shut down flow to one module. This applies to all units like clarifiers, aeration tanks, thickeners and digesters	Simultaneously, in the other module, remove the air diffuser facilities, motors &gearboxes in other units and store them carefully in the store. Do not disturb piping and valves
			The clarifiers may be hydraulically under loaded causing serious problems like septicity and foul odour. Try to install temporary pump set and return 100 % of treated sewage back to screen chamber	Simultaneously, verify whether it is possible to install a lower air compressor of the required air capacity calculated by pro rating the same to the flow and same head
			If possible install a new air compressor without changing the motor	If there is VFD facility for the existing air compressor, try to adjust the output prorated to the flow
			The sludge withdrawal from primary clarifier will give thin sludge and the thickener may not need separate dilution water	Consult a process design person before operating the dilution water pump set. Too much water into thickener is not recommended
			In the secondary clarifier, operate the return pump set as designed. The excess sludge wasting time and volume may have to be adjusted pro rata to the sewage flow versus design flow	Simultaneously, verify the MLVSS in the aeration tank. If the concentration is too low compared to the design concentration, throttle and reduce recirculation in the treated sewage recirculation pump set
			The digester may not be working efficiently due to smaller organic load and possibly smaller solids concentration. Do not take any action	The dewatering machines will have facilities for polyelectrolyte addition. Check the proper dosage in the lab. Do not add more polyelectrolyte than actually needed

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
			The sludge dewatering machines may not give the required sludge consistency. If watery, it has to be put through the dewatering machine again	Construct required facilities to store the first time dewatered sludge and the required pump sets to pump it back again to the dewatering machine
2.	Microorganisms do not develop	A balanced availability of organic material, nitrogen and phosphorous must be available otherwise organisms will not grow	In STPs of industrial clusters where the work is only in day shifts, the sewage is actually mostly urine and no night soil as the nature's call is finished by the population in their houses itself before coming to the industry. Locally available cow dung has to be dissolved in water, filtered to remove straw etc and added to aeration tank. Dosage should be determined to obtain at least 50 mg/l of BOD	Even after these measures, if microbes do not develop, supplement commercially available enzymes as per manufacturer's guidelines. Also add micro nutrients once a week. The Excel sheet for calculating the micro nutrients quantity is given in Appendix-B. Procure the chemicals, prepare a solution and add to the aeration tank slowly over an hour so that it mixes well with the tank contents. The addition is at the inlet end
			Same as above for batch type reactors like SBR	
		Toxic Material may be present in raw sewage	In case of sewage coming from one SPS, first off identify the line at inlet and divert it	First apply physico-chemical treatment to a stream carrying toxic material and then let it be allowed for further treatment
3.	Raw sewage flow is much higher than design flow	This can be adjusted to about 15 %	Make sure the hydraulics is adequate	If not, bypass after grit removal
4.	MLSS develops but does not survive	A peculiar problem may be the TDS of the sewage	Verify the design TDS and actual TDS	Locate the source & avoid it in the collection system
5.	White coloured foaming of aeration tank	New plants usually have such problems because the sludge is young and not aged. The foam may be	Try to spray the treated sewage using a temporary pump set twice in a day time shift to break the foam	By adopting these measures, the problem should be controlled within a month at the maximum

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
		removed without any worries	If possible attach a greenhouse nylon net to strong anchor nails on the side walls handling it carefully	
		F/M ratio is too high	Do not waste sludge from either secondary clarifier or aeration tank	
6.	Dark brown foaming of aeration tank	Older plants may have such problems due to very little sludge wasted in secondary clarifier,	Increase sludge wasting and verify whether MLVSS has increased to about 70 %. If air supply is available, increase it by using the VFD	If the problem persists provide a raw sewage equalization tank and ensure uniform raw sewage flow to the aeration tank
7.	Greasy very dark foaming of aeration tank	Most probably, filamentous organisms such as Nocardia might have come into the MLSS	Nocardia to be checked under a microscope by a microbiologist	Check and correct oil, grease & fat in raw sewage
			Increase sludge wasting by 10 % day till the desired level of MLSS is achieved	
8.	Very dark foam and mixed liquor is black	Insufficient oxygen has caused anaerobic conditions in the aeration tank	Check the DO in the aeration tank	If possible increase aeration air by VFD. If this is not available, report the matter to all including the plant in charge directly to supplement the aeration
9.	MLSS concentration varies between the parallel aeration tanks	Unequal flow distribution or unequal return sludge to the aeration tanks or both can cause this problem in both surface and diffused aeration	Check the flow rates and adjust the valves of return sludge lines to each aeration tank or division weirs in flow division boxes before entry into aeration tanks	
10.	Small amount of whitish foam at corners	This is actually a sign of a plant operating well		
11.	Sludge rises almost all over the clarifier weir and overflows	Toxic contents in raw sewage may be causing dispersed growth bulking in aeration system	Verify F/M ratio. Most probably this would have increased to a higher value than the design value	If the aeration tank is step aeration type, send the raw sewage to the second compartment
			Verify the DO in aeration tank. This might be very low or absent	If the aeration tank is a plug flow type, try to divert the raw sewage at least about 20 % of the distance away from the inlet

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
			Verify the MLVSS. Its value might be very low compared to the designed value	If the tank is a complete mix tank with uniform entry of sewage all along one side, try to cut off raw sewage for one hour every shift
			Verify the raw sewage pH for any sudden drop due to acidic effluents	If the plant has facilities to add a coagulant, try to use a non ionic polyelectrolyte for some time
		Microscopic examination by a microbiologist shows a large number of filamentous organisms	Check nitrogen, phosphorous, BOD ratio and adjust N and P by adding commercial NPK fertilizers	Distribute the raw sewage along the length of aeration tanks in plug flow reactor so that initial zones can recover
		If the STP is not designed for denitrification and if excess oxygen is given in aeration tank, there can be nitrification of ammonia, this nitrate will be denitrified in the sludge zone of secondary clarifiers and the rising bubbles will carry over the sludge solids from the sludge layers	Check for nitrification and reduce oxygen supply to aeration tank by reducing the air output of blowers / compressors but without affecting mixing energy requirement which are also equally important in diffused aeration systems	Assemble 50 mm SS crib mesh with lockable clasps of size equal to cross section of launders and of cubical shape, fill with loose foam and stack along the launder at intervals to trap the solids. Periodically remove, wash and restack
			If the aeration is by surface aerators adjust the submergence to reduce the oxygen transfer	If this is not possible, follow the foam filled cribs as mentioned above
12.	Sludge concentration in return sludge is low (<8,000 mg/L)	Sludge return rate is too high	Check return sludge concentration and solids level (balance) around final clarifier and settleability test	
		Filamentous growth	Check micro biota, DO, pH and nitrogen concentration; raise Do and pH, supplement nitrogen and add chlorine	
		Actinomycetes predominant	Check micro biota and dissolved iron content; if present, supplement nitrogen feed	
		Collector mechanism speed is inadequate	Adjust speed of collector mechanism	

Table A4.1-9 Biological nitrification-denitrification systems

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Nitrification does not occur	This can be due to insufficient oxygen supply, absence of required bicarbonate alkalinity and hindrance from toxic chemicals in sewage	Check for DO in the mixed liquor as it enters the secondary clarifier and find out if it is the same as in the design of the STP. If it is less, try to increase by using the VFD on the compressor	If there is still no nitirification, the problem may be elsewhere. Hence go to the next steps as given below
			Check the bicarbonate alkalinity and nitrogen ratio. The alkalinity expressed as $CaCO_3$ shall not be less than 7.5 times of nitrogen expressed as N	If the alkalinity is less, supplement it by adding sodium bicarbonate to the extent required. The quantity is to be calculated by the chemist
2.	Denitrification does not occur	This is due to inadequate contact time between raw sewage, return mixed liquor and return sludge and also due to inadequate nitrification itself	Check the nitrate in the influent to and effluent from the denitrification tank and compare with the design values. If it is much lower, check the N in the raw sewage and clarifier effluent to find out the nitrification	If everything appears normal, check whether the bottom floor level mixer is functioning in the anoxic tank portion and rectify the equipment, if necessary
			Check if the BOD in raw sewage has gone up compared to design value. If this is the case, the oxygen supplied is consumed by BOD reducing micro-organisms	If this is the case, in reality there is no immediate solution in a plant already constructed and in use. The best possible solution would be to restrict the raw sewage volume proportionately

Table A4.1-10 Secondary clarifier problems

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Problems in primary clarifier sludge issues as discussed earlier are equally applicable here also			
2.	Pin type of flocs in clarifier are seen and these flocs do not reduce the turbidity of effluent completely	The better form of MLSS settling in clarifier is “blanket settling.” The settling flocs trap any suspended matter and pull it down along with settling. The effluent may not appear very clear	Check for nitrification in kg / day as also BOD removal in kg / day. If the nitrification fraction is higher then such a pin head floc formation can occur. Increase the return sludge ratio to the extent possible	If the problem persists, the only method is to add a non-ionic polymer to the mixed liquor before it enters the clarifier

Table A4.1-11 Rotating biological contactors

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Very large bio mass sloughs off from the discs all of a sudden while rotating	This can be due to pH variations and / or sudden toxic chemicals in raw sewage	Check for pH variations in raw sewage every four hours for a week. If variation is large, , try to identify the source in the collection system and correct it	If the problem persists even after taking these measures, toxic chemicals are probably entering the sewage
			Check for metals in the raw sewage and detect any unusual increase. Trace the problem to its source and correct it there	If the problem continues even after taking these measures, the only remedy is to introduce an equalization tank for raw sewage
2.	Typical streaks of whitish bio mass over the discs observed frequently	The presence of hydrogen sulphide in the raw sewage and associated septicity can lead to this problem	Check the raw sewage for hydrogen sulphide odour, estimate the concentration and try to pre-aerate in the collection tank	An optional method is to introduce coarse bubble aeration in the first 25 % of the RBC drum by releasing compressed air through a pipe with perforations. This has been found to be very effective
3.	Solids build up in the RBC drums	The initial BOD concentration is higher than the designed value	Check the BOD loading as per design and adjust it suitably by limiting the sewage volume	Even after this if the problem continues, verify as hereunder
			Verify whether raw sewage SS are much higher than the designed SS and try to rectify the problem at the source in the collection system	In the meantime insert coarse bubble aeration in the drum as discussed earlier

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
			Sometimes, a mild non ionic polyelectrolyte can be added to the influent end to precipitate coagulant from BOD load	If the problem continues in spite of these measures, introduce primary settling before RBC and take the primary sludge to aerobic digesters
4.	After a period of power outage, when the RBC is re-started, it refuses to rotate, the motor creates a humming noise and the disc assembly needs an external push to set it rolling	When the power outage occurs, the biomass on the disc has water content. This water adds to the weight of the disc and initial torque of the motor is not adequate to overcome the inertia	Check alignment before trying anything else. If alignment has changed, call the equipment supplier	Ask the equipment supplier to verify and match the torque rating of the motor and the torque enforced by the wet disc assembly which is measured by the rope and weight method
5.	Growth of snails in discs	This is an associated phenomenon of RBS systems. Strictly speaking, they do not affect the BOD removal efficiency	A simple method is to temporarily increase the RPM of the disc assembly to just about double the designed value for a few minutes at a time and use a long pole to dislodge the snails back into the sewage drum	Also, reversing the direction of feed and outlet about once a month helps build up bio mass growth to uniform weight along the length of the shaft

Table A4.1-12 Biological phosphorous and nitrogen removal

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Treated effluent contains more phosphorous than designed	The phosphorous removal occurs in the anaerobic zone. If it is not removed fully, it can cause eutrophication in receiving water bodies	Check the anaerobic zone for DO. It should be zero or less than 0.2 mg/l. If DO is high, reduce the aeration air supply to hold the DO in aeration tank to not more than 1 mg/l. This is the root cause	The air supply to aeration tank can reduced if there is a VFD attached to the air compressor motor. If it is not there, demand it
2.	Treated effluent has low phosphorous content but the BOD is high at over 20 mg/l	This condition is possible if raw sewage BOD is higher than the design value	Check the raw sewage BOD and if needed, install supplemental air compressor to meet the extra oxygen needed for the higher BOD	Instead of supplemental air compressor, a high duty compressor can also be installed

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
3.	Treated sewage meets phosphorous removal requirements but the nitrogen content is much higher than required	Nitrogen removal and phosphorous removal occur in two separate zones and not together. Hence understanding the respective problem is necessary	Confirm the raw sewage nitrogen and BOD and the air actually pumped by the air compressor to be according to design. If the air supply is less, increase it	If all parameters are as per the design, raw sewage has nitrate inhibitors. Conduct lab studies and control the source in collection system

Table A4.1-13 Facultative ponds

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Weeds grow inside the pond sewage	Weeds attract and promote growth of insects like flies, mosquitoes and so on. They can also become a nuisance as reptiles may be found hidden in the weeds	Weeds do not grow if water is more than 1 m depth. Check the outlet level and the sludge depth	If sludge depth has built up and reduced the water depth, remove the weeds
			If there are two parallel ponds, take out one pond at a time from sewage flow at start of summer and pump out the top liquid using a portable diesel pump set into the other pond	Thereafter allow the sludge to sun dry and then till it by a tractor. Leave as-is for a week and then remove the sludge taking safety precautions
			The removed sludge is good soil filler and has to be put through a compost pile for at least a month. Try to use vermin composting	The disposal can be in the root zone of trees or spread over the outer slope of the bunds for better turf growth
2.	Scum forms in the corners and insects grow over it	Scum promotes insect growth and propagation, particularly flies and mosquitoes. It can cause insect borne epidemics if not removed	Do not try to remove the scum out of the pond. Take a long thin pole and beat the scum gently so that it breaks up at the surface	Once it breaks up, the gas bubbles propping the scum are released. The scum mat will sink into the pond
3.	Bunds are overgrown with weeds, small plants or even trees	The greatest risk of such growth is that someday this growth will break the bund and suddenly the sewage will flow out and fall into all wells or rivers in the zone causing a major health hazard or water borne epidemic	Physically shear off the growths. Do not pull the roots from the bund as this will loosen and break the bund. The sheared material must not fall into the pond	It is dangerous to stand on top of a tree and cut the tree branches. Use a crane and make the labourer sit inside its bucket. The cut weeds, twigs etc., can be placed into a netting tied to the bucket and taken out safely

<table>
<tr><th>No.</th><th>Troubles / Problems</th><th>Likely causes</th><th>First stage remedies</th><th>Second stage remedies</th></tr>
<tr><td>4.</td><td>Overhanging tree branches drop leaves on the pond and this causes shadow region on the pond surface</td><td>This is to be avoided because the pond requires sunlight to function and the blocking sunlight will cause septicity, and BOD removal will suffer</td><td>Identify the trees and mercilessly cut the branches overhanging the pond. Do not cut the tree as the cut roots will topple the bund</td><td></td></tr>
<tr><td>5.</td><td>Pond turns dense green in summer months</td><td>Accept it; this should not be taken as a problem</td><td>Leave it as it is and it will disappear on its own when monsoons set in</td><td>If the density is high recirculate the pond effluent by pumping</td></tr>
<tr><td>6.</td><td>DO level in pond water is very low and even at mid day it does not go above 2 mg/l</td><td>This need not necessarily be a problem as long as effluent BOD is under control</td><td>Raw sewage BOD may be very low and this may cause low DO level</td><td>If DO is present in the pond effluent, do not disturb it</td></tr>
<tr><td rowspan="2">7.</td><td rowspan="2">Oily sheen and shine slowly increases on the pond surface</td><td rowspan="2">This is risky. It blocks the solar heat energy from penetrating the pond, which prevents algae growth. This in turn stops oxygen production by algae, so removal of BOD from the pond is affected adversely</td><td>Check the raw sewage for oil & grease regularly. Sometimes, automobile service stations and industries will suddenly discharge waste oils into the collection system. Trace the source and control it</td><td>Demand the construction of a gravity oil & grease removal unit for raw sewage before the raw sewage is allowed into the pond This is a must</td></tr>
<tr><td colspan="2">A temporary and very effective method is to sink country wood poles around the inlet zone, tie fishing net and place straw inside this zone. The straw will absorb the oil & grease and should be left there until the oil & grease removal unit is built</td></tr>
</table>

Table A4.1-14 Aerobic ponds

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Weed grows inside the pond in the liquid	Minimum 1 m liquid depth is needed to prevent weeds from growing	Check and correct the sewage depth by adding an elbow or bend to the outlet pipe to get 1 m sewage in pond. Inlet pipe may remain submerged	Simultaneously verify whether the minimum freeboard is 0.5 m. If not, the bund should be raised all round
2.	Too much of algae in the pond sewage	This is inherent in aerobic ponds and cannot be avoided	As long as receiving water course has flow, algae are not a problem and the ecological system need not be disturbed	
3.	Receiving water course is dry, algae die there and foul odour is present	Algae are aquatic organisms. This is a dangerous situation as algal toxins may enter soil and ground water	The immediate remedy is to bypass the aerobic pond and avoid growth of dense algae	The final remedy is to use chemical treatment instead of aerobic ponds
4.	Foul odour of dead algae from ponds especially in high summer months	One possible reason is very small flow as compared to design flow, and thus very high detention time in the pond	Try to erect a temporary rock fill bund like a “coffer dam” and reduce the area of the pond pro rata to flow as compared to the design flow	The final remedy is to construct a regular cross bund, switch the flow into it and remove the rock fill

Table A4.1-15 Anaerobic ponds

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Foul odour of hydrogen sulphide (rotten egg)	This is an inbuilt mechanism when sulphate is reduced in anaerobic action	The only practical method is to use aromatic trees like Eucalyptus as live fence in two successive rows with first row at least 3 m away from the toe of the bund	
2.	Oily scum with shiny appearance is floating on the pond surface	This is also an inbuilt mechanism of such ponds	Try to install a simple gravity type underflow baffle tank at the inlet and trap the oil	Engage a licensed re-refiner to collect and take away the oil periodically
3.	Bubbles rise from the pond sewage and burst at the pond surface, which throws up black sludge	This is a good sign that the anaerobic system is functioning well. The end product of sulphide and methane gas lifts a column of sludge equal to its diameter and when bubble escapes to the air, the sludge disperses back into the pond	This is part and parcel of the anaerobic pond system and no action need be taken to control it. However, if the sludge in the pond has built up to leaving only about 30 cm of liquid depth, start desludging procedures as described in Section 4.1.13 Facultative ponds. If the pond is a single pond, construct a rock fill bund in the middle and proceed to desludge one after the other	

Table A4.1-16 Maturation ponds

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	These are to be dealt with similar to Section 4.1.14-Aerobic ponds			

Table A4.1-17 Land irrigation systems

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Applied sewage is ponding on land	This promotes flies, mosquitoes and may cause water borne epidemic; therefore, it should be controlled quickly	Check the ground water level. Sometimes, this may be the problem	Stop irrigating and divert the sewage to a natural drainage course
2.	Sewage is running off over land instead of going in	If sodium is high, it will enter the soil and exchange the calcium and magnesium. Slowly the soil becomes hard as a rock and permeability is lost	Check the sodium content and verify whether it is within the permitted values application measured as Sodium Absorption Ratio (SAR) or Exchangeable Sodium Percentage (ESP)	If it is too high, stop irrigation for a prolonged period and wait for monsoon rains to slowly wash out the sodium by dissolution in rainwater
3.	Irrigated crop has suddenly become weak and dies	The root zone may be flooded and air entry to soil is sealed. This creates foul odour and results in water pollution	Free up the soil by tilling it ensuring that it can breathe	Drain the stagnating sewage by cutting ditch drains
4.	Nitrate concentration in ground water increases	Nitrogen is applied as nitrate and is not being taken up by plant. This can cause nitrate pollution in ground water	Check whether raw sewage nitrogen is being nitrified in the treatment plant	Verify the permissible loading rate and correct it if necessary
5.	Sprinklers do not sprinkle	Suspended solids in applied sewage have blocked the pores and organisms may have grown in the sprinkler end	Removal of suspended solids is very important before application to sprinkler systems	A well constructed soil filter can help instead of a mechanized system

Table A4.1-18 Chemical treatment systems

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Flocs do not form in rapid mixer & flocculator	Flocs form from chemical reactions in rapid mixer and build up in flocculation. However, initial flocs do not develop due to organics and SS	The raw sewage does not have the required acidity or alkalinity to react with the chemicals. Check the plant O&M manual and the actual chemicals being used	The added chemical may have impurities which prevent floc formation. Examples are lime powder and commercial alum
			The added chemical may be actually different that what is indicated on the label	Carry out lab test on the chemicals
		Hydraulic shear of the raw sewage is needed in the mixer. If the tank is a circular one, vortex alone will form and not shear	Install vertical radial baffles for half the radius to break the vortex and bring up the shear	If the first stage remedy does not work, change the tank to a square shape
2.	Flocs are formed in the flash mixer but these are broken up in the flocculator	The speed of the flocculator has to be slow enough to allow the flocs to be built up to bigger size	Take the rapid mixed sample in a glass beaker and slowly rotate it clockwise and then counter clockwise with a glass rod and watch the flocs	If the lab test proves floc can build up but the flocculator fails in the plant, then the flocculator needs to be changed
3.	Chemicals settle down in the flash mixer	The mixing energy is important to keep the chemicals in suspension	Increase the speed of rapid mix impeller and watch	If this not work, introduce additional compressed air
4.	Flocs overflowing in the sedimentation tank	The flocs are unable to settle down	The detention time may be too short. Check the time needed by allowing a sample to settle in a glass beaker and verify the detention time in the plant	If undersized, construct the required tank or use an additional tank and split the flow to both the tanks
			The shape of the tank also plays an important part. Horizontal flow rectangular tanks are usually not preferred. Circular tanks with conical hopper are better	In small plants, the best arrangement will be a square shaped tank with conical hopper bottom at 60 degrees to horizontal
		The flow pattern carries over the flocs and the inlet baffle is not effective	Refer the problem to the equipment supplier	

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
		The flow through the unit may be much higher than what is designed	Check the design manual of the plant and rectify the same	If needed, ask for one more unit to manage the flows
5.	Sludge does not dewater fully in drying beds	The water in the sludge may be a "bound water" and would need a "weighting agent" such as lime powder	Add lime powder to the wet sludge by using a paddle mixer equipment before using it on a filter bed	If it does not dewater even then, use a polyelectrolyte in addition to lime
			Other chemical such as $FeSO_4$ or $FeCl_3$ or saw dust may also apply with Lime powder	

Table A4.1-19 Treated sewage chlorination

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	The first aid kit is either empty or it has disappeared	This is most serious problem that can happen in a plant and needs emergency measures to be adopted bypassing procedures	The plant in charge shall directly purchase a ready kit and install it	The old kit if located can be used as standby
2.	The sodium hydroxide filled liquid tank is empty	This again is a major issue of a different kind and needs immediate action	Immediately stop all chlorination, close all chlorine containers and open the windows, doors, and ventilators	Call for emergency measures to fill the tank before re-commissioning the chlorination
3.	There is no water in the shower	This is not an emergency but all the same requires immediate attention	Keep at least three to four buckets of fresh water and paint the buckets in red colour to indicate it is for use in emergency situations only	Connect the shower to two different water sources so that at any one time, one of these will work
4.	There is no water in the "eye rinsing wash basin"			
5.	There is no residual chlorine in the chlorinated effluent	Strictly speaking, this is the desirable situation if the purpose of chlorination has been served in MPN count	Verify the MPN count of inlet to and outlet from chlorine contact tank. If the design value is not met increase the chlorine dose after lab estimation	Eventually take up re-appraisal of the chlorination system to deliver higher dosage and augment the facilities
6.	There is too much chlorine in the sewage coming out of chlorine contact tank	This can be because the inlet to chlorine contact tank is not having the designed demand (or) too much chlorine is being applied to the sewage	Check the chlorine in the contact tank outlet and compare with the design value. If it is higher by 1 mg/l, reduce the chlorine dosage	Request the plant chemist to calibrate the chlorine demand every week and indicate it on a wall board for all to see

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
7.	Testing of joints in the plumbing lines with ammonia solution swab shows white fumes	Chlorine gas when in contact with ammonia always gives whitish fumes	Immediately stop chlorination, close chlorine cylinder valves and open up all windows, doors, and ventilators. Switch on exhaust fans	Call the system supplier for a complete system check and rectification
8.	Coliforms count fails to meet required standards for disinfection	Inadequate chlorination equipment capacity	Replace equipment as necessary to provide treatment based on maximum flow	
		Short circuit in chlorine contact chamber	Conduct dye test Install baffles in the chlorine contact chamber Install mixing device in chlorine contact chamber	
		Solids build up in contact chamber	Clean contact chamber	
		Chlorine residual is too low	Increase contact time or increase chlorine feed rate	
		High TSS	Reduce TSS in effluent	
9.	Inability to maintain adequate chlorine feed rate	Malfunction or deterioration of chlorine water supply pump	Overhaul pump	
10.	Low chlorine gas pressure at the chlorinator	Insufficient number of cylinders connected to the system	Connect adequate number of cylinders to system so that feed rate does not exceed the recommended withdrawal rate for cylinders	
11.	Chlorinator will not feed any chlorine	Pressure reducing valve in chlorinator is dirty	Dissemble chlorinator and clean valve stem and seat. Precede valve with filter or sediment trap	

Table A4.1-20 Treated sewage disinfection by UV

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	There are no standardized methodologies in this section. Please follow whatever is prescribed by the system supplier			

Table A4.1-21 Treated sewage disinfection by ozonation

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	There are no standardized methodologies in this section. Please follow whatever is prescribed by the system supplier			

Table A4.1-22 Surface aerators

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Motor - high or uneven amperage	Moisture has entered the motor or winding breakdown has occurred	Have an electrician check the motor and replace with spare motor if available	Rewind the motor
		Amperage drawn is higher than the rated amperage of motor	Aerator submergence is more than the recommended value	Call the equipment supplier
		Excessive friction and heat in motor gear	Inspect and lubricate bearings and gears	Overhaul, if needed
2.	Gear reducer - bearing or gear noise	Lack of proper lubrication	Repair or replace oil pump Change oil	If problem persists, call the equipment supplier
			Remove obstruction in oil line	If problem persists, call the equipment supplier
3.	Shaft coupling - unusual noise and vibration	Cracked coupling	Call equipment supplier and replace coupling; align impeller shaft	
		Loose coupling bolts/ nuts as a result of vibration	Call equipment supplier and for torque bolts, use “locking” nuts, align impeller shaft	
4.	Aerator impeller - unusual noise and vibration	Loose blades	Call equipment supplier and repair torque blade bolts, use lock-washers, align impeller	
		Cracked blades	Call equipment supplier and replace torque bolts; align	

Table A4.1-23 Air blowers

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Unusual noise and vibration	Coupling misalignment	Stop the machine and realign	If difficult, call equipment supplier
		Loose nuts, bolts and screws	Stop the machine and realign	
2.	Delivery air is at lower pressure than rated pressure	Bypass valve open, leaks or breaks in distribution piping	Close the valve and check the pressure instantaneously	Proceed to check leaks in pipeline by soap solution test and rectify
3.	Air system - high pressure	Plugged diffusers in the aeration tanks	Check the records of pressure at each branch line and detect abnormalities	Remove, clean and refit diffusers in the abnormal line
4.	Air flow rate is lower than the rated flow	Higher ambient temperature than design conditions may be the reason	Check the ambient air temperature and if it is drastically high call the equipment supplier	

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
5.	System oil - low pressure	Oil level too low, oil filter dirty Valve sticks are open, incorrect oil	Drain and refill with proper oil type	
6.	System oil - high pressure	Incorrect oil type	Drain and refill with proper oil type	
7.	Oil discharge - low pressure	Suction lift too high Air or vapour in oil Coupling slipping on pump shaft	Purge air at filter Secure coupling	
8.	Low oil temperature	Oil cooler water flow too high	Throttle water flow	
9.	High oil temperature	Oil cooler water too low; incorrect oil type or insufficient oil circulation	Increase water flow Drain and refill with proper oil type Replace oil filter, check oil lines for restrictions	
10.	Hot bearings	Blower speed too high Defective bearings Oil cooler water flow rate too low	Reduce speed to recommended RPM Damage: Repair or replace. Increase water flow	Call equipment supplier to check bearings for clearance, hot spots, cracks or other damage. Repair or replace Increase water flow
11.	Motor doesn't start	Overload relay tripped	Correct and reset	
12.	Motor noisy	Noisy bearings	Check and lubricate	
13.	Motor temperature high	Restricted ventilation Electrical abnormality	Check openings and duct work for obstruction Check for grounded or shorted coils and unbalanced voltages between phases	If in doubt, call equipment supplier

Table A4.1-24 Air distribution system

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	High, low or no indication in meters	Loose movement, out of calibration, dirt	Clean and correct defects	
2.	Leakage in seals, gaskets and flex connections	Loose bolts or fittings Blown out	Tighten and or replace	
3.	Pipe corrosion	Condensate	Drain traps daily, install additional traps, flush pipes, and remove standing water	
4.	Sludge inside pipe	Vacuum action by reverse operation of blower	Flush pipe, install check valve on blower, repair check valve	If problem still persists, remove, clean and refit
5.	Dirt in pipes	No or inefficient air filtration	Install filters, and clean filters more frequently	
6.	Valves difficult to operate	Hardened grease Corrosion in valves	Remove old grease and apply seizing inhibitor, operate valves monthly, drain condensate traps daily	

Table A4.1-25 Air diffusers

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Some parts of aeration tank do not show release of air bubbles at the surface	Air is not being released from the diffusers at the floor level of the aeration tank	Loosen the joint at the walking platform and slowly lift the air drop pipe till air bubbles can be seen. This means the diffusers have choked and cannot get over the full sewage depth. Remove the drop pipe for cleaning	Another option will be in situ air purging by a portable mini air blower . This can be connected to the drop pipe by a “Tee” and closing the regular valve to purge the choked organic matter. This action can also be done routinely
			If the air system is designed for doubling the air when needed and if more than one air compressor is installed, briefly apply the air from both the compressors and purge the diffusers for about 5 minutes every hour for a few times	Most often this works very well but the system should have been designed for such an application. Please check the manual of the plant before attempting the first stage remedy. Take care that this double flow is not continued for more than five minutes in an hour

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
2.	Compressor shows full design pressure but there are no air bubbles coming out of aeration tank	This may be a serious problem. If the pressure gauge on compressor delivery is of the Bourdon type, most probably it has gone into permanent set showing the full pressure	Switch off the compressor and verify whether the Bourdon gauge goes back to its zero position. If it does not, replace with a new one	In general, Bourdon gauges are instantaneous measurement units and not permanent reading gauges. Change these gauges to proper diaphragm gauges
			The gauges are always best installed with pressure to current converter type transducers or transmitters	Request for such a change
3.	Pressure gauges are in order, compressor is in working condition but air bubbles do not rise from aeration tank	If air is not being released from anywhere in the aeration tank, it causes major leaks in transmission pipelines	If pressure gauges are available at all locations before changes of alignment of air transmission piping, try closing all these and open section after section to verify the leaky section below ground and rectify	If there is no leak, the compressor may be at fault. Check the amperage. If it is negligible then there is a mechanical problem with the compressor. Call the equipment supplier
4.	Air escapes in large bursts from a few places instead of uniform diffusion all over the tank	This may be due to detachment of the air header pipe and the diffuser head at the floor; hence the bulk of air escapes at the joint location	This is a major problem and will require a team of well qualified and properly protected divers to dive and fix the problem at site while the service team is on standby at site. Do not empty the tank because growing the microbes again is not easy	
5.	The entire contents appear viscous and shine like oil and air escapes at surface intermittently in large exploding bubbles	The MLSS concentration has gone out of control and become too high. They are mostly dead and cannot abstract the oxygen from the diffused air. This causes build up and sudden exploding of air bubbles	Check the MLSS and then the MLVSS. If both these values deviate very much from the design, waste fifty percent and let system recover	If this remedy also fails, there is almost surely a problem of shock loads or toxic substances coming in sewage. Check, identify locations in the collection system &rectify

Table A4.1-26 Power back up

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Sudden break/stoppage in Air supply to Areation Tank	Power Failure	At least 20-30 % capacity of aeration blower should be back by DG (diesel generator) sets to ensure minimum air supply to aeration tank for duration of 7-8 hours	Arrange for Dual power supply (through a separate power supply grid)

Table A4.1-27 Interpretation of routine laboratory results

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	COD value is much higher than BOD	If it is only sewage, this should not be the case. However, if there are large industrial effluents from chemical manufacturing industries, this can occur	Check the N and P also and compare with the old records. If the COD is higher, report the matter to locate the source	The performance of the STP may not be up to the designed value. Focus on indentifying the source and cutting it off properly
2.	pH values show sudden increase or decrease			
		Non biodegradable organic chemicals enter into sewage i.e. wax, lignin, cellulose etc.	Pretreatment with chemical coagulation is required	
3.	The colour of sewage keeps changing often			
4.	The treated sewage appears turbid and cloudy but the laboratory report records BOD of less than 20 mg/l	This can be the case where the algae present in the treated sewage	Take a Whatman number-42 filter paper and filter the treated sewage into a test tube of 25 ml and check the transparency and clarity. The colour may be that of green algae but there must be clarity. If the filtrate is still turbid and strong in colour, then the pond is overloaded	
			Increase quantity of return sludge so as to increase MLSS	

Table A4.1-28 Flow measuring systems

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Bulk flow meter reading appears to be incorrect	Any mechanical equipment may go out of order at any time. The operator must have the capacity to find out the flows from other non conventional methods and compare the readings	If there is a channel of at least 10 m straight length, mark the middle 10 m and conduct a float test. Take the observed velocity at 0.8 and find out the flow	If the pump house is within the plant, find out the timings of each pump set and calculate the flow from the pump name plate
			There may be a division box for the raw sewage to the primary clarifiers. Verify the weir length and depth of flow over the weir and record the readings only in the daytime for one shift and compare with the meter reading	It is not at all advisable to go into such locations when there is no daylight because these locations are above ground level with probably no facilities for night work. An error in day shift means the same error occurs at other times also

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
2.	Ultrasonic level sensor readings seem to be vastly different from previous recent readings	The ultrasonic level sensors actually measure the depth of the sewage water from the ultrasonic emitter. It actually measures the time from release to the return signal after bouncing back from the sewage surface, takes the average and is calibrated to the depth	Try to hold a mirror at the water surface by tying it to a long stick and note the reading given by the sensor. Actually measure the depth from the sensor to the water level if there is safe access, without getting into sewage	If the reading actually measured and that obtained with the mirror are tally, then there is no problem with the sensor. If the depth shown by the sensor is different by more than 5 %, the sensor must be serviced

Table A4.1-29 Septic tank and leaching systems where sewerage system is not in place

<table>
<tr><th>No.</th><th>Troubles / Problems</th><th>Likely causes</th><th>First stage remedies</th><th>Second stage remedies</th></tr>
<tr><td rowspan="2">1.</td><td rowspan="2">Sewage backs up into the house</td><td rowspan="2">The problem is directly related to the leach pit only because a septic tank is only a flow through tank</td><td colspan="2">The key point is to minimize the water used for bathing and washing clothes. This will solve many problems</td></tr>
<tr><td>Open the septic tank outlet chamber, pour a bucketful of water gently and watch whether it goes into leach pit immediately. If it does not flow, the leach pit has become saturated. The simplest remedy is to use the services of septage clearance vehicle and empty the septic tank periodically</td><td>Construct a fresh leach pit if there is space. If there is no space, try to clean up the old leach pit and construct an up flow filter and discharge the effluent to the street drain. Sometimes gravity will not permit this. In such cases, use a septage vehicle, which is the only answer to this problem</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Foul smell comes out of the ventilating cowl</td><td rowspan="2">This is the result of the process in the septic tank, and cannot be stopped. But it can be treated</td><td>Spray the mosquito net of the cowl with bleaching powder solution daily and keep it wet</td><td>If the problem continues, a biological filter consisting of gunny cloth of coir wetted with bleaching powder solution may be tied</td></tr>
<tr><td>If space is available construct a smaller septic tank and up flow filter only for toilets and then allow it into the main septic tank</td><td>If the problem continues, the only solution is to frequently use the septage clearance vehicle</td></tr>
</table>

Table A4.1-30 Sequencing batch reactors (SBR)

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Raw sewage flow is less than the design flow	This is a usual problem in some cases in the initial period	If the flow is adequate to run one of the modules, use that module alone and leave the other one unused	If the flow is small even for this, use the SBR tank as an ASP for 20 hours, then stop the flow and decant. During this time divert the flow to the other module. Once decanting is completed, start that module and pump the raw sewage from the temporary module to it
			If the air compressor output air volume is too much, use the VFD to reduce the same to match the raw sewage flow	Always ensure that the residual DO in the aeration is not less than 1 mg/l during aeration
2.	Raw sewage flow is higher than the design flow	This type of problem is very rare	Try to use all modules simultaneously except one and run the plant in continuous mode and decanting mode as above	The spare module will be used to receive the raw sewage when the other modules are in decanting mode and then sewage is pumped
Almost all other issues discussed under ASP shall apply here also				

Table A4.1-31 Moving biofilm bed reactors (MBBR)

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Raw sewage flow is less than the design flow	Almost all other issues discussed under SBR apply here also		
2.	Raw sewage flow is higher than the design flow	Almost all other issues discussed under SBR apply here also		
3.	Almost all the media are floating at the liquid surface only and do not mix fully into the depth of reactor	This happens in some tank geometries and because the specific gravity of the media is just about the same as that of water	Mixing equipment are available as sidewall mounted facilities which bring about a circular motion of the media in vertical plane. These can be simply fixed on a steel post and anchored to the concrete base. This is similar to erecting a submersible pump set. If anchoring facility is not available, hire a qualified diver from fire service	

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
4.	Media floats in air/surrounding area with or without foam	Gas or air trapped in media reduces its density	1. Water sprinkling 2. Mosquito type net be placed above reactor	Increase height of side walls
Almost all other issues discussed under ASP apply here also.				

Table A4.1-32 Membrane bio reactors (MBR)

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Raw sewage flow is less than the design flow	Almost all other issues discussed under SBR apply here also		
2.	Raw sewage flow is higher than the design flow	Almost all other issues discussed under SBR apply here also		
3.	Membrane permeate volume is reducing slowly	In general, this is because the MLSS cannot be filtered by the membranes. The problem may occur in both suction type and pressure feed types If sludge bulking occurs, it is due to the filamentous organisms. Usually at high MLSS of 10,000 mg/l filamentous organisms do not create any problems	Look under the microscope for organisms like Nocardia or Sphaerotilus natans-like filamentous bacteria. Get assistance from a qualified microbiologist. If these are detected, do not panic. Take a sample in a one litre glass jar and observe the settling. If sludge settles to 30 % in half hour, it is still OK	If it does not settle and the jar appears cloudy even after an hour, then there is a need to intervene. The first step is to flush the membranes if these are fixed (or) to remove, clean and rinse if these are removable. In the meantime, identify the bulking reasons as stated under ASP and try to solve the problem. Do not allow the problem to continue. It will choke the membrane
4.	Membrane permeate often brings out microbial suspended solids	May occur when some membranes give way and the microbes escape through it at higher pressure differences	Try to methodically isolate each module by isolating valves and study the problem	After identifying the module, remove it and get it duly serviced before replacing it on line
Almost all other issues discussed under ASP apply here also				

APPENDIX 4.2 OPERATIONAL PARAMETER

4.2.1 PARAMETERS

Typical values of loading parameters for primary and secondary clarifiers and various activated sludge modifications commonly used in India are furnished in Table A4.2-1 and Table A4.2-2, respectively.

Table A4.2-1 Table parameters for clarifiers

Type of Settling		Overflow rate, $m^3/m^2/day$		Solid loading, $kg/day/m^2$		Side water depth, m	Weir loading, $m^3/m/day$
		Average	Peak	Average	Peak	Average	Average
Primary Clarifiers	Primary Settling only	25 - 30	50 - 60	–	–	≥ 2.5 - 3.5	125
	Followed by secondary treatment	35 - 50	80 - 120	–	–	≥2.5 - 3.5	125
	With activated sludge return	25 - 35	50 - 60	–	–	≥3.5 - 4.5	125
Secondary Clarifiers	Secondary settling for activated sludge	15 - 35	40 - 50	70 - 140	210	≥3.0 to 3.5	185
	Secondary settling for extended aeration	8 - 15	25 - 35	25 - 120	170	≥3.0 to 4.0	185

Note: Where the mechanized aerobic treatment is used after UASB reactor, the settling tank design shall be based on conventional activated sludge process as above.

Table A4.2-2 Parameters of activated sludge systems

Process Type	Flow Regime	MLSS	MLVSS /MLSS	F/M	HRT	θc	Q_R/Q	BOD removal	kg O_2/kg BOD removed
		mg/L	ratio	Day^{-1}	hrs	days	ratio	%	ratio
Conventional	Plug flow	1,500-3,000	0.8	0.3-0.4	4-6	5-8	0.25-0.5	85-92	0.8-1.0
Complete mix	Complete mix	3,000-4,000	0.8	0.3-0.5	4-5	5-8	0.25-0.8	85-92	0.8-1.0
Extended aeration	Complete mix	3,000-5,000	0.6	0.1-0.18	12-24	10-25	0.5-1.0	95-98	1.0-1.2

4.2.2 LOADING RATE

a. HRT (Hydraulic retention time)

The loading rate expresses the rate at which the sewage is applied in the aeration tank. A loading parameter that has been developed empirically over the years is the hydraulic retention time (HRT), θ, day.

$$\theta\,(\text{day}) = \frac{V}{Q} \qquad (A4.1)$$

Where,

V : Volume of aeration tank, m^3, and
Q : Sewage inflow, m^3/day

Another empirical loading parameter is volumetric organic loading which is defined as the BOD applied per unit volume of aeration tank, per day.

b. Specific substrate utilization rate

A rational loading parameter which has found wider acceptance and is preferred, is specific substrate utilization rate, U, per day which is defined as:

$$U\ (\text{day}^{-1}) = \frac{Q(S_0 - S)}{VX} \qquad \text{(A4.2)}$$

Where,

S_0: Influent organic matter as BOD_5, g/m^3
S : Effluent organic matter as BOD_5, g/m^3
Q: Sewage inflow, m^3/day
V: Volume of aeration tank, m^3
X: MLSS conc. in aeration tank, g/m^3

c. SRT (Sludge retention time)

A similar loading parameter is mean cell residence time or sludge retention time (SRT), θ_c, day:

$$\theta_c\ (\text{day}) = \frac{VX}{Q_w X_s} \qquad \text{(A4.3)}$$

Where,

V: Volume of aeration tank, m^3
X: MLSS concentration in aeration tank, g/m^3
Q_w: Waste activated sludge rate, m^3/d
X_s: MLSS conc. in waste activated sludge from secondary settling tank, g/m^3

d. F/M ratio

If the value of S is small compared to S_0, which is often the case for activated sludge systems treating municipal sewage, U may also be expressed as Food applied to Microorganism ratio.

$$F/M = QS_0 / XV \qquad \text{(A4.4)}$$

Where,

Q: Sewage inflow, m^3/day
S_0: Influent organic matter as BOD5, g/m^3
V: Volume of aeration tank, m^3
X: MLSS concentration in aeration tank, g/m^3

4.2.3 OXYGEN REQUIREMENTS

Oxygen is required in the activated sludge process for the oxidation of a part of the influent organic matter and also for the endogenous respiration of the micro-organisms in the system. The total oxygen requirement of the process may be formulated as follows:

$$O_2\ \text{required (g/d)} = (Q\,(S_0 - S)/f) - 1.42\,\Delta_X \qquad \text{(A4.5)}$$

Where,

f : Ratio of BOD to ultimate BOD
1.42 : Oxygen demand of biomass, g/g
ΔX is biological sludge produced per day.
$\Delta X = Q \times Y \text{ observed} \times (S_0\text{-}S)$
Yobs = $Y/(1+Kd\times\theta C)$
Where Y is 0.5
Kd is 0.06

The formula does not allow for nitrification but allows only for carbonaceous BOD removal. The extra theoretical oxygen requirement for nitrification is 4.56 kg O_2/per kg NH_3 -N oxidized to NO_3 - N.

The total oxygen requirements per kg BOD, removed for different activated sludge processes are given in . The amount of oxygen required for a particular process will increase within the range shown in the table as the F/M value decreases.

4.2.4 OXYGEN TRANSFER CAPACITY

Aerators are rated based on the amount of oxygen they can transfer to tap water under standard conditions of 20°C, 760 mm Hg barometric pressure and zero DO. The oxygen transfer capacity under field conditions can be calculated from the standard oxygen transfer capacity by the formula:

$$N = \frac{N_s (C_s - C_L) \times 1.024^{(T-20)} \alpha}{9.17} \qquad \text{(A4.6)}$$

Where,

N : Oxygen transferred under field conditions, kg O_2/kW/hr

N_s : Oxygen transfer capacity under standard conditions, kg O_2/kW/hr

C_s : Dissolved oxygen saturation value for sewage at operating temperature, mg/L

C_L : Operation DO level in aeration tank usually 1 to 2 mg/L

T : Temperature, °C

α: Correction factor for oxygen transfer for sewage, usually 0.8 to 0.85

Values of C_s is calculated by arriving at the dissolved oxygen saturation value for tap water at the operating temperature and altitude as in Table A4.2-1 and Table A4.2-2 and then multiply it by a factor which is usually 0.95 for domestic sewage without undue industrial effluents and with TDS in the normal range of 1,200 to 1,500 mg/L.

Table A4.2-3 DO saturation vs. temperature in Celsius in tap water at MSL

The relationship between temperature and oxygen solubility	
Temperature(degree C)	Oxygen solubility (mg/L)
0	14.6
5	12.8
10	11.3
15	10.2
20	9.2
25	8.6
30	7.5
35	6.9
40	6.4
100 (boiling)	0.0

Table A4.2-4 DO correction factor for altitudes

Altitude(feet)	Altitude(meters)	Factor
0	0	1
500	152	0.98
1000	305	0.96
1500	457	0.95
2000	610	0.93
2500	762	0.91
3000	914	0.89
3500	1067	0.88
4000	1219	0.86
4500	1372	0.84
5000	1524	0.82
5500	1676	0.81
6000	1829	0.80

4.2.5 SLUDGE RECIRCULATION RATE

The MLSS concentration in the aeration tank is controlled by the sludge recirculation rate and the sludge settle ability and thickening in the secondary sedimentation tank.

$$\frac{Q_R}{Q} = \frac{X}{X_s - X} \qquad \text{(A4.7)}$$

Where,

Q_R : Sludge recirculation rate, m^3/d

Q: Sewage inflow, m^3/day

X: MLSS concentration in aeration tank, g/m^3

X_s: MLSS conc. in waste activated sludge from secondary settling tank, g/m^3

4.2.6 EXCESS SLUDGE WASTING

Excess sludge = (A/(0.6 to 0.8)) + B

A is calculated by the following equation and 0.6 to be used for extended aeration and 0.8 is used for conventional activated sludge.

$A = Q \times Yobs\ (S_0\text{-}S)a$

Yobs = Y/(1+Kd×θ_C)
Where Y is 0.5
kd is 0.06

B = Q×inert TSS removal
Inert TSS = Influent TSS – Influent VSS
TSS removal in primary settling tank is 60 percent.
Inert SS removal in primary settling tank is 80-90 percent.
VSS removal in primary settling tank is 20-40 percent.
θ_C is from Figure A4.2-1 for the lowest operating temperature.

Excess sludge in kg/day = Yobs × BOD $_{inlet}$ × Flow MLd

Calculate excess sludge kg/day from the thumb rule in this section.

Adopt the higher value.

Excess sludge volume (m^3/day)
= Excess wasted (kg/day) × 1000/MLSS in clarifier underflow

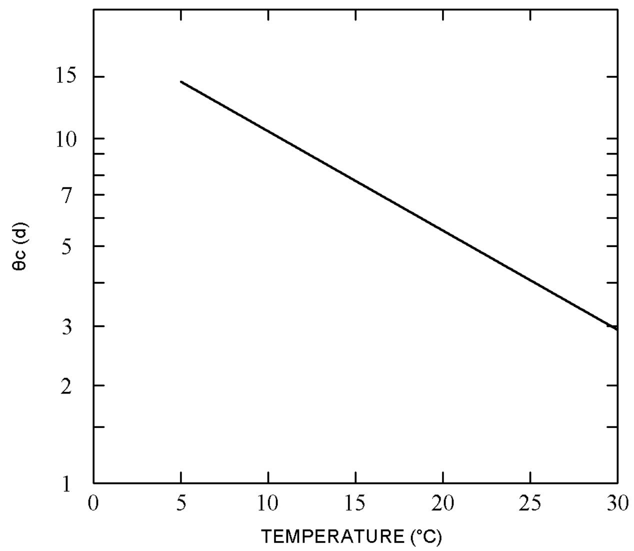


Figure A4.2-1 SRT as a function of aeration basin temperature for 90-95% BOD removal

APPENDIX 4.3 CALCULATION

4.3.1 EXTENDED AERATION ACTIVATED SLUDGE TANK

An extended aeration activated sludge tank has the following dimensions for treating the waste with following characteristics;

Length	= 60m
Width	= 20m
Water depth	=5m
Flow	=7,500 m^3/day
Influent BOD	=200 mg/L
Effluent BOD	=10 mg/L
Influent SS	=200 mg/L
Influent VSS	=150 mg/L
MLSS	=4,000 mg/L
SV_{30}	=400 mL
MLVSS	=2,800 mg/L
Yobs	=0.4 mg VSS/ mg BOD
Kd	=0.04day^{-1}

Determine:

a. Hydraulic retention time, day
b. BOD loading, kg/day
c. BOD volumetric loading, kg/m^3.day
d. Microorganisms in aeration tank, kg
e. F/M ratio, kg/kg.day
f. SVI, mL/g
g. Excess sludge generation, kg/day
h. Excess sludge concentration, mg/L
i. Excess sludge volume, m^3/day
j. SRT, day
k. Return sludge flow rate, m^3/day
l. Oxygen requirement, kg/day

Solution:

$$\text{a. Hydraulic Retention Time (days)} = \frac{\text{Volume}}{\text{Discharge}}$$

$$\text{Volume} = 60(\text{m}) \times 20(\text{m}) \times 5(\text{m}) = 6{,}000(\text{m}^3)$$

$$\text{HRT} = \frac{6{,}000(\text{m}^3)}{7{,}500(\text{m}^3/\text{day})}$$

$$= 0.8\,(\text{days}) = 19.2\,(\text{hours})$$

$$\text{b. BOD Loading (kg / day)} = \text{BOD (kg / m}^3) \times \text{Flow(m}^3\text{ / day)}$$

$$= 200(\text{mg / L}) \times \frac{1{,}000\text{ (L)}}{1(\text{m}^3)} \times \frac{1(\text{kg})}{1{,}000{,}000(\text{mg})} \times 7{,}500(\text{m}^3\text{ / day})$$

$$= 1{,}500(\text{kg / day})$$

c. $$\text{BOD Volumetric Loading}\,(\text{kg}/\text{m}^3\cdot\text{day}) = \frac{\text{BOD Load}(\text{kg}/\text{day})}{\text{Volume}(\text{m}^3)}$$

$$= \frac{1{,}500(\text{kg}/\text{day})}{6{,}000(\text{m}^3)}$$

$$= 0.25\,(\text{kg}/\text{m}^3\cdot\text{day})$$

d. $$\text{Microorganisms in Aeration Tank}\,(\text{kg}) = \text{Volume}(\text{m}^3)\times\text{MLSS}(\text{kg}/\text{m}^3)$$

$$= 6{,}000(\text{m}^3)\times 2{,}800\,(\text{mg}/\text{L})\times\frac{1{,}000\,(\text{L})}{1(\text{m}^3)}\times\frac{1(\text{kg})}{1{,}000{,}000(\text{mg})}$$

$$= 16{,}800(\text{kg})$$

e. $$\text{F}/\text{M Ratio}\,(\text{kg}/\text{kg}\cdot\text{day}) = \frac{\text{Flow}\times\text{BOD}}{\text{Volume}\times\text{MLVSS}}$$

$$= \frac{\text{BOD Load}\,(\text{kg}/\text{day})}{\text{Microorgan isms in Aeration Tank}\,(\text{kg})}$$

$$= \frac{1{,}500\,(\text{kg}/\text{day})}{16{,}800\,(\text{kg})} = 0.089\,(\text{kg}/\text{kg}\cdot\text{day})$$

f. $$\text{SVI}\,(\text{ml}/\text{g}) = \frac{\text{Sludge Settled}\,(\text{ml}/\text{L})}{\text{MLSS}\,(\text{g}/\text{L})}$$

$$= \frac{400\,(\text{ml})}{4(\text{g})}$$

$$= 100\,(\text{ml}/\text{g})$$

g. $$\text{Excess Sludge Generation} = \text{Px}\,(\text{SSkg}/\text{day})$$

$$= \text{Yobs}\times Q\times(S_0 - S) + Q\times(\text{TSS}_{in} - \text{VSS}_{in})$$

$$= 0.4(\text{VSSkg}/\text{BODkg})\times 7{,}500(\text{m}^3/\text{d})\times(200-10)(\text{mg}/\text{L})\times\frac{1{,}000\text{L}}{1\text{m}^3}\times\frac{1\text{kg}}{1{,}000{,}000\text{mg}}$$

$$+ 7{,}500(\text{m}^3/\text{d})\times(200-150)(\text{mg}/\text{L})\times\frac{1{,}000\text{L}}{1\text{m}^3}\times\frac{1\text{kg}}{1{,}000{,}000\text{mg}}$$

$$= 570(\text{kg}/\text{day}) + 375(\text{kg}/\text{day})$$

$$= 945(\text{kg}/\text{day})$$

h. $$\text{Excess Sludge Concentration}\,(\text{mg}/\text{L}) = \frac{1{,}000{,}000}{\text{SVI}}$$

$$= \frac{1{,}000{,}000}{100}$$

$$= 10{,}000(\text{mg}/\text{L})$$

i. $$\text{Excess Sludge Volume}(\text{m}^3/\text{day}) = \frac{\text{Excess Sludge}\,(\text{kg}/\text{day})}{\text{Sludge Concentration}\,(\text{kg}/\text{m}^3)}$$

$$= \frac{945(\text{kg}/\text{day})}{10{,}000(\text{mg}/\text{L})\times\frac{1{,}000\text{L}}{1\text{m}^3}\times\frac{1\text{kg}}{1{,}000{,}000\text{mg}}}$$

$$= 94.5(\text{m}^3/\text{day})$$

$$\text{j. SRT(day)} = \frac{\text{Microorganisms in Aeration Tank(kg)}}{\text{Microorganism Wasted (kg / day)}} = \frac{16{,}800\ (\text{kg})}{570\ (\text{kg/day})} = 29.4\text{days}$$

$$= \frac{\text{Total MLSS in organisms in Aeration Tank (kg)}}{\text{Total Sludge Wasted(kg / day)}}$$

$$= \frac{6{,}000(\text{m}^3) \times 4{,}000(\text{mg/L}) \times \frac{1{,}000\text{L}}{1\text{m}^3} \times \frac{1\text{kg}}{1{,}000{,}000\text{mg}}}{945\ (\text{kg/day})} = 25.3\text{days}$$

$$\text{k. Re turn Sludge Flow Rate} = Q_r$$

$$= \frac{V_{30} \times Q}{1{,}000(\text{ml}) - V_{30}}$$

$$= \frac{400(\text{ml}) \times 7{,}500(\text{m}^3 / \text{day})}{1{,}000(\text{ml}) - 400(\text{ml})}$$

$$= 5{,}000(\text{m}^3 / \text{day})$$

$$\text{l. Oxygen Re quirement } (\text{kgO}_2 / \text{day}) = 1.47 \times \text{mass of BOD removed(kg / day)}$$

$$- 1.42 \times \text{mass of organisms wasted(kg / day)}$$

$$= 1.47 \times 7{,}500(\text{m}^3 / \text{day}) \times (200 - 10)(\text{mg / L})$$

$$\times \frac{1{,}000\text{L}}{1\text{m}^3} \times \frac{1\text{kg}}{1{,}000{,}000\text{mg}} - 1.42 \times 570(\text{kg / day})$$

$$= 2{,}094(\text{kg / day}) - 809(\text{kg / day})$$

$$= 1{,}285(\text{kgO}_2 / \text{day})$$

4.3.2 PRIMARY SEDIMENTATION TANK

Characteristics of influent to and effluent from primary sedimentation tanks are as follows;

Flow rate =10,000 m^3/ day
Influent BOD = 200 mg/L
Influent SS = 300 mg/L
Effluent BOD = 140 mg/L
Effluent SS = 100 mg/L

Find:

a. The BOD removal efficiency of the primary sedimentation tank, %
b. SS removal efficiency of the primary sedimentation tank, %
c. Dry sludge generated, kg/day
d. Volume of sludge generated, m^3/day if sludge concentration is 40,000 mg/L.

Solution:

$$\text{a. BOD Removal Efficiency (\%)} = \frac{(\text{Influent BOD} - \text{Effluent BOD}) \times 100\%}{\text{Influent BOD}}$$

$$= \frac{(200 - 140) \times 100}{200}$$

$$= 30\ (\%)$$

$$\text{b. SS Removal Efficiency (\%)} = \frac{(\text{Influent SS} - \text{Effluent SS}) \times 100\%}{\text{Influent SS}}$$

$$= \frac{(300 - 100) \times 100}{300}$$

$$= 66\ (\%)$$

$$\text{c. Sludge Solid generated (kg/day)} = \text{Flow}(m^3/\text{day}) \times (\text{TSS}_{in} - \text{TSS}_{out})(\text{mg/L})$$

$$= 10{,}000(m^3/\text{day}) \times (300 - 100)(\text{mg/L}) \times \frac{1{,}000\text{L}}{1\text{m}^3} \times \frac{1\text{kg}}{1{,}000{,}000\text{mg}}$$

$$= 2{,}000\ (\text{kg/day})$$

$$\text{d. Volume of Sludge generated} = \frac{\text{Sludge (kg/day)}}{\text{Concentration of sludge}(\text{kg}/m^3)}$$

$$= \frac{2{,}000\ (\text{kg/day})}{40{,}000(\text{mg/L}) \times \frac{1{,}000\text{L}}{1\text{m}^3} \times \frac{1\text{kg}}{1{,}000{,}000\text{mg}}}$$

$$= 50\ (m^3/\text{day})$$

4.3.3 CIRCULAR SECONDARY SEDIMENTATION TANK

A circular secondary sedimentation tank has the following dimensions for treating the waste with following characteristics;

Diameter =20m
Depth =3.5m
Inflow =10,000 m^3/day
Return sludge flow=5,000 m^3/day
MLSS =4,000 mg/L

Find:

a. Surface overflow rate,
b. Detention time,
c. Solids loading rate, and
d. Weir overflow rate.

Solution:

$$\text{a. Surface Overflow Rate (day)} = \frac{\text{Flow}(m^3/\text{day})}{\text{Surface Area}(m^2)}$$

$$= \frac{100{,}000(m^3/\text{day})}{3.14 \times 10 \times 10(m^2)} = 31.8 m^3/m^2.\text{day}$$

$$\text{b. Detention Time (day)} = \frac{\text{Volume}(m^3)}{\text{Flow}(m^3/\text{day})}$$

$$= \frac{3.14 \times 10 \times 10 \times 3.5\,(m^3)}{10{,}000(m^3/\text{day})}$$

$$= 0.219(\text{days}) \text{ or } 2.63(\text{hrs})$$

$$\text{c. Solids Loading Rate}(kg/m^2.\text{day}) = \frac{(\text{Inflow} + \text{Return Sludge Flow})(m^3/\text{day}) \times \text{MLSS}(mg/L)}{\text{Surface Area}(m^2)}$$

$$= \frac{(10{,}000 + 5{,}000)(m^3/\text{day}) \times 4{,}000(mg/L) \times \frac{1{,}000L}{1m^3} \times \frac{1kg}{1{,}000{,}000mg}}{3.14 \times 10 \times 10(m^2)}$$

$$= 191(kg/m^2.\text{day})$$

$$\text{d. Weir Over Rate }(m^3/m.\text{day}) = \frac{\text{Flow}(m^3/\text{day})}{\text{Weir Length (m)}}$$

$$= \frac{10{,}000\,(m^3/\text{day})}{3.14 \times 20\,(m)}$$

$$= 159\,(m^3/m.\text{day})$$

APPENDIX 5.1 TROUBLESHOOTING IN SLUDGE TREATMENT FACILITIES

Table A5.1-1 Sludge thickening by gravity thickeners

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Typical septic odour of hydrogen sulphide	Any thickener will invariably produce a typical odour. Do not try to disturb the system because of this alone	Check the per day total of sludge volumes and dilution water pumped into the thickener. Compare with per day total of sludge withdrawn and thickener overflow. Check for volume balance If the outlet is lesser, sludge stays longer and is likely to choke and become septic. Withdraw more sludge	If this fails to solve the problem, investigate a sludge flocculation system like the picket fence, etc. This may have given way below the liquid level. If the ampere of the motor is very low compared to design consumption, call the equipment supplier to attend to the system. Do not attempt it by yourself
2.	Thickened sludge is not what is designed for	Typically a minimum detention time is needed for sludge solids to break free of bound water and thicken at the bottom. If this is not occurring, the thickened sludge will be very weak	Check volumes of sludge and dilution water entering the tank from their flow meters. Reduce the flows so they do not exceed design values. Check flocculator also	Even after this, if the problem persists, the reason lies with the type of sludge and not the thickener. Proceed to clarifier sludge sections
3.	Biological growth over the outlet weir surfaces becomes very dense	This is related to the escape velocity over the weir length and temperature conditions. Do not alter the process conditions if they are as per the design	The simplest remedy is a daily scrubbing of the weir surface by a wire brush and a long handle while walking along the outer platform	Even after this, if the problem persists, remove the V notch plate and level the weirs as shown in Part-A , Figure 5-29
4.	Sludge solids are overflowing the outlet weirs	As long as the inflow and outflow rates are not exceeding the design values, this problem has nothing to do with the thickener. Do not alter the process	Proceed to the sections on clarifiers. Sludge from secondary clarifier may be very loose and not settling down. Follow the remedy	Even after this, if the problem continues, add polyelectrolyte to the thickener feed well temporarily
5.	Drive motor trips often	Too much of sludge at the bottom or a foreign object is obstructing the free movement of the flocculator paddles	Try increasing the sludge withdrawal frequency temporarily for a day. Most probably this will solve the problem	Even after this, if the problem continues, check the gearbox visually for any broken teeth and call the equipment supplier
6.	Chocking of sludge pump	Top Layer may become dry as a result of direct sunlight	Roof may be provided to protect from direct sunlight	

Table A5.1-2 Anaerobic sludge digesters

<table>
<tr><th>No.</th><th>Troubles / Problems</th><th>Likely causes</th><th>First stage remedies</th><th>Second stage remedies</th></tr>
<tr><td colspan="5">This is an identified high risk unit operation for any person trying to look into this unit or enter it. Sometimes strobe lights are installed inside the digester to light up the inside so that it can be seen through a fixed glass plate on the cover slab and viewed from outside. This shall not be allowed as a simple spark at the cable terminal can blow up the digester by igniting the methane gas inside it. All investigations of digester performance should be made indirectly by observing the performance parameters and never by directly entering the digester. Persons smoking near the digester or while standing near the top dome are likely to cause severe accident. There is at least one case of the operator and the dome getting blown up because of smoking.
In actual practice, there is not much an operator can do to correct the digester mechanism if it is not functioning because work on such equipment is a highly specialized task requiring high skills in explosive zones. The operator can attend only to the pump and motor of externally circulated sludge mixing type digesters, in which standard horizontal foot mounted centrifugal pumps are coupled to motors. All other types of equipment are prohibited from being repaired by the operator and shall be attended to only by the equipment supplier or his service personnel.
Hence troubleshooting of digesters will be confined only to process control in this section</td></tr>
<tr><td rowspan="3">1.</td><td rowspan="3">Gas production is less than the designed output</td><td>Gas production is a function of the VSS and detention time and mixing efficiency in the digester. Measure the VSS in feed sludge in the lab and verify loading rate from feed flow. Compare with design values</td><td>If the feed VSS is too low, then gas production will surely be very small. If the feed VSS is too high, then also gas production will suffer. First check the value of VSS</td><td>If the conditions are as per the design, it is a clear case of mixing system failure. Call the equipment supplier. Do not correct it except in case of externally re-circulated pumped sludge</td></tr>
<tr><td rowspan="2">Sometimes, the pH of the digester may be less due to too much of acidification. This can be checked in the lab and compared with past records</td><td>Raising the pH to 6.8 - 7.2 is required. Though lime solution is the easier option, the use of sodium hydroxide is preferable because it does not create problems of precipitates in the digester or the sludge pipelines</td><td rowspan="2">Even after these measures, if the problem persists, the reason is not with the process but with either the mixing equipment in the digester or the sludge quality coming out of the clarifiers. First check on the sludge quality as per earlier sections. If the quality is in order, call the equipment supplier to inspect the mixing equipment and bring it to maximum efficiency. This shall not be attempted by operator</td></tr>
<tr><td>The feeding of the solution shall be by a solution tank and acid-alkali proof dosing pump mounted at ground level. The delivery pipeline shall be thick walled UPVC pipeline discharging into the sludge suction sump</td></tr>
</table>

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
2.		Sometimes there is an auto toxicity problem when high TDS waters are used by the habitation. The sulphate in the water gets into sewage. This gets into digester liquid. The sulphate reduces to sulphide. This is partly converted to hydrogen sulphide gas. The unreacted sulphide is toxic to digesters in the range 50 mg/l in dispersed sludge and 250 mg/l in granular sludge. In digesters, it is usually dispersed sludge	Check the sulphate content of the digester feed and digested outlet. Estimate the sulphide produced as one third of the sulphate. Estimate 40 % of this value as unreacted sulphide. Also estimate sulphide in the digested liquid by titration in the laboratory. Consult a process specialist on this further to establish sulphide toxicity as the reason	The way to reduce this toxicity is to prevent the sulphates from getting reduced to sulphide in the first place. But this is not possible inside a digester. A higher degree of mixing usually expels the hydrogen sulphide gas faster and thus promotes more formation in the digester liquid. This reduces the unreacted sulphide remaining in the digester
3.	Foul or sour odour	Usually, a well digested sludge does not smell offensive. If the digested sludge smells sour and foul, the digester has probably become sour and the pH may have dropped	Follow the procedure for raising the pH of the digester by lime or preferable sodium hydroxide as described earlier	
4.	Smell of hydrogen sulphide when walking around the base of the fixed dome on the digester	Apply soap solution to all piping joints to verify any leaky joints or cracked pipes. It can also be the digester sidewalls which are above the sludge level but usually this is not the case	Erect a sign board in local language and all familiar languages that gas is leaking and persons shall not go to the top of digesters	Do not try to fix the problem by yourself. Call the equipment supplier to attend to it
5.	Smell of hydrogen sulphide when walking around the base of the floating dome on the digester	Floating dome covers are usually fabricated from steel or synthetic materials. The joints are the sources of the leak. It can also be the digester sidewalls which are above the sludge level but usually this is not the case		

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
6.	Smell of hydrogen sulphide when walking around the base of the inflatable gas holder on the digester	Usually these are inflatable gas balloons made of synthetic material and are of multi layered construction. Unless there is an external puncture, these do not leak. The actual leak may occur at the base where the gas cover is jointed with the digester which again is through a piping. Thus, the fastening around the joint piping should be checked	The simple soap solution test will help in identifying the leak. If this is the case, the fasteners are to be fixed	Do not try to fix the problem by yourself. Call the equipment supplier to attend to it
7.	Floating gas dome on the digester is not truly vertical but is tilted	The holding down weights on the rim are not properly adjusted	Try small adjustments at a time by adding or removing the weights	Once it becomes vertical, record the work in the site register
8.	Gas pressure in the gas line from digester is higher than the design value	Gas is not being withdrawn regularly or gas production is more than the design	Use the flame trap to release and burn off the required volume of the gas	
9.	Gas pressure in the gas dome is less than the design value	Gas production is not adequate	Take no action but attend to the sludge section as discussed earlier	
10.	Mixing systems	Get an authorized agency to inspect, service and leave a report at regular intervals which can be monthly intervals		

Table A5.1-3 Mechanical sludge dewatering devices

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Metallic noise in moving parts	May be due to worn out bearings or absence of lubrication	Lubricate moving parts	Refer bearing problems to equipment supplier

Table A5.1-4 Sludge drying beds

No.	Troubles / Problems	Likely causes	First stage remedies	Second stage remedies
1.	Fires occur in drying beds	This is due to methane gas in high summer months ignited by a spark from an electrical line or due to somebody smoking nearby	Switch off electrical supply to the drying bed zone. If there are people nearby ask them to switch off their cell phones and move away	Erect a warning board that cell phones should be switched off for a distance of about 10 m from the edges of the drying beds
2.	Wet sludge is ponding for a long time and does not filter	The drying bed might have choked or the sludge applied without digestion	Cut off the sludge flow to the bed and allow it to filter through slowly. Till it lightly by a long boom crane from all sides and restart	If the F/M ratio is higher than 0.2 in biological aeration, demand that a digester be provided. If F/M is less and tilling does not help, scrap out and restack
3.	Drying beds are full of water from rains	Nothing that can be done about this. If rainfall is frequent, demand mechanized dewatering facility		

APPENDIX 6.1 TYPICAL LEDGER AND RECORDS

Table A6.1-1 Operational record: Power receiving and transforming equipment

Date:

Time	Transaction		Receiving						Wastewater pump transformer					No.2 blower			Lighting transformer					Main building power trans				
	Contact: 463kW								3φ415V 150kVA					6600V 80kW			1φ210V 150kVA					3φ210V 300kVA				
	Center		M102	M103	M102	M103	Center		Center		L101			Center			Center		L102			Center		L105		
	Wattage-h		Voltage	Current	Power	Wattage	Wattage-h		Wattage-h		Voltage	Current	Temperature	Wattage-h		Current	Wattage-h		Voltage	Current	Temperature	Wattage-h		Voltage	Current	Temperature
	kWh		V	A	%	kW	kWh		kWh		V	A	°C	kWh		A	kWh		V	A	°C	kWh		V	A	°C
	Reading	Difference	6600	60			Reading	Difference	Reading	Difference	210	714	140	Reading	Difference	10.1	Reading	Difference	210	714	140	Reading	Difference	210	714	140
1																										
2																										
3																										
4																										
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21																										
22																										
23																										
24																										
Today's Reading																										
Yesterday's Reading																										
Difference																										
Multiplying ratio	×720		×10						×10					×10			×10					×10				
Wattage																										

Transaction wattage-h	kWh
Max. wattage per hour	Time kWh
Max. kWh/Contact kWh	%

Non-utility generation	Wattage	Time
Today's reading		
Yesterday's reading		
Difference		
Multiplying ratio	×10	
Generated wattage-h		

Power	No.2 main building equipment	No.2 main building equipment	Grit chamber equipment	Reservoir water	Blower for adjustment
Today's reading					
Yesterday's reading					
Difference					
Multiplying ratio	×10	×10	×10	×10	×10
Generated wattage-h					

Instructions:

1. Voltage is obtained by measuring RS phase (RT phase in case of single phase). Current is obtained by measuring R phase.
2. Indicate the max. wattage per hour by transaction wattage.

Table A6.1-2 Monthly report: Electric power receiving

	For transaction			Receiving	Sewage pump	No.2 blower	Main building power	Main building lighting	Sewage treatment power	Main building facility power	Grit chamber facility power	Reservoir water	Blower for adjustment	Pump well draining	Power by non-utility power generation	Hours of generation
	Contract: 463kW				150kVA	80kW	300kVA	150kVA	200kVA	178kW	91kW	91kW	30kW	11kW	500kW	
	kWh	Msx./h	%	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	h
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26																
27																
28																
29																
30																
31																
Total																
Max.																
Min.																
Ave.																
Ratio																

Summary		
Transaction		kWh
Contents	Pump	kWh
		%
	Blower	kWh
		%
	Power	kWh
		%
	Lighting	kWh
		%
	Others	kWh
		%
Max./h		kWh
Max./Contract		%
Electricity Charge		INR
Effluent volume		m^3
Charge/ flow rate		INR/m^3
Non-utility power generation		
Power		kWh
Running hours		h
Contents	Failure	h times
	Inspection	h times
Oil consumption		L
Fuel		ms/kWh

Source: JICA, 2011

Table A6.1-3 Ledger for electrical equipment

	Classification		File No.	

Name		Location		Related Ledgers	( )	( )
		Fixed asset No.			( )	( )

Items on name plate	Capacity			Rotor	Voltage	V	Others	Insulator type			
	Number of poles				Current	A		Insulation resistance allowance			
	Phase				Type			Rotating direction			
	Frequency	Hz		Rotation rate		rpm		Lead wire direction			
	Voltage	Primary V	Secondary V					Impedance voltage			
	Current	A	A	Specification			Test performance chart	Frequency			
	Mode1			Manufacturer				Voltage			
	Specification			Lot No.				Current			
				Date of mfg.				Loss			
	Mode1	( )	( )	Reducer	Reduction ratio			Measuring position	1) mm	2) mm	
	Sleeve: Diameter	( )	( )		Mode 1				3) mm	4) mm	
	Sleeve: Length						Related charts	Name	Chart No.	Name	Chart No.
	Coil: Wire: Type				Manufacturer						
	Coil: Wire: Thickness			Starting resistor	Voltage	V					
	Coil: No. of coils				Current	A	Special notes				
	Coil: Total weight				Resistance	Ω					
					Mode 1						
					Manufacturer						

Source: JICA, 2011

Table A6.1-4 Electrical facility ledger (Distributing board)

	Classification No.			File No.	

Name		Problem		Related Ledgers	( )	( )
		Fixed asset No.			( )	( )

Indicating Instrument	Specification	Grade	Mode1	Quantity	Protective instrument, relay	Adjustment range	Adjustment time	Mode 1	Lot No.	Manufacturer	Date of mfg.

( ) Breaker				Disconnector		Transformer		
Mode 1		Specification	kV A	Mode 1		PT CT		
Weight	kg	Oil quantity	L	Specification	kV A	Transforming ratio		
Breaking capacity			kVA at	High-voltage soluble material		Specification load		
Operation power	Input	V	A	Mode 1		Mode		
	Out put	V	A	Specification	A	Lot No.		
Lot No.		Date of mfg.		Receiving wire		Manufacturer		
Manufacturer				Type		Quantity		
Other				Thickness	mm	Others		

Use	Knife-edge switch, NFB			Soluble material		Electromagnetic switch		Electromagnetic Connector		Thermo electric Connector	Supply wire (sq.m.) (mm^2)	Load kW	Indicator lamp	White	PC
	Specification A	Voltage	Pole	Holder	Element	Model	Qty.	Model	Qty.					Red	PC
														Green	PC
													Size of distributing board		
													Height		mm
													Width		mm
													Depth		mm
													Operation switch		
													Distributing board		
													Date of mfg.		
													Manufacturer		
													Lot No.		
													Chart No.		
													Related ledger		
Other items															

Source: JICA, 2011

APPENDIX 6.2 PREVENTIVE MAINTENANCE

6.2.1 MOTOR

a. Daily

- Check bearing temperatures
- Check for any undue noise or vibration

b. Monthly

- Nothing special other than the daily checks

c. Quarterly

- Blow away dust and clean any splashes of oil or grease
- Check wear of slip ring and brushes; smoothen contact faces or replace, if necessary. Check spring-tension. Check brush setting for proper contact on the slip-ring.
- Check cable connections, terminals and insulation of the cable near the lugs: clean all contacts; if insulation is damaged by overheating investigate and rectify. All contacts should be fully tight.

d. Semi-annual

- Check condition of oil or grease; and replace if necessary. While greasing avoid excessive greasing.
- Test insulation by megger.

e. Annual

- Examine bearings for flaws, clean and replace if necessary.
- Check end-play of bearings and reset by lock-nuts, wherever provided.

f. Bi-annual

- Same as annual

6.2.2 PANEL, CIRCUIT BREAKER, STARTER

a. Daily

- Check the phase-indicating lamps.
- Note readings of voltage, current, frequency, and others.
- Note energy-meter readings.

b. Monthly

- Examine contacts of relay and circuit-breaker. Clean, if necessary.
- Check setting of over-current relay, no-volt coil and tripping mechanism, and oil in the dash-pot relay.

c. Quarterly

- Check fixed and moving contacts of the circuit- breakers/switches. Check and smoothen contacts with fine glass-paper or file.
- Check condition and quantity of oil/liquid in circuit-breaker, auto-transformer starter and rotor-controller.

d. Semi-annual

– *Nothing special.

e. Annual

– All indicating meters should be calibrated.

f. Bi-annual

– Same as annual.

6.2.3 TRANSFORMER SUBSTATION

a. Daily

– Note voltage and current readings.

b. Monthly

– Check the level of the transformer oil.
– Confirm that the operation of the GOD (ground operated disconnection) is okay.
– Check temperatures of the oil and windings.
– Clean radiators to be free of dust or scales.
– Pour 3 to 4 buckets of water in each earth-pit.

c. Quarterly

– Check condition of the H.T. bushing.
– Check the condition of the dehydrating breather and replace the silica-gel charge, if necessary. Reactivate old charge for reuse.

d. Semi-annual

– Check di-electric strength and acid test of transformer oil and filter, if necessary.
– Test insulation by megger.
– Check continuity for proper earth connections.

e. Annual

– Check resistance of earth pit/earth electrode.

f. Bi-annual

– Complete examination including internal connections, core and windings.

Source: CPHEEO, 1993

APPENDIX 6.3 TROUBLESHOOTING FOR ELECTRICAL FACILITIES

Table A6.3-1 Electric motors

Trouble	Cause	Remedy
Hot bearings	Bent or sprung shaft	Straighten or replace shaft
	Excessive belt pull	Decrease belt tension
	Misalignment	Correct coupling alignment
	Bent or damaged oil rings	Replace or repair oil rings
	Oil too heavy or too light	Use recommended oil. Use of oil of very light grade is likely to cause the bearings to seize
	Insufficient oil level	Fill reservoir to proper level when motor is at rest
	Badly worn bearings	Replace bearings
	Bearing loose on shaft or in bearing housing	Re-metal shaft / housing or replace shaft or bearing housing
	Insufficient grease	Maintain proper quantity of grease in bearing
	Deterioration of grease or lubricant contaminated	Remove old grease, wash bearings thoroughly with kerosene and replace with new grease
	Excessive lubricant	Reduce quantity of grease. Bearing should not be filled more than the two-third level
	Broken ball or rough races	Clean housing thoroughly and replace bearing
Motor dirty	Ventilation passage blocked. Windings coated with fine dust or lint (dust may be cement, sawdust, rock dust, grain dust and the like)	Dismantle entire motor and clean all windings and parts by blowing off dust, and if necessary, varnish
	Bearing and brackets coated inside	Clean and wash with cleaning solvent
	Rotor winding coated with fine dust / cement	Clean and polish slip ring. Clean rotor and varnish
Motor stalls	Motor over loaded	Check for excessive rubbing or clogging in pump
	Low voltage	Correct voltage to rated value
	Open circuit	Fuses blown, check overload relay, starter and push button
	Mechanical locking in bearings or at air gap	Dismantle and check bearings. Check whether any foreign matter has entered air gap and clean
Motor does not start	No supply voltage or single phasing or open circuit or voltage too low	Check voltage in each phase

Trouble	Cause	Remedy
	Motor may be overloaded	Start on no load by decoupling. Check for cause for overloading
	Starter or switch/breaker contacts improper	Examine starter and switch/ breaker for poor contact or open circuit. Make sure that brushes of slip ring motor are making good contact with the rings
	Rotor defective	Check for broken rings
Motor runs and then stop	Overload replay trips	Examine overload relay setting. Ensure that the relay is set correctly to about 140-150% of load current. Check whether dashpot is filled with correct quantity and grade of oil
		Consult manufacturer on suitability for design duty and load
Motor does not accelerate to rated speed	Voltage too low at motor terminals because of line drop	Check voltage, change tapping on transformer
	Broken rotor bars	Look for cracks near the rings
Motor takes too long to accelerate	Excess loading	Reduce load. (Note that if motor is driving a heavy load or is starting up a long line of shafting, acceleration time will increase)
	Timer setting of starter is incorrect	Check whether timer setting of star-delta or autotransformer starter is less than acceleration time required for the torque of driven equipment
	Applied voltage too low	Correct the voltage by changing tap on transformer. If voltage is still low, take up the matter to power supply authority
Motor overheats while running	Check for overload	If overloaded, check and rectify cause of over load. Overloading may be due to system fault, for example, if pipeline bursts, the pump may be operating at low head causing overload of motor. Vortices in sump also may cause overload
	End shields may be clogged with dust, preventing proper ventilation of motor	Blow off dust from the end shields
	Motor may have one phase open	Check to make sure that all leads are well connected
	Unbalanced terminal voltage	Check for faulty leads or faulty connections from transformers
	Weak insulation	Check insulation resistance, examine and re-varnish or change insulation
	High or low voltage	Check voltage of motor and correct it to the extent possible
	Rotor rubs on stator bore	Replace worn bearings
		Check for true running of shaft and rotor
Motor vibrates after	Motor misaligned	Realign

Trouble	Cause	Remedy
connections have been made	Weak foundations or holding down bolts loose	Strengthen base plate/ foundation; tighten holding down bolts
	Coupling out of balance	Balance coupling
	Defective ball or roller bearings	Replace bearing
	Bearings not in line	Line up properly
	Single phasing	Check for open circuit in all phases
	Excessive end play	Adjust bearing or add washer
	Resonance from supporting structure or foundation or vibration of adjoining equipment	Consult expert
Scraping noise	Fan rubbing air shield or striking insulation	Check for cause and rectify
	Loose on bed plate	Tighten holding down bolts
Motor sparking at slip rings	Motor may be over loaded	Reduce the load
	Brushes may not be of appropriate quality and may not be sticking in the holders	Use brushes of the recommended grade and fit properly in the brush holder
	Slip ring dirty or rough	Clean the slip rings and maintain its smooth glossy appearance; ensure they are free from oil and dirt
	Slip rings may be ridged or out of turness	Turn and grind the slip rings in a lathe to a smooth finish
Leakage of oil or grease on winding	Thrust bearing oil seal damaged	Clean the spilled oil on winding. Replace oil seal
	Excessive oil, grease in bearing	Reduce quantity to correct extent. Grease should be filled up to maximum half space in bearing housing

Table A6.3-2 Capacitors

Trouble	Cause	Remedy
Leakage of heclor*	Leaking welds & solders	Repair by soldering
	Broken insulators	Replace insulators
Overheating of unit	Poor ventilation	Arrange for circulation of air either by reinstalling in a cool and ventilated place or arrange for proper ventilation
	Over voltage	Reduce voltage if possible, otherwise switch off capacitors
Abnormal bulging	Gas formation due to internal arcing	Replace the capacitor
Cracking sound	Partial internal faults	Replace the capacitor

Trouble	Cause	Remedy
HRC Fuse blowing	Short external to the units	Check and remove the short
	Over-current due to over voltage and harmonics	Reduce voltage and eliminate harmonics
	Short circuited unit	Replace the capacitor
	kVAR rating high	Replace with bank of appropriate kVAR
Capacitor not discharging	Discharge resistance low	Correct or replace the discharge resistance
Unbalanced current	Insulation or dielectric failure	Replace capacitor unit

*Leakage of Heclor from terminals, insulators or lid etc. is not a serious trouble. After cleaning, the nuts should be tightened carefully, araldite shall be applied if necessary and the capacitor should be put into circuit. If the leakage still continues, refer the matter to manufacturer.

Table A6.3-3 Starters, breakers, and control circuits

Trouble	Cause	Remedy
Starter/breaker not switching on	Non availability of power supply to the starter / breaker	Check the supply
	Over current relay operated	Reset the relay
	Relay not reset	Clean and reset relay
Starter / breaker not holding on ON-Position	Relay contacts are not contacting properly	Check and clean the contacts
	Latch or cam worn out	Readjust latch and cam
Starter/breaker tripping within short duration due to operation of over current relay	Over current relay setting incorrect	Check and reset to 140-150 % of normal load current
	Moderate short circuit on outgoing side	Check and remove cause for short circuit
	Sustained overload	Check overcurrent setting
		Check for short circuit or earth fault
		Examine cause of overload and rectify
	Loosen connection	Clean and tighten
Starter / breaker not tripping after overcurrent or short circuit fault occurs	Inadequate lubrication to mechanism	Lubricate hinge pins and mechanisms
	Mechanism out of adjustment	Adjust all mechanical devices such as toggle stops, buffers, springs as per manufacturer's instructions
	Failure of latching device	Examine surface, clean and adjust latch. If worn or corroded, replace it
	Relay previously damaged by short circuit	Replace overcurrent relay and heater

Trouble	Cause	Remedy
	Heater assembled incorrectly	Review installation instructions and correctly install the heater assembly
	Relay not operating due to: -Blown fuse -Loose or broken wire -Relay contacts damaged or dirty -Damaged trip coil -C.T. damaged	-Replace fuse -Repair faulty wiring; and ensure that all screws are tight -Replace damaged contacts -Replace coil -Check and repair / replace
Overheating	Contacts burnt or pitted.	Clean the contacts with smooth polishing paper or if badly burnt /pitted, replace contacts. (Contacts should be cleaned with smooth polishing paper to preserve faces. File should not be used)
	Loose power connection	Tighten the connection
	Sustained overcurrent or short circuit / earth fault	Check cause and rectify
	Poor ventilation at location of starter / breaker	Improve ventilation
Overheating of auto transformer unit	Winding design improper	Rewind
	Transformer oil condition poor	Replace transformer oil in auto-transformer unit
Contacts chatter	Low voltage	Check voltage condition. Check momentary voltage dip during starting. Low voltage prevents magnet sealing. Check coil voltage rating
	Poor contact in control circuit	Check push button station, (stop button contacts), auxiliary switch contacts and overload relay contacts; test with test lamp
		Check for loose connections in control circuits
	Defective or incorrect coil	Replace coil. Rating should compatible for system nominal voltage
Contacts welding	Abnormal inrush of current	Check for grounds & shorts in system as well as other components such as circuit breaker
	Low voltage preventing magnet from sealing	Check and correct voltage
	Short circuit	Remove short circuit fault and ensure that fuse or circuit breaker rating is correct
Short push button and / or over heating of contacts	Filing or dressing	Do not file silver tips. Rough spots or discolouration will not harm tips or impair their efficiency
	Interrupting excessively high current	Check for short circuit, earth fault or excessive motor current

Trouble	Cause	Remedy
	Discoloured contacts caused by insufficient contact pressure, loose connections, etc.	Replace contact springs, check contact for deformation or damage. Clean and tighten connections
	Dirt of foreign matter on contact surface	Clean with carbon tetrachloride
	Short circuit	Rectify fault & check fuse or breaker rating whether correct
Coil open circuit	Mechanical damage	Examine and replace carefully. Do not handle coil by the leads
	Burnt out coil due to over voltage or defect	Replace coil
Magnets & other mechanical parts worn out/broken	Too much cycling	Replace part and correct the cause of damage
Noisy magnet (humming)	Magnet faces not mating correctly	Replace magnet assembly. Hum may be reduced by removing magnet armature and rotating through 180°
	Dirt oil or foreign matter on magnet faces	Clean magnet faces with carbon tetrachloride
	Low voltage	Check system voltage and voltage dips during start
Failure to pick-up and / or seal	Low voltage	Check system voltage and voltage dips during start
	Coil open or shorted	Replace coil
	Wrong coil	Check coil voltage rating which must include nominal voltage and frequency of system
	Mechanical obstruction	With power off, check for free movement of contact and armature assembly. Remove foreign objects or replace contactor
	Poor contact in control circuit	Check and correct
Failure to drop out	Gummy substances on pole faces or in mechanism	Clean with carbon tetrachloride
	Worn or rusted parts causing binding, for instance coil guides, linkages	Replace contactor
	Improper mounting of starter	Review installation instructions and mount properly
Failure to reset	Broken mechanism worn parts, corrosion, dirt, etc.	Replace overcurrent relay and heater
Open or welded control circuit contacts in over current relay	Short circuit in control circuit with too large rating of protecting fuse	Rectify short circuit in general. Fuses over 10A rating should not be used

Trouble	Cause	Remedy
Insufficient oil in breaker/ starter (if oil cooled)	Leakage of oil	Locate point of leakage and rectify
Oil dirty	Carbonisation of moisture from atmosphere	Clean inside of tank and all internal parts. Fill fresh oil
Moisture present in oil	Condensation of moisture from atmosphere	Same as above

Table A6.3-4 Panels

Trouble	Cause	Remedy
Overheating	Bus bar capacity inadequate	Check and provide additional bars in combination with existing bus-bars or replace bus-bars
	Loose connection	Improper ventilation
	Improper ventilation	Improve ventilation
Insulator cracked	-	Replace the insulator

Table A6.3-5 Cables

Trouble	Cause	Remedy
Over heating	Cable size inadequate	Provide a cable in parallel to existing cable or higher size cable
		Increase clearance between cables
Insulation burning at Termination	Improper termination in lug termination	Check size of lug. If not properly crimpled, correct it
		Check whether all stands of cable are inserted in lug. Use a new or higher size lug if necessary

Table A6.3-6 Transformers

Trouble	Trouble shooting procedure	Cause	Remedy
Abnormal noise	Listen to the noise at various points of the transformer and find out the exact location by means of a solid piece of wood or insulating material placed on body of transformer tank at various points. This helps in determining whether the noise is from the inside of the transformer or is only an external one	a) External Noise: A loose fixing bolt/nut of the transformer b) Noise originating from the inside of the transformer: In the case of old transformer, possibly due to the windings having become slightly slack	a) Tighten the fixing bolts and nuts and other loose metallic parts b) In the case of small transformer and if such facilities are available, open the transformer and remove any slackness by placing shim made of insulated board. In case of large transformers, contact the manufacturer or transformer repairer
High Temperature	The temperature rise of transformer during 10-24 hours of operation is observed. The input current, oil temperature are noted down at intervals of half an hour and tabulated	a) Transformer is over loaded b) Transformer room is not properly ventilated c) Certain turns in the winding are short circuited	a) Reduce the load to the rated load b) Improve the ventilation of the transformer room to achieve effective air cooling c) Major repairs are necessary and should be taken up in consultation with an experienced Electrical Engineer and transformer repairer
	The transformer becomes hot in a relatively short period; transformer oil escapes from the conservator or there is even appearance of gas	The transformer has a major defect	Take action for major repairs in consultation with an experienced Electrical Engineer and transformer repairer
	Abnormal heating of one terminal	Poor termination either inside or outside the transformer	a) External contacts should be checked and put in order especially those in the aluminium bus bars b) If heating persists, action for major repairs should be taken in consultation with an experienced Electrical Engineer
Tripping of circuit breaker or blowing of fuses	-	a) Short circuit in the windings b) Damage in the insulation of the winding or in one terminal	Action for major repairs should be taken in consultation with an experienced Electrical Engineer and transformer repairer

Trouble	Trouble shooting procedure	Cause	Remedy
Frequent change of silica gel colour	-	a) Breather leakage b) Breather oil level low c) Absorption of moisture	a) Replace packing b) Check oil seal. Top up oil c) Remove moisture completely
Oil leak at joints / bushing / drain valve	-	a) Defective packing b) Loose tightening c) Uneven surface d) Bushing cracked e) Drain, valve not fully tight	a) Replace packing b) Tighten properly c) Check and correct it d) Replace bushing along with washer e) Tighten valve and plug
Low insulation resistance	-	a) Moisture absorption by winding b) Contaminated oil c) Presence of sludge	a) Heat the windings, by operating transformer on no-load, and check whether insulation resistance improves. If no-improvement is observed after operation for 5-6 hours, filter the oil b) Replace with proper oil c) Filter or replace the oil
Water inside tank	-	a) Defects in joints b) Moisture condensation c) Oil mixed with water when topping up	a) Rectify the defect b) Drain water and dry the moisture in winding c) Heat the winding on no-load. Recheck dielectric strength and filter if necessary
Overheating of cable ends and cable terminals	-	Loose connections	Check and tighten the connections
Neutral ground conductor (earth strip) burnt	-	a) Loose connections b) Large fault current	Replace the grounding conductor

Source: CPHEEO, 2005

APPENDIX 7.1 MINIMUM LABORATORY EQUIPMENTS NEEDED FOR TESTS

Table A7.1-1 Minimum laboratory equipments needed for tests

Equipment	Type of Plant	
	(A) For consent parameter (BOD, SS, pH)	(B) For plant operating parameter
Analytical Balance	x	x
Autoclave		x
Centrifuge		x
Chlorine comparator		x
Colony counters		x
Demineraliser		x
Dissolved Oxygen sampler		x
Drying oven (hot air)		x
Fume cupboards		x
Gas liquid chromatograph		x
Hot plates	x	x
Incubator 20°C/27°C (BOD)	x	x
Incubator 30°C (Bacteriological)		x
Kjeldahl Digester Unit		x
Magnetic stirrers		x
Microscope, binocular with oil immersion and movable stage counting cell		x
Membrane Filter Assembly		x
Muffle Furnace		x
Orsat or equivalent gas analysis apparatus		x
pH comparator (Colorimetric)	x	x
pH meter with reference & spare electrodes		x
pH meter portable	x	x
Refrigerator		x
Sedwick Rafter funnel		x
Sludge sampler		x
Soxhlet extraction unit		x
Spectrophotometer (atomic absorption)		x
Spectrophotometer with or without U-V rage or photo electric colorimeter		x
Total organic carbon analyser		x
Turbidimeter		x
Vacuum pump		x
Water bath (thermostat controlled)		x
Dessicator	x	

*NB: (1) For plant operating parameters, equipment as needed will also be provided in the laboratory of STP.
(2) Equipment in column B may be in plant laboratory itself or in a regional laboratory to serve multiple STPs.

APPENDIX 7.2 SUGGESTED LABORATORY SERVICE INFRASTRUCTURE FOR MONITORING WATER QUALITY

Table A7.2-1 Suggested laboratory service infrastructure for monitoring water quality

S.No.	Level	Minimu Recommended Staff	Remarks
1	Basic Laboratory a. Primary Health Centre / Village Level	1. Lab. Assistant /Technician 2. Lab. Attendant	For routine bacteriological and physicochemical tests, the samples should be sent to municipal / district level laboratory periodically
	b. Municipal / District Level (Plant capacity > 50MLd)	1. Chief Analyst 2. Chemist 3. Bacteriologist 4. Assistant Chemist 5. Lab. Assistant / Technician 6. Lab. Attendants 7. Driver 8. Helper	Whenever STP laborotory is existing
2	State / Regional Level Laboratory	1. Chief Analyst (Higher Scale) 2. Chemist 3. Bacteriologist 4. Biologist 5. Assistant Bacteriologist 6. Assistant Biologist 7. Lab. Assistant / Technician 8. Lab. Attendants 9. Driver 10. Helper	

Note: 1. Kindly refer to Manual on Water Supply and Treatment, III Edition, May 1999.
2. The level and the no. of the personnel shall be decided by the respective agencies depending on magnitude of

APPENDIX 9.1 HEALTH AND SAFETY POLICY

The agencies involved in the project development such as the owner, consultant and contractor jointly or separately shall have a written statement prescribing the health and safety policy of the organisation.

The health and safety policy conveys the management commitment and intent of the organisation towards health and safety, its organisation and arrangements to ensure that the set objectives are met. It also provides a framework for establishing, maintaining and periodically reviewing health and safety objectives and targets.

Health and safety policy shall meet the requirements of Building and other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 and IS 18001.

The policy shall be communicated to all stakeholders through display and other means. The policy shall be displayed in local language(s) which may be understood by majority of the workmen.

Guidelines on operation and maintenance of sewerage and sewage treatment for operators to help them in practicing their works in accordance with health and safety requirements specified for sewerage works are presented below:

9.1.1 APPLICABLE FACTORS

The applicable factors under this important section will be the procedures to be followed by the operator while working in confined spaces, type of shoes to be worn, personal hygiene and climbing ladders plus a formal appreciation of first aid.

9.1.2 WORKING IN CONFINED SPACES

This category is the worst location for possible fatal accidents in the STP. A confined space is defined as (1) Cramped entry and exit, (2) Absence of broad daylight and ventilation and (3) Places meant for very limited persons like one or two only to go in. The dangers are caused by

- Oxygen less situation
- Flammable situation
- Toxic gas presence
- Engulfment hazards
- Shouts not being heard outside
- Wet and / or slippery surfaces
- Loosely fitted objects that may fall down

The precautions to be taken before entry into these spaces when required are

- Certifying by the plant superintendent in writing that it is free of H_2S, CO and Methane
- Availability of a portable air compressor which draws free unpolluted air and pumps in
- Personal Respirator with adequate Oxygen cylinder and the Miner's lamp
- Availability of a strong rope tied to the person and rescue team in position
- The person to have undergone training in safety with St. John Ambulance
- The person to have comfortable and tight fitting garments

- The person to wear anti-skid shoes only
- The person to have special goggles securely worn over the eyes
- The person to complete his urination and toiletries before entry
- The person to have been in continues duty for at least a week as on that date
- The person not to have returned from medical leave within 7 days of the date of entry
- The person not to a be a known asthmatic or cardiac patient
- The person not to be aged more than 35 years
- Above all, a person who is not mentally scared to get in.

9.1.3 TYPES OF SHOES TO BE WORN

Very often, it is believed that any shoe in the market is good for working in a STP. This is not correct. There are special anti-skid shoes with metal cladding over the fingers portion. These are to be provided by the employer and the operator should not use it outside the STP.

9.1.4 PERSONAL HYGIENE

The following procedures should be followed by the operator scrupulously in and out of the STP.

- Keep the fingers of the hand away from ears, nose, eyes, mouth and unnecessary scratching
- While handling any equipment, wear gloves or poly bags slipped over the palm and wrists
- When there is an injury to the hand, do not handle any equipment or collect sample
- Before and after food and work wash hands with Dettol , soap and fresh tap water
- After the work, take a bath before leaving the STP
- Ensure fingernails are cut properly and there are no deposits
- Insist on two separate lockers one for formal cloths and one for STP cloths
- Ensure you are vaccinated by the employer against Hepatitis, Typhoid, Rubella [for women], Tetanus, Diphtheria, Pox and Measles.
- Insist on mediclaim to be taken for you by your employer
- Insist on personal accident policy to be taken by your employer

9.1.5 CLIMBING LADDERS

This is one location of accidents for want of certain simple precautions as follows.

- Make sure the ladder is anchored to the floor securely and not simply resting
- Ensure that the ladder is provided with non conducting shoes and not resting on wet surfaces
- Feel the firmness of each step before you put your whole weight on it
- Tie the top of the ladder to a firm anchor once you climb there
- Ensure that at least 3 steps are rising above the level where you are required to work

- If it is simply resting, call an assistant to stand up and buttress it without slipping
- Verify whether the horizontal clearance is minimum one fifth for one meter length of ladder
- Avoid doing any work by standing on the top 2 or 3 steps of the ladder
- Do not use Bamboo Ladders. They may be weak and suddenly collapse
- Never catch the sides of a ladder. Catch the upper steps
- Do not catch any part of a steel ladder without at least a poly slip on cover over the palm
- Make sure nobody walks below the ladder while you are using it
- Finally, do not climb unless you need to !

9.1.6 ELECTRICAL RELATED SAFETY

- Unless you are qualified for the job, do not undertake it even to replace a fuse or bulb
- Ensure that you have the appropriate gloves, shoes and garments that fit reasonably tight
- Always use local circuit cut-outs before attending to repairs
- Avoid metallic ladders and metallic tape measures near electrical systems
- The best ladder is one made out of teakwood and preserved with anti-termite treatment
- Never work alone and keep an assistant with you all through the work
- Always, de-energize and ground a circuit before venturing any repairs
- Always use approved instruments like tong testers etc and not naked wire and bulb
- Free hanging neck chains are to be removed and kept in pockets while on the job
- All tools shall be insulted in their handles
- Do not latch on to other metallic fittings like piping, etc., while on the job
- If require to use flashlights, use those made of external non-metallic parts
- If wires are found to be dangling, do not attempt to clamp them. Instead, try to reroute them

9.1.7 FIRST AID KIT, SUPPORT FACILITIES & DISPENSATION

The first aid kit should minimally include the following

- A leaflet explaining how to use the kit
- Sterilized dressings of assorted sizes
- Plaster casts for waterproof casts
- Bandages of assorted sizes
- Adhesive plasters of assorted sizes and a blunt edges stainless steel long scissors
- Sterilized water of at least 2 liters
- Eye protection pads

- Safety pins of assorted sizes
- Disinfectant lotions
- Unused sealed twin blade razor
- Eyebaths with double showers focussing on the eyes
- An easily identifiable and reachable shower bath with non-slip grip type flooring
- Wall hung charts showing artificial resuscitation in both English and local language
- Wall hung posters showing the telephone numbers, locations and names of medical centers
- Wall hung posters of ambulance centers, rickshaw stands and truck terminals
- Brief history of previous accidents and lessons learned therefrom
- A well ventilated rest room with a cot and mattress of standard height
- A facility for accessing safe drinking water and an instant heater geyser

If the person is having breathing difficulty, check clothing around the chest and neck and loosen them and then turn him flat on back and chin up and apply artificial resuscitation and later shift his position sideways to the recovery position. If the person is having a cut wound, apply pressure on the upper portion of the limbs and tie up the limb reasonable tight to prevent blood loss. If the person has fainted, just check for breathing and whether he needs artificial resuscitation and administer. In all cases, rush to a nearest medical center. . If the person is frothing in the mouth, do not interfere and rush to the nearest medical center.

9.1.8 OPERATOR'S RESPONSIBILITIES

The responsibilities of the operator are most important and are as follows.

- Familiarize with the wall charts, wall posters and telephone procedures to medical centers
- Do not go into a work unless you have observed the environment and understood it.
- All water other than from tap water is to be considered as unsuitable for human contact
- Do not operate any equipment unless you are trained in it.
- If you feel something unusual in a moving machinery, do not panic, call your superintendent
- Do not hide other's unsafe practices from your employer. Please report discretely
- Never hurry up in physical motion when on duty. Be safe and steady in your movements
- Never chit chat in working areas or while standing on structures of the STP
- Never climb up or climb down cat ladders by facing the airside of the ladder. Face the wall
- Always use reasonably and conformably fitting dresses. Remove neck chains while on duty
- Smoke if you like, but only in the designated smoking room or yard and extinguish the butt

- Ensure that you set an example to be followed not reported upon.

9.1.9 LEPTOSPIROSIS

This is strange disease caused by rats which fall into water source and spread the respective viruses. The disease is normally noticeable only under advanced conditions and usually the treatment and recovery is prolonged. Rats are a menace in sludge drying beds in hot climates as they seek asylum from the heat and find food easier. The drinking water sump should be checked by you every day in your shift to ensure that there is no ratfall into the sump. If you detect it, immediately shut off all water connections to the STP and immediately alert your plant superintendent and the chief executive officer. Also inform the health officer of the local authority.

9.1.10 THE WATCHWORD

The watchword should be your own safety in the first place, so that alertness becomes automatic.

9.1.11 TESTS FOR CHLORINE

Chlorine is not recommended to be used with sewage under any circumstances on a continued scale. However, under special circumstances, chlorine may be applied for a brief period like in flood seasons when large quantities of sewage may be bypassed. During these times, some knowledge of chlorination safety is necessary. The important points are as follows.

- Chlorine gas has specific gravity of 2.49 (Air =1)
- Normally chlorine is got in steel cylinders in gas form and depressurized for use
- The gas may leak sometimes from the joints or the cylinders
- The gas has a pungent smell
- Dip a cotton swab in ammonia solution and move it near the cylinder and joints
- If white fumes are observed, it shows chlorine is leaking there
- The gas will be settling down at the ground level and sink into pits
- As the gas spreads on the ground, the grass will be scorched leaving a tell-tale
- Never bend low while testing for chlorine with a swab
- Stand erect and use an extension twig or stick
- Closing the valve of the cylinder may stop leaks at the joint in the cylinder
- Closing the valve will also help in checking whether the cylinder is leaking
- If the cylinder is leaking, try to douse the cylinder continuously with gentle water shower
- This will dissolve the chlorine and help in containing the quick spread of the gas
- Call the supplier or the fire department immediately
- Ensure nobody is working at ground level or in pits near the cylinder
- Do not try to wrap any cloth etc. over the leaking cylinder. Closeness is to be avoided.
- The chlorine smell will anyway make it impossible to be near the cylinder
- If available, locate a nearby pit into which the container can be gently rolled.
- Carry out the rolling using long handled sturdy rods or bamboo ladders

- Once rolled into the pit, do not peed down into it. You are only containing the gas there
- In case someone swoons due to chlorine gas, rapidly remove him to the first floor
- If first floor is not available, use at least an office table to elevate him
- Allow fresh air and avoid crowding around him
- Keep him facing up and the head well back and tongue not in the way
- Apply artificial respiration mouth to mouth
- Voluntarily carry out a monthly drill in artificial respiration
- Always keep a cool head and never get perturbed
- Never try to find out how this leak occurred before you have stooped the leak
- Use plenty of common sense

APPENDIX 9.2 CHARACTERISTICS OF COMMON GASES CAUSING HAZARDS

Table A9.2-1 Characteristics of common gases causing hazards

SI No	Name of Gas	Chemical formula	Common properties	Specific gravity or vapour density	Physiological effects	Maximum safe limit %	Exposure % ppm		Explosive limit %		Likely location of highest concentration	Most common sources
						60-minutes	8 hours		lower	upper		
1.	Carbon dioxide	CO_2	Colourless, odourless when breathed in large quantities may cause odd taste, non poisonous	1.53	Cannot be endured at 10 for more than few minutes even if subject is at rest and oxygen content is normal acts on respiratory nerves	4.0 to 6.0	0.5	5000	–	–	At bottom when heated may stratify at points above bottom	Products of combustion sewer gas sludge gas also issued from carbonaceous states
2.	Carbon monoxide	CO	Colour less odourless, tasteless inflammable poisonous non irritating	0.97	Combines with haemoglobin of blood headache in few hours at 0.02%, unconsciousness in 30 mins at 0.2 % to 0.25 %, and total unconsciousness in few minutes at 0.1%	0.04	0.005	50	–	–	Neat top especially if present with illuminating gas	Manufactured fuel gas, fuel gas products combustion products of motor exhausts fuel almost any kind
3.	Chlorine	Cl_2	Yellowish green colour detectable in very low concentration, non-inflammable	2.49	Irritates respiratory tracts. Kills most animals in very short time at 0.1 %	0.0004	0.0001	1.0	–	–	At bottom	Chlorine cylinders and feed line leaks
4.	Gasoline	C_2H_2 to C_8H_{25}	Colourless, odour noticeable at 0.03% inflammable	3.0 to 4.0	Anaesthetic effect when inhaled rapidly fatal at 2.4 % dangerous for short exposure at 1.12 to 2.2 %	0.4 to 0.7	0.1	1000	1.3	6.0	At bottom	Service stations, garages storage

SI No	Name of Gas	Chemical formula	Common properties	Specific gravity or vapour density	Physiological effects	Maximum safe limit %	Exposure % ppm		Explosive limit %		Likely location of highest concentration	Most common sources
						60-minutes	8 hours		lower	upper		
5.	Hydrogen	H_2	Colourless, odourless tasteless inflammable	0.07	Acts mechanically to deprive tissues of oxygen: does not support life	–	–	–	4.0	74.0	At top	Manufacture fuel gas sludge
6.	Hydrogen sulphide	H_2S	Rotten egg odour in smell concentration odour not evident at high concentration, colourless inflammable	1.19	Exposure for 2 to 15 minutes at 0.01% impairs sense of smell exposure to 0.07 to 0.1% rapidly causes acute poisoning paralyses respiratory centre, death in few minutes at 0.2 %	0.02	0.001	10	4.30	46.0	Near bottom but may be above bottom. If air is heated and highly humid	Coal gas, petroleum, sewer gas, fumes from blasting sludge gas
7.	Methane	CH_4	Colourless odourless tasteless highly inflammable non poisonous	0.55	Acts mechanically to deprive tissues of oxygen does not support life	Probably no limit provided oxygen percentage is sufficient	1.0	1000	5.0	15.0	Normally at top extending to a certain depth	Natural gas, sludge gas manufactured fuel gas, sewer gas in swamps or marshes.
8.	Nitrogen	N_2	Colourless tasteless non inflammable principal constituent of air (about 79%)	0.97	Physiologically inert	–	–	–	–	–	Near top but may be found at bottom	Sewer gas, sludge gas also issues from some rock strata
9.	Oxygen	O_2	Colourless tasteless odourless supports combustion non	1.11	Normal air contains 21% of oxygen. Below 16% first signs	–	–	–	–	–	Variables at different levels	Oxygen depletion from poor

SI No	Name of Gas	Chemical formula	Common properties	Specific gravity or vapour density	Physiological effects	Maximum safe limit %	Exposure % ppm		Explosive limit %		Likely location of highest concentration	Most common sources
						60-minutes	8 hours		lower	upper		
			poisonous		of anoxia appears even in people who are resting. Below 14% anoxia such as faulty judgement even with minimal exertion. Below 10% dangerous to life. Below 6% is fatal.							ventilation and absorption of chemical combustion of available oxygen
10.	Sludge Gas	About 60% CH_4 and 40% CO with small amounts H_2, N_2, H_2S, O_2	May be practically odourless, colourless, inflammable	0.94	Will not support life	Would vary widely with compositio n	–	–	5.3	19.3	Near top of structure	For digestion of sludge in Tanks

Source: CPHEEO, 1993

APPENDIX 9.3 CONFINED SPACE ENTRY PROCEDURE

The following steps are recommended prior to entry into any confined space:

1. Ensure that all employees involved in confined space work have been effectively trained.
2. Identify and close off or reroute any lines that may carry harmful substance(s) to, or through, the work area.
3. Empty, flush, or purge the space of any harmful substance(s) to the extent possible.
4. Monitor the atmosphere at the work site and within the space to determine if dangerous air contamination and/or oxygen deficiency exists.
5. Record the atmospheric test results and keep them at the site throughout the work period.
6. If the space is interconnected with another apace, each space must be tested and the most hazardous conditions found must govern subsequent steps for entry into the space.
7. If an atmospheric hazard is noted, use portable blowers to further ventilate the area; retest the atmosphere after a suitable period of time. Do not place the blowers inside the confined space.
8. If the only hazard posed by the space is an actual or potential hazardous atmosphere and the preliminary ventilation has eliminated the atmospheric hazard or continuous forced ventilation alone can maintain the space safe for entry, entry into the area may proceed.

The following must be observed before entry into a permit-required confined space:

1. Ensure that all personnel involved in confined space work have been effectively trained.
2. Identify and close off or reroute any lines that may carry harmful substances to, or through, the work area.
3. Wear appropriate, approved respiratory protective equipment.
4. Ensure that written operating and rescue procedures are at the entry site.
5. Wear an approved harness with an attached line. The free end of the line must be secured outside the entry point.
6. Test for atmospheric hazards as often as necessary to determine that acceptable entry conditions are being maintained.
7. Station at least one person to stand by on the outside of the confined space and at least one additional person within sight or call of the standby person.
8. Maintain effective communication between the standby person, equipped with appropriate respiratory protection, should only enter the confined space in case of emergency.
9. The standby person equipped with appropriate respiratory protection, should only enter the confined space in case of emergency.
10. If the entry is made through a top opening, use a hoisting device with a harness that suspends a person in an upright position. A mechanical device must be available to retrieve personnel from vertical spaces more than five feet (1.5meters) deep.
11. If the space contains, or is likely to develop, flammable or explosive atmospheric conditions, do not use any tools or equipment (including electrical) that may provide a source of ignition.
12. Wear appropriate protective clothing when entering a confined space that contains corrosive substances or other substances harmful to the skin.

13. At least one person trained in first aid and cardiopulmonary resuscitation (CPR) should be immediately available during any confined space job.

Source: EPA, 2008

APPENDIX 9.4 CONFINED SPACE PRE-ENTRY CHECKLIST

Table A9.4-1 Confined space pre-entry checklist

CONFINED SPACE PRE-ENTRY CHECK LIST /CONFINED SPACE ENTRY PERMIT

Date and Time issued: Date and time expires:

Job Site space ID.: Job Supervisor:

Equipment to be worked on: Work to be performed:

Standby personnel:

Atmospheric checks:

Time:

Oxygen: %, Toxic: ppm

Explosive: % Carbon Monoxide: ppm

Tester's signature:

1.Source isolation (No entry): NA Yes No

Pumps or lines blinded, disconnected, ( ) ( ) ( )

or blocked

2.Ventilation modification: NA Yes No

Mechanical ( ) ( ) ( )

Natural ventilation only ( ) ( ) ( )

3.Atmospheric check after isolation and ventilation:

Time:

Oxygen: % > 19.5% Toxic: ppm < 10 ppm H_2S

Explosive: % LFL < 10% Carbon monoxide: ppm < 35 ppm CO

Tester's signature:

4.Communication procedures:

5.Rescue procedures

6.Entry, standby, and backup persons Yes No

Successfully completed required training ( ) ( )

Is training current ( ) ( )

7.Equipment: NA Yes No

Direct reading gas monitor tested ( ) ( ) ( )

Safety harnesses and lifelines for entry and standby persons ( ) ( ) ( )

Hoisting equipment ( ) ( ) ( )

Powered communications ( ) ( ) ( )

SCBAs for entry and standby persons Protective clothing ( ) ( ) ( )

*SCBA: Self-contained breathing apparatus

All electric equipment listed for Class I, Division I, Group D

and non-sparking tools ( ) ( ) ( )

8.Periodic atmospheric tests:

Oxygen: % Time: ; : %, : ; : %,: ; : %,

Explosive: % Time: ; : %, ; : %,: ; : %,

Toxic: % Time: ; : %, : ; : %,: ; : %,

Carbon-monoxide: % Time: ; : %, : : %,: ; : %,

We have reviewed the work authorised by this permit and the information contained herein. Written instructions and safety procedures have been received and are understood. Entry cannot be approved if any brackets ( ) are marked in the "No" column. This permit is not valid unless all appropriate items are completed.

Permit prepared by (Supervisor): Approved by (Unit Supervisor):

Reviewed by (CS Operations Personnel):

This permit has to be kept at the job site. Return job site copy to safety office following job completion.

Source: EPA, 2008

APPENDIX 9.5 FIRST AID

9.5.1 TREATING WOUNDS

a. Caring for a skin tear

- Expose and treat the part with the wound taking care to not move it unnecessarily. Firstly, start removing clothes with no skin tear below and later, carefully remove clothes with skin tear below.
- Considering that bacteria may have entered the wound, first wash and disinfect your hands and apply antiseptic solution over a width of 2 to 3 cm around the wound. Using disinfected tweezers, apply disinfected gauze, and cover with bandage to prevent infection.

Take the following precautions to prevent infection of the wound:

- Always use paper, towel, cloth or hands that have been disinfected.
- Disinfect the wound and remove debris in the wound using tweezers. Leave debris that cannot be removed as-is; do not touch it with your finger.
- Do not wipe or wash the wound. If there is slight bleeding, do not try to stop the bleeding unnecessarily, since bacteria may be removed during initial bleeding.
- Remove the dirt in the wound using aqueous hydrogen peroxide. If the wound has oil or grease, wipe it off from around the wound to the outside using volatile oil or benzene, etc., and disinfect the wound using ethanol.
- Wound to the head, chest or stomach is generally a serious matter even if it looks minor from the outside. Notify the doctor as soon as possible after the patient has rested.

b. Care when there is no skin tear

- Limbs
  If the wound is minor, apply antiseptic solution. If swollen, apply cold compress; if there is suspicion of fracture or dislocation, tie a splint and apply a bandage.
- Head
  Even if the injury is minor, treat with care. If the person has headache or nausea, cool the head. If unconscious, or if there is bleeding from the ear, eye or nose, or if the patient is agitated, internal wound in the cranium may be a possibility; in such a case, let the patient lie down with the head kept high and immediately notify the doctor.
- Chest
  If the chest pain is unbearable and patient coughs suddenly, or if the patient's breathing is laborious, or if blood is mixed with the sputum, allow the patient rest, and then immediately summon the doctor.
- Abdomen
  In case of severe pain or swelling in the abdomen, or nausea, there is a possibility of an internal injury. In such a case, ask the patient to fold his knees and lie down so that the skin on the abdomen sags. Never give any drink to the patient. Summon the doctor quickly.

c. How to stop bleeding

- Stopping bleeding by applying pressure directly

Place clean gauze or handkerchief on the wound and apply pressure directly with your hand.

If the bleeding is from a large blood vessel, and if bleeding does not stop even after you apply pressure using one hand, apply pressure with both hands leaning so that your body weight also exerts pressure.

Take care not to touch the blood to prevent contamination when you try to stop the bleeding.

- How to use a tourniquet

  If there is considerable bleeding from a large blood vessel such as an artery in the arm or the leg, wrap a piece of cloth loosely around the part closer to the heart than the wound, and insert a stick or similar hard item through the knot.

  Insert a backing cloth between the stick and the arm so that the skin is not injured.

  Gently rotate the stick until the cloth tightens over the artery and bleeding stops. When the bleeding stops, fix the stick so that it does not move.

  If the arrival of the first aid team is likely to be prolonged, loosen the tourniquet once in 30 minutes to 1 hour so that blood just starts oozing; after blood flows for 1 to 2 minutes, tighten the tourniquet.

d. Treating electricity-related injury

- When electric current enters from the left hand, it flows through the heart; therefore, the symptoms are more pronounced when current enters from the left hand.
- The injury is more serious at the part where the electric current leaves the body than where it enters the body.

The following treatment is recommended:

- Turn off the switch. Wear dry leather shoes or rubber shoes, and dry leather or rubber gloves. Use bamboo or wood to isolate the person from the electric wire, or use a piece of cloth or wool to grip the hand and the clothes to pull the person away from the electric wire.
- Do not touch the person with your bare hands or with a wet object or metal.
- Place the person face up at a well-ventilated location; if the person has suffocated, revive with artificial respiration. If the person is delirious or has cramps, try to cool his head.

9.5.2 GAS POISONING

- Occurs when inhaling simple asphyxiant gas (nitrogen, hydrogen, helium, methane, ethane) and chemical asphyxiant gas (carbon dioxide, cyanide compound)
- If considerable amount of gas has been inhaled, move the patient quickly to a location with fresh air; if necessary, give fresh oxygen through oxygen supply kit, and immediately summon a doctor.

9.5.3 CHLORINE

- If chlorine gas has been inhaled

  Immediately call for the doctor, follow the doctor’s instructions and take the actions mentioned below.

  Gently move the patient from the gaseous location to a safe place, preferably to a room of about 20°C. Keep the patient's head and back high while laying him to rest and cover the body with a blanket.

If the patient has difficulty in breathing, give oxygen using oxygen supply kit.

If breathing has stopped, give artificial respiration by the prone, face-down method.

- If chlorine has come in contact with the skin

  Immediately wash the affected part with plenty of water. Quickly remove clothes wetted by liquefied chlorine and summon the doctor for further treatment.

- If chlorine has entered the eye

  Immediately wash the eye with water keeping the water running for 15 or more minutes and summon the doctor for further treatment.

- Measures during leakage of chlorine gas

  Wear protective gear such as breathing apparatus. Before checking the leakage locations, wear protective gear and spray ammonia. Leakage is indicated at the location where white fumes are emitted.

  Roll leaking cylinders into the neutralization pit.

  Thereafter, request experts to repair the leaking equipment.

- If there is an unexpected leakage and a possibility that the scope of danger may expand.

  Contact the relevant department based on the contact system drawing in an emergency determined beforehand.

  If necessary, notify personnel nearby, and evacuate them to the windward side.

  At the same time, neutralize the leaked gas.

9.5.4 ARTIFICIAL RESPIRATION

Artificial respiration may be carried out to revive a person whose heart has stopped. The procedure for cardiopulmonary resuscitation (CPR) is given below.

- Check consciousness
- Ensure air passage is satisfactory
- Check breathing
- Start artificial respiration
- Check for signs of circulation
- Heart massage
- Cardiopulmonary resuscitation (CPR)

Source: JSWA, 2003

APPENDIX 9.6 SEWAGE TREATMENT PLANT ACCIDENT REPORT

Table A9.6-1 Sewage treatment plant accident report

SEWAGE TREATMENT PLANT ACCIDENT REPORT

Date of this report Name of person injured

Date of injury Tim Occupation

Home address

Age sex Check First aid case or disabling(lost time)injury

Employee or staff injury on duty or Off duty Visitor injury

Date last worked Date returned to work

Person reporting

DESCRIPTION OF ACCIDENT

1.Description of Accident (Describe in detail what happened) (Name machine, tool, appliance, part, gears, pulley, etc.):

2.Accident occurred where? If vehicle accident, make simple sketch of scene of accident.

3.Describe nature of injury and part of body affected (Amputation of finger laceration of leg, back strain, etc.):

4.Were other persons involved? (If yes, give names and addresses)

5.Names and addresses of witnesses.

6.If property damage involved, give brief description.

7.Name and address of physician.

8.Treatment given for injures

Source: EPA, 2008

APPENDIX 10.1 MECHANICAL CLEANING OF SEPTIC TANKS

The requirement of suction machines for emptying septic tanks in the towns where septic tanks exists (full or partial) for a specified population is calculated based on the following assumptions.

1. No. of households in a town having population of 1 Lac (@ 5 persons in an household) - 20000 household i.e. 20000 Septic tanks
2. Septic tanks need to be cleaned once in 2 years. Hence the requirement septic tanks to be cleaned per year will be about 10000.
3. To clean 10000 septic tanks in a year, the requirement of lorries is 8 numbers
4. Septic tank cleaning is by ordinary vacuum tugs which can hold only 6000 liters maximum. The regular jet rodding cum suction machines must not be used for septic tank cleaning because the jet rodding portion of the machine is wasted. As such 10,000 septic tanks to be cleaned means sewer lorries (not jet rodding cum suction machines) shall alone be used. Cost wise 5 such sewer lorries can be purchased instead of a single jet rodding cum suction machine.

• Number of septic tanks to be cleaned	10,000
• Size of a typical septic tank	2m * 1m * 1.2m
• Volume to be sucked out	2.5 cum
• Sewer lorry capacity	6 cum
• Number of septic tanks that can be cleaned in one trip	2 numbers
• Time taken for onward, suction and return	4 hours
• Hours available for day shift	8 hours
• Number of trips per day per lorry	2 trips
• Number of septic tanks sucked out per day per lorry	2*2 = 4 numbers
• Lorry maintenance and down time days per year	30 days
• Effective days per year per lorry	365-30=335 days

- Number of septic tanks sucked by lorry per year 335*4 = 1340
- Number of lorries needed per year 10000 / 1340 = 8 lorries

Sewer lorries are to be barred from operating in other than general shifts because the noise nuisance it will create to the neighbours in the night and the risk of the lorry operator discharging surreptitiously in the nights at various places plus security concerns.

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