No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
NATIONAL RIVER CONSERVATION DIRECTORATE (NRCD)
MINISTRY OF ENVIRONMENT AND FORESTS

THE STUDY
ON
WATER QUALITY MANAGEMENT PLAN
FOR
GANGA RIVER
IN
THE REPUBLIC OF INDIA

FINAL REPORT

VOLUME III MASTER PLAN FOR PROJECT CITIES

VOLUME III-11 (SUPPORTING REPORT) CASE STUDY OF SEWAGE TREATMENT PLANTS

JULY 2005

TOKYO ENGINEERING CONSULTANTS CO., LTD.
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FINAL REPORT
ON
WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER
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ABBREVIATIONS

AD/MM	Average Day / Max Month
ADF	Average Daily Flow
ADWF	Average Dry Weather Flow
AIWSP	Advanced Integrated Wastewater Stabilization Ponds
AL	Aerated Lagoon
AS	Activated Sludge
ASR	Aquifer Storage and Recovery System
Avg	Average
AWT	Advanced Wastewater Treatment
BOD	Biochemical Oxygen Demand
CI	Cast Iron
CMS	Cubic Meter per Second
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
CWR	Clear Water Reservoir
DLW	Diesel Locomotive Work
DO	Dissolved Oxygen
DPR	Detailed Project Report
ES	Equalization/Storage
FAB	Fluidised Aerated Bioreactor
FS	Feasibility Study
FSA	Future Service Area
GAP	Ganga/Gomti Action Plan
GoAP	Gomti Action Plan
GIS	Geographical Information System
gpd	Grams per day
GOI	Government of India
GOJ	Government of Japan
GWI	Ground Water Infiltration
HDR	High-Density Residential
HP	Horse Power
I/I	Infiltration/Inflow
ISC	Indian Standard Code
JICA	Japan International Cooperation Agency
JS	Jal Sansthan
KVA	Kilo Volt Ampere
LDR	Low-Density Residential
lpcd	Litres per capita per day
lpm	Litres per minute
lps	Litres per second
MC	Municipal Corporation
MDR	Medium-Density Residential
mg/l	Milligrams per Litre
ML	Million Litres
mld	Million Litres per Day
MLSS	Mixed Liquor Suspended Solids
MP	Maturation Pond / Master Plan
MPN	Most Probable Number per 100ml
MPS	Main Sewage Pumping Station
MPS	Meter per Second
MUD	Ministry of Urban Development
MoEF	Ministry of Environment and Forests
N/A	Not Available
NBC	National Building Code
NH_3-N	Ammonia-Nitrogen
NRCD	National River Conservation Directorate
NSA	Non Sewerage Area
O&M	Operations and Maintenance
PDWF	Peak Dry Weather Flow
PFR	Project Feasibility Report
PS	Pumping Station
PSC	Pre-Stressed Concrete
RAS	Return Activated Sludge
SMF	Sankat Mochan Foundation
SPS	Sewage Pumping Station
SS	Suspended Solids
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UASB	Up flow Anaerobic Sludge Blanket
UFW	Unaccounted for Water
UPJN	Uttar Pradesh Jal Nigam
UPPCB	Uttar Pradesh Pollution Control Board
USAID	United States Agency for International Development
UV	Ultra Violet
VCP	Vitrified Clay Pipe
WAS	Waste Activated Sludge
WRF	Water Reclamation Facility
WSP	Waste Stabilization Pond
WTP	Water Treatment Plant
YAP	Yamuna Action Plan

CHAPTER 1

INTRODUCTION

(SUPPORTING REPORT)
CASE STUDY OF SEWAGE TREATMENT PLANTS

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Since the commencement of the centrally sponsored programme on river pollution control in 1985, more than 70 sewage treatment plants have been constructed under the Ganga Action Plan (GAP) and Yamuna Action Plan (YAP). These plants are based on a range of technologies involving varying levels of mechanisation, energy inputs, land requirements, costs, skilled manpower etc. In the early stages, the selection of technology was based on past experience and its perceived performance efficiency. Moreover, at different stages of these Action Plans a number of technologies have been tried out on pilot scale and some of them have been scaled up for larger capacity plants. Over last 20 years a considerable experience and expertise has been built up within the country in this sector. However, the level of performance of these plants with regard to effluent quality, energy consumption, process stability, resource recovery, sustainability of initial and O&M costs etc. has been varied.

1.2 OBJECTIVES OF THE STUDY

In this context, JICA Study Team carried out a case study of sewage treatment technologies / plants especially for works implemented under Yamuna Action Plan with the objectives to:

- Assess their overall performance, treatment efficiency and suitability under given conditions
- Assess land, energy and capital requirements per unit volume of treatment

In addition, the study also covers aspects relating to institutional arrangements, manpower and training for STPs etc.

1.3 STRUCTURE OF THE REPORT

Chapter 2 provides brief methodology followed in the assignment. Chapter 3 gives a synopsis of the two river action plans viz. GAP and YAP covering the approach and technologies adopted for water pollution control and pilot interventions. Chapter 4 gives a description of a range of sewage treatment technologies e.g., aerobic energy intensive, anaerobic, natural systems and advanced solutions which have been adopted at various stages of the two Action Plans. For each of the technologies, this chapter brings out key features, performance level, specific requirements for land, energy and capital (initial and recurring), operation and maintenance aspects, advantages, disadvantages and applicability aspects. Chapter 5 provides an assessment of pilot interventions for disinfection of treated sewage which were implemented under YAP and again offers strategic considerations from the point of view of their desirability, feasibility and sustainability. Chapter 6 provides a situation analysis on institution aspects of YAP I relating to the core component of sewage treatment. Chapter 7 provides recommendations for institutional arrangements and strengthening.

CHAPTER 2

METHODOLOGY

CHAPTER 2 METHODOLOGY

The methodology for the assignment comprised a combination of desk research, field visits to selected STPs, interaction with project implementing agencies, urban local bodies, project management consultants, technology providers, as well as technology developers. Salient aspects of the methodology are presented in the paragraphs that follow.

2.1 REVIEW OF BACKGROUND DOCUMENTS

A set of background documents such as detailed project reports, feasibility reports, project reviews, technology appraisal reports and research publications have been referred during the course of this assignment. A formal review of works implemented under GAP-I was carried out in 1995 by a team of experts drawn from various engineering academic institutions. Report of this review provided significant information regarding STP technology selection and their performance in the states of UP, Bihar and West Bengal. Similarly a review of YAP works was carried out in 2002 by IIT Roorkee. Among others, this report provides an updated information base on the infrastructure provided at 15 locations under YAP and performance of STPs. In addition, performance appraisal reports of some of the pilot STPs, disinfection plants and the MIS reports of MOEF on water quality monitoring were referred. A review of these background documents was carried out from the point of view of technical, financial, operational and institutional sustainability. A long list of documents referred during the study is provided in reference section report while some of the key documents are listed in Table 2.1 below.

A range of information on the YAP STPs was available from the Tokyo Engineering Consultants, New Delhi office which had served as the Project Management Consultants for the YAP. As a result, reliable information on project costs, year of construction, year of commissioning, etc. was available from detailed project reports as well as from the MIS reports.

Table 2.1 Key Documents Referred during The Study

Title	Agency / Author	Year
Status paper on the river action plans	Ministry of Environment and Forest	September, 1998
Evaluation of Ganga Action Plan	Ministry of Environment and Forest	April, 1995
Yamuna action plan – Approach paper	Ministry of Environment and Forest	Undated
Performance review of Yamuna Action Plan	Alternate Hydro Energy Centre IIT Roorkee	July, 2002
Pollution study for Yamuna action plan – II : Executive summary and strategic considerations	Tokyo Engineering Consultants Co., Ltd, Japan	October, 2002
The study on water quality management plan for Ganga river in the Republic of India – Progress report (1)	Tokyo Engineering Consultants Co., Ltd., Japan; and CTI Engineering International Co., Ltd., Japan	July, 2003
Status report on Dinapur sewage treatment plant and surroundings	Central Pollution Control Board, New Delhi	November, 2001
Special assistance for project implementation for Yamuna action plan project – Final report.	SAPI team for JBIC	June 2000
Wastewater treatment for pollution control	Soli J. Arceivala	1998
A design manual for waste stabilisation ponds in India	Mara, D.D. et. al.	1997
A guide to the development of on-site sanitation	R. Franceys, J. Pickford and R. Reed., WHO	1992
Report on institutional strengthening – Yamuna action plan project	ACORD, New Delhi	March 2001
Inception report – JBIC funded Agra municipal reform project	IPE Consultants, New Delhi	March, 2003

2.2 FIELD VISITS

Selective visits were made to STPs in Haryana, Delhi and UP for first hand evaluation of some of the technologies. Among the full scale plants two facilities each of UASB, stabilisation ponds, conventional activated sludge process were covered and among the pilots one plant each of BIOFOR, fluidized aerated bed process (FAB) and submerged aerated fixed film (SAFF) were visited for the case study. One full scale plant based on FAB technology at Lucknow constructed under Gomti Action Plan was also covered. In addition, five pilots on disinfection of treated sewage were also covered and their performance and comparative advantages assessed. A list of these STPs is provided in Table 2.2.

Based on our discussions with the concerned O&M agencies during these fact finding visits a profile of each of the STPs was developed. This included flow scheme and coverage of key aspects of plants e.g., performance, area requirement, energy consumption, capital and O&M costs, and O&M arrangements. In addition discussions with the concerned field agencies were carried out to assess the institutional aspects of the project.

Table 2.2 Treatment Plants Covered during the Case Study

Plan/ Places	STP covered	Remarks
Ganga Action Plan : Sewage treatment		
Varanasi	Rouging filter activated sludge plant at Dinapur	80 mld plant having sludge digestion, biogas utilisation and wastewater irrigation
Allahabad	Activated sludge plant	60 mld conventional ASP plant with sludge digestion, biogas utilisation and wastewater irrigation
Yamuna Action Plan : Sewage treatment		
Vrindavan	Two STPs based on waste stabilisation pond technology	4 and 0.5 mld plants
Mathura	One of the two WSP based STPs	12.5 mld Masani nala plant
Agra	UASB based STP	78 mld with biogas utilisation
Faridabad	One of the three UASB based STP	20 mld plant with biogas utilisation
Gaziabad	Pilot on sewage treatment through plantation (Karnal technology)	3 mld
Delhi	One of the two full scale STPs based on BIOFOR technology	10 mld STP at Sen Nursing Home nala
Govt. of Delhi's plan : Sewage treatment		
Delhi	High rate ASP cum BIOFOR-F based STP at Rithala	182 mld STP, the largest and most advanced system covered in the study
Delhi	ASP based Okhla STP	One of the latest STPs at Okhla
Delhi	Duckweed pond at Wazirabad	1 mld
YAP : Pilots on sewage treatment		
Delhi	FAB technology based STP at Molarband	3 mld decentralised plant in a low income community
Delhi	SAFF based STP at Tikri Khurd	--do--
YAP : Pilots on disinfection of treated sewage		
Delhi	UV technology based plant	Installed on downstream of the above mentioned BIOFOR plant as a polishing unit
Faridabad	UV technology based plant	Downstream of a UASB plant
Faridabad	Solar energy based disinfection plant	--do--
Noida	Chlorination based disinfection plant	--do--
Karnal	Down hanging sponge bio-tower	Polishing unit downstream of a UASB. Covered in previous phase of the study.
Gomti Action Plan : Full scale STP		
Lucknow	FAB based 42 mld full scale plant	Recently commissioned full scale plant

Additional Survey of STPs in West Bengal

a)	Chandan Nagar STP	18mld	Trickling Filter
b)	Panihati STP	12mld	WSP
c)	Bangur STP	45mld	ASP

2.3 ANALYSIS

The sewage treatment plants have been reviewed on a broad criteria which includes technology performance, ability to meet desired effluent quality standards, land requirements, energy requirements, initial and recurring costs, potential for resource recovery etc. Life cycle costs of various plants have been worked out considering a life of 35 years for civil structures and 7 years for the electrical and mechanical components. This parameter provides a better comparison between different technologies where the initial and recurring costs may vary by several orders of magnitude. Similarly, though less rigorous analysis has been carried out for the pilots on disinfection. Based on these analyses, conclusions and strategy for the ongoing master planning activity for the four cities in UP have been developed.

It will be noted that this report does not intend to serve as a guide for designing of components of STPs based on different technologies. As a result, typical design values, loadings, and retention times etc. are not provided.

2.4 ORGANISATIONS MET

During the course of the assignment, the following organisations were contacted for obtaining relevant information on the subjects of sewage treatment technologies and urban sanitation under the two river action plans under review.

Project implementing agencies

- Delhi Jal Board
- UP Jal Nigam
- Haryana Public Health Engineering Department

Urban local bodies

- Municipal Corporation of Delhi
- Agra Nagar Nigam
- Vrindavan Municipal Council
- Gurgaon Municipal Council
- Noida Authority

Technology providers

- Degremont India Ltd., New Delhi
- Thermax Ltd., New Delhi
- Geo Miller Pvt. Ltd., New Delhi

CHAPTER 3

BACKGROUND ON RIVER ACTION PLANS IN INDIA

CHAPTER 3 BACKGROUND ON RIVER ACTION PLANS IN INDIA

An urgent need for improving the water quality of the Indian rivers was realised in early eighties when the then Central Board for Prevention and Control of Water Pollution released findings of its basin-wide comprehensive study on the extent of water pollution in the Ganga basin. Severe depletion of water quality was observed in particular stretches of Kanpur, Allahabad, Varanasi, Patna, Kolkata etc. Against the desired level of 3 mg/l of BOD, it was found to be in the range of 16-20 mg/l. In view of the public health and environmental consequences of such deterioration in water quality of the holiest river, a strategy for sustained intervention was conceived in mid eighties. This led to formulation of the Ganga Action Plan under which a series of water pollution control measures were implemented in major urban centres along the river. Subsequently, recognising the extent of water pollution in the largest tributary of Ganga, i.e. river Yamuna, a separate action plan was formulated with similar objectives and strategy. The plan was called Yamuna Action Plan and was implemented over almost a ten year period from 1994 to 2003. Over the years a significant capacity for sewage treatment of over 1586 mld has been created through construction of 57 odd sewage treatment plants in the two river basins. Salient aspects of the two major river action plans with regard to the approach for wastewater treatment are presented in the sections that follow.

3.1 APPROACH FOR CONTROL OF WASTEWATER

As per the findings of the CPCB survey, almost 70% of the water pollution load was being generated by the domestic sector and the remaining 30% was contributed by the industrial and dairy farm (livestock) sectors. Considering this distribution pattern, the urgency for desired improvement, and the fact that the discharges from the industrial sector were regulated by the prevailing institutional set up under the Water (Prevention of Pollution) Act, 1974 and Environment (Protection) Act, 1986, discharges from the domestic sector were the focus of these Action Plans. The strategy involved a basin wide approach wherein major urban locations were targeted for control of domestic wastewater discharges.

In this regard, both ‘end-of-the-pipe’ as well as ‘up-the-pipe’ solutions were considered. The three key components of the strategy were as follows :

- Interception of drains/nallas to prevent flow of wastewater into the river and their diversion for wastewater treatment;
- Construction of centralised sewage treatment plants; and
- Construction of community toilets and individual on-site sanitation facilities for urban low income population

In addition, the Action Plans included other components e.g., ghat improvements, setting up of crematoria etc., however they are not relevant under the scope of the current study and therefore are not discussed here.

Ganga Action Plan

Ganga Action Plan was taken up in year 1985 with the objective of achieving measurable improvement in river water quality and to bring it to a level which could be considered safe for bathing (Class B) in selected stretches. The quality was defined in terms of key parameters as shown in Table 3.1. This criterion primarily entailed that the background biological oxygen demand of river water be brought down from 16 to 3 mg/l.

Table 3.1 Desired Receiving Water Quality Standards Under GAP-1

Parameter	Unit	Value
BOD	mg/l	3
DO	mg/l	5
Total coliform count	MPN/100 ml	10,000
Faecal coliform count	MPN/100 ml	2,500

In order to achieve this level of water quality, all the 25 class I towns (1985 population > 100,000) along the river were identified for appropriate interventions. Out of these, 6 towns were in UP, 4 were in Bihar and 15 were in West Bengal. The component-wise break up of various schemes implemented under the Plan is given in Table 3.2.

Table 3.2 Wastewater Realted Components Of GAP-I

GAP Component	Planned schemes	Remarks
Domestic wastewater		
Interception and diversion	88	Sewage pumping stations
Sewage treatment plants	35	At 35 locations, in all 43 STPs comprising 32 new and 11 old plants were commissioned
On-site sanitation	43	Community toilets complexes
Sub-total	166	
Others	105	Crematoria, bathing ghats etc.
Total	261	Out of these 259 schemes were implemented

Out of an estimated 1340 mld of sewage generated in the identified towns (in 1985), it was planned to intercept 873 mld of wastewater (=65%) and create an equivalent capacity for treatment. Apparently, this approach was adopted in view of resource constraints and short time horizon. However, GAP continued for almost 15 years and it came to a formal close on April 1, 2000. During this period, 259 schemes were implemented and about 880 mld of sewage treatment plant capacity at 43 different STPs was created (MOEF, 2003). Among the various STPs commissioned under the Plan, 11 were existing STPs which were identified for renovation and capacity augmentation while new plants were constructed at 32 locations. A town wise listing of STPs is provided in Appendix B.

Norms for discharge of STP effluent

All the STPs were designed to produce an effluent which would comply with the discharge criteria shown in Table 3.3 which was commonly specified by the State Pollution Control Boards under the prevailing norms of Water (Prevention and Control of Pollution) Act, 1974. Specifically the effluent would have a BOD of 30 mg/l and suspended solids of 100 mg/l.

Table 3.3 Discharge Standards For Treated Sewage under GAP

Parameter	Unit	Value
pH	-	5.5 -9
Temperature	ºC	40
BOD	mg/l	30
COD	mg/l	250
TSS	mg/l	100
DO	mg/l	Not specified
NH4 – N	mg/l	50
NO3 – N	mg/l	Not specified
Total coliform	MPN/100 ml	Not specified
Faecal coliform	MPN/100 ml	Not specified

As noted from the above Table while at that stage the bacterial quality of treated wastewater was not specified, but as shown in Table 3.1, the criteria for the receiving water body was very well specified. In view of this, the GAP STPs typically did not include tertiary or polishing treatment steps for removal of pathogenic bacteria.

Yamuna Action Plan

In view of the fact that river Yamuna is the largest tributary of river Ganga and drains a densely populated area of North India, it was considered to be the obvious target for backward integration of GAP. With this objective, a separate programme Yamuna Action Plan (YAP) was formulated as the second phase of GAP and it was implemented during 1993 – 2003.

In principle the approach adopted under YAP was on the same lines as that under GAP-I where 15 Class-I cities were identified in Haryana, Delhi and UP for priority interventions. These interventions were primarily tailored for creation of new infrastructure such that raw sewage overflows into the river could be prevented. Similarly a relatively smaller component on 'low-cost' sanitation laid emphasis on creation of community toilet complexes in low income communities and on busy public places. A summary of sewerage and sewage treatment works carried out under YAP is presented in Table 3.4.

Table 3.4 Sewerage and STP Works Carried Out Under Yamuna Action Plan

	Unit	States		
Components of sewerage/wastewater interventions		Haryana	Delhi	UP
A. Interception and diversion of open drains	km	172	-	42
B. Sewage pumping stations	Nos.	21	-	28
C. Sewage treatment plants				
Installations	Nos.	11	-	15
Capacity creation	mld	303	-	399
D. Low cost sanitation				
Community toilet complex	Nos.	75	959	561
Squatting seats	Nos.	1160	27000	2910
E. Pilot / decetralised STPs				
Mini STPs (2 x 3 mld FAB and 2 x 2 mld SAFF)	Nos.	-	4	-
Micro STPs (15 m3 Johkasou)	Nos.	-	10	-
Decentralised STPs (10 mld BIOFAR)	Nos.	-	2	-
Disinfection of STP effluent (1 / 2 mld, various technologies)	Nos.	3	1	1

Notes :
1. FAB : Fluidised aerated bed reactor
2. SAFF : Submerged aeration fixed film reactor
3. BIOFOR : Biological filter oxygenated reactor

Norms for discharge of STP effluents

Under this Action Plan, the receiving water quality criteria remained the same as was in case of GAP however, the discharge criteria for treated effluent in terms of concentration of suspended solids was made stringent. It was brought down from 100 mg/l to 50 mg/l.

However, over a period of time with increasing experience in operation of a range of STPs it was realised that in addition to the organic content in the wastewater, the bacterial content is, if not more, but of equal concern from the point of view of public health. Although no standards were prescribed for level of pathogenic bacteria in treated STP effluents, but towards the end of the plan desirable and maximum limits for the faecal coliforms were suggested which are 1000 and 10,000 MPN/100 ml respectively.

3.2 TECHNOLOGIES ADOPTED FOR STPs

A wide range of technologies have been adopted under the two river actions plans which are briefly described in the following sections.

Technologies under GAP-I

Out of the 880 mld treatment capacity in 43 STPs, 11 existing / old plants which were renovated comprised 151 mld (17%) and the 32 new STPs accounted for about 728 mld or 83% of the total. The distribution of STP capacity under different technologies is given in Table 3.5 and town wise plant details are presented in Appendix A.

Activated sludge process was the most preferred technology option accounting for 48% of the total STP capacity created under GAP-I. If its design variants i.e., aerated lagoons and RF-AS are clubbed together, ASP accounts for almost 62% of the total capacity. UASB technology which was introduced on pilot and experimental basis accounted for 6% of the total capacity while waste stabilisation pond technology accounted for 16%. Four existing STPs and two new STPs had trickling filter technology which together accounted for 15% of the total GAP-I capacity. Aerated lagoon which is a hybrid of activated sludge process and lagoon system was tried out at three places and accounted for 5% of the total GAP-I capacity. A combination of trickling filter and activated sludge process in the form of RF/AS (Roughing filter – Activated sludge process) has been implemented only at one location at Varanasi.

Among the three states covered in GAP-I, the state of UP mostly opted for ASP technology. Similarly all the three UASB technology based plants were also installed in UP. This is presumably due to the low land requirement of these technologies which were installed in densely populated urban centres of the state.

Table 3.5 Technology Wise Distribution of STP Capacity Created under GAP-I

	Nr. of plants		STP Capacity, mld			% of total in GAP	
Technology	**Old**	**New**	**Old**	**New**	**Total**	**New**	**Total**
ASP	4	10	61.0	362	423	50	48
UASB		3		55	55	8	6
WSP	3	12	13.5	126	140	17	16
TF	4	2	76.8	58	135	8	15
AL		3		47	47	6	5
RBRC		1		0.3	0.3	0	0
RF-AS		1		80	80	11	9
Total	11	32	151	728	880	100	100

(Source : MOEF, 1998)

Notes:

ASP : Activated sludge process
UASB : Upflow anaerobic sludge blanket process
WSP : Waste stabilisation pond
TF : Trickling filter
AL : Aerated lagoon
RBRC : Rotating biological rope contactor
RF/AS : Roughing filter – Activated sludge process

In the state of Bihar, two ASP based new plants were actually part of the renovation scheme of two existing ASP plants. At three locations the option of aerated lagoon was included.

In the state of West Bengal, among the new STPs eight plants were based on waste stabilisation pond technology, two were based on trickling filter technology and three were based on ASP technology. In terms of treatment capacity, they accounted for 110 mld, 58 mld and 102 mld respectively. The preference for WSP based systems at eight out of 13 plants (11 out of total 21 old and new STPs) could apparently be associated to the socio-cultural preference for aquaculture in the state. It should also be noted that among the new installations it was only in case of West Bengal that the technology of trickling filter was adopted – it was already existing at three locations and was chosen for two new locations.

All the activated sludge plants were based on conventional process. On the other hand, the trickling filter plants were designed as high rate biofilters. Both these systems were followed by sludge digestion with the objective of resource recovery.

Among the lagoon type systems both the aerated lagoons and waste stabilisation ponds were developed with the objective of promoting aquaculture. The WSPs were also termed as improved oxidation ponds which comprised of a series of anaerobic, facultative and maturation ponds.

Pilots on new technologies

A 5 mld STP based on UASB technology was implemented on a pilot basis in Kanpur to assess the suitability of the technology for domestic wastewater. While the technology was proven to be effective for strong industrial wastewaters and was under investigation for domestic wastewater overseas, it was never tried out in India on either of the two.

After studying the performance of the pilot plant for a few years, a full scale UASB plant of 36 mld capacity was constructed in the same complex, primarily for treatment of tannery wastewater. However, the innovative aspect of the treatment scheme was mixing of sewage with the tannery wastewater in a ratio of 3:1 to make the latter more amenable to treatment.

Simultaneously another full scale UASB plant of 14 mld was constructed at Mirzapur, this time for treating only the domestic wastewater. In view of the fact that the USAB effluent does not meet discharge standards, all the three plants were used in conjunction with a settling pond called 'final polishing unit' to achieve desired BOD and suspended solids reduction. These being pilots and experimental plants, their performance was varied. However they were found to be promising in terms of energy consumption, biogas yield and reduced requirements for sludge disposal.

Technologies under YAP

The experience under GAP was mixed in terms of efficiency of treatment versus energy consumption and cost of operation and maintenance. Drawing lessons from GAP, the YAP opted for energy neutral and energy recovery technologies for sewage treatment. The experience gained from the experimental UASB plants in Kanpur and Mirzapur and from the waste stabilisation ponds was used extensively in this Plan. The key factors that influenced selection process against the conventional aerobic systems were their high energy requirements, unreliable power supply situation in the GAP-I states, and higher O&M costs; while those in favour of UASB and WSP were their robustness, low or no dependence on electricity, low cost of O&M and low skilled manpower requirement. Moreover, the possibility of resource recovery from biogas and aquaculture respectively also influenced the selection process. Among the large capacity plants, in all 28 STPs comprising 16 UASBs, 10 WSPs and 2 BIOFOR technology STPs with aggregate capacity of 722 mld were constructed. UASBs accounted for an overwhelmingly high 83% of the total created capacity.

In addition, two STPs of 10 mld capacity were constructed in Delhi based on BIOFOR technology which is a new and patented system. Although these were limited scale trials, they were not considered pilots. Town wise particulars of various STPs constructed under YAP are presented in Appendix B while Table 3.6 presents a summary of technology distribution.

Table 3.6 Technology Wise Distribution of STP Capacity Created under YAP

	Nr. Of plants	STP Capacity, mld	% of total in YAP
Technology			
UASB	16	598	83
WSP	10	104	14
BIOFOR	2	20	3
Total	26	722	100

The state of Haryana almost entirely opted for UASB technology where 10 out of the 11 plants were based on this. On the other hand in the state of UP there was a balance in terms of numbers of STPs based on UASB and WSP technologies. Generally for larger flows UASBs were considered while for smaller flows WSPs were adopted. Preference for WSPs in UP could be attributed to State's experience with complex and energy intensive activated sludge process based plants during GAP-I as well as with the pilot UASBs at Kanpur.

Pilots on new technologies

During YAP a great deal of flexibility was offered for innovation and experimentation with some of the newer sewage treatment technologies which offered high end performance with regard to treated effluent quality and compactness. The pilots focused on advanced treatment technologies where the schemes included a combination of one or all of physico-chemical treatment, high rate oxidation process, high rate secondary settling systems, tertiary treatment for polishing/disinfection, and sludge treatment through belt press etc.

The pilot STPs were constructed on decentralised scale for treating domestic wastewaters from low income communities in Delhi. These comprised 2 STPs of 3 mld each based on fluidized aerated bed (FAB) technology and 2 STPs of 2 mld each based on submerged aerated fixed film (SAFF) technology respectively. These plants are termed as ‘mini STPs’.

In addition, 10 very small size treatment plants of 15 cum/day capacity were constructed which were attached to community toilet complexes. These plants are based on Johkasou concept of Japan which means small individual household level wastewater treatment system. They involve a combination of typical processes such as sedimentation, diffused aeration, attached biomass, disinfection etc. and are prefabricated with fibre reinforced plastic. These are very compact plants and are appropriately called ‘micro STPs’. Detailed features of these plants are described in another report “Case Study on Low-Cost Sanitation under River Action Plans”.

Pilot on sewage application for plantation

A six hectare plot was used for this pilot to assess the effectiveness and suitability of ‘Karnal technology’ which involves application of screened and degritted sewage for plantation of rapidly growing tree species. This pilot was carried out at Gaziabad along side an UASB plant wherein 3 mld of sewage after screen and grit chamber was diverted for irrigation of the plantation on alternate days. Ridge and furrow arrangement was made on the entire plot and about 12000 eucalyptus trees were planted at a spacing of 2 m x 2 m. The trees are reported have grown four times faster than under normal conditions.

Pilots on disinfection

In view of the emerging concerns on bacterial contamination in receiving water, particularly from the anaerobic processes, the need for disinfection of treated effluent was felt. Five pilot plants based on different disinfection technologies were set up to assess their performance for meeting the desired norms. These comprised 2 UV based plants, 1 chlorination plant, 1 solar reactor and 1 down hanging sponge bio-tower. The latter is an innovative system designed on the lines of a trickling filter except that the media comprises sponge (polyurethane) which is attached to a series of hanging plastic sheets. Capacities of these pilots were between 1 to 2 mld and except for one, they were all installed on downstream of UASB plants.

STPs in Delhi

While a variety of technologies were being tried out under the Yamuna Action Plan, concurrently over 1000 mld of sewage treatment capacity was being added in Delhi under the river pollution control programme of the Government of NCT Delhi. During last 10 years or so, about 13 STPs have been constructed in the capital which are all based on either conventional activated sludge process or its variants e.g., extended aeration process or advanced multistage aeration processes. While the city could not afford to install WSP based STPs due to land constraints, neither did it opt for the USAB technology based STPs. The latter technology was judged to be not at par with the ASP technology in terms of its capability to deliver desired quality of effluent. Two of the recently commissioned STPs in this group have been covered in the current study which are namely at Okhla and Rithala. Former is a conventional activated sludge process plant while the latter involves two stage treatment comprising high rate activated sludge process followed by second stage aeration and rapid sand filtration. Both the plants have sludge digesters where the biogas yield is reported to be consistently high. The latter plant is equipped with a state-of-the-art biogas to electricity generation system and is virtually self sufficient in its energy requirement. Profiles of both these plants are provided later in the report under relevant sections.

CHAPTER 4

ASSESSMENT OF TECHNOLOGY OPTIONS FOR SEWAGE TREATMENT

CHAPTER 4 ASSESSMENT OF TECHNOLOGY OPTIONS FOR SEWAGE TREATMENT

This chapter covers case studies of various sewage treatment plants which have been surveyed during the assignment and which are based on different technologies. The description is divided along different technologies and a particular STP of that category is covered under the respective section. Each section is divided into three parts i.e., brief description of the plants, case study including life cycle cost computation and a technology sheet. This is followed by general conclusion on the suitability of the technology for sewage treatment.

The case study worksheets provide information on plant particulars, land requirements, performance, level of resource recovery if any, life cycle cost computations covering the capital costs for civil and mechanical components, electrical costs, manpower costs, repairs and where applicable, the chemical costs. This approach is followed for all the technologies to enable ease in comparison. Life cycle costs have been worked out considering a life of 35 years for the civil components and 7 years for electrical and mechanical components. Costs of all the plants have been projected to year 2003 based on the corresponding whole sale price indices.

Based on the information and the result of analysis from these case studies, the technology sheets have been developed which provide a general profile covering key features, performance, specific requirements, options, do’s and don’ts; unit values for capital investment, O&M costs and life cycle costs, and; advantages, disadvantages and applicability of the technology.

4.1 ACTIVATED SLUDGE TREATMENT TECHNOLOGY

Following three plants have been covered under the current study :

- 60 mld STP at Allahabad
- 80 mld STP at Varanasi
- 72 mld STP at Okhla, New Delhi

In addition, another STP based on activated sludge process was covered which is at Rithala, Delhi. However, in view of its advanced features and second stage treatment through a rapid sand filter, it is covered separately under the section on advanced technologies.

The first two plants in the above list were constructed under the Ganga Action Plan while the last plant was constructed under the programme of the Government of NCT Delhi. These plants have been constructed during last 10-12 years. Oldest among them is the Varanasi STP which was commissioned in 1991 while Okhla plant is the latest which was commissioned in 2001. A detailed profile of each of these plants is presented in Appendix C and a comparative calculation of key parameters is presented in Table 4.1. A brief description of salient features of these plants is presented in the paragraphs that follow.

STP at Allahabad

STP at Allahabad is based on the conventional activated sludge process and it involves typical flow scheme of screens, grit removal, primary sedimentation, aeration and secondary sedimentation. In addition it has the facility for sludge digestion, gas cleaning and bio-energy generation through a set of duel fuel engines. The plant has been constructed in three modules of 20 mld each and there is provision for an additional module of 20 mld.

An unusual feature of the flow scheme at this STP is return of the secondary settled sludge not only to the aeration tank but also to the primary sedimentation tank (PST). Moreover, as against the normal practice of withdrawing excess sludge from secondary settling tank, the sludge is withdrawn only from PST. This arrangement has several lacunae:

- It leads to re-suspension of settled sludge in to the wastewater stream
- It leads to increased solids load on the PST and thereby affects the fundamental characteristics of the sedimentation process as well as affects its efficiency
- It leads to onset of anaerobic digestion in the primary treatment stage itself which is exhibited by the presence of gas bubbles in PST, and
- The gas bubbles in turn naturally reduce the solids removal efficiency from the PST

Moreover, as the excess sludge is wasted only from the underside of the PST, the primary and secondary sludges are thickened together in a common thickener. This does not allow effective thickening of two sludge streams which have different settling characteristics and thereby leads to higher hydraulic load on the downstream digester. Normally the two streams are thickened separately.

Table 4.1 Case Study And Life Cycle Cost Computation of ASP Technology Based STPs

Assessment parameter		ASP, Allahabad	Dinapur RF-AS, Varanasi	Okhla ASP, Delhi	Literature	MOEF guideline
River action plan		GAP	GAP	GoNCTD		
Capacity	**mld**	**60**	**80**	**72**		
Hydraulic loading	%	92	100	100		
Plant Area	ha	11.00	20.00	10.50		
Area per mld	ha/mld	**0.18**	**0.25**	**0.15**	0.11-0.14	0.4
Performance						
Effluent BOD	mg/l	29-33	13-77	<30	<30 with 85-92% removal	
Effluent COD	mg/l	280	98-168	40-60		
Effluent DO	mg/l	3	3	2		
Effluent SS	mg/l	40-44	25-121	30		
Effluent faecal coliform	MPN/100 ml	1E+06 - 1E+07	1E+05 - 1E+08	nav, Total Coliform 1E+04-1E+05	60-90% removal	
Sludge digestion		Included	Included	Included	Integral part	
Biogas generation	m^3/d	3200	2000-2500	5700	na	
Bio-energy generation	kWh/d	nil	2500	Distributed for domestic consumption		
Resource recovery – biogas	Rs. pa	nil	1,360,000	nav		
Resource recovery – sludge	Rs. pa	nil	1,240,000	204,400		
Resource recovery – effluent	Rs. pa	Significant, though notional	102,000	nil		
Total resource recovery	Rs. pa	notional	2,702,000	apprx. 1,000,000		

COMPUTATION OF LIFE CYCLE COST

Assessment parameter		ASP, Allahabad	Dinapur RF-AS, Varanasi	Okhla ASP, Delhi	Literature	MOEF guideline
Contract Value of Plant Civil + E & M	Rs. million	165.0	80.0	183.2		
% of Work Civil Works		60%	60%	56%		
	Rs. million	99.0	48.0	102.6		
% of Work oE & M Works		40%	40%	44%		
	Rs. million	66.0	32.0	80.6		
Year of construction		1998	1991	2001		1998
Whole sale price index						
WPI : Year Of construction		132.8	73.7	155.7		132.8
WPI : (Dec 2003 estimated)		159.7	159.7	159.7		159.7
Unit cost of STP						3.5-4*
Cost of Plant (as in Dec 2003)						
Civil Works	Rs. million	119.1	104.0	105.2		
E & M Component	Rs. million	79.4	69.3	82.7		
Total Cost of Plant	Rs. million	198.4	173.4	187.9		
Unit cost of STP	Rs. million/mld	3.3	2.2	2.6	4.33-5.12	4.2-4.8*
Operation & Maintainance Costs						
Technology Power Requirement	kWh/d	nav	nav	14800		
Non Technology Power Requirement	kWh/d	nav	nav	400		
Total Daily Power Requirement	kWh/d	13500	14400	15200		
Unit power requirement	kWh/mld	225	180	211	182-228	
Daily Power Cost @ Rs 4.80/ KWhr	Rs.	64800	69120	72960		
Annual Power Costs	Rs. million	**23.65**	**25.23**	**26.63**		
Manpower Operation & Maintainance Cost	Cost/MM					
Manager	18000	1/2	2	1		
Chemist / Operating Engineer	8500	2	5	4		
Operators	5000	30	26	10		
Skilled Technicians	6500	6	6	8		
Unskilled Personnel	3000	6	36	20		
Cost of manpower	Rs. million	**2.80**	**4.27**	**2.57**		

Repairs cost

Assessment parameter		ASP, Allahabad	Dinapur RF-AS, Varanasi	Okhla ASP, Delhi	Literature	MOEF guideline
Civil Works per Annum as % of Civil Works Cost		0.5%	0.5%	0.5%		
E&M Works as % of E&M Works Cost		3.0%	3.0%	2.0%		
Civil Works Maintainance	Rs. million	0.60	0.52	0.53		
E & M Works Maintainance	Rs. million	2.38	2.08	1.65		
Annual repairs costs	Rs. million	**2.98**	**2.60**	**2.18**		
Total annual O&M costs	Rs. million	**29.42**	**32.09**	**31.38**		
Unit O&M costs	Rs. million/mld pa	**0.49**	**0.40**	**0.44**		0.36*
Uniform present worth over life cycle of plant of 35 years @ 5% rate of interest						
Uniform present worth factor		16.37	16.37	16.37		
Capatalised O&M Cost over 35 Years	Rs. million	799.15	802.78	844.38		
Capital cost of plant (2003)	Rs. million	198.4	173.4	187.9		
Land Cost @ Rs 5 mill / ha	Rs. million	55.00	100.00	52.50		
Life cycle cost (excluding land) (2003)	Rs. million	**997.57**	**976.15**	**1032.29**		
Unit life cycle cost (2003)	Rs. million/mld	**16.63**	**12.20**	**14.34**		

Notes

1. Literature values as reported in S.J. Arceivala in 'Wastewater treatment for pollution control', 1998
2. Electrical and mechanical component of the plant cost also includes duel fuel generator costs
3. Construction of Okhla plant was spread over 6 years, final cost is therefore indexed for the year of completion i.e., 2001
4. Allahabad project involved a gap of 10 years between award of contract and construction. However, the construction was done in a limited time period in 1998 and therefore the cost corresponds to year of completion
5. Considering life span of 7 years for electrical and mechanical parts, four replacements at 2003 prices are considered while calculating the capitalised O&M costs over 35 years
6. Repairs costs are worked out on projected civil and mechanical costs for year 2003
7. Land costs are not included in the life cycle costs as their rise or fall is not represented by CPI and there would be significant variations among different towns and over the years. However, ball park estimates are provided if one would like to add them with the plant costs
8. Area at Okhla STP, Delhi corresponds to built up area
9. Plant area at Allahabad STP corresponds to ultimate capacity of 80 mld
10. STP performance for Allahabad based on the data provided by UPJN

11. STP performance for Varanasi is based on the data monitored by CPCB in 2001 and COD values based on monitoring of 1995 review team
12. STP at Varanasi involves a roughing filter followed by an ASP
13. Whole sale price index is taken from 'Statistical Outline of India 2002-2003', Tata Services Limited and the available value for 2002 is modified for year 2003 by (-)1%

14. WPI for year 1991 for Varanasi plant is based on backward projection of the revised series with 1993-94 as 100
15. Unit costs under last column were derived from 'Status paper on river action plans' and the values are adjusted for year 2003

The sludge digester is operated under mesophilic conditions without temperature control, insulation or sludge heating arrangement. As a result its performance varies from season to season giving suboptimal biogas yield, and there are wide fluctuations in the total quantity available for subsequent uses. Average biogas availability is about 3200 cum/d which is about 58 cum/mld of sewage treated. In comparison to this, one of the recent digesters at Rithala (Delhi) with temperature control is producing about 89 cum/mld of sewage treated.

A biogas desulpherisation unit has been installed however it has been out of use for a long time due to a combination of reasons i.e., (a) non-availability of the required chemical reagents, (b) lack of maintenance and (c) lack of incentive for use of the biogas in subsequent duel fuel engines. Moreover, the desulpherisation unit does not have the final step for processing the sulphur bearing alkaline wastewater stream as is found at the state-of-the-art facility at Rithala STP in Delhi.

Performance of the plant

With regard to the effluent quality, as shown in Table 4.2 under almost full hydraulic loading conditions, the annual average BOD and suspended solids values are found to be 30.9 and 88.8 mg/l representing removal efficiencies of 78% and 89% respectively. While there is no doubt that an activated sludge plant can deliver equal or still better performance, the above values are rather close to the specified discharge limits. The corresponding monthly averages over a period of a year have a standard deviation of 1.25 indicating an unusually consistent process performance which is not so common in actual practice. Average efficiency of Faecal coliform removal is found to be 91% with effluent concentrations in the range of 10^6 to 10^7/ 100 ml. on the whole, the treated effluent has acceptable aesthetic value and it is utilised extensively for irrigation of vegetable crops.

Resource recovery

Although an elaborate bio-energy generation system involving duel fuel generators has been installed, its potential is not exploited effectively due to a combination of factors:

- Lack of funds for procurement of diesel
- Electricity charges linked to contracted minimum load irrespective of actual consumption
- Inadequate quantity of biogas for meeting entire energy requirement of the plant
- Higher cost of duel fuel generated captive power compared to that received from the grid

Clearly, there is no incentive in utilising the bio-energy and therefore currently entire quantity of biogas is flared. In view of this, there is general lack of interest in optimising the performance of the digesters as well.

Table 4.2 Performance of ASP Based STP at Allahabad

Month/ Year	Flow	BOD			SS			Faecal coliform		
		Infl.	Effl.	Rem.	Infl.	Effl.	Rem.	Infl.	Effl.	Rem.
	mld	mg/l	mg/l	%	mg/l	Mg/l	%	*	*	%
Jan-02	60	130	31	76	375	43	89	7.07E+07	1.34E+07	81
Feb-02	64	153	33	78	400	43	89	1.21E+08	1.62E+06	99
Mar-02	59	150	31	79	379	42	89	1.43E+08	1.11E+07	92
Apr-02	57	131	32	76	375	44	88	1.26E+08	8.28E+06	93
May-02	53	128	31	76	378	42	89	1.43E+08	1.78E+06	99
Jun-02	46	131	31	76	354	42	88	1.60E+08	1.47E+07	91
Jul-02	33	138	32	77	383	44	89	1.37E+08	1.91E+07	86
Aug-02	33	NA	NA	NA	375	40	89	7.60E+07	1.04E+07	86
Sep-02	37	142	29	80	377	40	89	1.29E+08	1.68E+06	99
Oct-02	45	132	29	78	385	42	89	1.43E+08	1.11E+07	92
Nov-02	64	150	30	80	380	42	89	1.43E+08	1.46E+07	90
Dec-02	59	139	30	78	386	41	89	9.33E+07	4.94E+06	95
Jan-03	73	140	33	76	383	44	89	7.30E+07	1.02E+07	86
Feb-03	70	137	30	78	386	43	89	1.18E+08	1.39E+07	88
Mar-03	73	143	31	78	381	43	89	1.15E+08	1.08E+07	91
Avg.		138.9	30.93	77.66	379.80	42.33	88.85	1.19E+08	9.84E+06	91.17
Std. dev.			1.27			1.25				

* (MPN/100 ml)

Operation and maintenance

The routine operation and maintenance of the plant has been given on labour contract to a local agency, however, an interesting aspect found only at this plant is that the operation of the laboratory has been retained with the supervising agency i.e., the UP Jal Nigam. This arrangement apparently enables higher involvement of the UPJN staff and better control over the performance of the contractor.

STP at Varanasi

The STP at Varanasi essentially comprises a combination of roughing filter and conventional activated sludge processes. Roughing filter comprises a high rate trickling filter which is generally provided in cases where industrial wastewater is expected to join sewage. At Varanasi, this was indeed the case when the plant was planned and commissioned in 1991, however of late the contribution from industrial sector (textile dyeing) has declined significantly and the plant is processing almost entirely the domestic waste. Current hydraulic loading is found to be between 100 to 150% of the designed capacity.

As in the case of Allahabd STP, at this plant also the flow scheme for return sludge involves bringing the settled secondary sludge back to the primary sedimentation tank (PST) and excess sludge withdrawal from the latter. Similarly, rising gas bubbles are observed which indicate onset of anaerobic digestion in primary sedimentation tank itself. Presence of floating scum and sludge blanket in the PST can be attributed to this feature of the return sludge scheme. Although effluent quality data at intermediate stages of the STP are not available, it is understood that solids overflow and thereby solids loading on the subsequent stages would be high.

It is unusual that there are no sludge thickeners at this plant and the excess sludge from the PST is introduced directly into the digesters. While on the other hand the digesters have been provided with improved features of mechanical mixing arrangement as well as with heating of sludge from the waste heat released from the duel fuel engines. Unlike the current state-of-the-art practice of egg shaped digesters, here they are of cylindrical shape with a dome type roof. Incidentally the digesters have developed structural defects and the gas leaks out through the cracks in the roof. Average biogas production is reported to be between 2000-2500 cum/day which is approximately equal to 31 cum/mld of treated sewage. This is in contrast to the earlier quoted figures of 58 cum/mld and 89 cum/mld for Allahabad and Rithala STPs respectively. From the currently produced gas quantity and known calorific value, it is possible to generate about 3200 kWh of electricity/d (equivalent to 133 kW excluding the diesel contribution) while the total installed capacity of the duel fuel generation system is ambitiously high at 1.6 MW.

For the same reasons as cited in case of the STP at Allahabad, the duel fuel engines are underutilised. The cogeneration system for heat recovery and heating of sludge has become dysfunctional as the hot water coils are clogged due to scale formation. A gas desulpherisation unit was not provided as H_2S concentration was considered to be in traces.

Another unusual feature of this STP is the steep fall in hydraulic gradient along the flow scheme. Apparently the water level in secondary settling tanks is about 2.5-3 m below ground and in the treated effluent sump it is about 3.5 m below ground. As a result, high degree of pumping is involved at multiple stages of the plant. From the point of view of safety against flooding this type of arrangement may not be desirable.

Performance of the plant

Long term effluent quality data show BOD and suspended solids in the range of 13-77 mg/l and 25-121 mg/l respectively. The corresponding removal efficiencies are found to be in the range of 49-86% and 57-97% respectively. The Faecal coliform values in the effluent are found to be of the order of $10^5 – 10^8$/100 ml and their removal efficiency varies between wide limits from 6% to 99% (CPCB, 2001). Among other factors, the higher BOD and SS values are attributed to hydraulic over loading as well as to the inappropriate return sludge scheme. However, the treated effluent has good aesthetic value.

Resource recovery

From resource recovery point of view, this is the only STP where sludge is being sold for agricultural application. It is interesting to note that a number of local micro-enterprises have evolved which are involved in collecting the sludge, processing and blending it with other mineral additives. This value added product is then sold as a soil conditioner to tea plantations in the north-east state of Assam. Estimated revenue from sale of sludge to the UPJN is about Rs. 1.24 million/annum. In addition, the notional value of electrical energy generated from the biogas is estimated to be Rs. 1.4 million/annum. The value of total resource recovery including revenue from effluent used for irrigation etc. is estimated to be Rs. 2.7 million/annum. However, with respect to the initial or recurring costs of the plant, this is not significant.

Operation and maintenance

From maintenance point of view, the roughing filters experience high wear and tear of turntable. During the course of a field visit one of the filters was found to be out of operation for the same reason. However, the filter media which is of rather large size (7-10 cm) requires cleaning once in 7-8 years.

Unlike most other STPs in UP and the current trend of engaging private agencies, this STP is operated and maintained by UPJN staff. This is because of large size of existing workforce which was inducted way back in 1991. However works of small quantum are given out on short term job work basis. There are 12 supervisory staff and over 70 operational staff which appear to be rather large.

STP at Okhla

The flow scheme of recently commissioned 72 mld Okhla STP is by and large on the same lines as that of the Allahabad STP. The difference are in the type of screens and grit chambers which are mechanised and more effective as well as cause less exposure to the workers; and final gas utilisation.

As in the other two STPs, here also the secondary settled sludge is introduced back into the primary settling tank with similar though reduced adverse consequence on its performance. The excess sludge is withdrawn and wasted from the underside of the PST. There are no sludge thickeners and the sludge is fed directly into the digesters. Understandably, the required digester volume is fairly large as there are 6 large size reactors adding up to about 16,200 cum of total storage volume. One of the unique features of the digesters is their mixing arrangement which is done by recirculating the biogas itself rather than through mechanical devices.

Performance of the plant

As per the information available from the in-house laboratory of the plant, it is found to be working satisfactorily with effluent BOD and SS being under 10 mg/l and 20 mg/l respectively. The concentration of dissolved oxygen in the final effluent is around 2 mg/l while the COD is between 40-60 mg/l. The effluent has high aesthetic value as it does not contain any colour or odour.

Resource recovery

Approximate quantity of biogas generation is estimated to be 5700 cum/d which comes to about 79 cum/mld of treated sewage and compares well with the unit yield of other well performing digesters. Unlike other STPs, here the biogas is not utilised for electrical energy generation. Instead, along with the biogas from other STPs located at the same complex (aggregate installed capacity over 600 mld) it is distributed for domestic and institutional consumption through a pipeline distribution system.

Total quantity of sludge produced per day at the PST stage is estimated to be 288 cum while after the drying beds it comes down to 34 cum with 30-40% dry solids. Raw sludge production approximates to about 4 cum/mld of treated sewage. Off take of dried sludge for agricultural application has declined and lately the plant is facing difficulty in disposing off the sludge.

Key decision parameters of ASP plants

In terms of the key decision parameters, the unit values for the three plants are computed as shown in Table 4.1 and have been summarised in Table 4.3. The unit land requirement is found to be between 0.15 to 0.25 ha/mld. In this regard, the value suggested by MOEF is higher as it also considers capacity expansion possibility in future. The initial investment costs are found to be in the range of Rs. 2.2 to 3.3 million/mld and they are found to be lower than those suggested in literature and by MOEF. Life cycle cost of Varanasi plant which is the oldest among the three is the lowest at Rs. 12.2 million/mld, while for the Allahabad STP it is highest at Rs. 16.6 million/mld.

Table 4.3 Key Decision Parameters of ASP based STPs

		Unit requirements				
	Capacity	**Land**	**Energy consumption**	**O&M costs (2003)**	**Capital costs (2003)**	**Life cycle costs (2003)**
STP location	Mld	ha/mld	kWh/mld	Rs. million/mld	Rs. million/mld	Rs. million/mld
Allahabad	60	0.18	225	0.49	3.3	16.6
Varanasi	80	0.25	180	0.40	2.2	12.2
Okhla	72	0.15	211	0.44	2.6	14.3
Literature[1]		0.19-0.23	182-228	-	4.33-5.12	-
MOEF[2]		0.4	-	0.36	4.2-4.8	-

1. Source : Arceivala, 1998
2. Source : MOEF, 1998
3. Capital and life cycle costs are excluding land costs.
4. Cost values in the last two rows have been adjusted for year 2003 based on the whole sale price indices.

Suitability of activated sludge process

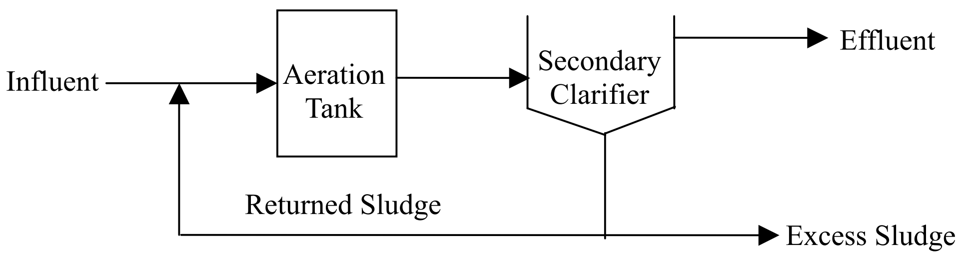
Activated sludge process is one of the oldest and widely popular technologies for sewage treatment. It is a proven technology for diluted as well as concentrated wastewaters and is used extensively for treatment of mixed and industrial wastewaters. A considerable experience is available within in the country with regard to construction, operation and maintenance aspects of the technology. In addition to the conventional or standard rate process, a number of variants have been developed with regard to the reactor configuration, aeration system, duration of aeration, sludge recirculation, operating conditions etc. to achieve varying levels of removal of carbonaceous and nitrogenous oxygen demand; and denitrification and nutrient removal. However, in Indian context only simpler versions of the process are found.

Based on the study of the three activated sludge process based STPs it can be concluded that in general a well operated and maintained activated sludge plant is able to produce effluent of acceptable quality in terms of BOD, suspended solids, dissolved oxygen and aesthetic value.

BOX 4.1 : TECHNOLOGY SHEET - ACTIVATED SLUDGE PROCESS

A reactor with chosen mixing regime in which settled microbial mass (sludge) pumped from underflow of the downstream clarifier is suspended and aerated, through mixing devices at the top or supply of compressed air from the bottom, with incoming wastewater for bio-oxidation of organics.

Schematics



Key features

- Aeration of wastewater in presence of high concentration of suspended microorganisms.
- Surface aerators or diffused air system for mixing aeration tank content and supply of oxygen

- Pumping some fraction of underflow (settled sludge) from clarifier to maintain desired level of active biomass in the reactor (aeration tank)
- Wasting of excess sludge
- Proven and tested for more than 7-8 decades all over world.
- Can be designed to select microbial growth rate that results in controlled quantities of excess sludge and varying degree of nutrient removal.
- Several modifications/advances possible to meet specific requirements

Performance

Very good performance in terms of BOD and SS. Treated effluent can most often satisfy the effluent discharge standards. Performance is critically dependent on sludge settling characteristics and design of secondary clarifier. Sludge settling characteristics are typically influenced by bio-flocculation which in tern depends on growth rate of microbes. Growth rate is generally controlled by operating biological solids retention time or food to microbe ratio.

Specific requirements

- Un-interrupted power supply for aeration and sludge recirculation.
- Maintenance of biomass concentration in the aeration tank and proper settling in the secondary clarifier.

Options

- Several variants and advanced versions which yield varying degree of performance depending upon the energy input, sludge recycle ratio, aeration time, mixing regime in the aeration tank and settling device exist. Different technology providers have come up with patented design for aeration, flocculation and settling.

Dos and Don'ts

- Prevent mixing of industrial effluents with toxic elements.
- Carefully monitor the reactor sludge levels and sludge withdrawal.
- Regular painting/coating of corrosion susceptible materials/exposed surfaces.

Capital cost

The capital cost is in the range of Rs. 2 - 4 million per mld. Approximately 55 % cost is of civil works and remaining 45 % is for electrical and mechanical works.

Operation and Maintenance

- Careful monitoring and control of MLSS and MLVSS in the aeration tank.
- Regular maintenance of aeration and recycle system.

O & M Costs

The O & M costs based on the data collected from various plants varies in the range of Rs. 0.3 – 0.5 million/year/mld.

Advantages

- Performance is not significantly affected due to normal variations in wastewater

characteristics and seasonal changes
- Less land requirements

Disadvantages

- High recurring cost
- High energy consumption
- Performance is adversely affected due to interruption in power supply for short period
- Foaming, particularly in winter season, may adversely affect the oxygen transfer, and hence performance
- Requires elaborate sludge digestion/drying/disposal arrangement

Applicability

The most widely used option for treatment of domestic wastewater for medium to large towns where land is scarce.

4.2 TRICKLING FILTER TECHNOLOGY

No plant based on this technology could be covered during the current study as this was has not adopted under YAP. However, as mentioned earlier about 6 plants of various capacities were commissioned (both renovated and new construction) during GAP, among which all except one were constructed in West Bengal.

Broadly, all these trickling plants can be classified as medium to high rate filters. For instance the STP at Howrah is a medium rate trickling filter system with recirculation ratio of 87% and designed hydraulic loading of 28 m/d. On the other hand the roughing filter included as the 1st stage a pre-treatment at the STP at Varanasi described in the previous section has hydraulic loading as high as 64 m/d.

Performance of the plants

Based on the latest available monitoring data of five of these plants as shown in Table 4.4, it is noted that the average effluent BOD is 36-55 mg/l (reduction efficiency 60-70%) and the suspended solids concentration is 48-73 mg/l (reduction efficiency 45-65%). In addition, the average effluent DO level at various STPs are found to be in the range of 1.5 to 5 mg/l. Thus in principle, the STPs are able to produce acceptable effluent quality and the technology in general can enable compliance with the discharge standards except for desired norms for Faecal and total coliforms.

Table 4.4 Current Performance of Trickling Filter Based STPs under GAP

	Influent		Effluent		Removal	
Location	**BOD**	**TSS**	**BOD**	**TSS**	**BOD**	**TSS**
Kamarhati	mg/l	mg/l	mg/l	mg/l	%	%
Range	80-130	120-200	32-48	40-70	-	-
Average	109	150	43	53	61	65
Kalyani						
Range	105-235	100-180	42-62	60-100	-	-
Average	156	135	55	73	65	46
Chandan Nagar						
Range	105-165	80-140	36-56	20-80	-	-
Average	133	106	49	48	63	55
Serampore						
Range	130-245	100-220	32-68	20-90	-	-
Average	174	152	48	54	72	64
Howrah						
Range	95-185	80-190	18-52	20-60	-	-
Average	135	138	36	48	73	65

(Source : MOEF, 2003)

O&M problems

With regard to the operation and maintenance aspects there have been some concerns. For instance a trickling filter plant at Okhla which was constructed in 1950s had to be taken out of operation and decommissioned, among other for the following two reasons:

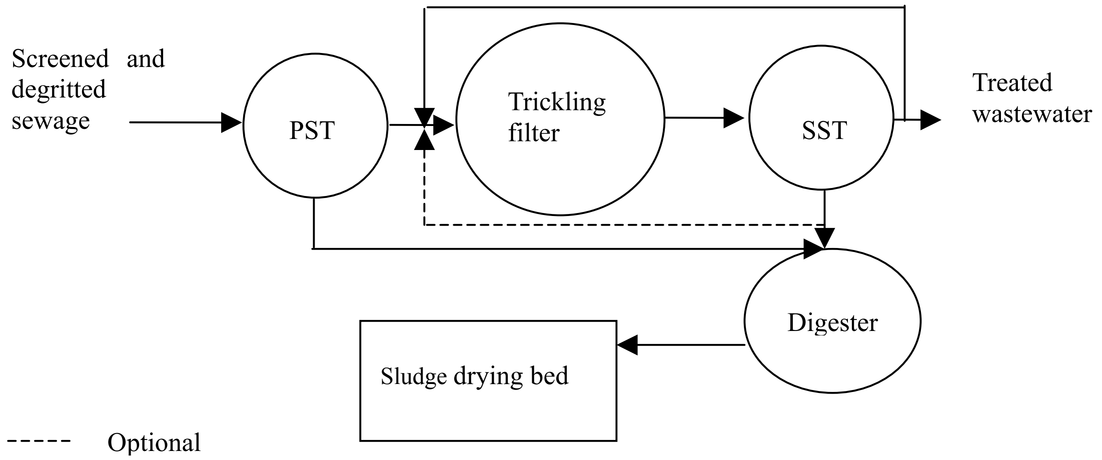
- High wear and tear of the turn table and therefore higher maintenance costs
- Clogging of the distribution arm due to the presence of small plastic bags

As already mentioned, similar problem is experienced at Dinapur roughing filter. On the other hand, trickling filter at Kalyani in West Bengal encountered problems of clogging apparently due to smaller size of the media than what is recommended for high rate applications. Another small capacity trickling filter based STP at Bhagwanpur complex in Varanasi, which was renovated under GAP, is found to be affected due to problems of similar nature and during a field visit it plant was found to be out of operation. Apparently, effectiveness of the screens at the beginning of the STP plays a crucial role in determining trouble free operation of a trickling filter plant.

BOX 4.2 : TECHNOLOGY SHEET - TRICKLING FILTER

A biologically active filter bed of stone or plastic media wherein the attached biomass helps in removal of dissolved and suspended organic matter from wastewater under aerobic conditions.

Schematic



Key features of the technology

- Aeration during trickling of the waste
- A proven 100 year old technology
- Rugged system with simple and silent operation
- Lower process monitoring requirement
- Consistent effluent quality

Performance

As no plant of this type could be covered under the current study, specific plant performance data is not available, however as per the information in literature based on Indian experience the following performance is expected from well functioning trickling filters :

	Low rate filters	High rate filters (Stone media)	High rate filters (Plastic media)	Roughing filters
BOD removal %	80-85	65-85	65-85	40-65
Nitrogen removal %	15-20	10-15	10-15	Nil
Phosphorus removal %	10-20	<10	<10	Nil
Coliform removal %	60-90	60	60	-

Note : Super high rate trickling filters are also used where packed plastic media upto 12 m height is provided.

Performance is made consistent and improved by providing for appropriate level of recirculation of effluent.

Excess sludge production @ 0.8 kg/kg of BOD removed

Specific requirements

- Stone or plastic media of required specifications

Land requirement

- Between 0.28 to 0.65 ha/mld

Power requirement

- Minimum technology energy consumption of 180 kWh/mld

Options

- Slow and high rate trickling filter

- Roughing filter for pre-treatment of sewage mixed with industrial wastewater
- Super high rate filters with plastic media in 10-12 m tall reactors
- Multi-stage trickling filter for nitrification and/or high BOD removal
- Trickling filter followed by activated sludge process / solid contactor
- Sludge and/or treated effluent recirculation
- Side walls with opening for additional aeration
- Submerged aeration from under the media

Dos and don'ts

- Provide effective and efficient mechanical screens to prevent problems of clogging
- Provide for recirculation of effluent to avoid low flow conditions and reduce odour and flies

Capital costs

- NA

Operation and maintenance

- Efficient operation of screens to prevent clogging
- Provide consistent hydraulic loading to prevent damage to the biofilm
- Maintenance of the turntable
- Cleaning of stone filter media once in 5-7 years or more

O&M costs

- NA

Advantages

- Simple operation of the plant requiring lower skilled manpower
- Rugged system less prone to hydraulic and organic over loading
- Reduced requirement for process monitoring
- Sludge with better settling characteristics

Disadvantages

- Blockage of ports in distribution arm
- Blockage of biofilter due to excess biomass growth or floating matter
- Frequent mechanical breakdown of the turntable
- Odour and filter flies may not be unavoidable

Applicability

- Stand alone treatment in slow rate filter for sewage
- As a roughing filter for high BOD wastewater
- In combination with ASP for high and consistent performance
- Possibly as a post treatment operation for UASB effluent

(Source for key parameters : Arceivala, 1998)

4.3 WASTE STABILISATION PONDS

A WSP treatment system comprises a series of anaerobic pond, a facultative pond and a maturation pond. The process of treatment is completely dependent on natural forces for biological degradation and bacterial die-off and does not involve external energy or chemical inputs.

During the this assignment, following plants based on this technology were visited :

- 0.5 mld plant, Vrindavan,
- 4 mld plant, Vrindavan, and
- 12.5 mld plant, Mathura

In addition, two operational plants for which relevant information was available from secondary sources are included in the analysis. These are 8 mld plant at Karnal and 30 mld plant at Howrah. Furthermore, for the purpose of comparing with recent cost data the proposed 9 mld plant at Palwal (Haryana) has also been included in the analysis. For these six plants located in three different states a comparative analysis of operational and investment parameters is presented in Table 4.5 whereas profiles of only 0.5 mld WSP at Vrindavan, 12.5 mld WSP at Mathura, and the 30 mld WSPs at Howrah are developed which are attached as Appendix D to this report. Salient features of the three visited plants are described below.

WSP (0.5 mld) at Vrindavan

Typically the small capacity plants have been provided with a manually cleaned bar screen and a grit chamber followed by a series of deep and shallow ponds. Depending on the situation, variations in the flow scheme are adopted. For instance at 0.5 mld plant at Vrindavan only anaerobic and facultative ponds of one and four days detention are provided while the maturation pond has been excluded. The reasons for adopting such scheme could have been lack of space, less stringent effluent quality requirement as there is no scope for utilisation of effluent for irrigation, etc. Incidentally, post construction, the plant is surrounded by residential colonies and there is no scope for capacity expansion.

In case of all the WSP plants constructed at Vrindavan, Mathura, Agra and Etawah the problem of ground water contamination was reported soon after their commissioning. In view of this, at these locations the ponds had to be provided with impervious lining comprising polymer sheet and a layer of cement concrete.

Performance of the plant

From the performance point of view, effluent BOD and SS values are 40-79 mg/l and 54-139 mg/l respectively. The corresponding removal efficiencies are around 50% and 63% respectively. Effluent Faecal coliform value is in the range of 10^6 to 10^8 /100 ml and the average removal efficiency is 85%. Less than optimal performance of the plant is attributed to hydraulic overloading of around 60 to 80 % and the truncated flow scheme which does not have maturation pond, which is necessary for removal of pathogenic bacteria. As against the original scheme of retention of 1 d in anaerobic pond and 4 d in the facultative pond, the current flow regime allows for retention of only 0.5 d and slightly more than 2 d respectively. Clearly this is not sufficient, especially in the facultative pond where such short periods would lead to wash out of algal cells and the aquatic plants may not establish.

Table 4.5 Case Study and Life Cycle Cost Computation of WSP Technology based STPs

Assessment parameter		Vrindavan	Vrindavan	Mathura	Karnal	Palwal (planned)	Howrah	Literature	MOEF
River action plan		YAP	YAP	YAP	YAP	GoH	GAP		
Capacity	**mld**	0.5	**4**	**12.5**	**8**	**9**	**30**		
Hydraulic loading	%	180	90-100	130	100	100	100		
Plant Area	ha	0.5	6.00	14	18.50	18.75	23.50		
Area per mld	ha/mld	**1.00**	**1.50**	**1.12**	**2.31**	**2.08**	**0.78**	**0.9 – 2.6**	1
Performance									
Effluent BOD	mg/l	40-79	30-60	70-100	20-30	-	13.0	75-85% removal	
Effluent COD	mg/l	nav	Nav	na	nav	-	na		
Effluent DO	mg/l	nav	Nav	na	2-3	-	5		
Effluent SS	mg/l	54-139		44-70		-	39.0		
Effluent faecal coliform	MPN/100 ml	1E+06 – 1E+08		1E+05 – 1E+08	1.0E+04	-	na	60-99.9% removal	
Sludge digestion		na	Na	na	na	na	na	na	
Biogas generation	m^3/d	na	Na	na	na	na	na	na	
Bio-energy generation	kWh/d	na	Na	na	na	na	na	na	
Resource recovery – biogas	Rs. Pa	na	Na	na	na	na	na	na	
Resource recovery – sludge	Rs. Pa	No buyers for the sludge	No buyers for the sludge	No buyers for the sludge	Sludge is not removed since commissioning	na	nav.	Accumulation @ 0.08 m3/person-year or 2 m3/mld	
Resource recovery – effluent/aquaculture	Rs. Pa	Notional in irrigation. Fish kill observed	Increased auction value of municipal farm	Fish kill observed	Fish kill observed	na	2-500,000 from aquaculture	Nitrogen loading determines feasibility of aquaculture	
Total resource recovery	Rs. Pa	notional	Notional	nil	notional	na	2-500,000		

COMPUTATION OF LIFE

Assessment parameter		Vrindavan	Vrindavan	Mathura	Karnal	Palwal (planned)	Howrah	Literature	MOEF
CYCLE COST									
Contract Value of Plant Civil + E & M	Rs. Million	3.0	15.0	40.0	10.0	19.0	51.3		
% of Work Civil Works		98%	98%	98%	98%	98%	98%		
	Rs. Million	2.9	14.7	39.2	9.8	18.6	50.3		
% of Work oE & M Works		2%	2%	2%	2%	2%	2%		
	Rs. Million	0.1	0.3	0.8	0.2	0.4	1.0		
Year of construction		2000	1998	2000	2000	2003	1995		1998
Whole sale price index									
WPI : Year Of construction		145.3	132.8	145.3	145.3	159.7	112.6		132.8
WPI : (Dec 2003 estimated)		159.7	159.7	159.7	159.7	159.7	159.7		159.7
Unit cost of STP									1.2-1.5
Cost of Plant (as in Dec 2003)									
Civil Works	Rs. Million	3.2	17.7	43.1	10.8	18.6	71.3		
E & M Component	Rs. Million	0.1	0.4	0.9	0.2	0.4	1.5		
Total Cost of Plant	Rs. Million	3.3	18.0	44.0	11.0	19.0	72.8		
Unit cost of STP	Rs. Million/mld	6.6	4.5	3.5	1.4	2.1	2.4	1.1-1.44*	1.4-1.8*
Operation & Maintainance Costs									
Technology Power Requirement	kWh/d	nil	Nil	nil	nil	nil	nil		
Non Technology Power Requirement	kWh/d	nil	Nil	nil	nil	nil	nil		
Total Daily Power Requirement	kWh/d	nil	Nil	nil	nil	nil	nil		
Unit power requirement	kWh/mld	nil	Nil	nil	nil	nil	nil		
Daily Power Cost @ Rs 4.80/ KWhr	Rs.	Nil	Nil	nil	nil	nil	nil		
Annual Power Costs	Rs. Million	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		
Manpower Cost	Cost/MM								
Manager	18000	1/5	¼	½	1/8	1/8	¼		
Chemist / Operating Engineer	8500	0	0	0	1	1	1		
Operators	5000	1	1	2	1	1	2		
Skilled Technicians	6500	0	0	1	4	4	18		

Assessment parameter		Vrindavan	Vrindavan	Mathura	Karnal	Palwal (planned)	Howrah	Literature	MOEF
Unskilled Personnel	3000	6	7	8	8	8	12		
Cost of manpower	Rs. Million	**0.32**	**0.37**	**0.59**	**0.79**	**0.79**	**2.11**		
Repairs cost									
Civil Works per Annum as % of Civil Works Cost		0.2%	0.2%	0.2%	0.2%	0.2%	0.2%		
E&M Works as % of E&M Works Cost		3.0%	3.0%	3.0%	2.0%	3.0%	3.0%		
Civil Works Maintainance	Rs. Million	0.01	0.04	0.09	0.02	0.04	0.14		
E & M Works Maintainance	Rs. Million	0.00	0.01	0.03	0.00	0.01	0.04		
Annual repairs costs	Rs. Million	**0.01**	**0.05**	**0.11**	**0.03**	**0.05**	**0.19**		
Total annual O&M costs	Rs. Million	**0.33**	**0.41**	**0.71**	**0.82**	**0.84**	**2.30**		
Unit O&M costs	Rs. Million/mld pa	**0.65**	**0.10**	**0.06**	**0.10**	**0.09**	**0.08**		0.05
Uniform present worth over life cycle of plant of 35 years @ 5% rate of interest									
Uniform present worth factor		16.37	16.37	16.37	16.37	16.37	16.37		
Capatalised O&M Cost over 35 Years	Rs. Million	5.62	8.19	15.07	14.22	15.22	43.46		
Capital cost of plant (2003)	Rs. Million	3.3	18.0	44.0	11.0	19.0	72.8		
Land Cost @ Rs 5 mill / ha	Rs. Million	2.50	30.00	93.75	92.50	93.75	117.50		
Life cycle cost (excluding land) (2003)	Rs. Million	**8.92**	**26.23**	**59.04**	**25.21**	**34.22**	**116.21**		
Unit life cycle cost (2003)	Rs. Million/mld	**17.83**	**6.56**	**4.72**	**3.15**	**3.80**	**3.87**		

Notes

1. Literature values as reported in S.J. Arceivala in 'Wastewater treatment for pollution control', 1998
2. Plant costs for Vrindavan and Mathura include pond lining cost which was subsequently caried out to prevent ground water contamination
3. Considering life span of 7 years for electrical and mechanical parts, four replacements at 2003 prices are considered while calculating the capitalised O&M costs over 35 years
4. Palwal plant is outside the scope of YAP but information has been included as it provides latest estimates
5. Palwal WSP is designed for a total retention time of 23 days and therefore the unit land area is high
6. Repair costs are worked out on projected civil and mechanical costs for year 2003
7. Land costs are not included in the life cycle costs as their rise or fall is not represented by CPI and there would be significant variations among different towns and over the years. However, ball park estimates are provided if one would like to add them with the plant costs
8. Whole sale price index is taken from Statistical Outline of India 2002-2003, Tata Services Limited and available value for 2002 is modified for year 2003 by (-)1%

WSP at Mathura

This plant has a typical three ponds in series configuration with 1 day detention in anaerobic pond, 4 days in facultative pond and 3 days in maturation pond. The bar screens installed at sewage pumping station as well as at the STP are manual and are found to be ineffective in removal of plastic bags and small pouches. Often functioning of even the non-clogging vertical pumps is affected. The floating material is then removed manually from anaerobic pond through an improvised screen attached to a long bamboo. This feature of the plant leads to creation of small heaps of such removed objects along the perimeter of the ponds and gives unaesthetic looks.

As seen in other small to medium capacity STPs, the grit chambers are also manually cleaned type and the deposited grit is removed once in about 10 days. Since the bottom storage volume of the grit chambers is limited, the grit tends to escape into the next stage of the plant. Exposure of STP workers to infectious wastewater at the bar screen and grit chamber stage is a cause for concern from their occupation health point of view

Rest of the process is rather straight forward and does not involve any major monitoring, control etc. Bacterial activity in anaerobic ponds is found to be aggressive which is exhibited by the presence of gas bubbles. Similarly the algal biomass in facultative ponds is found to be well developed which is exhibited by the uniform green colour of the impounded water as well as by the absence of any gas bubbles representing absence of anaerobicity.

Performance of the plant

The plant is operating at 30% hydraulic overload as well as some extent of organic overload as the influent also carries a fraction of industrial wastewaters from the city. Representative influent and effluent quality data is shown in Table 4.6 below.

Table 4.6 Performance of Wsp Based STP at Mathura

	BOD (mg/l)			SS (mg/l)			F. Coliform (MPN /100 ml)		
	Inlet	Outlet	% rem	Inlet	Outlet	% rem	Inlet	Outlet	% rem
January	na			na			na		
February	102	30	70.6	121	62	48.8	9.1E+08	2.2E+08	75.824
March	308	29	90.6	1058	44	95.8	1.3E+08	2.0E+06	98.462
April	192	28	85.4	313	70	77.6	6.4E+07	6.0E+05	99.063
May	152	21	86.2	324	46	85.8	2.5E+08	3.0E+07	88.000
June	174	25	85.6	739	69	90.7	8.7E+08	8.1E+07	90.690
Average		27	83.7		58	79.7			90.4

(Source : MOEF, 2003)

The above data indicates that with regard to BOD and SS values the plant is performing well and the effluent is within desired ‘quality standards’. However, the faecal coliform values do not confirm the same trend. In a normal and well functioning WSP the faecal coliform removal efficiency is expected to be over 99.99% with effluent concentrations in the order of 10^3 to 10^4/100 ml. Whereas in this case the corresponding values are 90% and 10^5 to 10^8 /100 ml. Moreover, during a field visit it was learned that the influent and effluent BOD and SS values are well over the above stated figures and this is attributed to overloading and industrial discharges.

As per the plant operational guidelines, sludge removal from anaerobic pond is supposed to be carried out once in 6 months, however longer intervals are common. One of the ponds has been desludged recently, almost after three years of commissioning of the plant. Manual sludge removal entails emptying of the pond and thereby shutting off 50% part of the plant for a prolonged period. During this desludging period either the other part of the WSP is subjected to overloading or the wastewater is allowed to flow without adequate treatment. Moreover, in absence of a separate sludge storage facility e.g., a lagoon, the sludge is stacked along the boundary of the plant which leads to unaesthetic surroundings. The plant does not have arrangements to take care of these aspects.

Resource recovery

In line with the policy of resource recovery, a contract for developing aquaculture at this STP was awarded to a private agency. However, in recent months the problem of fish kill was experienced. This is apparently attributed to toxicity in the wastewater due to presence of industrial effluents. The issue became so serious that the District Magistrate of Mathura had to intervene to safeguard the public health and decided to suspend aquaculture at all the STPs in Mathura and Vrindavan. In view of this, all the contracts for aquaculture have been terminated and there will be no ‘resource recovery’.

This incident shows that ‘resource recovery’ in the form of aquaculture from a WSP is not as feasible as it may sound attractive. From a technical point of view, the fish kill could actually be due to nitrogen overloading in the maturation ponds which is leading to algal blooming and consequent oxygen depletion during night and early morning hours. In order to avoid fish kills, the maturation ponds need to be designed on the basis of nitrogen loading and not on the typical criteria of 3 days of hydraulic retention time. The impounding reservoir so designed could then be called an aquaculture pond which is typically 5-7 times larger than the conventional maturation pond.

Operation and maintenance

The operating agency UPJN has engaged a labour contractor for routine O&M of the STP. The team of contractor comprises 1 supervisor and 6 unskilled workers who are deployed in two shifts of 12 hours each. The plant does not involve rigorous process control or monitoring and by and large it is found to be well maintained and operated.

WSP at Howrah

The WSP at Howrah is the largest so far with a total treatment capacity of 30 mld. The flow scheme comprises three parallel anaerobic and facultative ponds which finally drain into two maturation ponds. The maturation ponds are effectively operating in series as this arrangement normally enables higher efficiency for pathogen removal. Retention times of these ponds are 1 day, 4 days and 3 days respectively which are in line with the typical range for the WSP system.

Performance of the plant

With regard to the performance of the plant, the representative influent and effluent quality data is as shown in Table 4.7 below. While the influent quite diluted as indicated by low BOD, the removal efficiency is between 80-90% and average effluent quality is found to complying with the discharge criteria. Moreover, the DO level at the outlet of facultative ponds is found to be as high as 11.4 mg/l and after maturation ponds it is 5.2 mg/l. However, data on removal of Faecal coliform is not available and can not be commented upon.

Table 4.7 Performance of WSP Based STPs at Howrah

Parameter	Unit	Influent	Effluent	% Removal
BOD_5	mg/l	64	13	80
SS	mg/l	315	39	88

(Source : Calcutta Metropolitan Water and Sanitation Authority, 1998)

Resource recovery

Although the facultative and maturation ponds are not designed based on nitrogen loading, the apparent low level of influent organic loading is making aquaculture feasible at this plant. Low loading is also reflected by higher dissolved oxygen level at the outlets of facultative and maturation ponds.

Looking at the aquaculture potential, Calcutta Metropolitan Water and Sanitation Authority, the implementing agency, has given O&M of the WSP not to a typical consulting outfit or to a labour contractor, instead to a fishermen's cooperative. The cooperative has agreed to carry out aquaculture in facultative and maturation ponds and in return pay around Rs. 0.35 million pa to CMWSA as a royalty. No major O&M problems are stated, however special security guards have been included in the cooperative's team to prevent theft of the aquaculture stock. As in case of East Calcutta Wetlands, the fishermen adopt traditional practices of aquaculture which have evolved over generations and are able to sustain their activities without any special training or monitoring inputs.

Key decision parameters of WSP plants

The operation and investment parameters for comparison for all WSP plants are summarised in Table 4.8 below. The unit land requirement for 30 mld plant at Howrah is rather low at 0.78 ha/mld, while for the rest they confirm with the values cited in literature. Land requirements for plants in Harayana are over 2 ha/mld and they possibly correspond to future expansion.

In general in case of large capacity plants the unit values for initial costs and recurring costs are in line with those available in literature and as suggested by the MOEF, while for the very small capacity plant of 0.5 mld at Vrindavan, the life cycle cost is about 3-5 times higher than the average. Among others, the reasons for this could be very low capacity and provision of impervious lining. The capital costs of two other WSPs at Vrindavan and Mathura are also inclusive of the cost for impervious lining and are therefore relatively high.

Table 4.8 Key Decision Parameters of WSP Based STPs

		Unit requirements				
	Capacity	Land	Energy consumption	O&M costs (2003)	Capital costs (2003)	Life cycle costs (2003)
STP location	mld	ha/mld	kWh/mld	Rs. million/mld	Rs. million/mld	Rs. million/mld
Vrindavan	0.5	1.00	-	0.65	6.6	17.83
Vrindavan	4	1.50	-	0.10	4.5	6.56
Karnal	8	2.31	-	0.10	1.4	3.15
Palwal*	9	2.08	-	0.09	2.1	3.80
Mathura	12.5	1.12	-	0.06	3.5	4.72
Howrah	30	0.78	-	0.08	2.4	3.87
Literature[1]		0.9-2.6	-	-	1.1 -1.44	-
MOEF[2]		1	-	0.06	1.4-1.8	-

1. Source : Arceivala, 1998
2. Source : MOEF, 1998
3. Capital and life cycle costs are excluding land costs.
4. Palwal STP is planned for implementation during 2003-04
5. Cost values in the last two rows have been adjusted for year 2003 based on the whole sale price indices.

It is found that the unit life cycle costs for medium sized STPs are about 30-50% of the ASP plants presented earlier. If the land cost is included, it may be at par with ASP, but still have an advantage as it is not vulnerable to power failures and other process disturbances typical of the latter.

Suitability of waste stabilisation ponds

The cumulative experience from Ganga Action Plan showed that among all the different technology options tried out in the past 15-20 years, the most effective and sustainable option has been that of improved oxidation ponds (i.e., waste stabilisation pond) (MOEF, 1998, pp. 16). This conclusion stems from the facts that the technology:

- Is based on natural processes, depends on solar energy and therefore it is appropriate for climatic conditions in the Indian sub-continent;
- Involves no mechanical or electrical equipment or feeding of chemicals and therefore is most simplified way of treating wastewater;
- Requires minimal trained manpower and can be operated by semi-skilled and unskilled municipal workers with little supervision; and therefore
- Has least unit operation and maintenance costs

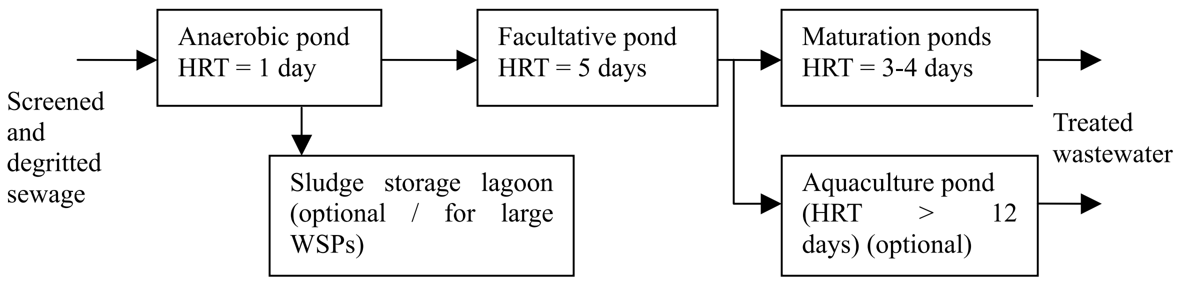
From Table 4.8 it is seen that even if land costs are included in the life cycle calculation for WSP plants, they would turn out to be economical compared to ASP or other STPs. Besides, they have the advantage of being energy neutral, i.e., they will continue to deliver acceptable effluent quality irrespective of the power situation. In addition, the following can be recapitulated:

- Well designed, operated and maintained WSPs can naturally achieve 99.99% of pathogen removal as well as 100% of Helminth egg removal
- WSPs can produce effluent of BOD under 30 mg/l, high DO levels and high aesthetic value
- WSPs are a complete solution in themselves without the need for any pre- or post- or polishing treatment
- WSPs operated in conjunction with duckweed ponds and aquaculture ponds offer a sustainable and tangible resource recovery option which can yield consistently high quality of effluent
- WSPs are an attractive option in places where the community has preference for aquaculture
- However, fish kills are observed in typical sized maturation ponds designed on conventional criteria of 3 days of hydraulic retention time. In order to prevent this and to have commercially feasible scale of aquaculture operations, the ponds should be designed based on nitrogen loading
- Over the years, the performance can deteriorate if anaerobic ponds are not desludged at regular interval
- Construction cost advantage may not hold in porous and fractured strata where the WSPs should be provided with impervious lining and especially for very small capacity plants
- At medium and large plants mechanised screens and grit chamber should be considered instead of the manually operated components
- At large installations, sludge management would become a critical aspect and suitable withdrawal devices, storage lagoons and disposal arrangements should be provided

BOX 4.3 : TECHNOLOGY SHEET - WASTE STABILISATION POND

A robust and natural system of wastewater treatment comprising anaerobic, facultative and maturation ponds in series, involving detention time of several days and requiring no external energy or chemical inputs or skilled monitoring inputs.

Schematic



Key features of the technology

- Essentially comprises three ponds in series with detention times of 1 day, 5 days and 3 days
- Anaerobic and facultative ponds enable BOD reduction while maturation pond enables pathogen removal
- Simple to construct, operate and maintain
- Does not involve installation of expensive electromechanical equipment
- Almost all WSPs (except very small plants) have adequate screening and grit removal facilities
- Operates on a combination of solar energy and natural forces and thereby involves least O&M costs
- Extremely robust and can withstand hydraulic and organic shock loads
- Can accept high levels of heavy metals (up to 60 mg/l) and therefore can treat domestic wastewater mixed with industrial effluents
- Can accept wastewaters from agro-industrial processes e.g., abattoirs, food processing units and dairies
- Efficient in removal of excreted pathogens
- Effluents from maturation pond are safe for reuse in agriculture and aquaculture

Performance

- Can reliably produce high quality effluent with low BOD, SS, Faecal Coliform and high DO levels
- BOD reduction of the order of 90 % and more
- Suspended solids reduction is less due to overflow of algae
- Coliform reduction could be up to 6 log units i.e., 99.9999%
- Total nitrogen removal between 70-90%
- Total Phosphorus removal between 30-45%

COMPARISON OF EFFICIENCY OF EXCRETED PATHOGEN REMOVAL IN WSP AND CONVENTIONAL TECHNOLOGIES

Excreted Pathogen	Removal in WSP	Removal in conventional treatment
Bacteria	Up to 6 log units	1-2 log units
Viruses	Up to 4 log units	1-2 log units
Protozoan cycts	100%	90-99%
Helminth eggs	100%	90-99%

1 log unit = 90% removal
2 log units = 99% removal

3 log units = 99.9% removal, etc.
(Source : Mara, 1997)

Specific requirements

- Soil and geo-hydrological survey during planning stage to assess risk of groundwater contamination
- Soils with permeability $\leq 10^{-7}$ m/s are preferred to avoid groundwater contamination
- Impervious lining in case of soils with higher permeability, shallow groundwater table and fractured strata
- Sulphate concentration in raw wastewater under 300 mg SO_4/l to avoid odour nuisance
- Neutralisation in case influent pH is below 6.2

Physical planning

- Ponds should be at least 200 m and preferably 500 m downwind of a residential locality
- Ponds should be away from areas of future expansion
- Ponds should be at least 2 km away from airports as these could attract birds
- There should be sufficient space on the upwind side for upto 5 rows of tree belt
- There should be sufficient space for a separate sludge drying lagoon, as sludge is generated @ 0.08 m3/person-year (Arceivala, 1998) which can be a major issue at large WSP plants.

Ground water contamination in Mathura - Vrindavan belt from WSP

During YAP, among others WSPs and polishing units were constructed at Vrindavan, Mathura, Agra and Etawah. After commissioning of the STPs, it was found that the ground water was getting contaminated due to seepage of sewage and the villagers in the vicinity started complaining. Subsequently, corrective measure in the form of a polymer and cement concrete lining was provided at each of the above mentioned locations. Cost of this correction on average was much more than the cost of WSP itself.

Therefore, geotechnical and geo-hydrological investigations become important while planning WSP technology based STP.

Land requirement

Capacity Q (mld)	$Q \leq 5$	$5 < Q \leq 10$	$10 < Q \leq 20$	$20 < Q \leq 30$	$30 < Q$	Literature*
Land (ha/mld)	1.5	1.5 - 2	1.12	0.8	nav	0.9 – 2.6

(* : Arceivala, 1998)

Energy requirement

Technology energy requirements would essentially be for operation of screen and grit chamber. At times where aquaculture ponds are provided, there may be a need for external aeration during summer seasons or pumping of ground water in winter season, however these components are typically not included. As the pond system does not require rigorous monitoring either, the non-technology power requirements would also be low. In totality, the system is energy neutral.

Options

- Multiple series of anaerobic and facultative ponds in parallel with common maturation pond
- System without maturation pond where only BOD reduction is required and concentration of pathogens is not a concern or; where phasing of investment is required
- System with multiple maturation ponds in case the treated wastewater is to be used for unrestricted irrigation (high pathogen removal)
- Maturation pond as aquaculture pond (in which case the detention period is determined based on nitrogen loading and is almost 15-20 times the above case)
- Duck weed pond as the last pond in the series of maturation ponds to control algae in the effluent

Dos and don'ts

- Preferably locate in vicinity of agriculture farms or aquaculture farms where treated wastewater can be utilised
- Conduct of an environmental impacts assessment of the proposed STP
- Detention period in maturation pond to be shorter than that in facultative pond
- Detention period in maturation pond to be not less than 3 days which is a minimum acceptable value for good algal growth and for avoiding wash out
- Two or more maturation ponds of smaller detentions period (each at least 3 days) in series to achieve higher pathogen removal
- For successful aquaculture and to prevent fish kill the last pond should be designed on nitrogen loading of 4 kg N/ha.day
- In case of large WSPs, equipment for removal of sludge from anaerobic pond and its safe disposal should be provided
- Avoid planting of trees on the embankments of facultative and maturation ponds as they will prevent sunlight and act as a wind barrier, both of which are essential for their functioning
- Exclude wastewaters having high sulphate concentration or low pH

Capital costs

Initial investment costs excluding the land costs for different capacity ranges are as follows :

Capacity Q (mld)	$Q \leq 5$	$5 < Q \leq 10$	$10 < Q \leq 20$	$20 < Q \leq 30$	$30 < Q$	Literature*
Cost (Rs. Million/mld)	4.5-6.6	1.4-2.1	3.5	2.4	nav	1.1 - 1.44

(* : Arceivala, 1998. Values for 1995-96 have been updated by 31% based on WPI values for 1995-96 and 2002-03(estimated)).

Note : cost values correspond to year 2003

Reference values available from case studies of Vrindavan and Mathura plants include costs of impervious lining and therefore the initial investment costs are comparatively high in the first and third columns.

Operation and maintenance

- Care during commissioning required for facultative pond to develop algal culture
- Regular cutting of embankment grass and its removal away from pond
- Regular removal of scum and floating vegetation from facultative and maturation pond
- Spraying on the scum in anaerobic pond with clear water, pond effluent or biodegradable larvicide to prevent fly breeding
- Removal of solids etc. in the inlets and outlets
- Protection and repairs of embankment
- Provision of small boat or raft to safeguard occupational health and safety of workers
- Maintaining pH around 7.5 in anaerobic pond to avoid odour nuisance
- Removal of sludge from anaerobic ponds when sludge occupies one third depth

- Preferably maintaining pH above 9 in maturation pond for higher removal of faecal bacteria
- Restricting level of suspended solids and algal growth in maturation pond for high light penetration which again results in higher faecal bacterial die off

O&M costs

Capacity Q (mld)	$Q \leq 5$	$5 < Q \leq 10$	$10 < Q \leq 20$	$20 < Q \leq 30$	$30 < Q$
O&M cost (Rs. million/mld/year)	0.1-0.65	0.1	0.1	0.1	nav

Note : cost values correspond to year 2003

Life cycle costs

Life cycle costs excluding the land costs for different capacity ranges are as follows :

Capacity Q (mld)	Q ≤ 5	5 < Q ≤ 10	10 < Q ≤ 20	20 < Q ≤ 30	30 < Q
Cost (Rs. million/mld)	12	3.5	4.7	4.2	nav

Note : cost values correspond to year 2003

Advantages

- The inherent simplicity of construction offers low cost technology option
- High quality effluent at least operating costs
- Low skill requirement for operation of the plant
- Fish yield from aquaculture ponds around 4-7 tonnes/ha/year

Disadvantages

- Large land requirement
- High cost of lining
- Likelihood of odour nuisance and mosquito breeding in poorly maintained WSPs
- Likelihood of groundwater contamination in porous and fractured strata

Applicability

- Under warm Indian climatic conditions
- For areas with easy availability of land
- In areas with social preference for aquaculture
- In area with low, unreliable or expensive power supply

4.4 UPFLOW ANAEROBIC SLUDGE BLANKET PROCESS

During the course of this study following four UASB plants were covered :

- 78 mld plant, Agra
- 20 mld plant, Faridabad
- 27 mld plant, Noida
- 70 mld plant, Gaziabad

Out of these four plants, the first two were studied in detail while the latter two were covered to validate the findings. In addition, background information on UASBs installed at Gurgaon, Panipat, Karnal and Yamunanagar was available from a recently conducted technology assessment study (Tare, 2003). This information has been included as it provides relevant numbers for comparison of similar plants with wide range of installed capacity. Key aspects of each of the plants are presented in comparative life cycle cost analysis in Table 4.9.

All the plants have a typical flow scheme comprising screens, grit chambers, UASB reactors, ponds as polishing units, sludge drying beds, gas holder and duel fuel generators. The screens and grit chambers are manually operated while at some places mechanically cleaned screens are also installed. The UASB section of the plant comprises modular reactors which typically have capacity varying between 10 to 15 mld. Profiles of two of the STPs under this category are presented in Appendix E and their salient features are described in the paragraphs that follow. A technology sheet is presented at the end of this section which summarises key aspects of the UASB technology in terms of unit requirements for land, power and investment for different capacity ranges.

UASB at Agra

The UASB plant at Agra is the largest in this category with a capacity to treat 78 mld of wastewater. The flow scheme comprises manual screens and grit chambers, six modules of UASB reactors (13 mld each), and final effluent polishing units. There are no sludge thickeners and the sludge is sent directly to the drying beds.

Considering large size of the plant, manual cleaning arrangement especially for the grit chamber causes difficulties in operation and leads to severe exposure for the workers. Apparently, a series of mechanical and manual bar screens are unable to remove thin and long plastic sheets which are causing choking problems in the distribution system installed in the UASB reactors. In order to minimise this problem, about 2-3 unskilled workers per reactor have been deployed to continuously remove the floating material through the improvised screens on a bamboo pole.

Table 4.9 Case Study and Life Cycle Cost Computation of UASB Technology based STPs

Assessment parameter		Gurgaon UASB	Ghaziabad UASB	Panipat UASB	Panipat UASB	Karnal UASB	YN UASB	Agra UASB	Faridbd UASB	Liter.	MOEF guidelines
River action plan		YAP	YAP	YAP	YAP	YAP	YAP	YAP	YAP		
Capacity	**mld**	**30**	**56**	**35**	**10**	**40**	**25**	**78**	**20**		
Hydraulic loading	%		80					64	80-90		
Plant Area	ha	9.71	12.70	10.12	3.04	8.10	10.52	20	5.8		
Area per mld	ha/mld	**0.32**	**0.23**	**0.29**	**0.30**	**0.20**	**0.28**	**0.26**	**0.29**	0.14-0.19	0.2
Performance											
Effluent BOD	mg/l		28-33					50-55	27-30	75-85% remove	
Effluent COD	mg/l	112	280	288-352	336	112-128	240-320		99-170	74-78% remove	
DO	mg/l	0	0	0	0	0	0	0	0	0	
Effluent SS	mg/l							89-111	25-45		
Effluent faecal coliform	MPN/100 ml	1E+06 - 1E+07							1.00E+05	-	
Biogas generation	m^3/d	nav	187.0	nav	nav	nav	nav	1000	280	0.08-0.1 m^3/kg COD removed	
Bio-energy generation	kWh/d	nav						128	160		
Resource recovery – biogas	Rs. pa	nav						nil	145,000		
Resource recovery – sludge	Rs. pa	nav						10,000	100,000		
Resource recovery – effluent	Rs. pa	nav						nil	nil		
Total resource recovery	Rs. pa	nav						10,000	245,000		
COMPUTATION OF LIFE CYCLE COST											
Contract Value of Plant Civil + E & M	Rs. miln	78.0	128.8	92.0	28.5	107.0	69.0	153.6	64.0		
% of Work Civil Works		65%	68%	67%	66%	64%	65%	65%	65%		
	Rs. miln	50.7	87.6	61.6	18.8	68.5	44.9	99.84	41.6		
% of Work oE & M Works		35%	32%	33%	34%	36%	35%	35%	35%		
	Rs. miln	27.3	41.2	30.4	9.7	38.5	24.2	53.8	22.4		

Assessment parameter		**Gurgaon UASB**	**Ghaziabad UASB**	**Panipat UASB**	**Panipat UASB**	**Karnal UASB**	**YN UASB**	**Agra UASB**	**Faridbd UASB**	**Liter.**	**MOEF guidelines**
Year of construction		1998	2001	1998	1998	1998	1998	1998	1999		1998
Whole sale price index											
WPI : Year Of construction		132.8	155.7	132.8	132.8	132.8	132.8	132.8	140.7		132.8
WPI : (Dec 2003)		159.7	159.7	159.7	159.7	159.7	159.7	159.7	159.7		159.7
Unit cost of STP											2.3-2.8*
Cost of Plant (as in Dec 2003)											
Civil Works	Rs. miln	61.0	89.8	74.1	22.6	82.4	53.9	120.1	47.2		
E & M Component	Rs. miln	32.8	42.3	36.5	11.7	46.3	29.0	64.6	25.4		
Total Cost of Plant	Rs. miln	93.8	132.1	110.6	34.3	128.7	83.0	184.7	72.6		
Unit cost of STP	Rs. miln/mld	3.1	2.4	3.2	3.4	3.2	3.3	2.4	3.6	2.9-3.7 *	2.8-3.4*
Operation & Maintainance Costs											
Technology Power Requirement	kWh/d	150	280	175	50	200	125	165	73		
Non Technology Power Requirement	kWh/d	260	500	300	100	350	240	660	262		
Total Daily Power Requirement	kWh/d	410	780	475	150	550	365	825	335		
Unit power requirement	kWh/mld	14	14	14	15	14	15	11	17	nil	
Daily Power Cost @ Rs 4.80/ KWhr	Rs.	1968	3744	2280	720	2640	1752	3960	1608		
Annual Power Costs	Rs. miln	**0.72**	**1.37**	**0.83**	**0.26**	**0.96**	**0.64**	**1.45**	**0.59**		
Manpower Cost	Cost/MM										
Manager	18000	1/4	1/4	1/4	1/8	1/4	1/4	2/5	1/4		
Chemist / Operating Engineer	8500	2	2	2	2	2	2	2	2		
Operators	5000	4	4	4	4	4	4	4	4		
Skilled Technicians	6500	4	4	4	4	4	4	4	4		
Unskilled Personnel	3000	12	16	12	8	12	12	24	10		
Cost of manpower	Rs. miln	**1.24**	**1.39**	**1.24**	**1.07**	**1.24**	**1.24**	**1.71**	**1.17**		
Repairs cost											
Civil Works per Annum as % of Civil Works Cost		0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%		

Assessment parameter		Gurgaon UASB	Ghaziabad UASB	Panipat UASB	Panipat UASB	Karnal UASB	YN UASB	Agra UASB	Faridbd UASB	Liter.	MOEF guidelines
E&M Works as % of E&M Works Cost		3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%		
Civil Works Maintainance	Rs. miln	0.25	0.44	0.31	0.09	0.34	0.22	0.50	0.21		
E & M Works Maintainance	Rs. miln	0.82	1.24	0.91	0.29	1.16	0.73	1.61	0.67		
Annual repairs costs	Rs. miln	**1.07**	**1.67**	**1.22**	**0.39**	**1.50**	**0.95**	**2.11**	**0.88**		
Total annual O&M costs	Rs. miln	**3.03**	**4.43**	**3.29**	**1.72**	**3.70**	**2.83**	**5.26**	**2.64**		
Unit O&M costs	Rs. miln/mld pa	**0.10**	**0.08**	**0.09**	**0.17**	**0.09**	**0.11**	**0.07**	**0.13**		0.2*
Uniform present worth factor		16.37	16.37	16.37	16.37	16.37	16.37	16.37	16.37		
Capatalised O&M Cost over 35 Years	Rs. miln	180.98	241.56	199.95	74.75	245.92	162.50	344.77	144.87		
Capital cost of plant (2003)	Rs. miln	93.8	132.1	110.6	34.3	128.7	83.0	184.7	72.6		
Land Cost @ Rs 5 mill / ha	Rs. miln	48.56	63.50	50.59	15.18	40.50	52.61	100.00	29.00		
Life cycle cost (excluding land) (2003)	Rs. miln	**274.77**	**373.67**	**310.58**	**109.02**	**374.59**	**245.48**	**529.48**	**217.51**		
Unit life cycle cost	Rs. miln/mld	**9.16**	**6.67**	**8.87**	**10.90**	**9.36**	**9.82**	**6.79**	**10.88**		

Notes

1. Although effluent BOD values are reported to be below 30 ppm, independent studies indicate them to be between 70-100 ppm
2. Literature values as reported in S.J. Arceivala in 'Wastewater treatment for pollution control', 1998 and values are updated for year 2003. Land requirement does not include area for polishing unit
3. Electrical and mechanical component of the plant cost includes duel fuel generator costs
4. Considering life span of 7 years for electrical and mechanical parts, four replacements at 2003 prices are considered while calculating the capitalised O&M costs over 35 years
5. Repairs costs are worked out on projected civil and mechanical costs for year 2003
6. Land costs are not included in the life cycle costs as their rise or fall is not represented by CPI and there would be significant variations among different towns and over

the years

7. Area values for first six columns represent only the built up area while those for Agra and Faridabad represent total acquired area for the STP
8. Area value given in literature does not include post treatment land requirement i.e., for FPU
9. Unit costs under last column were derived from 'Status paper on river action plans' and the values are adjusted for year 2003

Performance of the plant

Current hydraulic loading on the STP is 64% of the designed capacity. The wastewater comprises sewage and some percentage of industrial effluent from petha (sweet meat) and tannery industries and as a result the influent quality parameters are found to be higher than the designed values. As shown in Table 4.10 the final effluent BOD and SS values do not quite comply with the discharge standards of 30 and 100 mg/l respectively. Higher outlet BOD can also be attributed to solids overflow from the combined UASB-FPU system which is not uncommon in poorly operated systems.

Table 4.10 Performance of UASB Plant at Agra

	Raw sewage	UASB outlet	FPU outlet	% Removal
1st set of monitoring (May 13, 2002)				
BOD (mg/l)	262	83	55	79
SS (mg/l)	461	145	89	81
2nd set of monitoring (May 24, 2002)				
BOD (mg/l)	264	77	50	70
SS (mg/l)	444	133	111	75

(Source : IIT Roorkee, 2002)

As the FPU does not provide for re-oxygenation (either mechanically or through algal growth) aerobic biological action does not take place. The retention time of 1 day does not enable growth of algal cells. Therefore, BOD reduction at this stage is mainly attributed to removal of solids.

Corresponding effluent values for COD, instantaneous oxygen demand and dissolved oxygen are not available which are typically expected to be high for the effluent from an anaerobic process based STP. The effluent has dark brown colour which gives a poor aesthetic value. In view of these quality limitations, the effluent can not be considered at par with that from a typical activated sludge plant or a waste stabilisation pond system.

Resource recovery

Against the designed quantity of 1700 cum/d of biogas, current generation is of the order of 1000-1200 cum/d. A duel fuel generator is installed for utilising this biogas. However, it is run only during prolonged power cuts and during normal course most of the biogas is flared (Appendix E provides an analysis of Agra DFG system). General lack of incentive for maximising biogas generation or utilisation is due to following reasons :

a) Unlike aerobic processes, the anaerobic process is not prone to malfunctioning due to stoppage of flow or energy input
b) Minimum electricity charges corresponding to the installed load have to be paid any way
c) Limited budget for diesel purchase
d) Higher cost of captive generation from a mix of diesel and biogas compared to the grid supplied energy
e) Inability and restriction on transmission of excess electricity if any, to third parties

In view of this the generators are grossly underutilised.

Sludge generation is estimated to be about 420 cum/d which is equivalent to about 8.4 cum/mld of treated sewage. As there is no thickener, the dilute sludge is sent directly to the sludge drying beds. At times during winter and monsoon seasons, storage capacity of the drying beds is found to be inadequate. As there is no off take of dried sludge for agricultural application, almost 2500 cum of dried sludge is accumulating on the sides of the drying beds since commissioning of the plant in 2001.

Unless an appropriate system is put in place, disposal of sludge would become a critical problem.

In addition, there is large quantity of sludge accumulated in FPUs. Out of a total pond depth of 1.55 m sludge is occupying 0.4 m which is the designed storage depth. However, this has not been removed since commissioning apparently due to paucity of funds. As a result solids removal efficiency of these polishing units is likely to decline and solids overflow may be taking place.

UASB at Faridabad

There are three UASB based STPs at Faridabad, out of which the 20 mld plant has been covered under the current study. The flow scheme, sludge management and biogas utilisation arrangement at this plant are similar to those found at Agra. There are two reactor modules of 10 mld capacity each. An innovative feature observed at this plant in response to the negative DO balance in the effluent is construction of flow breakers in the outlet channel to create turbulence and thereby provide possibility for aeration.

Performance of the plant

Under almost 80-90% capacity utilisation, the long term performance of the STP is shown in Table 4.11. Average effluent BOD and SS are found to be rather low and quite close to 30 mg/l representing average removal efficiencies of 85 %. If this set of data is representative, the performance of the STP could be considered exceptional. However, in practice UASB based STPs are not known to deliver such high degree of removal efficiency.

Table 4.11 Performance of UASB Plant at Faridabad

Month	Raw sewage (mg/l)		UASB Outlet (mg/l)		FPU Outlet (mg/l)		% Removal	
	BOD	SS	BOD	SS	BOD	SS	BOD	SS
Jan 03	184	268	74	85	30	44	84	84
Feb 03	183	220	74	83	30	38	84	83
March 03	183	207	76	77	29	45	84	78
April 03	190	202	72	73	28	32	85	84
May 03	184	216	57	59	27	29	85	87
June 03	194	215	62	64	29	26	85	88
July 03	180	212	59	64	28	25	84	88
Aug 03	185	242	73	67	29	31	84	87
Sept 03	197	289	74	75	30	34	85	88
Oct 03	196	304	70	89	29	32	85	89
Average	187.6	237.5	69.1	73.6	28.9	33.6	85	86
Std. dev.	6.1	36.7	7.0	10.1	1.0	6.9	0.6	3.4

(Source : Monitoring record of PHED, Faridabad)

It is seen that while there is good deal of scatter in the raw effluent data, the treated effluent data appears to have high consistency with the FPU effluent BOD values having a standard deviation of only 1. This level of consistency in the time series appears less probable. Moreover, it is understood that typically performance of anaerobic processes is adversely affected during winter conditions. However, this aspect is not reflected by the FPU effluent BOD time series. The effluent has dark brown colour and offer poor aesthetic value.

Key decision parameters of UASB plants

The key operation and investment parameters for selected UASB plants are summarised in Table 4.12 below. The unit land requirement is found to be between 0.2-0.3 ha/mld including that for the FPU of

1 day detention. The unit O&M costs are found to be in the range of Rs. 0.07-0.17 million/mld/annum and the capital costs are in the range of Rs. 2.4 to 3.6 million/mld. For the largest capacity plant at Agra, the unit life cycle cost (35 years) is comparatively on the lower side at Rs. 6.79 million/mld, while for smaller plants at Faridabad and Panipat they are close to Rs. 11 million/mld. Average life cycle costs of UASB plants are lower than those of the ASP plants, however, if additional polishing treatment or larger FPU retention time is considered to maintain parity in final effluent quality, the difference will narrow down.

Table 4.12 Key Decision Parameters of UASB based STPs

		Unit requirements				
	Capacity	**Land**	**Energy consumption**	**O&M costs (2003)**	**Capital costs (2003)**	**Life cycle costs (2003)**
STP location	**mld**	**ha/mld**	**kWh/mld**	**Rs. million/mld**	**Rs. million/mld**	**Rs. million/mld**
Panipat	10	0.30	15	0.17	3.4	10.90
Faridabad	20	0.29	17	0.13	3.6	10.88
Yamunanagar	25	0.28	15	0.11	3.3	9.82
Gurgaon	30	0.32	14	0.10	3.1	9.16
Panipat	35	0.29	14	0.09	3.2	8.87
Karnal	40	0.20	14	0.09	3.2	9.36
Gaziabad	56	0.23	14	0.08	2.4	6.67
Agra	78	0.26	11	0.07	2.4	6.79
Literature[1]		0.14-0.19#	Nil	-	2.9-3.7*	-
MOEF[2]		0.2	-	0.2	2.8-3.4*	-

1. Source : Arceivala, 1998
2. Source : MOEF, 1998
3. Capital and life cycle costs are excluding land costs.
4. Cost in the last two rows have been adjusted for year 2003 based on the WPI indices.
5. # Excluding post treatment requirement

Suitability of UASB technology

The anaerobic processes, in general, and the Up-flow Anaerobic Sludge Blanket (UASB) process in particular, have proved to be very attractive and successful pretreatment options for some high strength industrial wastewaters world over. Lettinga and coworkers carried out research to extend the application of UASB process for the treatment of domestic wastewater. Consequent to this research in The Netherlands, an experimental 5 mld pilot plant was commissioned under Indo-Dutch Assistance programme to assess the potential of UASB process for the treatment of domestic wastewater under the Indian conditions. It was argued that such a process will be advantageous due to (i) low energy requirement, (ii) less operation and maintenance cost, (iii) less sludge production, and (iv) potential for resource recovery through generation of electricity from biogas and utilization of sludge cakes for agricultural purposes.

Based on the initial results from the pilot plant studies, speculations were made that UASB is a good alternative to activated sludge process which otherwise consumes high energy to destroy waste organics and; stabilization ponds that require large land which may be very expensive. Subsequently, wide scale applications of UASB process were advocated under GAP and YAP. As a result one full scale 14 mld plant was built under GAP and sixteen full scale plants of varying capacities were built under YAP. By now, long term performance data on the 5 mld pilot plant and several full scale plants based on this technology are available. In retrospect following may be stated regarding the status of applying UASB process for domestic wastewater treatment in India :

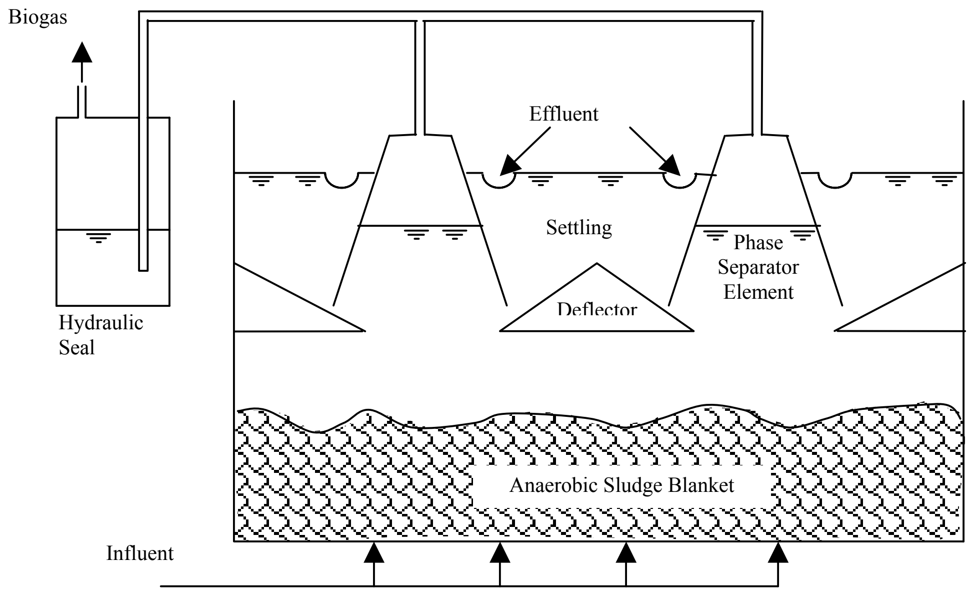
- UASB process with prior screening and degritting but without any primary settling has been able to bring down BOD of the domestic wastewater to 70 – 100 mg/l.

- The sludge produced from the UASB reactor is much less compared to the activated sludge process and easily dewatered within 7-10 d.
- Sufficient awareness exists about the UASB process, and it is possible to design, build and operate UASB based plants indigenously.
- Effluent from UASB reactor requires post treatment. The widely used post treatment is a Final Polishing Pond (FPU) with 1 d hydraulic retention time.
- The average hydraulic retention time through the plant is 32 h at an average depth of 2- 2.2 m.
- The land requirement for UASB plants is slightly less or comparable to the ASP based plants.
- The annual operation and maintenance cost of the plant is approximately 30 % of the ASP based plants.
- The routine operation of the plant is simple. However, the control of sludge wash out from UASB reactor is difficult and sludge withdrawal from the reactor requires skilled operations. In the absence of controlled sludge withdrawal, the plant performance is highly unstable and considerable variation in effluent quality occurs.
- Some plant performance data suggest that BOD of the FPU effluent can be below 30 mg/l, the effluent discharge standard for BOD for disposal into inland waters. However, most other studies and plant performance data including that of 5 mld pilot plant reveal that effluent BOD from FPU on an average lies in the range 70-100 mg/l which violates the effluent discharge standards for disposal into inland water bodies.
- In most plants the actual biogas production is less than that is assumed at the design stage.
- The removal of total and fecal coliforms is to the tune of 2-3 logs in UASB based plants with FPU, and is in general less than STPs based on technologies that maintain aerobic environments in the main biological units.
- The effluent from UASB based plants is anoxic, and in many instances has exhibited significant high initial/instantaneous oxygen demand creating adverse impact on the receiving bodies.
- The role of FPU as post treatment to UASB reactor effluent is not yet clear except that it may help in settling of solids that are washed out from the reactor. Prima facie, 1 day detention time is inadequate for DO improvement as it does not allow any aquatic plant (e.g., algae) growth.
- The options for post treatment proposed by various researchers are (a) facultative aerated lagoon with 1-3 days detention (b) a combination of duckweed ponds and WSP (c) a combination of facultative pond and maturation pond of at least 3 days detention each.

BOX 4.4 : TECHNOLOGY SHEET - UPFLOW ANAEROBIC SLUDGE BLANKET

A deep vertical reactor with arrangement for gas-liquid-solid separation at the top in which screened and degritted wastewater is allowed to flow upward through a bed/blanket of granular and flocculent mass containing consortia of anaerobic microbes that includes acid forming and methanogenic bacteria responsible for gasifying carbonaceous organic matter.

Schematics



Key features

- An improvisation of the septic tank concept
- Arrangement for distribution of the wastewater at or just above the floor of the reactor
- Thorough contact of wastewater organics with sludge bed/blanket
- Elaborate arrangement for gas-solid and solid-liquid separation and collection of biogas through gas domes
- Settling zone and arrangement for return of settled sludge back into the biologically active zone
- Collection of treated wastewater from the top of the reactor
- No mechanical components or external energy requirements in the reactor, thereby process not vulnerable to power cuts
- Low hydraulic retention time and hence smaller reactor size
- No primary treatment; suspended solids in the wastewater serve as carrier material for microbial attachment
- No external carrier material required for immobilization of microbes
- Recovery of gas with high calorific value
- Low sludge production
- Sludge with good dewatering characteristics
- Relatively simple routine operation and maintenance
- Biological activity can be restarted without any external seeding or special care after interrupted operations

Performance

UASB reactor can bring down the BOD of the domestic wastewater to 70-100 mg/l. In some cases effluent BOD as low as 30 mg/l has been reported. Most of the time suspended solids removal is good and can be as low as 50-100 mg/l. However, sludge washout from the reactor invariably occurs causing unstable performance, which leads to very high BOD and total suspended solids in the effluent. Strongly anoxic effluent does not enable its direct application for aquaculture or irrigation.

Specific requirements

- Use of anticorrosive materials/paints on exposed surfaces
- Frequent cleaning/desludging of distribution/division boxes and influent pipes
- Skilled supervision during start-up and for control of biomass levels within the reactor
- Post treatment of the UASB effluent is invariably required
- Control of toxic materials and sulfates in the wastewater

Land requirement

Capacity Q (mld)	Q ≤ 20	20 < Q ≤ 40	40 < Q ≤ 80	80 < Q	Literature*
Land (ha/mld)	0.3	0.3	0.25	nav	0.11 – 0.17

(* : Arceivala, 1998) : Excluding the post treatment requirement

Energy requirement

Technology energy requirements are essentially for operation of screen and grit chamber, sludge pump, and filtrate pump. Non-technology requirements correspond to office, lab, well, staff quarters. Typically the latter is more than the former. Combined energy consumption under different capacity ranges is as follows:

Capacity Q (mld)	Q ≤ 20	20 < Q ≤ 40	40 < Q ≤ 80	80 < Q	Literature*
Energy (kWh/mld)	17	14	11-14	nav	≈Nil

(* : Arceivala, 1998)

Options

- Exclusion of elaborate arrangements for gas collection, storage and utilization could enable further cost reduction
- Gravity sludge thickeners could enable reduced land requirements for drying beds
- Roughing filter as secondary step could enable solids removal as well as aeration
- Secondary settling tank instead of FPU could enable improved solids removal and reduce land requirement by excluding FPUs
- Facultative aerated lagoon with 3 days detention instead of a shallow FPU with 1 day would enable removal of both solids and anaerobicity and make the effluent at par with aerobic processes
- A combination of duckweed ponds and WSP
- A combination of facultative pond and maturation pond of at least 3 days detention each

Do's and don'ts

- Prevent mixing of industrial effluents with toxic elements and sulfates/sulfides
- Carefully monitor the reactor sludge levels and sludge withdrawal
- Regular painting/coating of corrosion susceptible materials/exposed surfaces

Capital cost

As on end of year 2003, the capital cost is found to be in the range of Rs 2.4 – 3.5 million per mld. Approximately 65 % cost is of civil works and remaining 35 % is for electrical and mechanical works. Unit capital costs excluding land costs for different capacity ranges are as follows :

Capacity Q (mld)	Q ≤ 20	20 < Q ≤ 40	40 < Q ≤ 80	80 < Q	Literature*
Cost (Rs. million/mld)	3.5	3.2	2.4	nav	2.9 – 3.7

(* : Arceivala, 1998. Values for 1995-96 have been updated by 31% based on WPI values for year 1995-96 and 2002-03(estimated))

Note : All costs correspond to year 2003

Average capital cost of the plants can be brought down if the elaborate system for gas collection and bio-energy generation is avoided. This conclusion stems from the fact that currently almost entire quantity of biogas is collected typically to be flared off and the duel fuel generators are not run for more than 1-3 hours/d. Considering higher cost of operation of duel fuel engines, lower dependence of plant on power and non-vulnerability of the process to power cuts, there is no incentive for the operating agency to exploit the energy value of the biogas.

Operation and maintenance

- Regular but controlled withdrawal of sludge
- Cleaning/desludging of division boxes and influent pipes
- Removal of scum and floating material from the settling zone

O & M costs

The O & M costs based on the data collected from various plants varies in the range of Rs. 0.1 – 0.17 lacs/annum. However, in general the present maintenance and operation practice is poor and needs significant improvements. Across various capacities the unit O&M costs are as follows :

Capacity Q (mld)	Q ≤ 20	20 < Q ≤ 40	40 < Q ≤ 80	80 < Q
O&M Cost (Rs. Million/mld/annum)	0.15	0.09	0.07	nav

Note : cost values correspond to year 2003

Life cycle costs

Life cycle costs excluding land costs and considering a life span of 35 years for the civil component and 7 years for the E&M component under different capacity ranges are given below:

Capacity Q (mld)	Q ≤ 20	20 < Q ≤ 40	40 < Q ≤ 80	80 < Q
Cost (Rs. million/mld)	10.9	9.3	6.7	Nav

Note : cost values correspond to year 2003

Advantages

- Minimal primary treatment of wastewater i.e. only screening and degritting is required
- Sludge handling is minimized
- Power supply interruptions have minimal effect on plant performance
- Can absorb hydraulic and organic shock loading

Disadvantages

- In general can not meet the desired effluent discharge standard unless proper post treatment is adopted.
- Effluent is anoxic and invariably exerts substantial initial/instantaneous oxygen demand
- Stability in performance is minimal unless sludge wash out is prevented
- Faecal and Total coliform removal is poor
- FPU with one day detention time is inadequate in polishing except for sludge settlement
- The atmosphere may be generally corrosive due to presence of hydrogen sulphide and ammonia in the air

Applicability

This technology is applicable with adequate post treatment such as Facultative Aerated Lagoon.

4.5 ADVANCED TECHNOLOGY OPTIONS

This section contains an assessment of the selected STPs which have been installed as pilots or on experimental basis adopting some of the advanced technologies. These are namely :

- BIOFOR technology based STP at Dr. Sen Nursing Home Nalla in Delhi
- Two stage ASP BIOFOR-F technology based STP at Rithala in Delhi
- Fluidized aerated bed (FAB) technology based STP at Molarband in Delhi
- FAB technology based STP at Lucknow
- Submerged aerated fixed film (SAFF) technology based STP at Holambi in Delhi

All these advanced technology based plants adopt aerobic processes with a fairly high degree of mechanical and electrical components, multistage treatment including physico-chemical steps, complex reactor and/or media arrangement and have several other innovative features for accelerated removal of suspended solids, sludge thickening, disinfection etc. These plants are designed to deliver effluent with final BOD of under 10 mg/l and SS under 20 mg/l with a high degree of consistency. Various features of each of the above plants are briefly discussed in the sections that follow.

BIOFOR TECHNOLOGY

Two STPs each of 10 mld based on BIOFOR technology (Biological filtration and oxygenated reactor) were installed on pilot basis at Dr. Sen Nursing Home Nalla and Delhi Gate Nalla in Delhi. The objective of setting up these STPs was to assess suitability of BIOFOR system, which is a patented technology, for very high end performance where land availability is a constraint and where the site is located in a prime and sensitive area. Under these constraints, the systems were required to be compact as well as free from any odour nuisance.

Moreover, it is understood that at the planning stage recycling of the treated effluent was envisaged for industrial application and therefore it was all the more important that the plant could consistently produce effluent of high quality. Subsequent to the commissioning of the plants, and due to unique circumstances, an agreement was reached between the sewage treatment authority and a power utility (thermal power plant) located adjacent to the STP for sale of effluent. As a result of this agreement, the treated effluent is being used as cooling water in the power plant and in exchange the STPs are getting free electricity. In view of the crucial role of these STPs for the power utility, of late the latter has agreed to take over their O&M responsibility as well.

A profile of the STP installed near Dr. Sen Nursing Home Nalla is presented in Appendix F and its salient features are described below. Life cycle cost analysis of this as well as four other STPs under the advanced technology category is presented in Table 4.13.

The main components of the treatment process of BIOFOR plant comprise coagulation and flocculation in a specially designed clarisettler, followed by two stage filtration through a special medial bed where organic degradation is facilitated by external oxygenation. It will be noticed that there are no primary or secondary clarifiers and conventional aeration reactor and as a result the entire system is very compact. Special design of the clarisettler enables simultaneous thickening of the sludge and thereby eliminates the need for a separate thickener and thus saves space.

Dosage of alum as coagulant is rather high at around 60 mg/l and then the sedimentation of flocs is enhanced by addition of polyelectrolites. In fact a bulk of the treatment takes place at this primary clarification stage where almost 90% of suspended solids and 70% of BOD are removed. The second stage of upflow rapid sand filtration is then considered more of a polishing treatment. In view of this, the technology can be characterised as a physico-chemical process and less of a biological process.

Table 4.13 Case Study and Life Cycle Cost Computation of Advanced Technology based STPs

Assessment parameter		BIOFOR, DSNH, Delhi	Two stage ASP BIOFOR-F, Rithala Delhi	FAB Molarband, Delhi	FAB, Lucknow	SAFF Holambi, Delhi
River action plan		YAP	GoNCTD	YAP	Gomti Action Plan	YAP
Process type		Physico-chemcial; and biological treatment in two stage aerated submerged filter	Two stage biological oxidation (ASP +BIOFOR F)	Extended aeration in two stage fluidized bed of plastic media	Extended aeration in two stage fluidized bed of plastic media	Two stage filtration through submerged plastic media with aeration
Capacity	**mld**	**10**	182	3	42	2
Hydraulic loading	%	100	88	10	100	50-60
Plant Area	ha	0.40	13.8	0.18	1.2	0.098
Area per mld	ha/mld	**0.04**	**0.08**	**0.06**	**0.03**	**0.05**
Performance						
Effluent BOD	mg/l	<10	<15	<10	<20	1.4
Effluent COD	mg/l	nav		88	<100	16
Effluent DO	mg/l	2-3	>1.5	1-2	1-2	na
Effluent SS	mg/l	<15	12-22	20	27	15
Effluent faecal coliform	MPN/100 ml	1.0E+06	nav	1.0E+05	1.0E+05	750
Sludge digestion		Not included	Included	Not required	Not required	Not required
Biogas generation	m^3/d	na	14,000	na	Na	na
Bio-energy generation	kWh/d	na	31,000	na	Na	na
Resource recovery - biogas	Rs. pa	na	**56,575,000**	na	Na	na
Resource recovery - sludge	Rs. pa	nil	nil	nil	Nil	nil
Resource recovery - effluent	Rs. pa	4,015,000	nil	nil	Nil	nil
Total resource recovery	Rs. pa	4,015,000	**56,575,000**	nil	Nil	nil
COMPUTATION OF LIFE CYCLE COST						
Contract Value of Plant Civil + E & M	Rs. million	53.9	914.7	13.8	126.6	14.0
% of Work Civil Works		58%	25%	33%	40%	40%
	Rs. million	31.3	228.7	4.6	50.6	5.6
% of Work E & M Works		42%	75%	67%	60%	60%

Assessment parameter		BIOFOR, DSNH, Delhi	Two stage ASP BIOFOR-F, Rithala Delhi	FAB Molarband, Delhi	FAB, Lucknow	SAFF Holambi, Delhi
	Rs. million	22.6	686.0	9.2	76.0	8.4
Year of construction		1998	2001	2003	2002	2003
Whole sale price index						
WPI : Year Of construction		132.8	155.7	159.7	161.3	159.7
WPI : (Dec 2003 estimated)		159.7	159.7	159.7	159.7	159.7
Cost of Plant (as in Dec 2003)						
Civil Works	Rs. million	37.6	234.5	4.6	50.1	5.6
E & M Component	Rs. million	27.2	703.6	9.2	75.2	8.4
Total Cost of Plant	Rs. million	64.8	938.2	13.8	125.3	14.0
Unit cost of STP	Rs. million/mld	6.5	5.2	4.6	3.0	7.0
Operation & Maintainance Costs						
Technology Power Requirement	kWh/d		32,000			
Non Technology Power Requirement	kWh/d		700			
Total Daily Power Requirement	kWh/d	2,200	32,700	400	4150	780
Unit power requirement	kWh/mld	220	180	133	99	390
O&M Charges for cogeneration system	Rs. million	-	2.4	-	-	-
Daily Power Cost @ Rs 4.80/ KWhr	Rs.	10,560	3,360	1,920	19,920	3,744
Annual Power Costs	Rs. million	**3.85**	**3.63**	**0.70**	**7.27**	**1.37**
Chemicals Costs						
Alum	kg/d	150	0	90	0	0
Polyelectrolyte	kg/d	10		3	0	0.25
Chlorine	kg/d	-	0	15	126	8
Caustic soda	kg/d	-	200	-	-	-
Alum @ Rs 4.30 / Kg	Rs. million	0.24	-	0.14	0.00	0
Ployelectrolyte @ Rs 280 /kg	Rs. million	1.02	0.2	0.31	0.00	0.03
Chlorine @ Rs. 9/kg	Rs. million	-	-	0.05	12.88	0.13
Caustic soda @ Rs. 13/kg	Rs. million	-	0.95	-	-	-
Total Chemicals Costs	Rs. million	**1.26**	**1.15**	**0.50**	**12.88**	**0.16**
Manpower Operation & Maintainance Cost	Cost/MM					

Assessment parameter		BIOFOR, DSNH, Delhi	Two stage ASP BIOFOR-F, Rithala Delhi	FAB Molarband, Delhi	FAB, Lucknow	SAFF Holambi, Delhi
Manager	18000	1	1	2/5	1	2/5
Chemist / Operating Engineer	8500	3	10	1/4	1	1/4
Operators	5000	8	15	1	6	1
Skilled Technicians	6500	8	25	2	8	2
Unskilled Personnel	3000	6	20	4	25	4
Cost of manpower	Rs. million	**1.84**	**4.81**	**0.47**	**2.20**	**0.47**
Repairs cost						
Civil Works per Annum as % of Civil Works Cost		0.5%	0.5%	0.5%	0.5%	0.5%
E&M Works as % of E&M Works Cost		3.0%	3.0%	3.0%	3.0%	2.0%
Civil Works Maintainance	Rs. million	0.19	1.17	0.02	0.25	0.03
E & M Works Maintainance	Rs. million	0.82	21.11	0.28	2.26	0.17
Annual repairs costs	Rs. million	**1.01**	**22.28**	**0.30**	**2.51**	**0.20**
Total annual O&M costs	Rs. million	**7.96**	**31.86**	**1.97**	**24.86**	**2.19**
Unit O&M costs	Rs. million/mld pa	**0.80**	**0.18**	**0.66**	**0.59**	**1.10**
Uniform present worth over life cycle of plant of 35 years @ 5% rate of interest						
Uniform present worth factor		16.37	16.37	16.37	16.37	16.37
Capatalised O&M Cost over 35 Years	Rs. million	239.18	3336.15	69.23	707.74	69.45
Capital cost of plant (2003)	Rs. million	64.8	938.2	13.8	125.3	14.0
Land Cost @ Rs 5 mill / ha	Rs. million	2.00	69.00	0.90	6.00	0.49
Life cycle cost (excluding land) (2003)	Rs. million	**304.00**	**4274.33**	**83.03**	**833.08**	**83.45**
Unit life cycle cost (2003)	Rs. million/mld	**30.40**	**23.49**	**27.68**	**19.84**	**41.73**

Notes

1. Capital costs for Rithala plant is indexed cost (for year 2001) of expenditure incurred over 6 years of construction

2. Repair costs are worked out on projected civil and mechanical costs for year 2003
3. Sludge from BIOFOR plant contains higher percentage of chemicals and polyelectrolites. Instead of digestion, it is transported to Okhla STP for drying and disposal. Therefore, land requirement shown above is excluding sludge drying beds
4. Sludge from FAB plants is stabilised and does not require digestion. It is dried in filter press or in drying beds and disposed off
5. For FAB plant the media is included under mechanical and electrical component with a life of about 7 years, however it may have a longer life
6. Resource recovery at DSNH STP is notional barter value of water for electricity, however it is not included in the life cycle cost calculations
7. Actual power consumption values have been taken for various plants
8. Rithala plant is meeting its almost entire energy requirements from the cogeneration system. Only externally bought energy has been included in cost calculations. During monsoon seaoson sludge availability goes down which leads to low biogas generation and thereby low bio-energy
9. Considering life span of 7 years for electrical and mechanical parts, four replacements at 2003 prices are considered while calculating the capitalised O&M costs over 35 years
10. Land costs are not included in the life cycle costs as their rise or fall is not represented by CPI and there would be significant variations among different towns and over the years. However, ball park estimates are provided if one would like to add them with the plant costs
11. Whole sale price index is taken from 'Statistical Outline of India 2002-2003', Tata Services Limited and the available value for 2002 is modified for year 2003 by (-)1%

Performance of the plant

As only a small fraction out of the flow of a major drain is lifted through pumps of designated capacity, it has been possible to consistently maintain 100% hydraulic loading on the plant. Under this uniform loading, the plant performance has also been consistent. The influent and effluent quality data is shown in Table 4.14. In recent months, the average BOD has been well below 10 mg/l and SS below 15 mg/l. Corresponding removal efficiencies across the plant are 94-99.9% and 98% respectively. However, from pathogen removal point of view there is wide variation and maximum values are of the order of 10^6 /100 ml while average removal is of the order of 2 on the log scale. As seen from these results, the effluent is of very high quality and it is not surprising that the power utility has agreed to barter it with electricity.

Table 4.14 Performance of Biofor Based STP at Dr. Sen Nursing Home Nalla, Delhi

	STP at Sen Nursing Nalla - 10 mld					
	BOD			Suspended solids		
Month	Inlet	Outlet	% rem	Inlet	Outlet	% rem
January ‘03	547	1	99.8	1585	37	97.7
February ‘03	269	2	99.3	453	11	97.6
March ‘03	269	2	99.3	453	11	97.6
April ‘03	242	14	94.2	633	12	98.1
May ‘03	246	6	97.6	469	11	97.7
June ‘03	291	2	99.3	791	14	98.2
October* ‘03	357	5	98.6	746	11	98.5
Average removal			98.2			97.8

(Source : MOEF, 2003 and * : Effluent quality log book maintained at the plant)

Land and power requirements

As bulk of the treatment is brought about by physico-chemical operations and solid removal is through high rate tube settlers, the foot print area of the plant is very low at 0.04 ha/mld (excluding sludge treatment component) compared to that of 0.25 to 0.4 ha/mld for ASP and 1 to 2.8 ha/mld for WSP. Average power requirement of the plant is about 220 kWh/mld. In addition, again due to its physico-chemical operations and high level of aeration, the odour nuisance is almost absent.

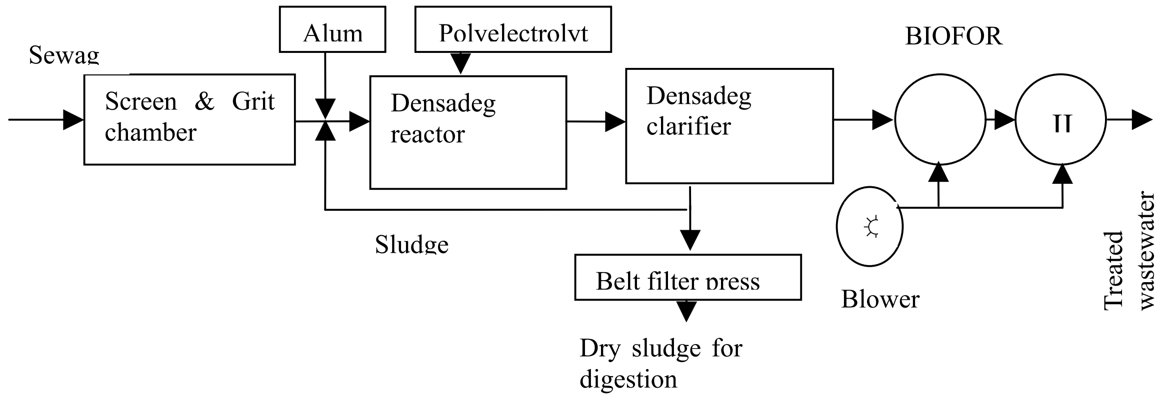
Thus BIOFOR technology scores well on land requirement aspects as well as on aesthetic aspects and could be an option where land availability is low and where the plant is to be located in a sensitive or high value area. Moreover this technology offers a sound and reliable option for situations where very high level of treated effluent quality is required on a consistent basis and where the high level of initial and recurring costs is justified by total recycling of the water.

Investment costs

Unit capital cost (2003) of this plant is about Rs. 6.5 million/mld and the unit O&M cost (2003) is about Rs. 0.8 million/mld/annum. Unit life cycle cost is assessed to be Rs. 30.4 million/mld. In comparison to an activated sludge process based plant, these are about twice the corresponding values. In comparison to a WSP system, the life cycle cost is about 5 to 10 times high.

BOX 4.5 : TECHNOLOGY SHEET - BIOFOR TECHNOLOGY (Biological filtration and oxygenated reactor)
A combined system involving physico-chemical operations for primary clarification and two stage granular filtration with enhanced external aeration

Schematic



Key features of the technology

- Enhanced primary treatment with addition of coagulants and flocculants
- High rate primary tube settlers and integrated thickening offering space economy
- Two stage high rate filtration through a biologically active media and with enhanced external aeration
- Co-current upflow movement of wastewater and air enable higher retention and contact
- Treatment scheme excluding secondary sedimentation but recycling of primary sludge
- Deep reactors enabling low land requirements
- A compact and robust system

Performance

- Suspended solids and BOD removal of 90% and 70% respectively in the primary clarifier
- High quality effluent with BOD under 10 mg/l and total system efficiency of 94-99.9%
- Low turbidity with suspended solids under 15 mg/l and total system efficiency of 98%
- Pathogen removal of 2 on the log scale

Specific requirements

- Addition of alum as coagulant (~ @ 60 ppm)
- Polyelectrolyte for high rate sedimentation (~ @ 0.2-0.3 ppm) in tube settlers
- Compact clarifier (Densadeg) with sludge thickening
- Polyelectrolyte for sludge dewatering (~ @ 3 kg/t of dry solids)
- Sludge recycling to Densadeg reactor
- Special and patented granular filter media 'Bioloite' made of clay
- External aeration for biofilters
- Backwash of BIOFOR bed and recycle of the wastewater
- Treatment (digestion) and disposal of sludge from clarifier (not provided at the STPs due to space limitations)
- Power consumption around 220 - 335 kWh/ml.

Land requirement

Capacity Q (mld)	$Q \leq 5$	$5 < Q \leq 10$	$10 < Q \leq 20$	$20 < Q \leq 50$
Land (ha/mld)	NA	0.04	NA	NA

The above unit area does not include land requirement for sludge drying beds.

Sludge production

Thickened sludge @ 1 t/mld – about 14.5 cum/mld

Options

- Sludge drying beds
- Sludge digestion in internal or external facility
- Tertiary treatment for disinfection

Capital costs

Capacity Q (mld)	Q ≤ 5	5 < Q ≤ 10	10 < Q ≤ 20	20 < Q ≤ 50	50 < Q ≤ 100	100 < Q ≤ 200
Cost (Rs. million/mld)	na	6.5-8.1	na	na	na	na

(Costs correspond to year 2003)
Note : Only two references are available for BIOFAR STPs of 10 mld capacity

Operation and maintenance

- Regular and high dosage of alum and polyelectrolytes
- Cleaning of tube settlers, sludge withdrawal and recirculation
- Sludge treatment and disposal

O&M costs

Capacity Q (mld)	Q ≤ 5	5 < Q ≤ 10	10 < Q ≤ 20	20 < Q ≤ 50	50 < Q ≤ 100	100 < Q ≤ 200
(Rs. million/mld/ year)	na	0.86	na	na	na	na

Annual O&M costs comprise of contract cost (48 lakh), electricity (36 lakh) and sludge transport (2 lakh).

Life cycle costs

Capacity Q (mld)	Q ≤ 5	5 < Q ≤ 10	10 < Q ≤ 20	20 < Q ≤ 50	50 < Q ≤ 100	100 < Q ≤ 200
(Rs. million/mld)	na	30.4	na	na	na	na

Costs correspond to year 2003, an expected life span of 35 years and 5% rate of interest.

Advantages

- Compact layout as a result of high rate processes
- Higher aeration efficiency through co-current diffused aeration system
- Space saving as secondary sedimentation is dispensed
- Able to withstand fluctuations in flow rate and organic loads
- Compliance with stricter discharge standards
- Effluent suitable for industrial applications e.g., cooling water or ground water recharging
- Effluent suitable for UV disinfection without filtration
- Absence of aerosol and odour nuisance in the working area
- Absence of corrosive gases in the area
- Lower operation supervision enables lesser manpower requirement

Disadvantages

- Continuous and high chemical dosing in primary clarification
- Undigested sludge from primary clarification requiring post treatment

Applicability

The **BIOFAR** treatment system is suitable under complex situations requiring :
- Consistently high effluent quality
- Compact lay-out in congested locations
- Minimum impact on the local environment (e.g., odour control) in sensitive locations

4.6 HIGH RATE ASP BIOFOR-F TECHNOLOGY

With regard to the Indian wastewater treatment scenario, the 182 mld STP at Rithala in Delhi represents a state-of-the-art system which was commissioned in 2001. This plant does not fall under the scope of YAP, however it was implemented concurrently by the Govt. of NCT Delhi. Case study of this plant has been included here for its novelty and sophistication which enable consistently high degree of treatment. This plant has also been designed for very high end performance involving multistage treatment. However, unlike the DSNH STP described in the previous section, effluent at this plant after such high degree of treatment is currently not being utilised for any gainful application.

Profile of the plant is presented in Appendix G while a comparative computation of life cycle costs is presented in Table 4.13. A separate technology sheet is presented in Box 4.6 and the salient features are described below.

Some of the unique features of the main treatment process are absence of primary sedimentation, high rate activated sludge process, second stage aeration and granular filtration through a biologically active filter media. The activated sludge process is operated under high rate conditions by maintaining higher organic loading on the reactor and keeping MLSS concentration of around 4000 mg/l. Subsequent granular filtration is carried out through a bed of multiple media with the top layer comprising specially produced clay granules called 'biolite'. Residual organic matter gets biologically oxidised when the pre-aerated effluent passes through the 'biolite' layer.

Moreover, the grit chamber is also based on dissolved air floatation system where the concentrated stream is separated in another tank and the grit is removed mechanically through a screw pump/impeller. This type of grit chamber offers high removal efficiency as well as involves least occupational health hazard typically seen at other STPs.

In addition to the main process line, the plant has special sludge treatment arrangement comprising thickening through dissolved air floatation system and anaerobic digestion under controlled temperature conditions. The biogas processing and utilisation stream comprises chemical desulpherisation and dynamic cogeneration of electrical and thermal energy through state-of-the-art biogas engines.

Performance of the plant

With regard to the final effluent quality, the process scheme is apparently guaranteed to produce effluent with BOD and SS concentration below 15 mg/l and 20 mg/l respectively. As shown in Table 4.15, under current hydraulic loading of 88% the plant is achieving designed effluent quality. Coliform concentration is not monitored and therefore the final value in treated effluent or process removal rates are not available. However, typical removal of 2 order of magnitude is expected considering sustained aerobic conditions and filtration.

Table 4.15 Performance of High Rate Asp Biofor-F Technology based STP

	Design values		Current actual values	
	BOD (mg/l)	**SS (mg/l)**	**BOD (mg/l)**	**SS (mg/l)**
Influent	200	410	130	230
Effluent	15	20	9-16	12-22

Resource recovery

Besides the high quality effluent, the plant scores high on biogas generation and its utilisation for electricity generation. As a result of controlled temperature operation and continuous mixing through gas circulation, the digesters produce about 14,000 cum of biogas/day. This biogas is utilised for power generation in state-of-the-art biogas engines and the available waste heat is utilised for heating the sludge to about 24 to 26º C. Though this temperature is not close to the optimum of 37º C for mesophilic digestion (as the available waste heat is not enough) it is still effective as it prevents wide fluctuations and disruption of bacterial activity typically observed at other STPs during winter season. The performance of the digesters can be gauged from the fact that they are guaranteed to meet almost 85% of the total power requirements of the entire STP. Against a requirement of 36,000 kWh/d, the plant is authorised to draw only about 5000 kWh/d from the grid and the rest it is supposed to meet from captive generation through the biogas driven gas engines. Under the current hydraulic and organic loading the plant is able to generate about 32,000 kWh/d of electricity (and an estimated 40,000 kWh/d of thermal energy). However, during monsoon season, due to dilute wastewater the quantum of sludge generation and as a consequence the biogas and power generation are reported to go down. The annual savings on energy costs are estimated to be of the order of Rs. 56 million which constitutes a significant resource recovery.

Land and power requirement

The treatment system is effective in removal of dissolved organics and suspended solids in a comparatively small plot of land. While the approach of excluding primary sedimentation leads to higher organic load on aeration tank, but it also avoids the need for a separate primary thickener. The combined effect of these features and high rate operations enables economy on land requirement. The unit land requirement of the plant is about 0.08 ha/mld as compared to that of 0.25 to 0.4 ha/mld for ASP and 1 to 2.8 ha/mld for WSP.

On the other hand, the unit power requirement of the plant is about 180 kWh/d which is comparable to ASP plants described earlier. However, here the distinguishing feature is meeting 85% of requirements through captive generation of bio-energy which helps in reducing the operation costs.

Investment costs

In view of the high level of mechanisation and sophistication, undoubtedly the initial costs are high at Rs. 5.2 million/mld compared to those of ASP plants which are around Rs. 2.2 to 3.3 million/mld. However, due to captive energy generation the recurring cost of the plant is only Rs. 0.18 million/mld/annum as against that of ASP plants which is found to be between Rs. 0.4 to 0.5 million/annum/mld.

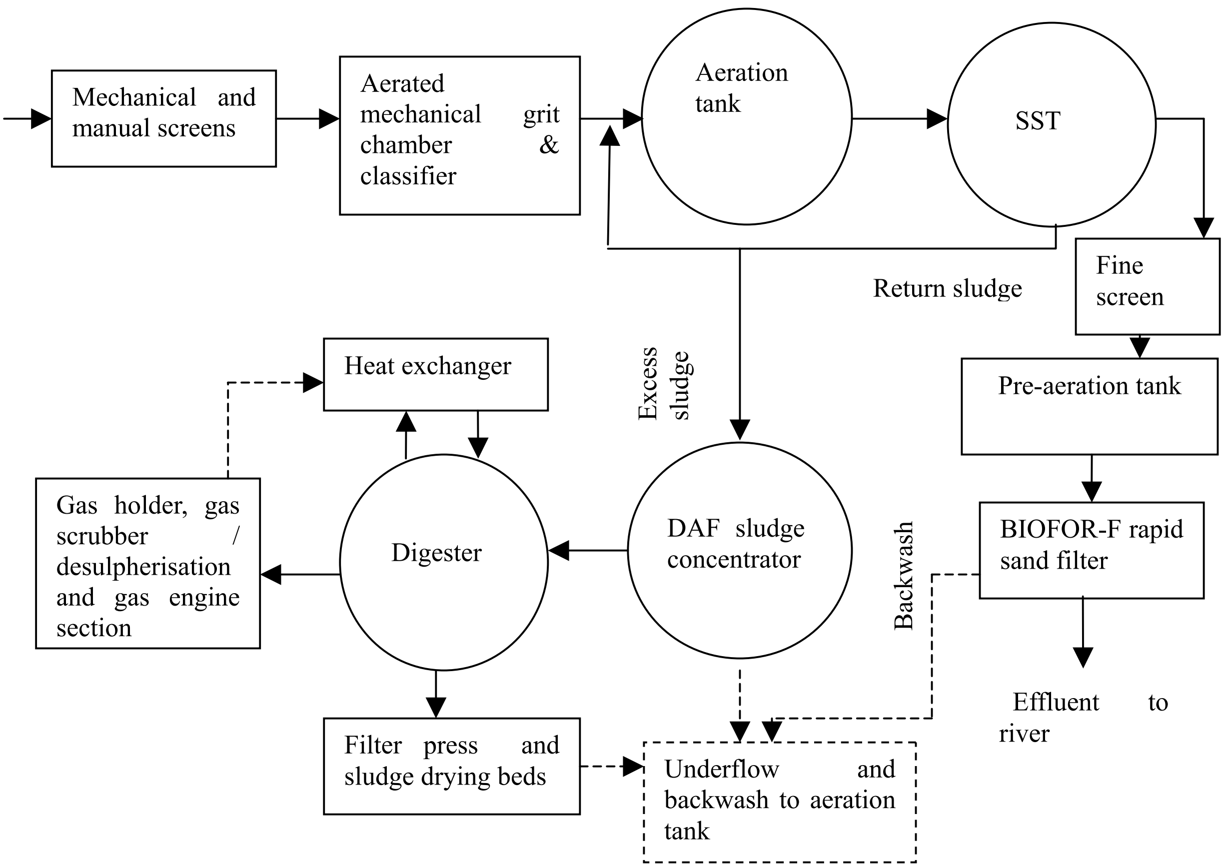
Unit life cycle cost over a span of 35 years is estimated to be over Rs. 23 million/mld compared to Rs. 12 to 16 million/mld for the ASP plants. One of the reasons is high percentage of E&M component which may require replacement every 7-10 years.

While clearly the life cycle cost of this technology is well above that of the ASP and understandably other technology based STPs, it offers an efficient and compact solution for meeting high quality on a consistent basis. As in case of the previous plant, this type of technology may be appropriate only under high demanding situations where the effluent could be recycled for industrial applications and thereby justify high initial and recurring costs.

BOX 4.6 : TECHNOLOGY SHEET - HIGH RATE ACTIVATED SLUDGE BIOFOR - F TECHNOLOGY

High rate activated sludge process with improvised reactor and aeration configuration followed by second stage aerobic biological degradation in a rapid sand filter comprising special active filter media

Flow scheme



Notes :
1. DAF : Dissolved air floatation system for sludge concentration
2. BIOFOR-F : Multimedia down flow rapid sand filter
3. In addition, a 1 mld polishing plant is installed for meeting the service water requirements

Key features

- In general, the plant has high level of mechanisation and sophistication
- The flow scheme excludes primary sedimentation tank
- Superior aerated grit chamber and classifier
- Circular aeration tank with tapered air diffusion system
- Second stage aeration and rapid sand filtration through a biologically active filter media
- Dissolved air floatation for sludge thickening
- Digester heating and temperature controlled anaerobic sludge digestion
- Mixing of digester contents through biogas
- Dynamic cogeneration of electrical and thermal energy through gas engines

Specific requirements

- Multiple grade of filter media for combined rapid filtration and biological oxidation

- Poly electrolytes for sludge thickening in filter press
- Gas cleaning chemicals and bioreactor for desulpherisation

Options
None, as the plant is complete in all respects

Land requirement
- Unit land requirement : 0.08 ha/mld

Power requirement
- Unit power requirements : 180 kWh/mld
- 85% requirement being met through captive generation from biogas cogeneration system

Performance
Effluent BOD < 15 mg/l and SS < 20 mg/l respectively over a wide range of hydraulic and organic loading.

Sludge production
- Post digester sludge volume is about 8.1 m^3 per million litre of sewage treated
- Post sludge drying beds the volume is 1.5 m^3 per million litre of sewage treated at around 40% dry solid

Biogas generation
- Biogas generation from sludge digestion : 77 m^3/d

Capital costs
- Unit Capital cost (2003) : Rs. 5.2 million/mld

O&M costs
- Unit O&M costs (2003) : Rs. 0.18 million/mld/annum

Life cycle cost
- Unit life cycle cost (2003) over 35 years : Rs. 23.5 million/mld

O&M aspects
- The activated sludge process is operated as a high rate aeration process with volatile suspend solids in the range of > 4000 mg/l and DO around 2 mg/l
- Circular aeration tanks with tapered arrangement for submerged diffused aeration enable efficient control over oxygen demand - supply conditions
- Sludge recirculation and wasting is continuous which provides consistency in the operation of aeration tanks as well as the digesters
- Sludge thickening through dissolved air floatation enables 4 fold increase in dry solids concentration
- Severe frothing problem is experienced in downstream units e.g., aeration after secondary settling tank, BIOFOR-F, conveyance channels etc.
  - High skilled manpower is required for operation of different reactors, digesters, gas cleaning system and cogeneration system.

Advantages
- Compact layout as a result of high rate processes
- Higher aeration efficiency through diffused and tapered aeration system
- Space saving as primary sedimentation is dispensed
- Compliance with stricter discharge standards
- Effluent suitable for high end industrial applications
- Stable digester performance and consistent gas production
- Almost self sufficient in energy requirement due to gas engine based cogeneration system
- Absence of aerosol and odour nuisance in the working area

Disadvantages
- None, except high life cycle cost

Applicability
The high rate activated sludge cum BIOFAR-F treatment system is suitable under complex situations requiring :
- Higher effluent quality for recycling purposes
- Compact large capacity plants under limited land availability situation
- Large installations with option for bio-energy generation
- Minimum impact on the local environment (e.g., odour control) in sensitive locations

4.7 FLUIDIZED AERATED BED TECHNOLOGY

Two fluidized aerated bed (FAB) technology based STPs were installed under YAP on a pilot scale each for a capacity of 3 mld. In addition, a full scale plant of 42 mld has been recently commissioned in Lucknow under Gomti River Action Plan. In view of the novelty of the technology and claimed high performance by the technology providers, one of the pilots located at Molarband in Delhi and the Lucknow plant have been briefly covered under the current study. A technology sheet on FAB is presented in Box 4.7 and key aspects are covered in Table 4.13 which compares all the STPs under advanced technology category. Salient aspects are discussed in the paragraphs that follow.

Process scheme

The flow scheme comprises application of screened and degritted sewage without primary sedimentation to two fluidized aerated bed reactors which essentially operate in series. This is followed by secondary sedimentation in lamella settlers.

The two FAB reactors are 5 m deep each offering a detention time of only 45 minutes. The reactors are aerated through a submerged aeration system. However, their unique feature is the presence of special plastic media which is used as the base material for the growth of the biomass. The media is about 2 cm in diameter and has a height of about 1 cm. Internal structure of the media is such that it offers large specific surface area for growth of the biomass. Quantity of media is not specified by the technology provider, but it is adjusted at the time of commissioning according to the expected organic load and desired effluent quality.

Because of the combined effect of the low density of media, hydraulic arrangement and submerged aeration, the bed of the media is kept in fluidized form. As a result the FAB rectors function as hybrid of attached and suspended growth processes offering advantages of both. The flow regime in the reactor is completely mixed type which again helps in higher contact between the biomass and the dissolved organics.

In order to prevent carry over of the media, special submerged stainless steel screens are installed at the outlet of FAB reactors. However, if bar screens at the beginning of the plant are not effective in removing plastic sheets, there is risk of clogging of the submerged screens and thus disruption in hydraulic flow through the plant. To prevent this situation, special air flushing valves are installed at these screen which operate intermittently.

As a large quantity of the biomass is grown and retained on the media, there is no requirement for sludge recirculation and associated process monitoring for maintaining a specified MLSS concentration. Apparently the process operates at a low food to micro-organism ratio and from that point of view it corresponds to an extended aeration system. However, from hydraulic retention point of view it achieves the same level of performance in a much shorter period of only 90 minutes compared to 12 hours or above in the latter. As the sludge produced from the FAB reactors is in fully stabilised form, the technology does not require a sludge digester.

The systems installed at Molarband and Lucknow conform to the above general arrangement and principle of treatment, there are minor location specific differences. The Molarband plant is designed as a decentralised sewage treatment facility in a congested low income locality and it receives concentrated sewage from 18 community toilet complexes which are connected to the sewerage network. As a result it has adopted additional feature of concurrent coagulation and flocculation. Moreover, due to space constraints, it has adopted belt filter press instead of the typical drying beds for sludge treatment.

On the other hand, at Lucknow the influent is diluted as it is lifted from the outfall of an open drain and therefore addition of coagulants and flocculants is not included. The sludge after thickening is sent directly to sludge drying beds.

In order to comply with the norm for Faecal coliform level in the final effluent, at both the plants the tertiary treatment step comprises chlorination with a dosage of 2-4 ppm and contact time of 20-30 min. While at Molarband a separate contact chamber has been provided, at Lucknow an additional circular wall around the lamella settler tank provides the necessary volume for disinfection to take place.

Land and power requirements

As a result of the compact design, the foot print area of the Molarband and Lucknow plants are very low at 0.06 ha/mld and 0.03 ha/mld. Similalry the power requirements are 133 kWh/mld and 99 kWh/mld respectively. In case of a typical extended aeration system the corresponding values are 0.1 ha/mld and 228 kWh/mld respectively (Arceivala, 1998). Thus in comparison to the latter type of system, a FAB technology based plant offers significant land and energy economy. The lower energy requirements could be attributed to arrangement for biomass retention and submerged aeration system.

Performance of the plant

With regard to the performance of the plants, the influent and effluent quality from grab sample is shown in Table 4.16. While the Molarband plant is receiving only one tenth of the designed flow, it carries higher organic and solids load than what is typically found in sewage. Compared to the nalla flow lifted at Lucknow, it is almost 3-4 times stronger in BOD and SS values and corresponding removal efficiencies are found to be 97%.

The plant at Lucknow is receiving almost 100% hydraulic loading. While removal efficiencies are some what lower, the final effluent quality is well within the discharge standards. At times the plant has been subjected to hydraulic overloading to the extent of 62 mld (48% overloading). It is expected that the increased surface overflow rate would lead to wash out of solids from the reactor and the tube settler. However, as per the available effluent quality data monitored by the O&M agency, the suspended solids and BOD concentrations are found to be 26 mg/l and 24 mg/l respectively. These values are quite in line with those observed on the days of normal flow. However, it must be noted that the average influent BOD is way below the designed BOD of 250 mg/l and on the day of overloading under consideration it was found to be only 140 mg/l.

It should be noted that the final effluent characteristics correspond to post chlorination stage and undoubtedly this also helps in reducing the chemical and biological oxygen demand to a certain extent. Effluent quality at pre-chlorination stage is not monitored and therefore removal efficiency exclusively from the FAB reactors can not be commented upon.

Investment costs

Unit capital costs of Molarband and Lucknow plants are Rs. 4.6 million and Rs. 3 million/mld respectively. A life cycle cost analysis for both plants has been carried out on the same lines as for all other STPs covered under the study. Unit life cycle costs for Molarband plant comes to about Rs. 29 million/mld and that for the large capacity plant at Lucknow comes close to Rs. 20 million/mld. Apparently the cost of proprietary plastic media in the initial cost is found to be high at around 30% of the total. On the other hand, the life cycle costs for ASP based plants are in the range of Rs. 12-16 million/mld and for WSP based plants they are in the range of Rs. 3-6.5 million/mld. In comparison, the unit life cycle cost for BIOFOR based DSNH STP is Rs. 30 million/mld and that for a much higher capacity STP at Rithala is Rs. 23.5 million/mld.

Table 4.16 Performance of FAB Technology based STPS

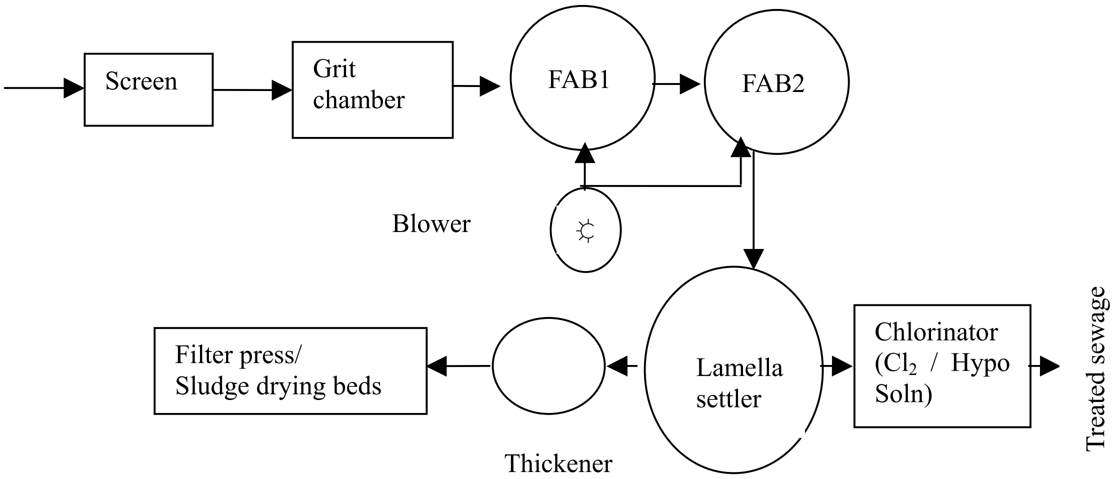
		Lucknow			Molarband, N. Delhi		
	Unit	Influent	Effluent	% removal	Influent	Effluent	% removal
BOD	mg/l	120	19	84	357	9.2	97
COD	mg/l	260	68	74	920	88	90
SS	mg/l	140	27	81	650	20	97
Faecal Coliform	MPN/ 100 ml	9×10^6	600	99.9933	10^7	640-730	99.993

(Source : Plant log book at Lucknow and Molarband, New Delhi, 2003)
Note : Effluent characteristics correspond to post-chlorination stage.

BOX 4.7 : TECHNOLOGY SHEET - FLUIDIZED AERATED BED TECHNOLOGY

A submerged attached growth aerobic process having fluidized bed of plastic media as the base for biofilm in deep reactors; the system works as a hybrid of activated sludge and tricking filter processes without the complexity of sludge recirculation and MLSS management.

Schematic



Key features of the technology

- A compact and robust system involving extended aeration process with submerged aeration
- Biomass growth on fluidized bed of plastic media enabling retention of biomass and long solid retention time in the reactor leading to low 'food to micro-organism ratio' and higher organic removal
- Two stage biological oxidation
- Flexibility in handling organic load by adjusting quantity of fluidized media
- Treatment scheme excluding primary sedimentation and sludge digestion
- Reactors up to 5 m deep enabling low land requirements
- Tube settlers again offer space economy
- Ability to withstand limited organic overload

Specific requirements

- Special grade plastic proprietary media custom made for offering high specific surface area
- Diffused aeration system
- Submerged stainless steel screens at the outlet of FAB reactors to prevent media overflow
- Tube settlers for compact clarifier

Options

- Addition of coagulant and polyelectrolyte for compact plants
- Tertiary treatment of chlorination
- Sludge treatment through thickener and bag filter press or drying beds

Land requirement

Capacity Q (mld)	Q ≤0.25	0.5 < Q ≤ 1	1 < Q ≤10	10 < Q ≤ 50
Land (sqm/mld)	600	600	600	300

Power requirement

- Electrical energy requirement between 99 to 170 kWh/mld

Performance

- High BOD removal with effluent concentration under 10 mg/l
- High suspended solids removal with effluent concentration under 20 mg/l
- Faecal coliforms removal of the order of 2-3 on log scale at FAB-2 stage

Dos and don'ts

- Effective multistage self cleaning screens required to prevent choking of FAB reactor outlets
- Adequate sludge storage facility or sludge drying beds to be provided

Capital costs

Capacity Q (mld)	Q ≤ 0.25	0.5 < Q ≤ 1	1 < Q ≤ 10	10 < Q ≤ 50
Cost (Rs. Million/mld)	480	200	4.6	3-5

Note : Apparently, the plastic media constitutes about 30% of the plant cost.
All costs are for year 2003

O&M costs

Capacity Q (mld)	Q ≤ 0.25	0.5 < Q ≤ 1	1 < Q ≤ 10	10 < Q ≤ 50
Cost (Rs. Million/mld/annum)	na	na	0.74	0.59

Life cycle costs

Capacity Q (mld)	Q ≤ 0.25	0.5 < Q ≤ 1	1 < Q ≤ 10	10 < Q ≤ 50
Cost (Rs. Million/mld)	na	na	29.1	20

O&M aspects

- Requires effective multi stage screens to prevent chocking of submerged screen at FAB outlet and tripping of system due to plastic bags and pouches
- Calibration of treatment capacity by adding or removing plastic media within 10-50% range
- Possibility of chocking at FAB outlet due to fluidized media. Requires effective air flushing value to prevent tripping of the system
- Blockage of media in case of excess biomass growth or low hydraulic loads
- Longer shutdowns may lead to septic conditions
- Restarting after a long shutdown may take long to stabilise
- Uncertainty regarding durability of media under varying climatic conditions
- Lack of availability of additional quantity of media which is a proprietary item may cause operational difficulties

Advantages

- Exclusion of primary treatment step of sedimentation
- Deep reactors enabling small space requirements
- Ability to effectively treat dilute domestic wastewaters
- Flexibility in calibrating the treatment capacity
- Elimination of the need for sludge recirculation and monitoring of MLSS in the reactor
- Capacity to handle shock loads
- Low head loss in the fluidized filter bed
- Low and stabilised sludge production eliminating the need for sludge digestion
- Simple and reliable operation
- Absence of odour and improved aesthetics
- Absence of emission of corrosive gases

Disadvantages

- Reliance on patented filter media
- Reliance on flocculants, polyelectrolyte and chemical disinfectant (optional)
- Requires skilled manpower
- Choking of reactor due to floating plastic matter

Applicability

The FAB technology based system is particularly applicable for :

- small to medium flows in congested locations
- sensitive locations
- decentralised approach
- reliving existing overloaded STPs

4.8 SUBMERGED AERATION FIXED FILM TECHNOLOGY

Along with two pilots described in the previous section, two additional pilots of 2 mld each have been installed under YAP in Delhi based on submerged aeration fixed film (SAFF) reactor design. As in case of the pilots on FAB, here again the objective was to provide a decentralised facility for a low income congested locality. Thus limited foot print of the plant was the main criteria for trying out the technology. One of the two plants located at Holambi was covered during the study. A technology sheet on SAFF is presented in Box 4.8 and key aspects are covered in Table 4.13 which compares all the STPs under advanced technology category. Salient aspects are briefly discussed in the paragraphs that follow.

Process scheme

The flow scheme comprises application of screened and degritted sewage without primary sedimentation to two trickling filter reactors which essentially operate in series. This is followed by secondary sedimentation in lamella settlers.

The media in the trickling filter comprises fixed corrugated plastic sheets which are arranged in the form of blocks stacked in multiple layers. The media depth is about 3.6 m while the side water depth in the reactor is 6 m. The biological oxidation process is enhanced through submerged aeration provided at the bottom of the trickling filters. The total hydraulic retention time in two reactors is close to 10 hours which is almost 7 times of what is provided in the FAB reactors.

As in case of the previous section, here also there is no digester or recirculation involved. The sludge comes out in stabilised form which is thickened and then dewatered in a filter press. A tertiary treatment has been provided for pathogen removal through chlorination.

Land and power requirement

On account of the deep reactors and high rate tube settlers, the plant offers a compact design. The foot print area is around 0.05 ha/mld which compares well with other systems in the advanced technology category. However, unit power requirements of this technology turn out to be rather high at 390 kWh/mld, as compared to FAB technology which requires any where between 99 to 170 kWh/mld.

Performance of the plant

Functioning of the plant has been affected due to clogging of the fixed plastic media. As the flow scheme does not include primary sedimentation and the screen are unable to completely remove plastic objects, this problem has been experienced several times during first year of operation. As mentioned earlier similar problems have been faced at conventional trickling filter plants which have led to their closure and decommissioning.

As per the information from the technology provider, from effluent quality point of view the plant has been able to achieve BOD as low as 1.4 mg/l and SS around 15 mg/l.

Investment costs

Unit initial invest cost of the plant is Rs. 7 million/mld. On account of higher power consumption, the unit O&M cost is also found to be Rs. 1.1 million/mld/annum. Moreover, its life cycle cost is found to be over Rs. 41 million/mld. Comparing these figures with FAB technology based plants, which is the closest competitor under the advanced technology category, all of them are found to be almost one and a half to two times higher. In fact, the unit life cycle cost of this plant comes out to be the highest among all technology categories beating the robust and sophisticated plants at Rithala and DSNH by a margin of 40 to 80% respectively.

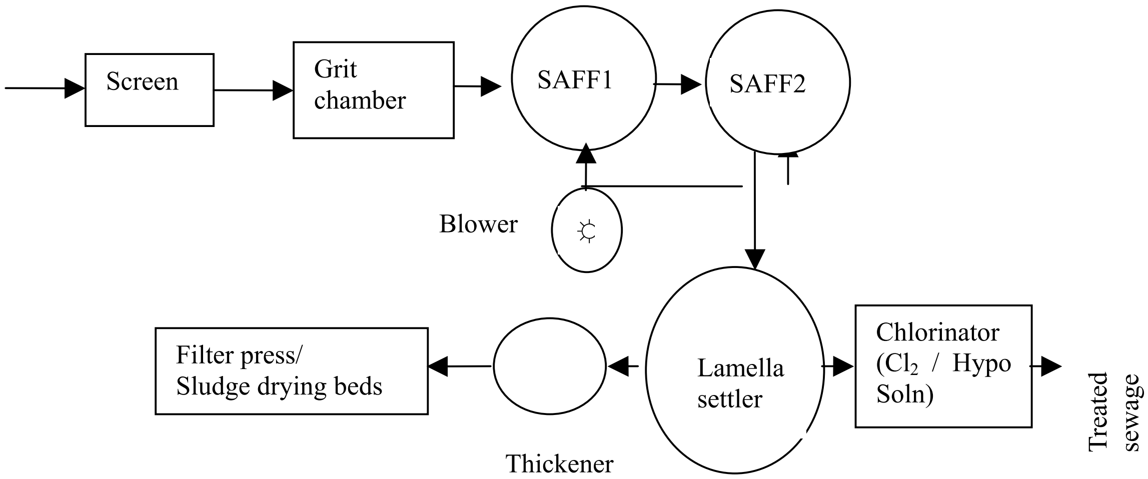
4.9 COMPARISON OF ADVANCED TECHNOLOGY PLANTS

It is seen that all the advanced technology plants are undoubtedly able to deliver a high quality effluent as claimed by the respective technology providers. The compactness of these technologies is reflected in their smaller foot print area which is between 0.03 to 0.08 ha/mld vis-à-vis ASP which typically requires between 0.2 to 0.4 ha/mld, and WSP which takes any where between 1 to 2.6 ha/mld. Thus they offer tremendous space economy.

BOX 4.8 : TECHNOLOGY SHEET – SUBMERGED AERATION FIXED FILM TECHNOLOGY

A submerged two stage tricking filter process having fixed bed of plastic media as the base for biofilm in deep reactors with enhanced aeration

Schematic



Key features of the technology

- Essentially a trickling filter with enhanced oxygen supply through submerged aeration
- Unconventional plastic media offering high void ratio and specific area compared to stone and aggregates
- Large biomass and long solid retention time in the reactor leading to low 'food to micro-organism ratio' and higher organic removal
- Two stage biological oxidation
- Treatment scheme excluding primary sedimentation and sludge digestion
- Reactors up to 6 m deep enabling low land requirements
- Tube settlers again offer space economy

Specific requirements

- Special grade plastic proprietary media offering high specific surface area
- Diffused aeration system
- Tube settlers for compact clarifier

Options

- Primary sedimentation and sludge treatment
- Tertiary treatment of chlorination
- Sludge treatment through thickener and bag filter press or drying beds

Land requirement

Capacity Q (mld)	Q ≤0.25	0.5 < Q ≤ 1	1 < Q ≤ 10	10 < Q ≤ 50
Land (sqm/mld)	na	na	0.05	na

Reference of only 2 mld plant is available.

Power requirement

- Electrical energy requirement 390 kWh/mld

Performance

- High BOD removal of 98% with effluent concentration under 10 mg/l
- High suspended solids removal with effluent concentration under 20 mg/l
- Faecal coliforms removal of the order of 2-3 on log scale at SAFF-2 stage

Dos and don'ts

- Effective multistage self cleaning screens required to prevent clogging of the media
- Primary sedimentation would be desirable to prevent clogging
- Adequate sludge storage facility or sludge drying beds to be provided

Capital costs

Capacity Q (mld)	Q ≤ 0.25	0.5 < Q ≤ 1	1 < Q ≤ 10	10 < Q ≤ 50
Cost (Rs. Million/mld)	na	na	7	Na

Note : Apparently, the proprietary plastic media constitutes higher percentage of the plant cost.
All costs are for year 2003

O&M costs

Capacity Q (mld)	Q ≤ 0.25	0.5 < Q ≤ 1	1 < Q ≤ 10	10 < Q ≤ 50
Cost (Rs. Million/mld/annum)	na	na	1.14	na

Life cycle costs

Capacity Q (mld)	Q ≤ 0.25	0.5 < Q ≤ 1	1 < Q ≤ 10	10 < Q ≤ 50
Cost (Rs. Million/mld)	na	na	41.73	na

O&M aspects

- Requires effective multi stage screens to prevent blockage of submerged media
- Blockage of media in case of excess biomass growth
- Uncertainty regarding durability of media under varying climatic conditions

Advantages

- Deep reactors enabling small space requirements
- Ability to effectively treat dilute domestic wastewaters
- Low and stabilised sludge production eliminating the need for sludge digestion
- Absence of odour and improved aesthetics
- Absence of emission of corrosive gases

Disadvantages

- Clogging of reactor due to absence of primary sedimentation

- Reliance on proprietary filter media
- High reliance on external energy input
- Requires skilled manpower

Applicability

The SAFF technology based system is particularly applicable for :

- small to medium flows in congested locations
- sensitive locations
- decentralised approach
- reliving existing overloaded trickling filters

However, the objective of this assessment is to compare their cost effectiveness, applicability and sustainability with respect to the simpler and traditional technologies. Key decision parameters of all the four different types of systems are summarised in Table 4.17. As expected, the unit energy consumption is high between 100 to 390 kWh/mld. FAB technology based systems are found to have relatively lower energy requirement while SAFF has the highest.

Table 4.17 Key Decision Parameters of Advanced Technology STPs

		Unit requirements				
	Capacity	**Land**	**Energy consumption**	**O&M costs (2003)**	**Capital costs (2003)**	**Life cycle costs (2003)**
STP location	**Mld**	**ha/mld**	**kWh/mld**	**Rs. million/mld**	**Rs. million/mld**	**Rs. million/mld**
BIOFOR, DSNH	10	0.04	220	0.8	6.5	30.4
ASP BIOFOR-F, RITHALA	182	0.08	180	0.18	5.2	23.5
FAB Molarband	3	0.06	133	0.66	4.6	27.7
FAB Lucknow	42	0.03	99	0.59	3	19.8
SAFF, Holambi	2	0.05	390	1.1	7	41.7

O&M cost of STP at Rithala is found to be the least due to the fact that almost 85% of its energy requirement is being met from bio-energy through captive generation in state-of-the-art gas engines. For a centralised facility, this type of system may offer a sustainable solution, provided relatively higher life cycle costs are justified. Apart from this, among the rest of the four plants, FAB based systems have the least unit O&M cost. Similarly, the full scale FAB plant compares well with regard to the unit O&M, capital and life cycle costs vis-à-vis ASP based plants. On the other hand, SAFF based plant has experienced major operational problems and its life cycle cost comes out to be the highest. In view of these findings this type of system is not found to be sustainable.

In general, the life cycle costs of advanced technology based STPs is 1.5 to 2 times higher than the ASP based plants. One of the reasons for higher life cycle costs is higher proportion of electrical and mechanical components which typically have shorter life span compared to the civil structures and may need to be replaced several times during the normal life of an STP. In view of the above, the advanced technology systems, particularly the FAB and ASP BIOFAR-F can be of relevance in situations where land is a major constraint and where high degree of treated effluent recycling is envisaged for industrial or other applications.

4.10 FACULTATIVE AERATED LAGOON TECHNOLOGY

Three STPs based on this technology were installed under GAP in Bihar. However, under YAP no such plants were included. Information on the current status and performance of the three STPs as well as their initial and running costs is not available and therefore no case study on this technology could be presented. Key features of this option are brought out in the technology sheet presented in Box 4.9 and some of the key aspects in its favour are discussed below.

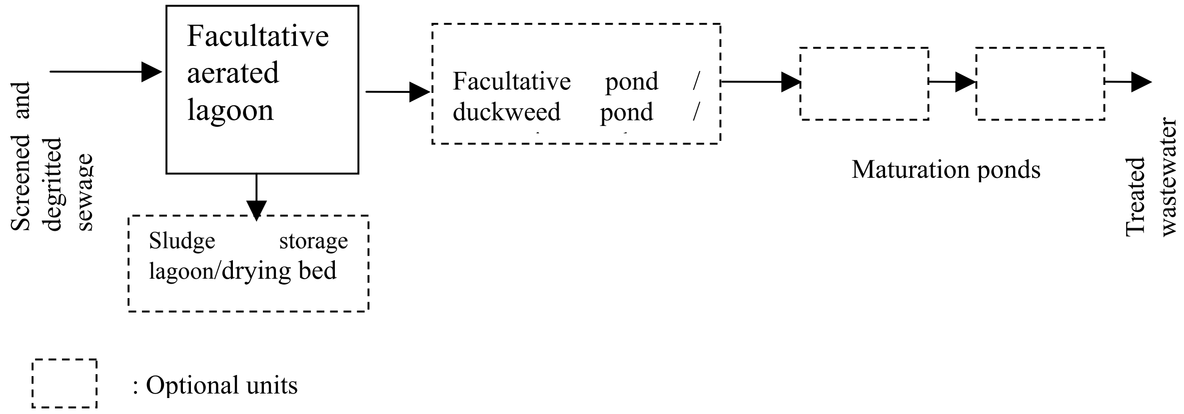
Considering the varied experience of a range of technologies, the option of facultative aerated lagoons (FAL) has been included here in view of the following :

- Simplicity of construction and ease and flexibility in operation
- Flexibility in design and future upgradability
- Lower land requirement compared to WSP technology
- Lower level of mechanisation and there by lower energy requirement compared to ASP technology
- Better quality of effluent without accompanying anaerobicity as in case of the UASB technology
- Reduced sludge management and process control requirement
- Reduced initial costs on account of exclusion of most of the structural, mechanical and electrical components

Land requirements of a FAL system at 0.3 to 0.4 ha/mld are comparable to ASP systems while its life cycle costs at around Rs. 6.25 million/mld are more or less of the same order of magnitude as those of WSP systems.

As a result, this option could fit in between the WSP and ASP or can be considered as an alternative to the ‘Final polishing unit’ typically provided on the downstream of a UASB reactor. This can also serve as an option for upgradation or rehabilitation of existing overloaded/ abandoned lagoon systems.

BOX 4.9 : TECHNOLOGY SHEET - FACULTATIVE AERATED LAGOON
A simple and robust combination of mechanical and natural processes involving deeper lagoons for combined action of aerobic and anaerobic bacteria in a single pond without the intricacies of a mechanised plant but capable of producing acceptable quality of effluent.   **Schematic**



Key features of the technology

- Simple flow scheme without primary or secondary settling and rigorous sludge recirculation
- Scheme excluding the need for separate sludge digestion
- Deep lagoon with anaerobic bottom layer and aerobic top layer
- Simultaneous degradation of sludge in the bottom and dissolved organics in the top layer
- Lower energy input corresponding to requirement for maintaining only desired DO levels in the top layer and not for creating completely mixed conditions

Performance

As no plant of this type could be covered under the current study, specific plant performance data is not available, however as per the information in literature based on Indian experience the following performance is expected from a well functioning facultative lagoon :

- BOD removal 70-90 %
- Suspended solids removal 70-80 %
- Coliform removal 60-99 %

Specific requirements

- Typical detention time of 3 days or more
- Depth between 2-5 m depending on local soil and groundwater conditions
- Effective outlet structure with baffles and stilling basin to prevent solids overflow

Land requirement

- Between 0.27 to 0.4 ha/mld (excluding optional units shown in the schematic)

Power requirement

- Minimum aeration power input of 0.75 kW / million litres, or
- Minimum technology energy consumption of 18 kWh/mld

Options

- Grit chamber as a preliminary treatment unit
- Multiple cells of lagoons in series for higher pathogen reduction
- Long narrow layout of lagoon for low dispersion coefficient
- Downstream ponds for polishing (facultative or duckweed and maturation)
- Arrangement for sludge withdrawal without the need for emptying of lagoon

- Provision of sludge storage lagoon

Dos and don'ts

- Avoid construction on porous soils and fractured strata or provide impervious lining
- Attain a balance between depth of lagoon and number of small capacity aerators to create two distinct zones of aerobic and anaerobic conditions in the top and bottom layers

Capital costs

- Rs. 2.2 to 2.9 million/mld (values updated from year 1996 to year 2003 based on WPI)

Operation and maintenance

- Maintaining DO of 2-3 mg/l in top layer
- Desludging of lagoon once a year or according to the situation

O&M costs

Not available, but expected to be between 0.15 to 0.2 million/mld/annum

Life cycle costs

A very ball park estimate based on the above two unit costs over 35 years of life span and considering 4 replacements of the mechanical and electrical components is Rs. 6.25 million/mld (year 2003).

Advantages

- Simple operation of the plant requiring lower skilled manpower
- Minimum civil, electrical and mechanical installation
- Scheme devoid of primary and secondary settling tanks as well as sludge digestors
- Lower energy costs compared to other aerobic processes
- Lower O&M cost

Disadvantages

- Possibility of groundwater contamination in porous and fractured strata
- High cost of lining

Applicability

- Stand alone system for sewage treatment
- As a post treatment unit for UASB reactor effluent
- As a pre-treatment unit for WSP
- As an upgradation option for overloaded WSPs

Note : Performance, unit land and power requirement, as well as the initial investment costs are based on information available in literature for Indian conditions (Arceivala, 1998)

4.11 DUCKWEED POND TECHNOLOGY

Although no STP based on this technology was installed either under the GAP and YAP, a pilot was implemented jointly by the Municipal Corporation of Delhi, the Central Pollution Control Board and Sulabh International in Delhi. The 1 mld pilot was created some time in 1994-95 by earmarking four ponds out of an existing waste stabilisation pond system of 12 ponds. It also included aquaculture as the last component for end use of the harvested duckweed. For last 9 years the system has worked satisfactorily and currently yields about Rs. 0.15 million of net income from sale of fish crop.

As in case of a typical WSP system, there are four ponds in series and each has an area of approximately 1 ha. Screened and degritted sewage is applied to the ponds where the first pond serves as an anaerobic settling pond, the second and third ponds serve for duckweed cultivation and the fourth pond is used for aquaculture. Average depth of water in the duckweed ponds is 1-1.2 m. In order to prevent drifting of duckweed, smaller cells of 10 m x 30 m are created by providing floating bamboo poles.

During the trial phase the plant was operated in a flow range of 1- 3 mld and the average hydraulic retention time varied between 5.4 – 22 days. At average flow conditions (i.e., 1 mld) the BOD surface loading was around 106 kg/ha/day and BOD volumetric loading was around 10.6 gm/cum/day.

Performance of the plant

Performance of the plant with regard to the effluent quality in terms of BOD, SS and faecal coliform is as shown in Exhibit 4.16 and it was found to be very satisfactory. The outlet BOD was in the range of 16-27 mg/l, and faecal coliform was around 2-8 x 10^3 MPN/100 ml. The latter corresponds to an average removal efficiency of 99.27 – 99.78%. In addition, the nitrogen and phosphorus values were also found to be low.

During a field visit it was found that duckweeds die out in severe winter conditions and during that period commercial feed material has to be used to maintain the stock of fish in the aquaculture pond. It is learned that on the other hand, during summer season the duckweed grows aggressively and a large quantity needs to be wasted.

The project which served as the role model for the Delhi pilot is located at Mirzapur in Bangladesh and has been in operation since 1990. This experimental project has a capacity to treat 125 m^3/d of wastewater and it occupies an area of 0.6 hectares (equivalent to 4.8 ha/mld). It receives domestic wastewater from hospital, school and residential areas. The system removes oxygen-consuming substances and pathogens to an extent comparable to algae based lagoons. It has been found to produce effluent almost to tertiary standards with very high level of nutrient removal. Based on the success of this project and considering low operational and maintenance requirements as well as lower energy and labour costs, about 150 facilities have been installed worldwide using such a system for treating municipal wastewater up to 30 mld (IDFC-MCD, 2003).

Table 4.18 Performance of Duckweed based STPs

		Stage of treatment		
Parameter	**Unit**	**Raw sewage**	**Primary settling**	**Duckweed pond**
BOD	mg/l	120-237	80-110	16-27
SS	mg/l	195-918	40-480	10-90
COD	mg/l	370-650	160-245	55-80
Total N	mg/l	16.5-79	11.7-46	10-25
Total P	mg/l	1.1-3.9	0.2-3.6	0.1-2.5
Faecal Coliform	MPN/100 ml	7.2-88 x 10^5	9-11 x 10^5	2-8 x 10^3

(Source : CPCB, 2001)
Notes :
1. Coliform removal is around 3 log scale.
2. % removals are not provided as the average values in the ranges given above are not available.
3. Data based on two case studies of Delhi and Bhubaneshwar

Resource recovery

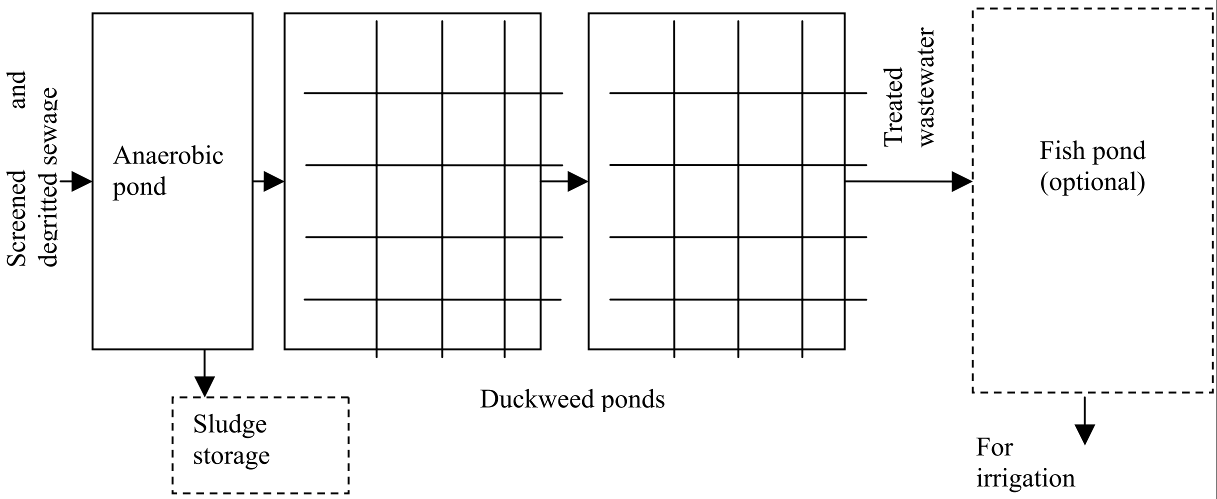
Yield of duckweed is found to be in the range of 41 – 135 gm/sqm/day and this is used in wet form for feeding the downstream aquaculture pond. A comparative assessment of duckweed fed aquaculture ponds with fresh water aquaculture ponds indicated that in the former case the yield was around 6 t/ha/year which was 300-400% higher than what is typically achieved in the latter system. Net monetary returns from the sale of fish are estimated to be of the order of Rs. 0.15 million /mld/year. (CPCB, 2001 & Sulabh International, Delhi pilot project).

Fish harvesting is done once a year during September-October and typically fishes grow up to 2 kg in weight and attain a length of about 35 cm. The plant is operated by a team of four personnel from Sulabh International who take care of all aspects of the process, including maintaining duckweed culture in separate ponds, introducing fingerlings in aquaculture ponds, feeding on regular intervals etc.

BOX 4.10: TECHNOLOGY SHEET - DUCKWEED POND

A natural system of wastewater treatment similar to waste stabilisation pond except that uptake of dissolved carbon and other nutrients is enhanced through sustained harvesting of floating aquatic plants called duckweed.

Schematic



Key features of the technology

- Natural and simple wastewater system involving sheltered pond like culture plots
- A large pond subdivided into smaller cells through floating bamboo or other material to break the wave and wind action
- Extremely rapidly growing floating duckweed vegetation serving as a dynamic sink for organic carbon, dissolved nutrients and minerals
- Thick mat of duckweed out-competing and inhibiting growth of other aquatic plants
- Pond functioning as a facultative lagoon with deeper layers under anaerobic environment
- Retention period in the system 7 – 21 days
- Shallow water depths from 1.25 m up to 2 m
- Continuous process requiring intensive management for optimum production
- Yield of large quantities of proteinaceous matter as fish feed or as a supplement for animal feed

Performance

Performance of the pilot project in Delhi has been presented in Table 4.18. Typical performance as given in literature is presented in Table below.

EXPECTED EFFLUENT QUALITY FROM DUCK WEED PONDS

Parameter	Unit	Inlet*	Outlet (detention, days)*			Average at outlet #
			7 d	12 d	20 d	
BOD	mg/l	60-70	40-50	20-25	5-6	< 30
SS	mg/l	100-120	60	30	<10	< 30
Total Kj. nitrogen as N	mg/l	35-40	20	10	<5	< 15
Total phosphorus as P	mg/l	-	-	-	-	< 6

(Sources : * Arceivala, 1998; # Metcalf & Eddy, 1995)

- For settled wastewater, BOD and SS below 30 mg/l are attainable at 12 d detention
- High nutrient and mineral removal due to uptake by duckweeds
- Low pathogen removal (due to reduced light penetration). However, CPCB pilot study recorded outlet faecal coliform count of 2000 to 8000 / 100 ml representing removal efficiency of 99.7% (27).
- Base stocking density of 600 g/sqm yields 50 – 150 g/sqm/day, which is equivalent to 0.5 to 1.5 tonnes of fresh duckweed/ha/day
- Commercial scale cultivation yielding 13-38 tonnes/ha/year of dry solids of duckweed

Specific requirements

- Primary treatment including screening, grease trap, grit removal and sedimentation
- Preferably the influent BOD, SS and ammonia to be under 80 ppm, 100 pm and 50 ppm respectively
- A series of smaller cells of around 10 m x 10 m to 10 m x 30 m to break the continuum in the pond (cell size as a function of wind speed, pond size and wave action)
- Cells borders made with floating bamboo mats or PVC profiles to shelter from wind and wave action
- Impermeable lining of clay or artificial liners in case of pervious and fractured strata
- Outlet structure with variable weir height
- Co-cropping of bamboo in the ponds
- Plantation of bamboo and banana trees along the perimeter to moderate temperature extremes and serve as a wind breaker
- Nitrogen loading of around 9 kg/ha/day
- Small size culture ponds for duckweed seedlings and as fish nursery ponds
- Duckweed drying and processing unit in case of large harvest and for sale as animal feed
- In case of downstream aquaculture ponds – introduce suitable species of fishes e.g., Grass Carp, Common Carp, Silver Carp, Rohu, Mrigal, Cattla, and freshwater prawns

Land requirement

- 2 to 6 ha/mld for 7 to 20 days of detention period.

Pond sizing depends on the following :

- Detention time required to attain desired effluent quality, and
- Yield of duckweed required to produce to a defined quantity of fish

Options

- Pre-treatment comprising anaerobic pond or primary sedimentation
- UASB and pre-aeration prior to a duckweed pond
- Downstream of a maturation pond in a WSP to complement suspended solids (algae) overflow
- In combination with aquaculture pond on downstream to utilise duckweed as fish feed
- Supplementary aeration in aquaculture ponds to augment oxygen supply in summer season

Dos and don'ts

- Inclusion of downstream aquaculture ponds for resource recovery and financial sustainability
- Feeding only settled sewage into duckweed ponds

- Protection of the ponds against flooding
- Avoid construction on porous soils, fractured strata and on alkaline soils
- Avoid duckweed ponds in cold climatic conditions

Capital costs

- Of the same order as WSP with additional cost of floating cell material

Operation and maintenance

- Daily attention and harvesting frequently to ensure productivity and health of duckweed colonies
- Avoid breakage of the thick mat of duckweed
- Prevent piling up or accumulation of weed culture on one side of the pond
- Prevent toxins and extremes of pH and temperature
- Prevent crowding due to overgrowth
- Prevent growth of other vegetation
- Vector control measures
- De-sludging of duck pond once in two years

O&M costs

- Rs. 0.18 million/mld/year

(Reference : Discussions with Sulabh International at Delhi pilot project)

- Pertain to manpower requirements for maintaining the primary treatment section, harvesting duckweed and management of fish ponds
- Post processing of duckweed for value addition as a fish feed or as animal feed supplement

Advantages

- Less sensitive to low temperatures, high nutrient levels, pH fluctuations, pests and diseases compared to other aquatic plants
- Reduced suspended solids in effluent due to elimination of algae
- Simultaneous significant nutrient removal
- Easy to harvest compared to water hyacinth
- Complete cover prevents breeding of mosquitoes and odour nuisance
- Yield of highly protein containing vegetative material (35-45%) as animal feed
- Duckweed as an excellent feed for aquaculture
- Realisation of tangible economic returns from sale of raw or processed weed or fish
- Least cost of O&M
- Creation of a micro-enterprise with sustainable income generation potential

Disadvantages

- Low pathogen removal due to reduced light penetration
- Duckweed die off in cold weather conditions

Applicability

- Low strength domestic wastewater or after primary sedimentation with influent BOD < 80 mg/l
- In combination with existing WSP
- Rural and semi urban settlements with easy land availability
- As a polishing pond for an existing activated sludge plant or other technology based STP

Suitability of duckweed ponds

Although duckweed pond technology is known to be a robust option and involves low operating cost, not much work has been carried out on it in India. Very limited references are available and that too of small sized or pilot sized plants. However, based on the available information the following can be concluded about this technology option :

- Duckweed ponds have the same or even better performance efficiency with regard to the BOD and nutrient removal.
- They can operate in conjunction with waste stabilisation ponds and/or maturation ponds to achieve complete and high degree of treatment in terms of BOD, SS and faecal coliform.
- Indian warm climatic conditions are favourable for rapid growth of duckweed which serves as a source of protein in fish and cattle feed thereby leading to tangible resource recovery from wastewater treatment
- They can serve as centres of job creation for community based organisations who can be involved in sustainable aquaculture production activities
- Unlike WSPs, more care and skill is required in their operation and maintenance as the weed needs to be harvested regularly and to be fed to the fishes or processed as animal feed
- Care is required in maintaining a thick layer of the weed to prevent growth of other competing aquatic plants such as blue green algae, etc.
- Furthermore, elaborate arrangement of floating barriers is required to break the wave or wind action and to prevent drifting of the duckweed mass
- As in case of WSP, the only drawback of this technology option is its large land requirement which may be difficult to obtain in large urban centres

Considering their higher sustainability which is of relevance under the current scenario, and particularly for the ongoing Ganga River Water Quality Management Plan, this technology option has been included in the current assessment. It offers a sound and remunerative alternative which could possibly be considered for :

- Small to medium scale situations
- Integration with the waste stabilisation pond systems or;
- Polishing of UASB effluent in combination with a pre-aeration step

4.12 Summary of Performance

Comprehensive information which guided assessment of the STP technologies is presented in Table 4.19.

Table 4.19 Assessment of Technology Options for Sewage Treatment Under Indian Conditions

Note :

S No	Factor	Units	ASP and its Minor Variants	Trickling Filters	UASB Process	Waste Stabilization Ponds	Duckweed Pond Systems	Facultative Aerated Lagoons	Advance Aerobic Process
1	Overall Hydraulic Retention Time (through the entire plant)	d	4*	0.5-1.0	1.33	8-15	7-20	1-2	0.3-0.5
2	Average Depth	m	4	3-4	1.75	1-1.5	2-3	2-3	4
3	Land Requirement	ha/mld	0.15-0.25	0.3-0.65	0.2-0.3	0.8-2.3	2-6	0.3-0.4	0.03-0.08
4	Energy Requirement	kWh/ml	180-225	180	10-15	Negligible	Negligible	18-25	100-400
5	Capital Cost	Rs million/mld	2-4	NA	2.5-3.6	1.5-4.5	Same as WSP	2-3	3-7
6	Annual Recurring Cost		0.3-0.5	NA	0.08-0.17	0.06-0.1	0.2	0.2	0.2-1.1
7	Life Cycle Cost		12-17	NA	7-11	3-7	Same as WSP	6-7	20-40
8	Expected Effluent Characteristics (range)								
	TSS	mg/l	30-50	30-50	50-100	50-100	30-50	50-100	<30
	BOD	mg/l	10-30	20-50	30-70	<30	<30	20-50	<10
	COD	mg/l	50-80	50-80	50-120	50-100	30-50	50-100	30-50
	FC (MPN)	No/100 ml	$10^4 – 10^5$	$10^4 – 10^5$	10^5-10^6	10^2-10^3	10^3-10^4	10^3-10^4	10^2-10^3
	TC (MPN)	No/100 ml	10^4 -10^6	$10^4 – 10^6$	10^5-10^6	10^2-10^4	10^3-10^4	10^3-10^5	10^2-10^3

1. No STP installation of trickling filter technology could be covered and therefore relevant cost information could not be generated.

CHAPTER 5

ASSESSMENT OF TECHNOLOGY OPTIONS FOR DISINFECTION

CHAPTER 5 ASSESSMENT OF TECHNOLOGY OPTIONS FOR DISINFECTION

The issue of pathogenic organisms in STP effluent has emerged in recent years. Besides the typical quality parameters of BOD, suspended solids and DO which have a direct impact on the quality of receiving water body/environment, the pathogens are known to have a direct impact on the public health. The intestinal pathogens and coliform are obligate anaerobes and unlike in an activated sludge plant, their die off rate in UASB environment is low. Recognising this aspect and in view of wider application of the anaerobic technology, the Central Pollution Control Board recently proposed inclusion of Faecal Coliform as one of the quality parameters in the national discharge standards for STP effluents. The suggested desirable and maximum permissible limits for Faecal Coliform are 1000 and 10,000 MPN/100 ml respectively.

In this context, five pilots on disinfection of treated sewage were implemented towards the later part of YAP with the objective of assessing overall feasibility and viability of different technologies. The locations of these pilots are shown in Table 5.1.

Table 5.1 Pilots on Sewage Disinfection Under YAP

Technology	Capacity	Preceding treatment	Location
Solar radiation system	1 mld	UASB followed by sedimentation in a pond	20 mld STP at Faridabad
UV system	2 mld	UASB followed by sedimentation in a pond	Same as above
UV system	2 mld	BIOFAR comprising physico-chemical and biological treatment	10 mld STP at Sen Nursing Home Nala, New Delhi
Down hanging sponge (DHS) bio-tower	1 mld	UASB effluent without sedimentation	40 mld STP at Karnal
Chlorination	2 mld	UASB followed by sedimentation in FPU	27 mld STP at Noida

Each of these pilot initiatives is briefly discussed in the paragraphs that follow.

5.1 DISINFECTION THROUGH SOLAR RADIATION

The core unit of the plant comprises a shallow pool of water measuring 10m x 14m wherein the water depth is maintained at 0.25m. Detention time provided in the pool is about 35 min. The plant is designed on the mechanism of photo-disinfection where in the solar rays of specific wavelength are known to kill the pathogenic bacteria. For night operation, a series of 70 tube-lights of 40 W each are positioned about 0.3 m above the water surface. The effluent from UASB and FPU system is given elaborate treatment for removal of suspended solids before feeding into the disinfection unit. This comprises coagulation, flocculation, and filtration (using sand pressure filters). In addition, the effluent quality is further modulated for enhanced bactericidal effect through a combination of the following:

(a) Aeration through supply of compressed air for raising DO level to 7-8 mg/l
(b) Addition of NaOH for raising pH to 8.5, and
(c) Addition of methylene blue (@ 0.5 ppm) for increased light absorption

The flow scheme for this plant is shown in Figure 5.1.

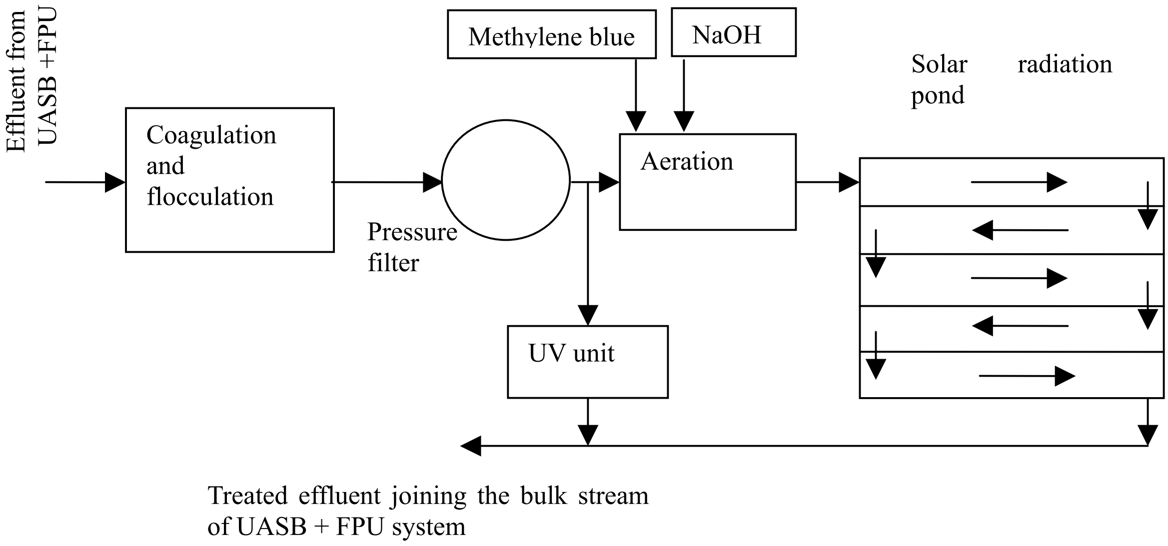


Figure 5.1 Solar and UV Disinfection Plants after UASB at Faridabad

Plant performance

Representative effluent quality data is presented in Table 5.2. It is seen that under the given set up, the faecal coliform count comes down from 10^6 MPN/100 ml to 500-900 MPN/100 ml. This represents a treatment efficiency of 99.9% (2 on log10 scale). It needs to be noted that this level of faecal coliform is achieved through a combination of manipulation of the feed water quality in terms of pH and DO and increased light absorption capacity. Results showing separate effect of enhanced pH and DO are not available and thus can not be commented; however it is to be understood that reduction achieved through the conditioning process itself could be significant. Information on the effectiveness of tube lights i.e., relationship between the intensity-wavelength-bactericidal effect is not available.

Table 5.2 Faecal Coliform Removal in Solar and UV based Pilot Plants

	Solar disinfection plant			UV disinfection plant		
Month	**Influent**	**Effluent**	**% removal**	**Influent**	**Effluent**	**% removal**
Nov. 03	1.30E+06	9.40E+02	99.928	1.30E+06	3.30E+03	99.746
Dec. 03	7.00E+05	7.00E+02	99.900	7.00E+05	4.00E+03	99.429

(Source : Plant effluent quality monitoring register)
Note : All coliform values are in MPN/100 ml.

Initial and recurring costs of solar disinfection

Capital cost of the combined solar and UV system was Rs. 10.4 million (year 2001) including the common pre-treatment component. Separate capital cost of the solar plant including the common polishing component is Rs. 7.2 million. The marginal polishing of STP effluent comes at a fairly steep cost; approximately estimated at Rs. 0.9 million/mld/annum which comprises 50% for electricity, 35% for chemicals and 15% for manpower and repairs. Life cycle cost (2003) for a period of 35 years works out to around Rs. 33.4 million/mld. High unit cost is due to pilot nature of the plant, however in full scale situations they are expected to be low.

Incidentally, location of the plant is such that the polished effluent can not be utilised for any gainful application (though ground water recharge could be a possibility), instead it is discharged along with the bulk of the UASB + FPU effluent in to a drain which is used for irrigation.

5.2 UV SYSTEM DOWNSTREAM OF AN UASB PLANT

On the side of the solar radiation based system, a 2 mld UV based disinfection system has also been installed to study and compare its performance with other available options. As shown in Figure 5.1, the pre-treatment for removal of suspended solids is common up to the sand filtration stage. The UV system comprises 10 modules each having 4 UV tubes of 39 W. Combined power load of UV module is only 1.6 kW, which represents total power consumption around 20 kWh/mld. Contact time in the module is 11 seconds. An aspect to be noted here is the limited life of UV tubes which is around 1 year or between 7500 to 9500 hours and therefore replacement of tubes would be an expensive affair.

Performance of the plant

As shown in Table 5.2, the faecal coliform count in UV system comes down from 10^6 MPN/100 ml to 2000-5000 MPN/100 ml. This represents an overall treatment efficiency of 99.7% (2 on log scale). It is to be noted that although the Faecal coliform concentration in the final effluent is below maximum limit, it is unable to achieve the desirable limit of 1000 MPN/100 ml. This lesser degree of performance could be attributed to either of the following:

- Higher than recommended suspended solids concentration after pressure filtration;
- Less than optimum energy rating of UV tubes,
- Less than optimum number of UV modules, and
- Low exposure time.

Initial and recurring costs

Separate cost for this plant is estimated to be Rs. 7.7 million (IIT Roorkee, 2002) (with proportional division of the pre-treatment component). Here again the cost of O&M is rather steep, around Rs. 8.5 lakh/mld/year. The life cycle cost (2003) for 35 years is estimated to be Rs. 27 million. Reasons for high unit costs are again due to the pilot nature of the plant and in full scale situation they are expected to be low.

5.3 UV SYSTEM DOWNSTREAM OF THE BIOFOR PLANT

A 2 mld UV disinfection system has been installed downstream of the BIOFOR plant at the Sen Nursing Home Nalla in Delhi. The system was imported from Ondeo Degremont, USA and was installed by its Indian subsidiary. Since the BIOFOR process involves a fairly high degree of physico-chemical and biological treatment, the effluent from this process has very low suspended solids and BOD. As a result and unlike the Faridabad pilot, no conditioning or pre-treatment is required for the stream entering into the UV system. The disinfection operation is rather straight forward and carried out in a compact unit. The system was found to be robust and did not require continuous supervision. It is designed to provide a minimum dosage of 69,928 microwatt-seconds per square centimetre at peak flow conditions. There are nine ballasts with four bulbs each representing 36 UV lamps which emit rays of 534 nm. Expected lamp life is between 8700 to 9000 hours with no fouling of quartz jackets. Retention time of water is around 12 seconds.

Performance of the plant

The system is designed for a high degree of treatment efficiency for reducing the faecal coliform count from 10^6 to 1000 MPN/100 ml. In practice the influent and effluent values are found to be 4.3×10^5 MPN/100 ml and zero - 200 MPN/100 ml respectively, which represents treatment efficiency of 99.95% and the effluent Faecal coliform number is well below the desirable limits. The stream of effluent undergoing disinfection is mixed with bulk effluent from BIOFOR and sent to the adjacent thermal power plant as cooling water.

Initial and recurring costs

The approximate capital cost of the plant is Rs. 4.47 million (year 2001) which excludes the high level of pre-treatment (SS < 12-15 mg/l) incidental from BIOFOR process and that is essential for effectiveness of a UV system. Therefore the initial and recurring costs would not be comparable in true sense.

Nevertheless, for computation of life cycle cost the recurring cost is considered approximately at Rs. 0.8 million/mld. Based on this, the life cycle cost (2003) for 35 years of effective life works out to be Rs. 21.36 million/mld.

5.4 DISINFECTION THROUGH CHLORINATION

Besides higher pathogens, the UASB effluent is known to have high COD and BOD. The nature of COD here is such that it exerts higher instantaneous oxygen demand. In view of this, any chemical disinfectant would have competing demands for first satisfying the instantaneous oxygen demand and then be available for bactericidal effect. Therefore, its required dosage is expected to be high. Besides, due to high humic substances, formation of chlorination byproducts i.e., trihalomethanes (THMs, primarily chloroform) is unavoidable.

In order to assess the above expected pattern, a pilot with chlorination on the downstream of a UASB at Noida was taken up. It has a capacity of 2 mld and the process involves dosing of bleaching powder/hypo solution and contact period of about 30 minutes in a rectangular baffled chamber. The plant performance was monitored by IIT Delhi in year 2003 over a period of 3 months (IIT Delhi, 2002). Findings of this study are briefly discussed below.

Performance of the plant

In laboratory experiments, chlorine dosage was varied over a wide range from 2 to 200 mg/l with the objective of attaining the desired faecal coliform level of 1000 MPN/100 ml. An optimum dosage of 20 mg/l was found for 30 minute of available contact time at the plant. As expected, the concurrent reduction in COD and BOD is found to be 38% and 26% respectively.

However, at the plant under typical operating conditions (chlorine dosage not specified) it was found that the faecal coliform count comes down from an average level of 3.5×10^6 /100 ml to 6.8×10^4 /100 ml, representing a removal efficiency of close to 98%. It is intriguing that the evaluation study did not monitor level of THMs.

A separate set of data monitored by the O&M agency at the plant level found chlorine dosage of 14 mg/l as optimum for achieving effluent faecal coliform count of 1000 MPN/100 ml. As against this, the dosage adopted in some of the advanced technology STPs described earlier is in the range of 3-5 mg/l.

The second set of data does not provide information on concurrent reduction of COD and BOD. However, it provides information on THM concentration which was found to vary in a wide range from 1.25 to 236 µg/l with an average value of 87 µg/l. If this data is representative then it is found to be within the range of the guidelines adopted by a number of countries for drinking water which have been set in the range of 25 to 250 µg/litre. As per the WHO guideline for drinking water quality the value of chloroform alone in drinking water is recommended as 200 µg/litre (WHO, 1999).

Thus as envisaged at the outset, all the three effects are happening i.e., reduction of COD, reduction of pathogens and formation of THMs. As a result, the effective dosage of chlorine for UASB effluent is also found to be 3 to 5 times higher than what is typically required, as mentioned earlier for effluent from an aerobic process e.g., activated sludge process which contains low level of dissolved and suspended organic matter. In the latter case concentration of THMs would be low due to lower concentration of humic substances and the perceived risk would also reduce.

Initial and recurring costs

The capital cost of this plant was Rs. 3.2 million. During the course of the current study a fact finding visit was planned to the plant. It was learnt that due to logistical and procurement difficulties, the plant has been closed since last 4 months. As a result, it has not been possible to obtain up to date information on chemical and energy costs; however, the revised estimated O&M costs as per the DPR for treating 2 mld flow for six months was Rs. 0.37 million (original estimate placed this costs at Rs. 0.97 million for six months) (UPJN, 2000-01). The annual O&M costs for this type of system then comes to Rs. 0.37 million per mld.   Based on this, the life cycle cost (2003) for 35 years comes to Rs. 10.33 million/mld.

5.5 DOWN HANGING SPONGE BIO-TOWER

The DHS bio-tower system is based on an innovative technology which was developed in the Nagaoka University of Technology, Japan, especially for effluents from UASB reactors. Under YAP, a pilot plant of 1 mld has been installed downstream of the UASB reactor at Karnal in Haryana during 2001 with the objective of evaluating its performance for removal of pathogenic bacteria. The system comprises a bio-tower of 5.3 m height and 5.5 m diameter where in two sponge modules of 2 m height are placed one above the other. As in case of a trickling filter, the wastewater is distributed through a rotating arm and aeration is achieved during the fall. The bio-tower offers a hydraulic detention time 1.5 hours and has a series of hanging curtains with 38-48 numbers of sponge rods 2.5 x 2.5 sq.cm. glued on them. Total sponge volume is 31 m^3 in a bio-tower of 126 m^3 (packing media occupying 25% volume). Aeration is enhanced due to drought action from the ports provided in the middle and bottom sections of the bio-tower and the clear spacing between the individual sponges. A clarifier of 3 m height and 7 m diameter is provided at the bottom of the bio-tower which collects the falling wastewater and enables separation of settleable solids, if any. A recycle ratio varying from 25 to 200% is adopted depending on the situation and effluent quality requirement. A technology sheet on DHS system is provided in Box 6.1 which brings out its various features.

The mechanisms on which bacterial die-off is effected comprise absorption/entrapment, predation and oxidation. The polyurethane media offers very high porosity and surface area for growth of attached biomass which enable significant reduction in organic matter. The high level of aeration achieved during the trickling down of effluent is considered to be one of the critical aspects for removal of pathogens which are considered to be anaerobes.

Performance of the plant

The plant has been under constant observation for last one and a half year and its performance based on the long term monitoring is presented in Table 5.3. The final effluent quality in terms of BOD and suspended solids is 6-15 mg/l and 8-12 mg/l respectively.

Table 5.3 Performance of DHS Bio-Tower Treatment Plant at Karnal, Haryana

	Unit	Raw sewage	UASB effluent	+ DHS effluent	+ FPU effluent
DO	mg/l	0	0	5.42	0
BOD	mg/l	142	46	6.2	38
Faecal coliform					
Lower limit	MPN/100 ml	7.8E+04	4.9E+04	3.3E+03	2.0E+04
Upper limit	MPN/100 ml	1.7E+07	1.4E+07	5.4E+05	1.6E+07
Suspended solids	mg/l	233	89	12	71
Ammonia Nitrogen	mg/l	17	20	4.8	20
Removal efficiency					
BOD	%		68	96	73
Faecal coliform					
Lower limit	%	Average removal efficiency is estimated to be 99.9%			
Upper limit	%				
Suspended solids	%		62	95	70
Ammonia Nitrogen	%		-	72	-

(Source : Harada et. al., 2003)

One of the positive aspects of the DHS system after UASB is the enrichment of DO up to 5 mg/l in the effluent. This is a significant feature as otherwise the effluent even after the FPU has an oxygen deficit and creates anaerobicity in receiving environment (water body or land) in the immediate vicinity of the discharge point. An additional advantage is higher level of nitrification wherein almost 72% of ammonia nitrogen is simultaneously removed from the effluent. Besides, the typical dark brown colour of the UASB reactor effluent is completely removed, and therefore the final effluent has high aesthetic value.

From land area point of view, its requirement is almost one twentieth of the typical FPU with 1 day detention period. Thus in terms of the conventional parameters, the performance of DHS system is excellent and it offers an effective and compact option for polishing effluent from an UASB reactor.

The pilot was planned with the objective of bringing down the Faecal coliform below 1000 MPN/100 ml; however, the actual values are found to be in the range 3.3 x 10^3 to 5.4 x 10^5/100 ml. Although this removal represents an average efficiency of 99.9%, the final number is still above the desirable limit and at times above the maximum discharge limits. Thus, it has not been able to fully comply with the discharge criteria for pathogenic bacteria for which it was originally installed.

Moreover, there are other concerns with regard to energy consumption, structural stability of the hanging curtains, falling sponges, etc. In view of these limitation and rather low coliform removal than originally perceived, further R&D work and cost optimisation would be required before full scale application can be considered. The DHS bio-tower is essentially a different version of conventionally employed trickling filters, and it may be advisable to compare it with the performance of trickling filter on equivalent water-fall height.

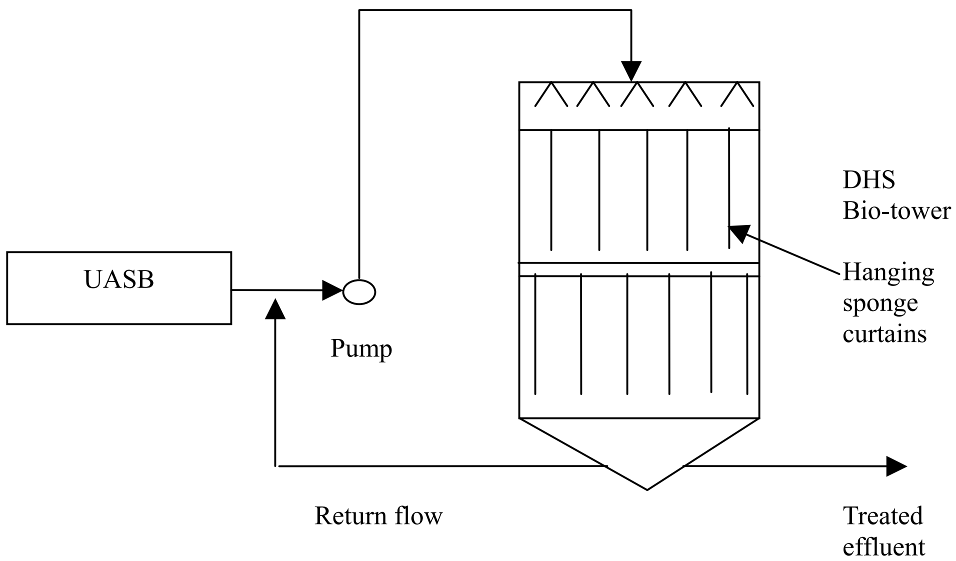
Initial and recurring costs

This being a pilot and first of its kind, the capital cost is high, being of the order of Rs. 4.5 million. However, it is perceived by the developers of he technology that cost optimisation is possible where it can be brought down by 50%. Operation and maintenance expenses are related to only the energy costs and repairs, if any. The estimated power requirement against a total head of about 12 m is 2 kW/mld and the daily energy consumption is about 48 kWh/mld. The annual O&M cost is estimated to be Rs. 0.37 million and the life cycle costs (2003) for 35 years of effective life is estimated to be Rs. 21.75 million/mld.

BOX 5.1 : TECHNOLOGY SHEET - DOWNFLOW HANGING SPONGE BIOTOWER

An innovative system for treatment of UASB effluent involving hanging curtains of sponge where the residual organic matter and pathogenic bacteria are removed through the combined mechanisms of absorption, predation and biological oxidation.

Schematic



Key features of the technology

- An improvisation of conventional trickling filter with high microbial population
- A series of curtains which provide base for sponge (polyurethane), the packing medium
- Bio-tower positioned over clarifier for space economy
- Treatment through the combined action of entrapment, predation and assimilation by active immobilised aerobic microbes
- Aeration of wastewater during downward flow through the draft action in bio-filter
- Incidental nitrification and scope for denitrification
- Free from the need for chemical dosing
- Compact polishing system offering high treatment efficiency
- Low energy and land requirements

Performance

High quality effluent with good aesthetic appeal. BOD and SS are under 10 and 20 mg/l respectively and DO is above 5 mg/l . However, Faecal coliform values are in the range of 3.3E+03 to 5.4E+05 MPN /100 ml which do not meet the suggested discharge criteria. This raises serious concern in considering DHS as an option for disinfection of treated wastewater.

Specific requirements

- Fabrication of sponge curtains
- Specific shape and size of the sponge rods (triangular prism of 2.5 cm x 2.5 cm)
- Skilled manpower and strong glue for fixing sponges
- Strong anchoring mechanism on top for the hanging curtains
- Low land area at a rate of ≈ 30 m^2 / mld
- Energy requirements 48 kWh/mld for pumping the wastewater and recirculation

Options

- Enclosure of alternative building materials to optimise the construction costs
- Recycle of effluent to UASB reactor for denitrification

Dos and don’ts

- Adopt a recirculation ratio on case by case basis
- Ensure strong draft of air through the bio-tower by providing enclosure around the curtains and openings at the bottom
- Use strong polymer fabric for sticking and hanging the sponge
- Provide strong anchor at the top for the curtains

Capital costs

- Rs. 4.5 million/mld

Only one cost reference from the 1 mld plant at Karnal is available. This being an experimental plant, the capital cost has been high. With larger capacity and reduced enclosure specifications, the overall cost of the bio-tower may be considerably reduced. However, the cost reduction by several orders of magnitude is necessary for this option to be cost effective.

Operation and maintenance

- Recycling of treated effluent on case by case basis
- Higher recycle ratio for increased pathogen removal
- Continuous pumping of wastewater on top of the bio-tower
- Intermittent sludge removal from clarifier
- Sponge replacement once in 10 years

O&M costs

O&M costs is estimated to be Rs. 0.37 million/mld/annum and it pertains to :

- Electricity consumption for lifting the wastewater to the top of the bio-tower and recirculation of treated effluent. This is a function of the head involved in lifting and can be optimised when the tower design is integrated with general hydraulic flow diagram of the entire STP. Energy costs can be minimised by integrating the bio-tower with the hydraulic profile of the UASB plant.
- Energy costs for intermittent sludge pumping
- Replacement of sponge once in 7-10 years

Advantages

- High quality effluent in terms of DO, BOD, faecal coliform and suspended solids
- Pathogen removal without external chemical addition
- Plant can be modified to meet nitrification and denitrification regulations in future
- DO rich effluent eliminating the oxygen stress on the receiving aquatic environment
- No side effects of formation of harmful chemicals as in case of chlorination
- Compact system with low land requirement; area requirement being one twentieth of the maturation pond/polishing unit for equivalent pathogen removal
- Able to withstand hydraulic and organic overloading as a result of large immobilised biomass
- Low energy requirement
- Very low sludge production
- Performance independent of weather conditions for bactericidal removal
- Effluent amenable for subsequent chemical disinfection with low dosage of chlorine
- A robust process and plant design requiring no supervision or monitoring
- Long life of the polyurethane based sponge media (7-10 years)

Disadvantages

- High recycle of treated effluent in case of higher desired coliform removal
- Effluent requires chemical disinfection to comply with the desirable discharge limit of 1000 MPN / 100 ml of pathogen
- Falling of sponges and hanging curtains and difficulty in putting them back in place

Applicability

- Downstream of an UASB reactor in locations with limited land availability

5.6 CONCLUSIONS ON PILOTS FOR DISINFECTION

Selective destruction of pathogenic bacteria through various means was tried out under YAP especially for UASB technology based plants. The methods used for this purpose can be classified under two broad categories where the treatment is brought about by chemical and physical agents. Besides the conventional chemical and UV systems, two innovative methods of solar radiation and DHS were also implemented. A comparison of the five systems is provided in Table 5.4.

Table 5.4 Comparason of Five Pilots on STP Effluent Disinfection Implemented under YAP

		Technology				
Parameter	**Unit**	**Solar**	**UV, Faridabad**	**UV, Delhi**	**DHS**	**Chlorination**
Degree of pre-treatment required		High	High	High	None	Low-moderate, though none provided
Preceding treatment		UASB	UASB	BIOFOR	UASB	UASB
Bactericidal effect						
Capacity	Mld	1	2	2	1	2
Outlet Faecal Coliform	MPN/100 ml	940	3300	0-200	4500	1000
Removal efficiency	%	99.9	99.5	99.999	98.2	99.17
Other benefits						
BOD reduction		incidental	nil	nil	87%	38%
DO level	mg/l	0	0	0	5	0
Nitrification		nil	nil	nil	72%	Nil
Side effects						
Formation of by products		None	None	None	None	Formation of THMs
Economics of treatment						
Land requirement	sqm./mld	160	24	6	30	25
Energy requirement	kWh/mld	NA	NA	NA	48	NA
Year of commissioning		2001	2001	2001	2001	2001
Capital cost	Rs. Million	7	7.5	4.475	4.5	3.2
WPI (2001)		155.7	155.7	155.7	155.7	155.7
WPI (2003)		159.7	159.7	159.7	159.7	159.7
Capital cost (2003)		7.2	7.7	4.6	4.6	3.3
Unit capital cost	Rs. Million/mld	7.18	3.85	2.29	4.62	1.64
Civil component	Rs. Million/mld	4.31	1.54	0.80	1.85	0.98
E&M component	Rs. Million/mld	2.87	2.31	1.49	2.77	0.66
Total O&M cost	Rs. Million/mld /annum	0.90	0.85	0.80	0.37	0.37
Life cycle cost (35 yrs)	Rs. Million/mld	33.40	27.00	21.36	21.75	10.33

Notes :
1. Costs for solar and UV pilots at Faridabad have been adjusted for the common components
2. Cost data for UV plant at Delhi may not be comparable as no conditioning is required after BIOFAR process
3. Uniform present worth factor based on 35 year period and 5% annual interest rate = 16.37
4. O&M costs capitalisation is done assuming constant annual expenditure over the life of the plant
5. Four replacements of E&M components are considered over the life of each plant

It is seen that chlorination has the least life cycle cost and it offers a fairly high degree of bactericidal efficiency. The technology is well established and robust and the chemical agent is cheaply and easily available. However there are concerns about THM generation, but the associated risk is of long term nature and difficult to assess. The risk due to presence of pathogens is of short term nature and perceived to be very high from the point of view of drinking water supplies. In this regard it is pertinent to quote from a WHO study on the subject of chlorination of drinking water supplies which concludes that “the estimated risks to health from disinfectants and their by-products are extremely small in comparison to the real risks associated with inadequate disinfection, and it is important that disinfection should not be compromised in attempting to control such by-products” (Disinfection and disinfection by products, WHO, undated web document). Having said that, it also needs to be realized that unavoidable THM formation would be comparatively high in case of effluent from UASB as it carries higher concentration of humic substances and thus adequate caution needs to be taken.

The DHS system has the second lowest life cycle cost (excluding the UV system of the type installed at DSNH at Delhi as it does not include polishing cost) but it offers much lower bactericidal efficiency. While the final Faecal coliform count is below the maximum permissible limit, it is still above the desirable limit of 1000 MPN/100 ml. Notwithstanding this, and looking at additional benefits of reduction in BOD, increase in DO level and concurrent nitrification, DHS may prove to be promising system for achieving multiple tertiary water quality objectives on the downstream of a UASB reactor. Concerns on technical robustness of the system i.e., life of curtains, sponges and structural aspects need to be addressed before it can be recommended for full scale installation. While DHS may appear to be a promising option for polishing UASB effluent, the choice of UASB as a pre-treatment process for domestic wastewater itself is a matter of debate because of diverse opinion available based on several full scale UASB installations in the country.

5.7 STRATEGIC CONSIDERATIONS FOR DISINFECTION OF STP EFFLUENT

One of the major perceived inadequacies in intervention schemes for controlling river pollution from domestic wastewater under GAP and YAP is the inability to reduce Total and Faecal Coliform (TC and FC) numbers in the treated effluents discharged directly or indirectly into the rivers to desired levels. This has led to a lot of criticism of the GAP and YAP by several social organizations, NGOs, and public at large. NRCD and other agencies involved in furthering the river cleaning/restoring processes are striving to address this issue in a meaningful manner.

Strategy in this regard must take into consideration the extent of the problem vis-à-vis the availability of resources, short and long term implications, sustainability and public perception. Any attempt to follow the practices recommended elsewhere, including formulation or adoption of standards, is bound to yield unsatisfactory results if ground realities and Indian social/cultural traditions are discounted. Moreover, from the point of view of presence of pathogens in natural water bodies, no real risk assessment studies have been done which would warrant high degree of removal from STP effluents. The issue of TC and FC must be dealt with in this perspective.

The intervention schemes for pollution reaching the rivers were based on CPCB survey which essentially focussed on organic load in terms of BOD/COD. It was perceived that reduction in BOD/COD load will have substantial positive impact on DO levels in the river. Accordingly, STPs installed for domestic wastewater treatment under GAP and YAP primarily targeted BOD/COD reduction. The reduction in TC and FC has been incidental. On the contrary some of the technologies considered to be favourable under Indian conditions (e.g. UASB) were known to give much less removal of TC and FC.

It is well established through several river water quality surveys that TC and FC levels in some stretches of the rivers Ganga and Yamuna are high. However, (i) the causes for high levels of TC and FC have not been ascertained unambiguously, (ii) effectiveness of reducing coliform numbers through further treatment with available technologies to achieve desired improvement in river water quality can not be guaranteed, (iii) standards for coliforms may have served well for drinking water but to implement them for wastewater discharge with arbitrary extrapolation, ignoring background TC and FC levels in rivers because of distributed sources of pollution or available dilution and natural die-off, is a matter of debate, (iv) substantial capital and/or recurring expenditure for setting and attaining coliform levels, when available resources for river cleaning projects are very limited and the primary goals of completely eliminating visible pollution and maintaining aesthetics are not achieved, can not be justified unless treated effluent is utilized for some high end applications, and (v) use of chemicals, particularly chlorine, the most commonly used method of disinfecting wastewater world over, is suspected to have much serious long term implications and may eventually increase burden on water treatment.

The disinfection methods can generally be applied to those treated effluents which meet certain quality requirements in terms of suspended solids, organic contents, etc., and is thus effective when high level of primary and secondary treatment is adopted. In India, the present allocation of resources for wastewater treatment is vastly inadequate and hence any attempt to use disinfection for raw or poorly treated wastewater is bound to be unsatisfactory.

Strategically, thus, the issue of coliforms may be taken up after the objectives of primary and secondary treatment, taken in this order, are completely satisfied. Certain removal capacity of the receiving environment can be depended on for coliform removal. In order to avoid any misgivings, all concerned including implementing agencies, social organisations, NGOs and public at large must be taken into confidence.

Disinfection of treated effluent using any of the available technologies, viz. chlorination and UV radiation may be adopted at places where objectives of secondary treatment are achieved well beyond effluent discharge standards in terms of BOD/COD and SS (e.g. BOD < 10 mg/l and SS < 20 mg/l). Such effluent quality is attained by using advance aerobic processes only (e.g. Biofor Plant at SNH, Delhi).

Results of the pilot studies reveal that various disinfection methods, namely UV, chlorination or solar radiation, are inefficient for coliform removal from UASB effluents. Disinfection of anoxic effluents is generally met with poor efficiency and hence must be avoided. Additionally, chlorination may require high dosages if used for anaerobic effluents and effluents with high ammonical and organic nitrogen.

DHS pilot plant used for post treatment of UASB yielded effluent quality comparable to the advance aerobic processes. The coliform removal is, however, not up to the desired level and fails to qualify as disinfection alternative. Further the UASB plus DHS system should be evaluated in comparison to any standard available aerobic processes of comparable efficiency. The choice of UASB as a pre-treatment process for domestic/low strength wastewater considering the lifecycle costs and effluent quality vis-à-vis ASP needs serious introspection.

Natural alternatives e.g., maturation ponds and duckweed ponds or their combination can be considered where land is available. A series of maturation ponds with short detention time offer high pathogen removal efficiency. These pond systems would turn out to be sustainable as their operating costs are minimal and they do not require any skilled operations. In addition, maturation ponds would offer an opportunity to exploit the aquaculture potential at a conventional STP and there by enable some form of tangible resource recovery. As the current norms for land procurement consider future expansion possibilities, the surplus land at the outset could be considered for pond based disinfection option. At a later stage, as and when the capacity expansion takes, the ponds can be replaced by technically advanced options. This strategy would help in lowering the initial O&M costs as well as provide opportunity for resource recovery and ground water recharge.

CHAPTER 6

SITUATIONAL ANALYSIS
FOR
YAP - CORE COMPONENT

CHAPTER 6 SITUATIONAL ANALYSIS FOR YAP - CORE COMPONENT

This chapter provides a situation analysis on institutional aspects of YAP I relating to core component, which includes I&D and treatment i.e. pumping stations, rising mains and STPs created under the project. The analysis includes a brief review of the organizational aspects of the institutions (with respect to YAP I) which are involved in both the construction as well as O&M of the project.

The situational analysis has been presented in two parts. First part focuses on project implementation highlighting the role of related institutions and key issues in implementation framework. The second part on operation and maintenance of STPs brings out current institutional arrangements and their status for O&M of STPs in the 3 participating states, existing situation in ULBs, training and monitoring aspects. The status of existing institutional arrangements in UP, Haryana and Delhi highlight the key issues in project organization structure, fund allocation and contract.

6.1 PROJECT IMPLEMENTATION

The following section covers the key issues in (1) roles of project organizations and (2) institutional planning and framework.

Project organisations and their roles

The National Rivers Conservation Directorate (NRCD) under the Ministry of Environment and Forest at the Centre, has been responsible for the overall implementation of YAP since 1993. At the state level (i.e. in Uttar Pradesh, Haryana and Delhi), designated state agencies known as the Project Implementing Agencies (PIAs) were given the responsibility for implementing the project. They were:

- In Haryana, Public Health Engineering Department (PHED) under the state Government of Haryana
- In UP, Uttar Pradesh Jal Nigam (UPJN), an autonomous organisation under the Department of Urban Development of Government of UP
- In Delhi, Delhi Jal Board (DJB) and Municipal Corporation of Delhi (MCD)

Each of these PIAs also worked as coordinators for monitoring and coordination of other state departments/ urban local bodies, responsible for the non-core component of the project. The roles of these institutions have been summarized below.

NRCD

In the central government, NRCD is the nodal agency for coordinating the implementation and monitoring of all river conservation projects and plans in India. It is a part of Ministry of Environment and Forests (MoEF). One of its key roles is to channelise Central Government funds to the concerned State governments for the implementation of the river conservation schemes.

PHED, Haryana

PHED, Haryana is responsible for both construction and O&M works in rural and urban water supply, storm water drainage, sewerage, low cost sanitation, solid waste disposal etc. It also builds and maintains public health and sanitation works of GoH buildings. It has been assigned the additional responsibility of implementation of YAP schemes in 6 towns of Haryana namely, Yamunanagar, Karnal, Panipat, Sonepat, Gurgoan and Faridabad. For this project, it has a set of engineers from Chief Engineer (CE) level to Junior Engineer (JE) level at respective project offices.

UPJN, GoUP

UPJN is an independent undertaking of GoUP (governed by the Water Supply and Sewerage Act, 1975), responsible for planning, design and execution of all water supply and sewerage works in UP. These are subsequently handed over to the appropriate agency for O&M. However, in rural areas, UPJN is also responsible for O&M of water supply schemes. It has been responsible for implementation of YAP schemes in 8 towns of Saharanpur, Muzaffarnagar, Gaziabad, Noida, Vrindavan, Mathura, Agra and Etawah. UPJN also has a dedicated team of engineers from CE to JE level for the execution of the project.

DJB, Delhi

DJB, established in 1998, by incorporating the previous Delhi Water Supply and Sewage Board Disposal Undertaking, is entrusted with the responsibility of production and distribution of water, and transport, treatment and disposal of wastewater for the Union Territory of Delhi.

Other relevant governmental organizations

In addition to the above PIAs, relevant governmental organizations that are involved in provision of sewerage services at the operating level are:

- Urban Local Bodies (ULBs) i.e. Nagar Nigams (Municipal Corporations), Nagar Palikas (Municipal Councils) or Nagar Parishads (Municipal Committees)
- Jal Sansthans in bigger KAVAL towns in UP
- State pollution Control Boards, responsible for river cleaning with the powers to check the operating organizations and industries from discharging untreated effluents in the river.
- City Development Authority, incharge of master planning and development of new property, enforcement of land use regulations in cities. For instance, Haryana Urban Development Authority (HUDA) develops new urban areas and hand over completed capital works to ULBs (roads, sanitation etc.) and water and sewerage to PHED. In UP, Lucknow Development Authority (LDA) for area around Lucknow and Delhi Development Authority (DDA) for Delhi performs this same function.
- State Housing Development Boards independently plans and implements housing and development schemes in states. For instance, Haryana Housing Board develops (on land bought from HUDA) housing clusters and accompanying infrastructure and sells to users.

Both City Development Boards and State Housing Development Boards, are responsible for building sewer lines within their colonies and maintaining them till the colonies are transferred to the concerned institution. The above are independent organizations established under separate legislation and have their own budgets and manpower.

Overlap of roles

As is evident from above, many organisations are involved in construction and O&M of sewerage component in the states. There is, thus, an overlap of roles and fragmentation of responsibilities in provision of sewerage services within the institutions. For example, Jal Sansthans (or other organization responsible for sewerage) have at times difficulties in cleaning sewer lines, which pass through blocked nallas, typically the responsibility of ULBs. Similarly, Development Authorities/ Housing Development Boards construct sewer lines within their colonies and fail to connect them to the main/ trunk sewers resulting in sewage overflow into nallas. In many places, Development Authorities, Housing Boards and other agencies are carrying out independent development of residential areas. These agencies typically make no provision for treatment of sewage generated in these areas and instead the sewage is discharged into the city wide sewerage system. However, they levy development charges for providing infrastructure from the prospective buyers but do not contribute towards capital or O&M cost of the STPs serving the city.

Organisationally, policy level integration and conflict resolution takes place at various levels in the State Urban Development Department, the Central Environment Ministry or the State government. However, inspite of the coordination mechanisms within the above organizations, there is no single point responsibility for the services. Also only ULBs are governed by an elected body, as a result of which there is no accountability to the people in other organisations.

The manner in which YAP I was formulated institutionally and the linkages within the related institutions have been shown in Figure 6.1.

Key Issues in project implementation stage

The main issue that emerges with project review is that there is lack of sufficient attention paid to sustainability aspects at the project implementation stage. For a multidisciplinary nature of the project of this nature (i.e. has both core and non core components), sustained outputs are typically a result of (1) how far the project satisfactorily addresses institutional, financial, economic and social concerns and the extent to which the respective roles of the individual organizations are reflected within the implementation plan, (2) the extent to which consultative and participative systems have been established for stakeholder involvement in planning. Both these issues were given minimal consideration in YAP I, which are discussed in detail below.

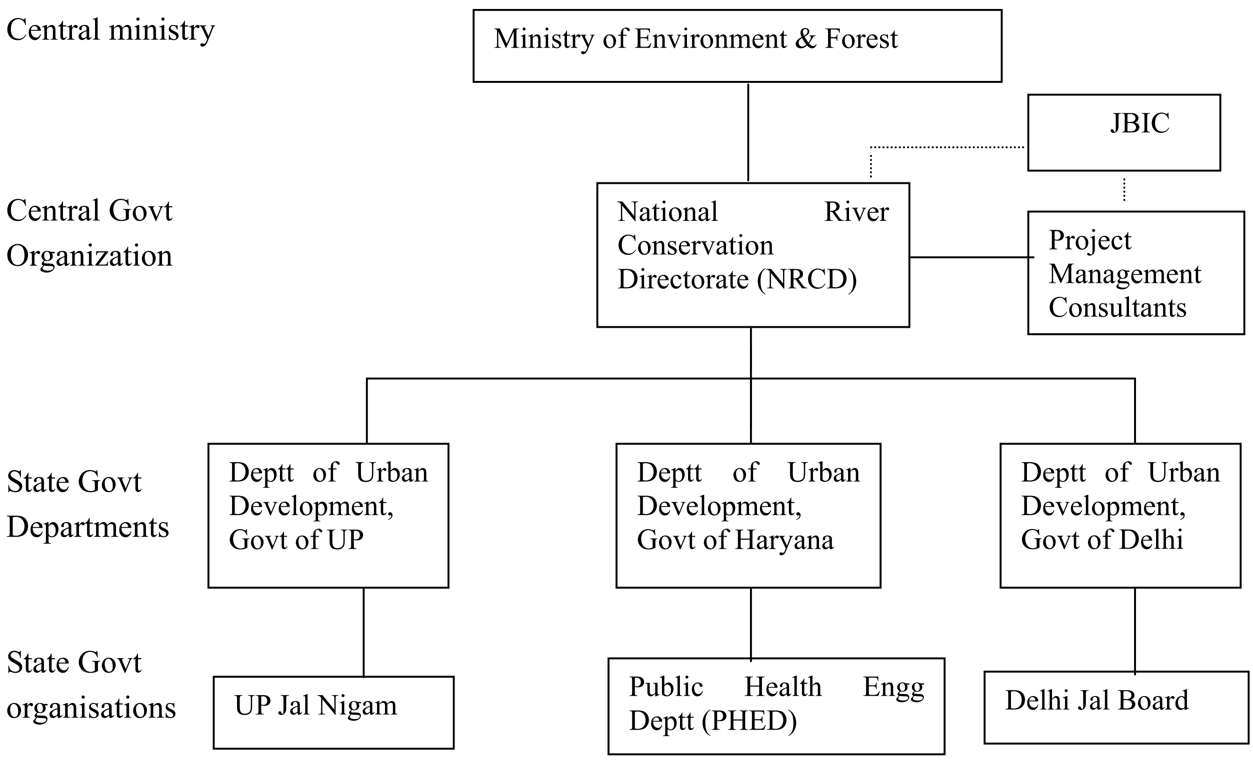


Figure 6.1 Project Institutional Framework of YAP I

Lack of integrated approach to project planning and implementation

Adopting a holistic and integrated approach to a project is critical from the point of view of its sustainability and ownership. In addition to the technical aspects, the softer components i.e. institutions, social, environmental, economic and financial factors are pre-requisites for successful sustainability of any project with heavy technical inputs at both project implementation stage as well as from operation and maintenance point of view. This is now well known and well documented.

Improvement in services cannot be sustained unless current institutional and financial constraints are overcome. Therefore technical assistance needs to be implemented at a pace that matches institutional and financial capacity, a necessary precursor for effective O&M of facilities. In particular, institutions need to work collaboratively on the planning and commissioning of new works, taking into account the institutional and financial capacity to operate and maintain them.

YAP I was primarily a technology driven project with minimal inputs during its first phase in other components especially institutions. There was absence of any concurrent institutional strengthening and capacity building efforts for the operating agencies. The engineers of ULBs and Jal Sansthans (operating agencies under YAP I) have little prior experience or knowledge of the STPs created under the project, let alone the capacity to operate and maintain the plants. The agencies are plagued by institutional and financial crisis, barely managing the current services. This aspect has been discussed in detail later in subsequent paragraphs. Ideally a project such as YAP would provide an opportunity for strengthening the ULBs and integrating sewerage and sanitation, thereby providing a basis for long term institutional sustainability.

In fact, STPs were by and large an emerging concept even for PIAs i.e. UPJN and PHED. While UPJN had some prior experience in setting up STPs under GAP, for PHED, Haryana it was a new area of work. Even though, PHED took assistance from consultants in preparing DPRs, no capacity was created concurrently within the organization. The executing agencies lacked experience in preparing DPRs. In general there was a lack of training and appropriate skill development in organizations involved in planning, design and management of the project.

Lack of involvement of key stakeholders

Key stakeholders (largely the organizations/ formal, semi formal institutions that the project would impact) of YAP 1 would broadly include MoEF, NRCD (at the central level), Deptt of Urban Development of UP, Haryana, Delhi, PIAs (at the state level), ULBs, Jal Sansthans (at local level), private sector, NGOs, and citizens of the participating towns.

The institutional framework of YAP I (refer Figure 6.1) included only NRCD, State Departments of Urban development and PIAs. There was a lack of involvement of other key operating institutions in the conceptualization and implementation of the project especially ULBs or Jal Sansthans (wherever existing) in participating towns, who are the prime stakeholders of the project and the likely eventual owners of the PSs and STPs.

Even though the project approval was accorded on the basis of a letter of commitment from all the concerned state governments/ ULBs of participating YAP towns, stating their intent to operate and maintain the facilities upon commissioning, this has turned out to be only a formality on paper. There was no consultation, participation or consensus of local agencies in either the design and planning process or execution stage of the core component. Moreover, no institutional strengthening efforts were directed at ULBs, the eventual owners of PSs and STPs. As a result, ULBs feel excluded and not ready to operate and maintain the facilities, and this emerges as one of the main reasons due to which the project has been able to achieve limited success. On the other hand, the PIAs have little accountability since they were not expected to operate the systems.

YAP I has been implemented essentially as an engineering project by providing the role of "nodal agencies" to large state level engineering organizations (PIAs). It has further affected process quality of especially software inputs (normally little appreciated by the technical organisations), critical to the sustainability of the project.

Private sector involvement as envisaged in the project was limited to the extent of engaging private contracting companies with prior experience in construction of STPs. However, they now have a role in operating and maintaining the plants. Moreover, no participation from NGOs or the local citizens was envisaged under the project.

Weak coordination mechanism to facilitate stakeholder involvement

Within governmental organizations, overlap of roles and fragmentation of responsibilities of the concerned institutions in the implementation of schemes, implies a need for considerable coordination at the operating level to ensure sustainable O&M of all YAP assets. For this a robust coordination and monitoring mechanism needs to be in place. Under YAP I, no separate Steering Committee was formed. Instead, the progress of the project was reviewed in regular NRCP quarterly Steering Committee meeting under the Chairmanship of Secretary, MoEF. The role of this Steering Committee is to review and assess the achievements of various central river action plans under NRCD ongoing in different states of India. There was no separate platform on which the various key stakeholders related to the project were represented (such as ULBs, or any other parastatal organizations like CPCB, SPCB etc.), to facilitate their coordination and involvement.

Considering the points brought out in the earlier paragraphs, it can be concluded that key stakeholder involvement needed at various levels on the project was absent.

6.2 OPERATION & MAINTENANCE OF STPs UNDER YAP

It was understood at the time of project implementation, that the operation and maintenance of the assets created under YAP I were likely be vested with the respective urban local bodies (ULBs) or Nagar Nigam/ Nagar Palikas (i.e. Municipal Corporation/ councils) as they may be called. This is based on the 74th Amendment to the Constitution of India, which has devolved considerable powers to the municipal bodies in order to strengthen and decentralize governance. This is expected to mitigate weaknesses in institutional arrangements as well as improve financial performance of local bodies. Under this Amendment, the functions of water supply, solid waste management and sewerage are vested with the ULBs.

In UP, till mid 70s, water and sewerage was being managed by Jal Kal Vibhag (water and sewerage department) within ULBs. After the Water Supply and Sewerage Act was passed in 1975, Jal Kal Vibhag was formed into a separate organization known as Jal Sansthans for 5 KAVAL towns of Kanpur, Allahabad, Varanasi, Agra and Lucknow in UP. Since then in these 5 towns, respective Jal Sansthans has been responsible for operation and maintenance of water supply and sewerage network of the cities. However, with the 74th Amendment there has been a move to merge Jal Sansthans back into Nagar Nigams, but this is still under consideration. In rest of the smaller towns, O&M of water and sewerage is the responsibility of respective smaller ULBs i.e. Nagar Palikas or Parishads.

In Haryana, all the towns have small ULBs i.e. Nagar Palikas or Parishads, which are responsible for all civic services except O&M of water supply and sewerage. PHED is responsible for construction, as well as O&M of water supply and sewerage in small towns. The only city in Haryana having a Nagar Nigam is that of Faridabad, which is also responsible for O&M of water supply and sewerage in the city.

In Delhi, Delhi Jal Board was established in 1998 by incorporating the previous Delhi Water Supply and Sewage Board Disposal Undertaking (previously under MCD). It is now responsible for maintaining the water supply, trunk sewers and STPs.

Operation and maintenance body for YAP I

At project execution stage, it was laid out that the O&M of the assets created under YAP would be the responsibility of ULBs, aided and supported by the state governments. This included a firm commitment by the ULBs that it agrees to bear the entire cost of O&M, and any shortfall in resources to be met by the state governments. However areas of concern have been as follows:

(1) In the current scenario, while contractually ULBs are responsible for STPs created under YAP, they lack effective technical resources, management structures and have weak financial bases to be able to manage the sewerage system and STPs. As a result, respective ULBs have yet to take over the assets physically.

(2) The STPs built under YAP I in 15 towns (8 towns in Uttar Pradesh, 6 towns in Haryana and Delhi) are being operated and maintained by the project implementing agency staff i.e. by UPJN in UP, PHED in Haryana or DJB in Delhi. However, these organizations have further contracted out the actual O&M to private contractors. The former organisations are only fulfilling the role of supervisors and caretakers.

(3) UPJN charges a fixed 19% centage on the project to take care of their overheads (which, it is learnt, often finances salaries of surplus UPJN staff), a significantly large amount for mainly supervising the STP contractors. This is considerably higher than a typical rate of 8% being charged by ULBs such as Agra Nagar Nigam. This, on one hand, increases the total O&M cost of the STPs and on the other, the ULBs stand as overall losers with the state government deducting funds equivalent to O&M cost of STPs from their State Finance Commission grants. Moreover, in UP, these funds are now being transferred to PIAs.

Existing situation in ULBs

The 74th Amendment to the Constitution of India, 1992, by devolving power to municipal bodies in urban centers aimed at strengthening governance concerning notably 18 major civic functions including water supply, solid waste management and sewerage. However, the existing financial and technical capacity of ULBs is inadequate. As a result, in general, existing level of provision of civic services is poor and inadequate in coverage.

Key issues that confront ULBs have been found to be similar. Issues that confront Agra Nagar Nigam and are applicable generically to most ULBs, are listed below[1]:

(1) Inadequate revenue moblisation

- Severe financial crisis as a result of dependency on the state for resources for mere survival. Insufficient funds even to manage their establishment and operational expenses No reforms for increasing productivity and revenue mobilization.
- Grossly untapped possible sources for revenue, specifically property tax system.

(2) Inadequate institutional capacity and poor human resource and financial management

- Over staffing and high establishment costs

[1] Refer Collaborative Study on Municipal Reforms in Agra Nagar Nigam, Final report Phase 1, August 2002, Price water House Coopers

- Centralized decision making and high instability of senior positions
- Low motivational levels and work culture that constraint need to perform
- Low skill base of staff and poor human resource management systems
- Poor and non-transparent financial management system. Accounting based on cash based single entry system fails to reflect real financial position.
- Poor monitoring systems

(3) Inadequate participation of stakeholders in service delivery

- Inefficient and lack of transparency in customer interface processes
- Overlap in responsibilities between multiple agencies involved in planning, asset creation and O&M hampering decision making and service delivery
- Limited private sector participation; ULBs lack pro active mechanisms to seek public participation
- No effort to manage public opinion and seek cooperation and participation in service delivery process; inactive CBOs

Current institutional arrangement for YAP

The current institutional arrangement in the participating towns of UP and Haryana have been summarized in Table 6.1 and 6.2 respectively. In all YAP towns of UP except Noida, UPJN is at present operating and maintaining the assets either through large private contractors for UASBs or through local contractors for WSPs. In case of Noida, the facilities were handed over to Noida Authority in 2002. In Haryana, the O&M is being carried out by PHED through private contractors, except in case of Yamuna Nagar and Karnal, where O&M is departmental (refer Table 6.2).

Similarly in Delhi, while the two pilot STPs of 10 mld are under the overall management of DJB, the contract for O&M has been given to Pragati Power Corporation Ltd. (PPCL) which has subcontracted the constructing company to operate and maintain the plants. Separately DJB is operating and maintaining 16 STPs of large capacities in Delhi, other than those constructed under YAP. For this, they have a separate sewage disposal works department.

In all cases, except Noida, the finance for operating and maintaining the STPs is coming from the respective state governments who then transfer the allocated state funds in the budget to the PIAs (i.e. UPJN, PHED, DJB).

Status in UP

As mentioned earlier, UPJN is the current O&M agency in UP, except in Noida. The PSs and STPs are being managed by UPJN's Yamuna Pollution Control Unit with its head office located in Lucknow. The overall UPJN institutional structure for YAP has been shown as Figure 6.2. As shown, CE (Ganga) is responsible for YAP at the HO under whom CEs at Gaziabad and Agra are managing the works. YPCU at Agra is responsible for supervision and monitoring of all works completed under YAP I in Agra, Mathura, Vrindavan, Etawah and Agra while YPCU at Gaziabad manages STPs in Saharanpur, Muzzafarnagar and Gaziabad. Some key issues related to institutional arrangements have been discussed below.

Institutional arrangement

On account of the inability of the ULBs to operate and maintain STPs, Government of UP issued an order in November 2000 for UPJN to do so and ULBs to pay towards this upkeep. All plants in UP, under UPJN ownership, have been further contracted out to private contractors for O&M. However, at Agra, the constructing agency is forced to operate the 78 mld UASB plant (commissioned in 2001) without any payment, as UPJN refused to take it over due to structural and design defects. Since the plant is to be handed over by the end of 2003, tenders have already been floated for O&M by UPJN.

At many plants (including in Mathura, Vrindavan, Agra, Gaziabad), it was observed that the O&M of pumping stations was also awarded to contractor engaged for O&M of STP. This is a good practice as it prevents coordination problems in running the system. For instance, if the sewage is not pumped from the PS (say due to a power cut), the STPs will not receive any flow or minor repairs may not be attended to in a timely manner.

Fund allocation

As per the GoUP directives in January 1999, deductions equivalent to the total STP O&M expenditure will be made in the total state grants to ULBs from the State Finance Commission. Expenditure towards electricity is to be made directly by the state government to the Electricity Board. For instance, Agra Nagar Nigam is losing out about Rs. 10 million every year on this account. This should act as a strong incentive for the ULBs to gear up and take over the STPs. UPJN's expenditure for running these plants is being covered indirectly by ANN.

However, expenditure funds have not been forthcoming to UPJN, which has been one of the major constraints in functioning of the STPs. The UP government budget has still not been finalized and passed for the current year 2003-04. The supplementary budget includes allocation for only minimum regular works for the past months and not for project works. Due to lack of funds, the private contractors have not been paid in most towns and are experiencing difficulties in maintenance, some even showing disinterest.

Table 6.1 Detail of STPs in UP under YAP I, As on Dec. 2003

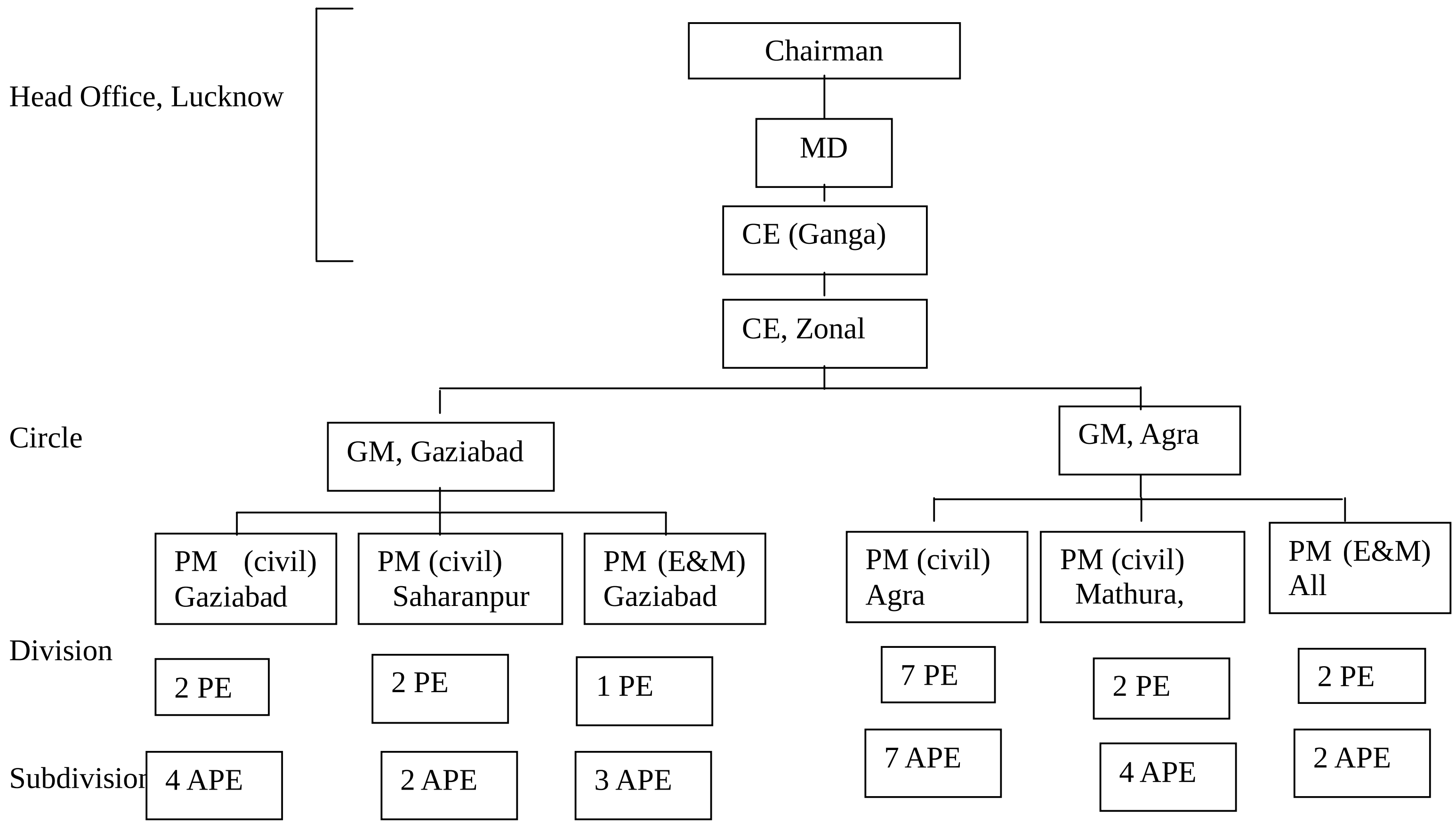
	Detail of STPs	Construction agency (UPJN/ name of contractor)	Current owner of STP	Current agency for O&M	Period of contract	Rate of contract (Rs. Lakhs per annum)
Saharanpur	1 UASB 30 mld	GSJ Envo	UPJN	Enviro Engineers	1	45.33*
Muzzaffarnagar	1 WSP 32.5 mld	Multiple Contractors	UPJN	Envirocon Engineering Co.	1	33.59*
Gaziabad	1 UASB 70 mld	NBCC	UPJN	Lakshmi Electricals	1	37.16*
	1 UASB 56 mld	GSJ Envo	UPJN	Enviro Engineers	1	32.63*
Noida	1 UASB 34 mld	Tandon Engineer Pvt Ltd	Noida Authority	Arezona Control Systems	1	11.4
	1 UASB 27 mld	Tandon Engineer Pvt Ltd	Noida Authority	Arezona Control Systems	1	11.4
Mathura	1 WSP 14.5 mld		UPJN	Local Contractor	1	
	1 WSP 12.5 mld	M/s Rakesh Yadav, Etawah	UPJN	Local Contractor	1	
Vridavan	1 WSP 4 mld	Brij Mohan Construction Co. Ltd, Aligarh	UPJN	Local Contractor	1	64 lakhs for both STPs + 8 PS + cost of diesel
	1 WSP 0.5 mld	n.a.		Local Contractor	n.a.	
Agra	1 UASB 78 mld	NBCC	UPJN	NBCC; still with construction co., not handed over to UPJN due to structural faults	-	-
	1 WSP 10 mld	Brij Mohan Construction Co. Ltd, Aligarh	UPJN	Local Contractor	1	2.9
	1 WSP 2.25 mld	M/s Hari Mohan, Agra	UPJN	Local Contractor	1	2.4
Etawah	1 WSP 10 mld	M/s Rakesh Yadav, Etawah	UPJN	Local Contractor	1	Approx. 3.2, incl MPS

Notes : (1) * includes O&M cost for pumping stations; excludes cost of power and major repairs
(2) For all contract rate of contract, excludes cost of power and major repairs

Table 6.2 Detail of STPs in Haryana under YAP 1, As on Dec. 2003

Town	Detail of STPs	Construction contractor (under PHED)	Current owner of STP	Current agency for O&M	Period of contract	Rate of contract (Rs. Lakhs per annum)
Yamunanagar	1 UASB 25 mld	California Design & Construction Co.	PHED	PHED	-	-
	1 UASB 10 mld	California Design & Construction Co.	PHED	PHED	-	-
Karnal	1 UASB 40 mld	California Design & Construction Co.	PHED	PHED	-	-
	1 WSP 8 MLD	Aparna Construction Co.	PHED	PHED	-	-
Panipat	1 UASB 10 MLD	Hydron, Ahmedabad	PHED	Hydron Enviro System, Faridabad	earlier 1 year; now for 3 years	12.5
	1 UASB 35 MLD	GSJ Envo	PHED	GSJ Envo, Delhi	earlier 1 year; now 2 years	earlier 20.5; now 19.5
Sonepat	1 UASB 30 mld	Western Pac (60%); NBCC (40%)	PHED	NBCC (for 15 months after commissioning); now Hydron	Now for 3 years	48 lakhs for 3 years
Faridabad	1 UASB 20 mld	Tandon Engineers Pvt Ltd, Delhi	PHED	Hydron Enviro System, Faridabad	3 years	35 lakhs for 3 years
	1 UASB 45 mld	NBCC	PHED	GSJ Envo, Delhi	3 years	49.5 lakhs for 3 years
	1 UASB 50 mld	Degremont India	PHED	Hydron Enviro System, Faridabad	3 years	58.4 lakhs for 3 years
Gurgaon	1 UASB 30 mld	GSJ Envo	PHED	GSJ Envo, Delhi	earlier for 1 year; now 3 years	19.2

Notes: (1) Rate of O&M contract excludes cost of electricity
(2) Contract does not include major repairs which are carried out departmentally



Notes: (1) While GM Gaziabad is responsible for schemes in Gaziabad, Muzzafarnagar, Saharanpur, Noida, GM Agra is responsible for Agra, Mathura, Vrindavan and Etawah; (2) MD: Managing Director; CE: Chief Engineer; GM: General Manager; PM: project manager; PE: Project Engineer; APE: Assistant Project Engineer

Figure 6.2 Current Organisation Structure of UPJN, UP for YAP I

YPCU organization structure

As shown in Figure 6.2, UPJN has a strong YPCU structure in terms of manpower spread. While a large structure has been retained for the project, it supports only those positions which are specified as per NRCD norms. The rest of the posts are funded by UPJN. It is understood that this level of staff has been retained in anticipation of YAP II project. Key concerns related to organization structure are detailed below.

(1) There is a presence of a heavy UPJN supervision structure for O&M of plants: Taking the case of Agra, for monitoring the activities of the contractor, along with the Project manager stationed at the office, UPJN Project Engineer (civil) spends 2-3 hours and assistant project engineer (civil) spends 5-6 hours at the plant everyday. Also PE and APE (electrical and mechanical - E&M) also provide their inputs whenever required. In addition 6 support staff i.e. 1 sweeper, 2 office boys, 2 security guards and 1 gardener has been provided by UPJN at the STP. Prima facie, there is a large UPJN presence at the plant that by and large runs by itself. This situation is applicable for all STPs.

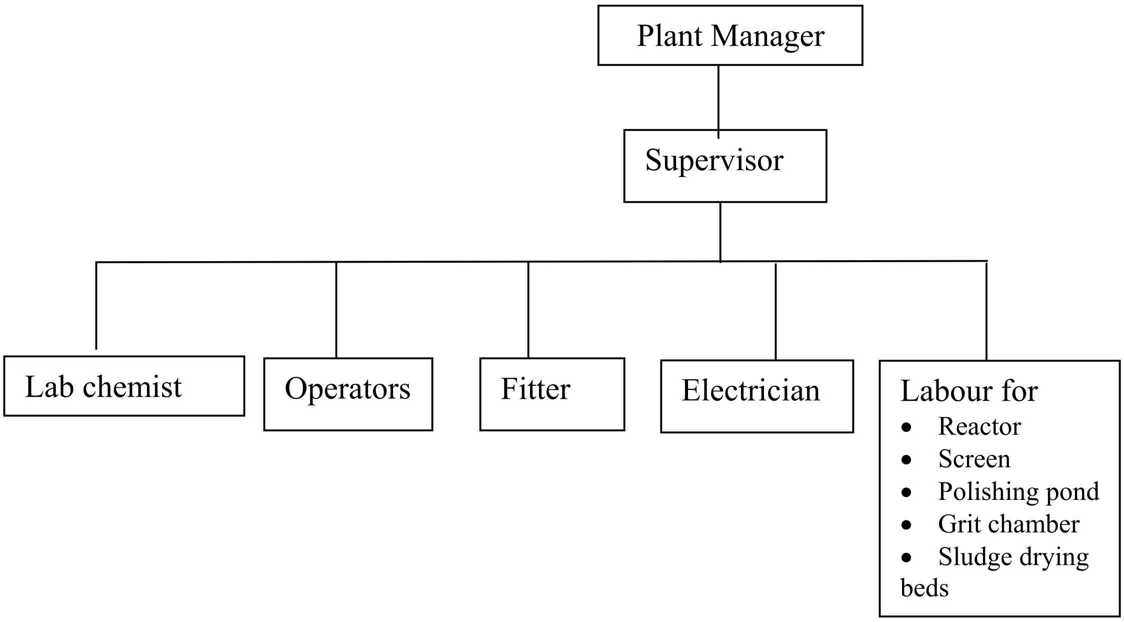
(2) There is no separate operation and maintenance branch in UPJN: UPJN's primary role is in construction of water supply and sewerage schemes for the state of UP. It operates and maintains water supply i.e. largely tubewells in villages. As such there is no expertise in O&M of large or complicated STPs. In addition, there are frequent transfers of engineers between towns as well as between water and sewerage due to which often engineers posted at YPCU have little or no experience in O&M of STPs.

(3) There is a possibility of confusion in authority limits given the parallel civil and E&M line of authority: There are separate and parallel civil and E&M divisions within YPCU. Even though UPJN's civil division (under the GM) has the overall charge of the plants, this leaves room for ambiguity in authority limits. For instance, during the consultants visit at Agra's 78 mld STP, the mechanical screens in the primary treatment section were not operational due to a power cut. Inspite of this the DG sets were not switched on. APE (civil), who was present on the site, claimed to have no authority to get the DG sets operational unless necessary order comes from the PE/ APE (E&M). This may be due to some personal differences, however, the supervision of O&M suffers on this account.

(4) There are frequent transfers of engineers within UPJN: There is a culture of frequent transfers on post in UPJN. Most of the engineers who were met in Agra division have been on the project for 6 months to a year. The General Manager in Gaziabad division has seen a new officer in average span of 6 months since 2002. As a result of transfers, there is loss of knowledge on the project as well as trained and experienced project personnel.

Contractor manpower at site

Figure 6.3 shows the organisation structure of O&M contractor (Enviro Engineers) at the 73 mld UASB plant at Gaziabad, which typically illustrates the manpower employed by all private contractors at YAP UASBs in UP. In general, at all the UASB STPs visited, the plants are under the overall management of an Engineer (or Plant Manager) who can be full time or part time as per requirement. The lab chemist and other staff/ labour are placed under a supervisor. For WSPs, the private contractors have generally hired unskilled labour.



Notes: While lab chemist, operators, fitters and electricians are skilled staff, labour (sweepers) hired at various stages of treatment plant are unskilled. In addition, there is support staff consisting of peons, gardeners, security guard, paid by UPJN

Figure 6.3 Organisation Structure of Contractor at Gaziabad 56 Mld UASB STP

Other related contractual issues

Period of contract

The contracts between UPJN and the private contractors have been ranging from a period of 1 to 2 years in the past years. The tenders are floated every year and the contact is awarded based on analysis of technical and financial quotations. While this is to assess the operational capacity of the contractor from UPJN's side, there are several disadvantages associated to this:

- A short period contract discourages the contractor from employing his full financial as well as personnel resources
- The contractor is unable to achieve economies of scale and rationalize his resources
- From UPJN's side, there is wastage of time and resources in floating and assessing the tenders every year

Tendering on annual contract is based on directions from headquarters of UPJN. It is understood that a policy is now in the process of being framed based on their experiences with private contractors, in order to rationalize resources and derive maximum benefits from such contracts.

Cost of contract

Generally, work is awarded to a company with the lowest quote. For instance, at Gaziabad this year, all the financial bids received were below the NRCD norms for O&M of STP of comparative capacity (i.e. Rs. 2 crores including power; Rs. 1.65 crs excluding power). Due to unavailability of an appropriate rating system and lack of capacity of UPJN staff, the contract went to the lowest bidder. As a result of a rather low rate, the contractor is often found cutting costs. For instance, hiring unskilled labour in 2 shifts for 12 hours each rather than the stipulated 3 shifts of 8 hours each. This is not in conformity with the labour laws. Other cost cutting possibilities could be positioning chemist both for plant supervision as well as for laboratory, reducing the dosing of chemicals, reducing number of samples for analysis etc.

Inclusion of lab under the contractor

Placing the laboratory and the employed chemist under the contractor's control puts a question mark on the authenticity of the lab test results, which primarily are the indicators of the STP's performance. Interestingly at Allahabad, the operation of the laboratory has been retained by UPJN, enabling it to monitor the working of the contractor closely and effectively.

Occupational health and safety (OHS) issues

It is observed that OHS aspects are severely compromised at almost all STPs. At Agra 78 mld UASB, some of the observations were made that are briefly described here.

- Walkways on the inlet chamber and screen channels are not robust and strong. They are improvised and locally fabricated and are exposed to corrosive environment. The possibility of their collapse under sudden heavy load can not be ruled out.

- The STP workers are expected to manually remove the screenings, grit, floating scum, sludge etc. During the process they are severely exposed to contaminated wastewater and as result are likely to be infected by pathogenic micro-organisms, helminths etc. Considering the working conditions (which are a result of compromise on technical robustness of the facilities installed at the STPs), it is perceived that the STP workers are affected by skin diseases, as well as other wastewater based diseases.

The violations are observed in manual cleaning of screens, grit channels, sludge in anaerobic pond as well as while removing the partially dry sludge from the sludge drying beds. In this context, it is advisable to consider the aspect of OHS aspects for STP workers while designing the facility and while deciding on the level of mechanisation in the plant.

Issues related to labour laws

As discussed, the contractor engages skilled, semi skilled and unskilled workers for running the plant, cleaning the various units, removing the screenings, grit and sludge, maintaining the machines, electrical equipment etc. As a typical factory, the plant runs for 24 hours and in principle it requires presences of operating personnel for all the three shifts. Accordingly the contractor should engage necessary number of personnel in 3 shifts. However, it is observed that the semi-skilled and unskilled workers are deployed in two shifts of 12 hours each. By adopting such working schedule, although the contractor is able to economise the costs, but it puts excess work load on the workers and is a violation of the rules of the Factories Act. Besides, from occupational health and safety point of view also there are concerns as the workers are severely exposed to raw sewage at screen and grit chamber as well as in the pump section.

Noida

2 STPS of 27 mld and 34 mld capacities constructed under YAP at Noida were handed over by UPJN to the administrative authority of Noida city (New Okhla Industrial Development Authority - hereafter referred as Noida Authority) in September 2002. Noida Authority is an autonomous organization under the Government of UP, whose primary role is to develop land and its infrastructure. Noida has been basically developed as an industrial town under Noida Authority. There is no municipality in Noida. All capital works and their operation and maintenance related with housing, commercial, roads, water, sewerage street lights is the responsibility of Noida Authority in all Noida sectors. The Authority is a large profit making organization whose main source of revenue is from the rent on lease of land,

completely owned by it in Noida. In fact, it also has been extending loans/ grants to GoUP. Therefore, it is not dependent on state government funds for O&M of STPs.

Noida Authority has various departments including industrial, commercial, institutional, housing, health. YAP STPs falls under the engineering department, which has two water and sewerage circles responsible for the O&M of STPs separately. For supervision of STPs, PEs in both circles, have one APE and one JE, all of whom have additional responsibility of O&M of water and sewer network in their areas. While the APE makes weekly visits, JE visits the respective STP once a day.

The 2 STPs were initially run departmentally for 6 months. Noida Authority, employed personnel for STPs on daily wages which included a technical supervisor, 2 supervisors, 4-5 sweepers for each STP. They were under the supervision of a JE. Subsequently, O&M was given to a contractor on trial basis for a period of 6 months, which has now been extended by another year. Discussions with Noida Authority indicate that the private contactor was hired, in view of the following advantages:

- To decrease the supervision time on STPs, given shortage of staff in Noida Authority
- To improve quality of work in relation to cost
- To avoid regularisation of daily wages staff, or creating more posts under Noida Authority, a more costly option in the long run
- To decrease overhead costs on STPs

No training has been imparted to any staff of either Noida Authority or the contractor. For monitoring, daily lab readings are noted by the chemist hired by the contractor. As given to understand, no independent tests to confirm lab results are carried out by the Noida Authority. Incidentally, the pilot on disinfection by chlorination implemented in Noida has stopped functioning due to lack of a long term monitoring plan, lack of budget and loss of knowledge due to recent transfers of officers.

Status in Haryana

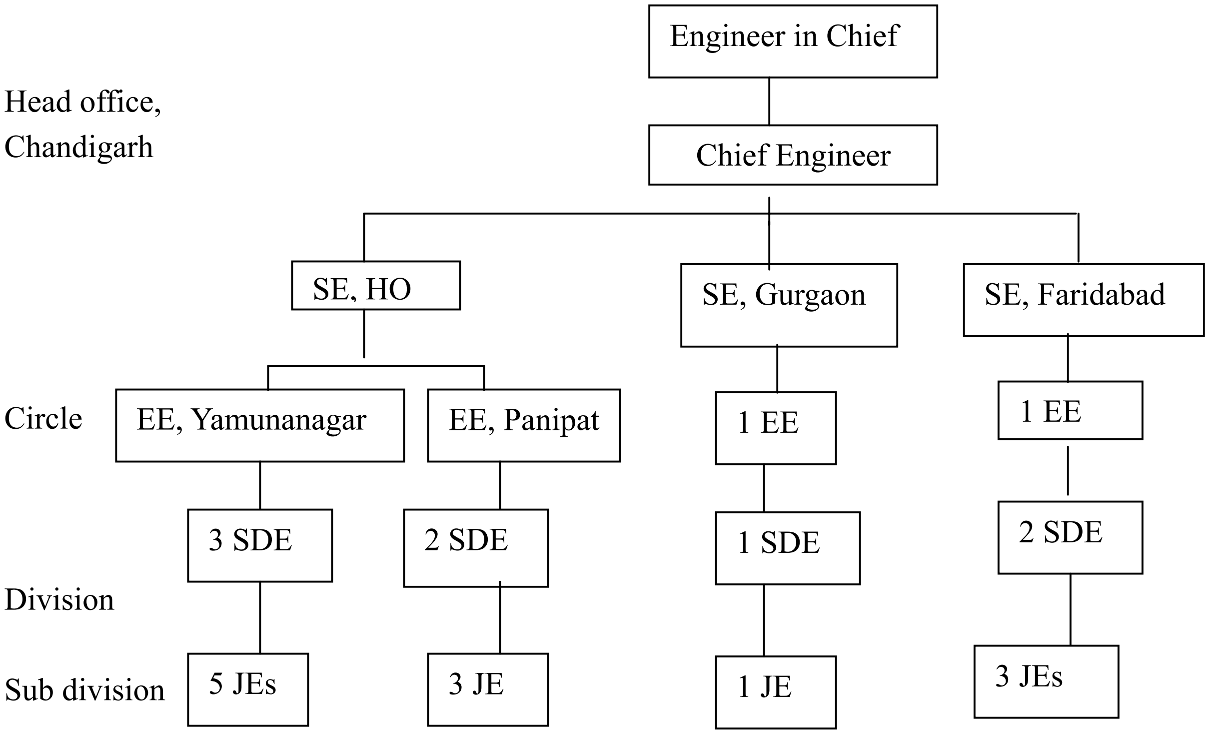
In Haryana, PHED has also retained its YPCU operating from its head office in Chandigarh. The overall existing institutional structure for YAP in Haryana is shown in Table 6.4. There are 3 Superintendent Engineers in 3 different circles of Gurgoan, Faridabad and one based at Chandigarh, under a Chief Engineer based at HO. Works at Sonepat, Panipat, Yamunanagar and Karnal are supervised by a SE (Chandigarh). Some key issues related to institutional arrangements have been discussed below.

Institutional arrangement

Since 1994, PHED has been responsible for O&M of sewerage system in all towns and under the directives of Government of Haryana is operating and maintaining these plants. Faridabad is the only town, which has a Nagar Nigam, while the rest of the Haryana towns have Nagar Palika/ Nagar Parishad. Recently Government of Haryana has moved to upgrade six more towns from the status of Nagar Palika (Municipal Council) to Nagar Nigam (Municipal Corporation), however, this has not been implemented yet. This will include two YAP towns of Panipat and Yamunanagar.

In Faridabad, the Nagar Nigam had declined to take over the O&M of STPs for atleast the next three years in view of their poor financial condition. In a meeting convened in December 2003, Faridabad Nagar Nigam also refused to contribute a proportionate cost towards the STP O&M, while Haryana Urban Development Authority (HUDA) agreed to do so for the sectors being maintained by them. However, it is understood that unlike in UP, no funds are being deducted from Faridabad Nagar Nigam on account of their inability to maintain the STPs.

At present, in Haryana YAP towns, all STPs have been contracted out to private companies under the supervision of PHED, except in Yamunanagar and Karnal where PHED is operating the plants by their own staff. Discussions with Yamunanagar officials indicate that internal O&M has succeeded in gainfully employing their surplus staff, achieving a higher level of responsibility and yielding high quality O&M in absence of incentives to cut costs. However, this needs to be verified as at other places there is general trend of hiring contractors for O&M.



Notes: (1) CE (urban) at HO has additional responsibility of YAP projects; SE at HO is responsible for physical works under YAP I in Sonepat, Panipat, Yamunanagar, and Karnal.
(2) STPs at Yamunanagar and Karnal (under EE at Yamunanagar), are being run by PHED staff. At Yamunanagar, 2 SDE and 3 JE for 2 UASBs and at Karnal, 1 SDE and 3 JE for 1 UASB and 1 WSP have been posted.
(3) At Faridabad, 2 SDE are supervising the 3 YAP STPs, under whom 3 JE are responsible for 3 plants.
(4) At Gurgaon, STPs are under the town division of PHED; no staff is posted separately for the STP i.e. YAP STP are an additional responsibility
(5) There is no separate construction and O&M wing or civil and mechanical wing in PHED.

Figure 6.4 Current Organisation Structureof PHED, Haryana for YAP I

Fund allocation

Since PHED is a state department, unlike UPJN, the fund flow is direct from the state government of Haryana to PHED. No funds are being deducted from the ULBs' account against O&M of STPs. The fund flow from the state government has been regular towards the O&M of YAP works to PHED, due to which the STPs performance have not suffered.

YAP organization structure

PHED, as in case of UPJN, has retained a heavy organization structure for running YAP STPs. Supervision of STPs is the full time responsibility of the staff posted at Yamunanagar, Panipat and Faridabad divisions. Only at Gurgoan, the single STP has been placed under the permanent town division of PHED, where it is an additional responsibility of the engineers. Key concerns related to organization structure are mentioned below.

(1) There is a fairly heavy PHED supervision structure for O&M of plants: Taking the case of Faridabad, for supervising the contractor, in addition to a full time EE, 2 AEs and 3 JEs have been retained for monitoring activities in 3 STPs.

(2) There are no separate operation and maintenance division in PHED: Inspite of PHED's role in construction as well as O&M of water supply and sewerage schemes for the state of Haryana, no distinction has been made between construction and O&M staff. An engineer could gain experience in both aspects on the job depending on where he gets posted. It is learnt, recently, the division between civil and mechanical cadre in PHED has been done away with. Typically there are transfers of engineers between water and sewerage as well as to different areas.

Contractual issues

Contractual issues in Haryana are more or less similar to the ones in UP. One reason for this is the fact that some contractors are the same in both states.

Status in Delhi

Under YAP two 10 mld STPs were commissioned in 1998 (Dr. Sen Nursing Home) and 1999 (Delhi Gate) in Delhi. Due to limited scope of works, no separate construction or monitoring units were created as was the case in UP and Haryana. Organisationally, sewerage in DJB is under sewage disposal works wing (SDW), with their electrical and mechanical unit being responsible for both construction and O&M of STPs. It has no separate line of engineers for construction and O&M. Water supply is a separate wing, however engineers are often transferred within the two wings in the normal course and it may happen that they acquire expertise in both water and sewerage construction and O&M aspects on their job.

Between 1998-99 and June, 2003, both the STPs were being managed by DJB staff (through private contractors). One EE in sewage disposal works was responsible for both STPs, in addition to his other sewage works. One full time AE and one JE were supervising both the plants.

In February 2003, an agreement (cleared at the Chief Minister, Government of Delhi level) was reached between DJB and Delhi Government's Pragati Power Corporation Ltd (PPCL), for O&M of STPs by the latter. As per this unique agreement, in exchange for free 20 mld of daily intake of treated wastewater from DJB, PPCL will operate and maintain the plants as well as cover the cost of electricity at the plants. This is physically possible due to the unique location of PPCL plant in proximity to the STPs. There is no exchange of funds between the two departments.

From June 2003, PPCL has sub-contracted the O&M of the STPs to a contractor for 2 year, which happens to be the original technology provider and construction agency. The organization structure of the contractor at the plants is on the same lines as shown in Figure 6.3. DJB has now withdrawn its supervisory staff from both the STPs. PPCL has deputed one supervisor in three shifts of 8 hour each separately at both plants for monitoring the activities of the sub contractor. The latter position is only part time.

6.3 TRAINING

No systematic training for any specific target group was planned under YAP I. Sporadic training efforts were carried on piecemeal basis. Concerns related with training are brought below.

(1) Overseas exposure visits of 1-2 weeks to Japan for some senior officials of NRCD and PIAs was conducted early during project implementation stage.

(2) Only one round of technical training organized in 2-3 batches at IIT Kanpur during 1996-98. Engineers of the rank of SE, EE and downwards were invited from UPJN as well as PHED. The objective was to familiarize them with the technology concepts as well as O&M issues. The training was classroom type based on lectures. It is learnt that:

- Participation was not full and selection of participants was not systematic, as a result the knowledge could not be transferred to the right target group. Engineers especially from UPJN, who may have been unrelated to the project, were nominated at short notice.
- Prior to the training no training needs assessment was carried out to ascertain either the content or structure of the training module to be imparted. For instance what aspects of STP i.e. process control, monitoring, laboratory etc, are to be covered or whether the training is to be classroom based and has a site visit component etc.
- It was a one time training. No followup or refresher trainings were carried out.
- A small group of engineers was trained, of which possibly only a few are posted at the project sites as on today. Engineers in UPJN Agra revealed, that having received no training and UASB being a new technology, it was the construction contractor who imparted knowledge on the process and design. APE (civil) posted at the UASB plant for O&M, familiarized himself on technological aspects through various technical articles and books on the subject.

(3) Training needs of other target groups such as operators were not addressed.

(4) No comprehensive O&M manual for any kind of STP technology has been developed under the project for ready reference of operating and maintaining staff. At some STPs, contractors have provided O&M manuals or alternatively some literature on their own technology. However, they are put to little use. Also, based on experience they need to be updated and be made readily available, but this typically does not take place.

6.4 MONITORING

Monitoring issues by the PIA staff have already been covered in earlier paragraphs. The following paragraphs highlight other important aspects of project implementation and day to day monitoring.

Monitoring for project implementation

As per the directives of NRCD in 1995, Citizen Monitoring Committees (CMC) were constituted in each project town to monitor the progress of execution and timely completion of schemes, their operation and maintenance and to facilitate public awareness and participation. For this purpose, the CMCs were to have representation from PIAs, other related governmental institutions, and local citizens and experts. For instance, in Faridabad, CMC is chaired by the Deputy Commissioner of Faridabad district and has representatives from PHED, Municipal Corporation, Haryana Pollution Control Board, Chief Medical Officer, State Health Department, and private members as nominated by the government. In Gaziabad, CMC is chaired by the Mayor of Municipality, with UPJN's Project manager as the secretary and includes members from UP State Electricity Board, Gaziabad Development Authority, and two NGOs. Clearly, these are bodies have more presence from government departments and the civil society is not well represented.

However these have not been effective as they have met only infrequently. In the towns visited, CMC have met ranging from twice to once a year, as against the stipulated quarterly meetings. It is reported that interdepartmental problems are discussed in these meetings and the primary objective of exploring and facilitating possible citizen participation remains only in principle.

At the project level, no mid term project reviews, evaluations or performance reviews have been carried out by independent professionals on behalf of JBIC. One performance review of YAP I was sponsored by NRCD in July 2002, wherein IIT Roorkee was retained to assess performance of all the core and non core schemes.

Day to day monitoring

Laboratories

Labs with equipment to carry out physio-chemical tests were set up under YAP I in all towns of Haryana and UP except Mathura, Vrindavan and Etawah. In the extended phase of YAP labs in Sonepat, Panipat, Gurgaon, and Noida were upgraded for bacteriological testing. At all places, as brought out earlier, these labs have been placed under the contractors, who have recruited full time chemists to carry out routine daily testing of the influent and effluent. This arrangement raises doubts on the authenticity of lab results. In addition, following observations were made related to labs.

- Systematic recording and presentation of data is not being carried out at some STPs. It is observed that the time series of the effluent quality is unusually consistent. For instance, the standard deviation for effluent BOD and SS concentrations are between 1-2. This pattern defies probability of wide variations and indicates that the data is manipulated.
- Validation and authentication of data recorded is seldom done by the PIAs. Occasional tests are carried out independently through private/ governmental labs, but they are not regular. State Pollution Control Board and Central Pollution Control Board carry out independent monitoring through random sampling once a month. However the reports are often not shared by the organization or usually get delayed by months.
- Lab equipment is lying out of order due to shortage of funds, which affects the sampling and recording of data.
- The activity of the lab was not being integrated with and into improved management of the plant. Data collected is not being analysed. For instance, log books for all flows and their relevant charecteristeics, particularly side stream could be kept to calculate mass loadings and make material balances. Similarly energy audit needs to be carried out to assess the efficiency of the treatment processes. Moreover, availability of lab is not leading to any optimisation of process during various stages by way of R&D work.

MIS and database

The project adopted a conventional database management system that focuses on outputs and inputs (physical and financial) as they relate to pre defined project targets, staffing levels and expenditure. Existing monitoring systems and formats present obvious static data but fail to be adequate for capturing process issues.

In addition, a web based MIS was established during the extended period of YAP I for the efficient monitoring of YAP and for prompt decision-making by NRCD and other stakeholders. The main objective was to interconnect all JBIC funded YAP towns to the central server placed at NRCD via Internet and customized software so that information can be disseminated and interchanged in an effective manner. The system was to be utilized for project monitoring and scheduling of assignment, in addition to regular monitoring of physical and financial progress of each of the schemes. The works carried out under this component included development of web-enabled application for end users, provision the computer hardware, hosting of YAP website http://www.yap.nic.in and training to all PIAs to use web-enabled application.

In spite of an extensive training, PIAs failed to even update the data and instead a software consultant had to be retained to maintain the website for one year. At present, the website is highly underutilized.

It is observed that a large number of research students access this website. Physical and financial progress of some schemes has been updated but this data has some discrepancy, as it hasn't been verified through various administrative levels. No final single point validation of data is carried out. Also, no data analysis of any kind (such as time series charts) is done to inform the project with respect to improvement in performance and decision making process.

CHAPTER 7

RECOMMENDATIONS
FOR
INSTITUTIONAL ARRANGEMENTS AND
STRENGTHENING OF STP

CHAPTER 7 RECOMMENDATIONS FOR INSTITUTIONAL ARRANGEMENTS AND STRENGTHENING OF STP

The following chapter provides recommendations for institutional arrangements and strengthening of the core component.

As identified in Chapter 7, there are several areas of institutional concerns that are affecting the performance of the STPs installed under YAP I. Recommendations for overcoming these have been classified as options for institutional arrangements and institutional strengthening, both of which have been described below. While institutional arrangements refer to the roles and responsibilities of the various institutions in provision of a service, institutional strengthening interventions focus on improving organizational effectiveness of the individual institutions. Prior to this, suggestions with respect to approach to project implementation have been made.

Approach to project implementation

Implementation approach that integrates investment in technology with a clear and strong focus on institutional (and financial) aspects is required for a successful and sustainable project. This implies that concurrent institutional efforts should match pace with technical inputs during the project cycle. Institutional efforts include organizational assessment of involved state and city level agencies and subsequently, their capacity building to enable them to effectively build, own and manage the assets created under the project.

A key input at the onset of the project would be working out an effective project institutional framework that sets out clearly the roles and responsibilities of the involved organizations. Often, relying on special implementing agencies at the cost of weak ownership by local governments has been established as a prime factor for failure of urban projects of this nature. For this purpose, ideally the ownership of the project should rest with ULB, the agency which would be finally responsible for operating and maintaining the STPs and PSs, in this case. This would ensure a high level of involvement and participation of the ULB in project planning as well as implementation stage. To achieve this, following two possibilities can be considered.

(1) Project ownership by ULBs: The project could be implemented through ULBs (instead of government engineering departments) who would be the nodal agency appointed to steer the project. The ULBs, in turn, can further invite suitable organisations such as UPJN, PHED for planning and construction (as in a client-contractor relationship). Although this arrangement is desirable, it may not be feasible, especially in smaller towns, where the legal and political power as well as the status of municipalities is much lower than that of UPJN or PHEDs. However, this possibility can be explored in large cities where Nagar Nigams exist. This may, however, necessitate strengthening the ULBs.

(2) Cost sharing by ULBs: The project could be implemented on the condition that ULBs share partial cost say 20% in the total project cost, which could be in the form of a loan from the state government repayable over say 30 years. This would ensure a firm commitment and a direct stake of the municipalities in the project and induce serious involvement as well as inclination to participate in all aspects at various stages of the project. In the interim period, aid for municipal reform can be extended to improve the financial and technical position.

Options for institutional arrangements

As is evident from Chapter 7, institutional arrangements for STPs and PSs in different states can differ considerably, depending on many factors such as the role of sectoral, state and local organizations, development and importance of the state, and political climate at the time of the project. Therefore, recommended institutional arrangements could be different for specific towns/ cities. Since the outputs of this case study would inform the Master plans being developed under the Ganga Water Quality Management Plan study in the four cities of Lucknow, Kanpur, Allahabad and Varanasi, only options that would be relevant for the institutional setup in the aforementioned cities of UP have been considered. However, while doing so, valuable inferences have been drawn collectively from the analysis of institutional arrangements under YAP I and lessons learnt thereof, in Haryana, UP and Delhi.

In each of the four cities mentioned above, Nagar Nigam or the Municipal Corporation (ULB) is responsible for provision of civic services including solid waste management. Each city has a separate body called Jal Sansthan, which manage O&M of water and sewage system. However, as per a recent GoUP order these are to be merged with their respective Nagar Nigams,. In Lucknow, it is understood that officially the merger did go through in 2002, but Lucknow Jal Sansthan is still being run as a separate organization.

Given the above scenario, the options for STP O&M have been determined under the assumption that

(1) Nagar Nigams would be the owners of STPs i.e. they would take over the STPs built under YAP.

(2) Jal Sansthans would eventually be integrated within respective Nagar Nigams as a separate water and sewage department.

The overall focus of the options/ interventions is greater and single point responsibility for operation of STPs, improved coordination, cost rationalization and an overall effective O&M regime. In this backdrop, the possible options for strengthening institutional arrangements for O&M of STPs are:

- Option 1: STP O&M by Nagar Nigam staff; UPJN engineers on deputation if required
- Option 2: STP O&M by private contractors

Each of these have been discussed in detail in the following paragraphs.

Option 1: STP O&M by Nagar Nigam/ Jal Sansthan staff; UPJN engineers on deputation if required

In this option, STP O&M is supposed to be carried out by Nagar Nigam itself with the help of Jal Sansthan staff. It is possible that in the transition period, Jal Sansthan remains a separate organisation under Nagar Nigam, but eventually, it is envisaged to function as a separate water and sewage department within Nagar Nigam. In either case, the staff of Jal Sansthans would come under the purview of Nagar Nigam.

Currently, it is understood, that major proportion of manpower and other resources of Jal Sansthans in the four cities under consideration, largely focus on O&M of water treatment and distribution system. The sewerage function is more or less limited to opening blocked sewer lines by sewer workers. Involvement of engineers in sewerage O&M is minimal. Therefore, considerable capacity would be required within Jal Sansthan-Nagar Nigam for effectively managing the sewerage O&M that might include complete O&M of STPs, in addition to undertaking maintenance works for branch and trunk sewers and their preventive maintenance using appropriate modern techniques and equipment. In order to build capacity, a separate unit for sewerage O&M under water and sewage department can be created. There would be two requirements for this purpose.

(1) Availability of engineers for O&M of STPs: O&M could be carried out by the Jal Sansthan-Nagar Nigam staff. In which case, it needs to be assessed whether the existing engineers in Jal Sansthans/ Nagar Nigam would be able to carry out the additional functions of O&M of STPs and PSs. If not, additional engineers may need to be inducted. Here, it is recommended to transfer engineers from UPJN on deputation to Jal Sansthan-Nagar Nigam rather than making new recruitments. This is feasible since UPJN currently appears to have extra capacity (in this case, some pay scale grade rationalization may need to be undertaken).

(2) Availability of relevant skills and knowledge: In both the above cases, the relevant staff would need to be trained on specific aspects. In the latter case i.e. with UPJN engineers on deputation, there may be an advantage of existing (on the job) trained engineers who may require only refresher/ advanced training. In any case, training requirements should be based on a training needs assessment of the specific target groups.

Advantages of this option include the following.

- Any surplus staff (technical or worker level) in Nagar Nigam/ Jal Sansthans/ UPJN can be gainfully employed. This also avoids the unpleasant situation of worker unrest against employing outside agencies as is being experienced at Kanpur and other places.
- In the process, level of operating efficiency may improve as a result of capacity building
- Nagar Nigam-Jal Sansthan can rationalize costs and cut overhead costs by reducing requirements of supervisory staff.

Disadvantages of the option include the following.

It would be difficult to consider this option immediately till Nagar Nigam is strengthened as an organization as it might add to the existing financial crisis

- Technical and managerial capacity will have to be considerably strengthened
- Control over quality and costs may be more difficult than in case of using external resources
- Lack of competitive spirit and consumer orientation (in Nagar Nigam-Jal Sansthan staff) may affect work output and quality.

Option 2: STP O&M by private contractors

In this option, a large private firm with some prior experience in operating and maintaining STPs, enters into a short term contract, say less than 3 years, for running large STPs or a small local contractor is engaged for running the WSPs (that require mainly semi or unskilled labour). This option is already gaining popularity for STPs installed under YAP I.

In India, a number of small scale informal public-private initiatives have emerged to fill the gaps in the existing delivery system. For instance, PHED in Ajmer has privatized O&M of the water filtration plant, pipelines and PS (pumping station) of the new water supply scheme from Bisalpur Dam. In Chennai, Water Board has contracted private operators to supply treated water in tankers to various locations. In addition, water treatment plant at Redhills and desalination plant on Marina Beach plus pumping stations have been privatized.

Advantages of this system are:

- It brings technical and managerial expertise and new technology in the sector, which currently lie outside the capacity of Nagar Nigam
- It improves the level of economic efficiency in both operating performance as well as use of

capital investment with better quality of service. Quality of service improves due to competitive bidding process, fear of loosing the contract and flexible management

- It lowers cost due to lower wages, coupled with higher productivity levels. No estimates of a cost comparison are available in O&M of STPs, however, a total of 44% savings in government costs have been reported by the SE of PHED in Ajmer by contracting out O&M of water supply system.
- It increases capacity without increasing overheads. No need for new recruitment in Nagar Nigam, which is not only difficult but also increases the already high staffing levels.
- Maintenance is carried out on a preventive basis rather than a breakdown basis, which reduces the frequency and duration of interruptions in service.
- It eases supervision. Managing privately contracted staff is easier since such staff is accountable for inefficiency, negligence and absence.
- It reduces political intervention in service provision to a limited extent

Disadvantages of the system are:

- Irregular payment to private contractors due to delay of funds from the state government may lead to loss of interest and motivation to do a quality job.
- Instances of labour unrest opposing private contracts have cropped up. Prime concern of labour unions is loss of existing and future jobs. It has gone to the extent of vandalizing the property at Kanpur STP and disrupting the functioning of city distribution network in Ajmer, Rajasthan
- Not many firms may have the required expertise since STP O&M through private contractors is a new system

However, there are some pre-conditions for success under which public-private partnership would be an effective as well as a profitable option. These are brought out below:

- The supervisory staffing levels (as in UPJN/ PHED) would need to be rationalized. EE and AE can devote only part time for supervision, while a full time JE can be made incharge of the operation of STP. This is detailed out in the following paragraphs.
- Given limited local capacity, choosing the right partner with adequate experience and resources, would be important for successful implementation.
- A tight contract management, although challenging, would be essential. This includes writing a technically and financially sound contract document, performance monitoring of contractors through a good balance of performance linked payment and penalties. Financial penalties against the contractors, in case of failure to meet the requirements of the contract, are important performance monitoring tools. Lessons learnt from managing the existing STP contracts can be incorporated into a better system
- Extending the contract to the best qualified bidder offering the lowest evaluated valid tender would work best. This essentially means that the lowest bid does not necessarily get the contract. Past experience has shown that the lowest bidder may not always have the prerequisite staff, experience, equipment, and access to credit to successfully carry out the task. Or, he may cut costs to perform the task in the quoted price.

While the purpose of presenting the above options is to provide some direction, the actual options for institutional arrangements could vary from city to city depending on the actual financial and technical status of the institutions, their arrangements, political will and policies existing at the time of implementation. Therefore, a city wise complete situational analysis needs to precede any realistic development of final options.

Institutional strengthening

There is a strong need for institutional and financial strengthening of the organizations responsible for provision of sewerage system. These have been discussed at two levels: (1) institutional interventions that focus on ULBs as the O&M agencies (2) institutional interventions specific to STPs and sewerage system.

Interventions specific to ULBs

With ULBs to be the eventual owners of the STPs, it is clear that providing institutional support to the sewerage function alone will not be effective in the whole scheme of things, given their financial and technical status. In order to achieve sustainable and perceptible impact, it is necessary to look at the institution as a whole. Moreover, interventions planned need to be systematic within the municipality, addressing all three identified critical areas of concern i.e. revenue mobilization, improvement in service delivery and institutional capacity development. This is because revenue mobilization and service delivery mutually reinforce each other, while institutional development (human resources and systems) is a key enabler for both.

Though the problems confronting the ULBs are similar, specific interventions will have to be designed and planned following detailed and careful study of the status of the existing situation of a particular corporation. While recognizing this, interventions planned under the Agra Nagar Nigam Reform Project have been highlighted to illustrate some solutions that can be offered.

In 2002, JBIC commissioned a collaborative study on municipal reforms in Agra Nagar Nigam to suggest measures for financial and institutional strengthening of Agra Nagar Nigam (ANN), which could be generally applicable and then be replicated to other ULBs in YAP towns. The study drew on best practices from other ULBs in India that have successfully implemented reform measures.

The objectives of the study were to:

- Facilitate the key stakeholders (especially senior management and municipal councilors) to develop a consensus on the nature and direction of reform process within ANN
- Sensitise key stakeholders through adoption of best practices in municipal management
- Demonstrate the impact of reform through a pilot exercise that can potentially be duplicated in other functional and geographical areas within ANN.

The project known as the Agra Municipal Reform Project (AMR), being implemented from March, 2003, has project components of property tax, public and private sector participation in service delivery and complaint redressal system. Areas for reform and their sub components have been summarised below.

Priority Areas identified for reform

(1) Improved resource mobilisation for ANN

- through implementation of Self Assessment System (SAS) for property tax for residential properties, a highly underutilized source of revenue, which includes building internal awareness and commitment, complete enumeration of properties, preparation of PT manual for citizens, software development, design collection system, train PT assessors, organize PR and tax mobilization camps.

- through imposition of Property tax on non residential properties based on capital cost method

(2) Improvement on service delivery

- through enhanced public participation in service delivery to build greater ownership towards local problems, and increase their willingness to pay for urban services. The action plan includes constituting ward committees, NGOs, resident welfare organizations, setting up Agra Safai Abhiyan in solid waste management, setting up a community development department in ANN, extensive public relation initiatives and constitution of RWAs and CBOs.

- by engagement of private sector in O&M for better service delivery for bringing qualitative and quantitative improvement in municipal services by fostering a competitive environment through four small pilot projects in primary and secondary collection of garbage, transportation to landfill site, primary collection and composting of bio degradable waste and O&M of streetlights.

(3) Building institutional capacity

- by improved financial management by reorganizing accounting department, computerization, budgetary control and reporting, internal control and audit, procurement and financial reporting.

- By providing a customer complaint redressal system at both front end (customers register and monitor complaints) and back end (follow up of complaints) for water supply and solid waste management. This includes development of CRS manual, training, reorganizing staff and infrastructure, monitoring of CRS.

Interventions specific to STPs

Some recommendations have been provided for three specific issues of human resources, training and monitoring based on the experience under YAP I. Each of these have been discussed separately below.

Human Resources

Recommendations for manpower requirement for managing the different types of STPs have been made based on the existing organisation structure of the private contractor managed STPs that were visited during the study. Manpower requirement for various capacities of ASP, UASB, OP and aerated lagoons have been worked out assuming STPs will be operated by private agencies (see Table 7.1). The recommendations have been made only for technical staff required at the STP site. Administrative/ support staff at the plant or supervisory staff requirement from PIA side has not been considered.

In comparison to ASP, level of skill required for WSP/ UASB is not high. For smaller capacity plants chemical analysis can be outsourced, therefore, chemists have not been considered. For advanced technology options, such as BIOFOR, manpower requirement has not been provided, however, it will be on the same lines as in case of ASP.

Table 7.1 Suggested Manpower Requirements for Types of STPs

S. no.	Position	ASP				UASB				WSP				Areated Lagoon			
		10 mld	40 mld	80 mld	120 mld	10 mld	40 mld	80 mld	120 mld	10 mld	40 mld	80 mld	120 mld	10 mld	40 mld	80 mld	120 mld
1	EE	-	-	1	1	-	-	1	1	-	-	-	-	-	-	-	1
2	AE	1	1	-	-	1	1	-	-	-	-	-	-	-	-	1	1
3	JE, E&M	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-
4	JE, civil	-	-	1	1	-	-	-	1	1	1	1	1	1	1	-	-
5	Fitter	1	1	2	2	-	1	1	1	-	-	-	-	-	1	1	2
6	Electrician	1	1	2	2	-	1	1	1	-	-	-	-	1	1	1	2
7	Chemist	1	1	1	1	-	1	1	1	-	-	1	1	1	1	1	1
8	Lab assistant	-	1	1	1	-	-	1	1	-	-	1	1	1	1	1	2
9	Operators	2	2	6	6	1	2	2	3	-	-	1	1	2	3	4	4
10	Labour	6	8	12	15	6	8	12	15	6	10	20	30	4	6	6	8

Notes:
* The manpower requirement has been indicated for plant operation; this does not include supervisory, administrative or support staff
* The above Table is only indicative; exact manpower requirement would depend on the actual capacity of STP, contractual agreement etc.

Item # 1,2: EE/AE equivalent to plant manager; should have experience in STP process operation; preferably with E&M specialisation
Item # 3: JE equivalent to supervisor; JE (civil) would be required for plant capacity with more civil structures
Item # 7,8: Level and qualification of the chemist would be a dependent on availability of laboratory, size of lab, complexity of treatment process
Item # 9,10: Manpower requirement has been worked out for one eight hourly shift; if the plant runs for longer hours, no. of operators, labour will increase accordingly. Actual no. of labour would depend on effectiveness of screening, quantity of sludge, method of sludge treatment

Training

With a large network of STPs having been created under YAP (25 STPs of both UASB and WSP technology) and GAP (around 35 STPs), there is a strong need for a systematic training in operation and management of STPs. It has been observed that in general, training that is imparted in various organizations is inadequate, one time and not need based. Therefore such training programs have little impact on person's job performance. To address this, a systematic training plan needs to be drawn up that will involve:

- Training needs assessment (TNA): often training needs are specific to target groups e.g. engineers, chemists, operators and should be identified based on specific problems the person may have in executing his job satisfactorily. For this a training needs assessment for all target groups is required to design suitable training programs/ courses.
- Design of training courses/ programs: Based on the TNA, appropriate courses can be designed for training in various aspects such as process control, monitoring etc. Need for integrating site visits, lectures/ experience sharing by construction companies and existing O&M agency staff, case studies etc. should be explored.
- Systematic selection and nomination of candidates for different categories of training programs
- Regular and refresher courses: It is important that training efforts are regular and refresher courses are conducted to upgrade skills and refresh knowledge.
- Training impact assessment (TIA): In order to assess the effectiveness and usefulness of any training, TIA should be carried out; and based on this, necessary improvements should be incorporated in the programs.

In USA and in some other countries, in order to ensure that only qualified individuals operate municipal and industrial wastewater treatment facilities, wastewater treatment operator certification is a mandatory licensing requirement under state law. This, thereby, implies that only certified i.e. trained operators are assigned the responsibility at any unit/ process of STPs. For instance, the state of Rhode Island in USA, has established a seven member Board of Certification of Operators of Wastewater Treatment Facilities. The Board, acting on behalf of their respective appointing organisations, provides guidance and expertise and make decisions relating to revisions in regulations, requirements for certification to be imposed on individuals or municipalities and other advisory opinions.

For such individuals employed or seeking employment in wastewater sector, many institutes offer program of training courses required for acquiring a certificate or preparing for the Certification Exam. One such program offers different courses including treatment plant operations, treatment and disposal, waterworks supervision, microbiology for operators, laboratory procedures, basic hydraulics and instrumentation and control etc.

In view of the increasing number of STPs in India, there may be a need for a similar institutional and legal mechanism to ensure proper and effective management of STPs.

Monitoring

Recommendations related with the laboratories for improved day to day monitoring are as follows.

- Operation of laboratories at the STPs may be excluded from the STP O&M contract and retained with the owner of STPs i.e. PIAs at present, as is the case in Allahabad. This enables independent and close monitoring of the contractor as well as ensures authentic sampling and recording of flows.
- Laboratory capacity at STPs need not be sophisticated. e.g. providing equipment for testing microbiological parameters and of heavy metals. Tests for advanced parameters can be carried out by outside independent agencies. Instead of providing such technology at all

laboratories situated at STPs at a high cost, capacity of relevant organisation/s (academic and/ or R&D) can be built up once to carry out this function for all STPs. This would ensure unbiased monitoring, without large training requirements at a lower capital cost, by an organisation with the requisite experience and knowledge.

- Data collected is analysed over time and for various characteristics to generate information that can be used to improve the plant performance.
- R&D work can be carried out for optimization of process during various stages. This can be in association with various engineering colleges, where research in wastewater treatment is being carried out.
- A comprehensive O&M manual specific to the particular plant is developed, either by the contractor or the technology provider. It should be as user friendly as possible for the various target groups e.g. it should be available in local language.

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Appendix A

APPENDIX A

STPs COMMISSIONED UNDER GANGA ACTION PLAN

Location	Existing STP, if any		New STP under GAP		Remarks
	Technology	Capacity, mld	Technology	Capacity, mld	
UP					
Rishikesh (Lakkarghat)			WSP	6	
Rishikesh (Swargashram)			RBRC	0.3	Decentralised STP for a small ashram/commune
Haridwar			ASP	18	SD included for biogas recovery
Farrukhabad-Fathegarh			WSP (without maturation pond)	4	
Kanpur (Jajmau 1)			UASB	5	First UASB in the country, implemented as a pilot for sewage treatment
(Jajmau 2)			UASB	36	Pilot for treatment of mixed tannery effluent and domestic sewage in a ratio of 1:3
(Jajmau 3)			ASP	130	Influent comprises domestic sewage
Allahabad			ASP	60	SD included for biogas recovery
Mirzapur			UASB	14	Upscaled plant after 5 years of experience at Jajmau pilot
Varanasi, (Bhagwanpur)	TF with SD	1.8	ASP	8	Plant has been stopped due to operational problems
Varanasi, (Dinapur)			RF-AS	80	Combined TF and ASP system; SD and biogas to power generation
Varanasi (DLW)			ASP	12	Decentralised STP for a public sector township and adjacent localities; SD
Bihar					
Chapra			WSP	2	
Patna (Eastern zone)			WSP	4	
Patna (Saidpur)	ASP	28	ASP	17	Old STP was renovated and capacity augmented
Patna (Beur)	ASP	20	ASP	15	--do--
Patna (Pahari/Southern zone)			AL	25	Excludes PST and has aquaculture pond in place of SST
Munger			AL	11	
Bhagalpur			AL	11	
West Bengal					
Chandan Nagar	WSP	4.5	TF	18	
Behrampore			WSP	4	
Nabadwip			WSP	4	
Kalyani	TF	11	WSP	6	

Location	**Existing STP, if any**		**New STP under GAP**		**Remarks**
	Technology	**Capacity, mld**	**Technology**	**Capacity, mld**	
Bhatpara (Gr.E)			WSP	10	
Bhatpara (Gr.B)	ASP	8.5	ASP	10	
	WSP	4.5			
Titagarh	ASP	4.5	WSP	14	
	WSP	4.5			
Panihati			WSP	12	
Baranagar-Kamarhati			TF	40	
Garden Reach			ASP	47	
South Suburban (E)			WSP	30	
Howrah	TF with SD	45			Over 30 year old plant was renovated and re-commissioned
Serampore	TF with SD	19			Over 30 year old TF was renovated which included SD and biogas exploitation
Bally			WSP	30	
Cosipore-Chitpur			ASP	45	

(Source : MOEF, 1995, 1998)

Note :

- ASP : Activated sludge process
- UASB : Upflow anaerobic sludge blanket process
- WSP : Waste stabilisation pond
- TF : Trickling filter
- AL : Aerated lagoon
- RBRC : Rotating biological rope contactors
- RF/AS : Roughing filter activated sludge process
- SD : Sludge digestion

Appendix B

STPs COMMISSIONED UNDER YAMUNA ACTION PLAN

Sl. No.	Location of STP	Technology / Capacity (mld)			Remarks
	Haryana : Haryana	**UASB**	**WSP**	**BIOFOR**	
1	Yamunanagar/Jagdhri Zone I & II	25			All UASB STPs are provided with duel fuel generation systems for conversion of biogas into electricity. Besides, sludge drying beds are provided as the final treatment method before its disposal or sale.
2	Yamunanagar/Jagdhri Zone III	10			
3	Karnal Zone I	40			
4	Panipat Zone-I	10			
5	Panipat Zone-II	35			
6	Sonepat	30			
7	Gurgaon	30			
8	Faridabad Zone I	20			
9	Faridabad Zone II	45			
10	Faridabad Zone III	50			
11	Karnal Zone II		8		Typically a combination of three or four ponds in series which comprise anaerobic, facultative and maturation ponds. Wastewater is applied after screening and degritting. Considering infrequent sludge removal, no separate arrangements are provided for sludge collection, removal or drying. This activity is expected to be carried out manually once in a few years.
	State : UP				
12	Saharanpur	38			
13	Ghaziabad THA	56			
14	Ghaziabad CHA	70			
15	Noida Sector 54	27			
16	Noida Sector 50	34			
17	Agra CIS Yamuna	78			
18	Muzaffarnagar		32.5		
19	Noida Sector 54		9		
20	Vrindavan Sewage Farm		4		
21	Vrindavan Kalideh		0.5		
22	Mathura		14.5		
23	Mathura Masani Nala		12.5		
24	Agra Trans-Yamuna		10		
25	Agra Bhuri Nagla Nala		2.25		
26	Etawah		10.5		
	State : Delhi				
27	Delhi Gate Nala			10	An elaborate physico-chemical and biological treatment system offering high end performance
28	Dr. Sen N.H. Nala			10	
	Total : 722 mld	598	104	20	

(Source : TEC- DCL, 2003)

Note : This list does not include pilot STPs

Appendix C

PROFILES OF ASP TECHNOLOGY PLANTS

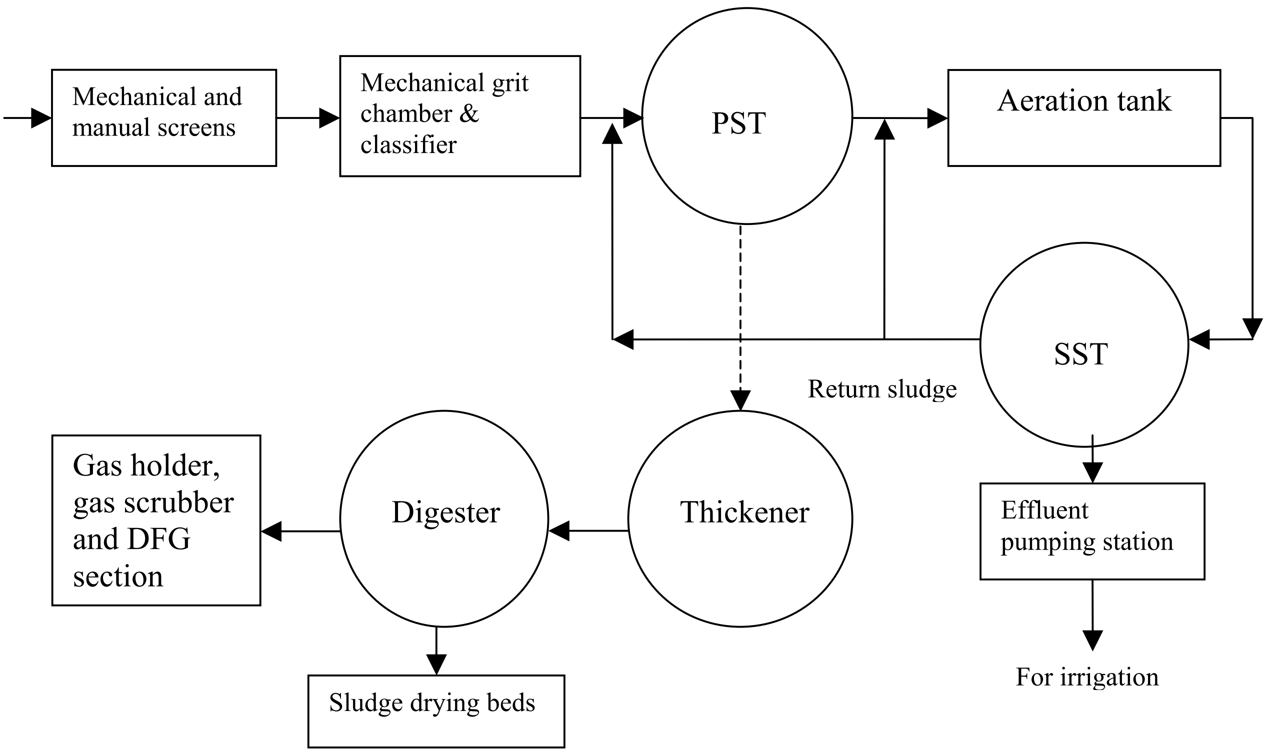
Box 1 : Profile of the activated sludge process based STP at Allahabad

Plant capacity : 60 mld

Year of commissioning : 1998

No. of streams : 3 streams each of 20 mld

Flow scheme



Plant performance

Long term monthly average effluent quality data show an unusually consistent performance of the plant. BOD is just below 30 mg/l and SS is always under 100 mg/l. Average value of faecal coliform in treated effluent is of the order of 10^6/100 ml and removal efficiency is over 90% representing one to two order of removal. Effluent has acceptable aesthetic value.

Power requirement

- Load during average flow conditions : 675 kW
- Average energy consumption : ≈ 13,500 kWh/d entirely from grid supply
- Average power cut : 1-3 h/d
- During power cut there is no influent and all the electro-mechanical components/units including surface aerators are stopped. Under prolonged cuts, anaerobic conditions set-in in the secondary treatment section of the plant.

Biogas generation

- Biogas generation from sludge digestion : 3200 m^3/d
- The digester is operated under mesophilic conditions without temperature control / insulation or sludge heating arrangement.

Biogas composition

Detailed analysis is not available, though in the initial stages hydrogen sulphide was found to be high and as a result an elaborate chemical desulphurisation unit was installed for treating biogas before utilising it in duel fuel engines.

Resource recovery – Biogas to energy

- Possible electrical energy from biogas : 3200 x 6 x 25% = 4800 kWh/d
- Generators : 3 nos. of duel fuel engines of 400 kW each, make Batliboi - Cummins
- Cost of bio-energy system : Rs. 40 million (1998)
- Fuel consumption : 50 l/h diesel in each engine on duel fuel mode or 115 lit/h on diesel mode
- Generation from duel fuel generators : Nil, as the system has not been run for last six months due to lack of funds for procurement of diesel
- Currently entire quantity of biogas is flared. As the biogas is not gainfully utilised at all, there is no incentive for optimising or maximising its output.
- Cogeneration system for heat recovery and heating of sludge is not provided
- A gas desulphurisation unit has been installed, however it is dysfunctional as the biogas is not utilised for running of the generators. Moreover, in absence of an operating manual or instruction sheet, there is loss of institutional memory on the part of the operators regarding chemicals, dosage, chemical supplying agency, plant erection agency etc.

Resource recovery – sludge

- Sludge generation is about 326 m^3/d at 3.5% dry solid basis after anaerobic digestion. Post sludge drying beds this sludge volume reduces to 24 m^3/d with dry solid at around 40%. At these two stages the unit sludge volume of generation is approximately 5.4 m^3 and 0.4 m^3 per million litre of sewage treated.
- Over a radius of 80 km there is no demand for sludge and as a result there is no tangible recovery. However, as the plant is operated by a private contractor, he has been given responsibility to dispose off the sludge. A sum of Rs. 40,000 pm is deducted from the fee of the contractor against assumed sale of sludge. (Dry sludge is assumed to be sold at a rate Rs. 55 per cum).
- It is not known as to how the contractor disposes the sludge and there are no contractual obligations or monitoring on the part of the supervising agency i.e., UPJN.

Resource recovery – treated effluent

- Although the treated wastewater is extensively utilised by the farmer community in Naini and Dandi sewage farms over 840 ha., no tangible revenue accrues from this activity. It is reported that some tax is collected by the local municipal body, however information on exact amount is not available. Notional resource recovery in the form of use of nutrients for increased agriculture and floriculture produce and economic benefits to farmer community are significant, but these have not been quantified.

Total resource recovery

- Total resource recovery from the four possible revenue streams of bio-energy (electricity), sludge (manure), effluent (irrigation water) and horticulture/ floriculture : Rs. 0.48 million pa.
- Total resource recovery as a percentage of current capital cost (Rs. 198 million) is an insignificant 0.24 %. With respect to original capital investment (Rs. 165 million) the recovery is 0.3%.
- Recovery as a percentage of current O&M cost (Rs. 29 million) : 1.6 %

O&M aspects

- Bar screens installed at the pumping station and the STP are unable to remove plastic bags and pouches.
- Mechanical grit removal and grit classifier is an effective system and minimises manual handling and risk to occupational health risk of workers.
- The sludge recirculation arrangement does not follow standard practice of introducing it only in to the aeration tank. Instead a major part is introduced into the primary settling tank. This arrangement increases solids load on the PST and leads to onset of anaerobic digestion in the primary treatment stage itself. This is exhibited by the presence of gas bubbles in PST which in turn reduce the solids removal efficiency.
- As against the normal practice of withdrawing excess sludge from secondary settling tank, at this STP it is withdrawn only from primary settling tank.
- As a result of this arrangement, the mixed primary and secondary sludge is thickened in a common thickener. This arrangement does not enable effective thickening as the two types of sludges have

different settling characteristics.

- A dedicated power supply line is provided, however power cuts are not uncommon
- O&M of the plant has been given on labour contract to a private agency
- O&M manual is available and a variety of plant performance data are monitored and meticulously processed.
- Laboratory has been kept under the control of UPJN as against the normal practice of giving it to the contractor. This arrangement enables higher involvement of the UPJN staff and better control over the performance of the contractor.
- Grab sample on daily basis, composite sample on weekly basis and sample for bacteriological analysis on fortnightly basis are collected and analysed in the in-house lab.
- Currently due to lack of fund the plant administration is facing difficulties in maintaining smooth functioning of the STP. For instance the contractor has not been paid for last 6 months, the laboratory chemical stock has not been replenished and some of the instruments have not been repaired. Most importantly there are no funds for purchasing diesel which is one of the essential inputs for running the 'duel fuel engines'. Moreover, the desulphurisation chemical stock has also not been replenished for long and there is a risk of corrosion of engines if and when they are run using a combination of diesel and biogas.

Manpower

- UPJN supervisory staff : GM; PM (Civil) – 5 PEs – 7 APEs; PM (E&M) – 2 PEs – 7 APEs ; 1 Chemist – 1 Lab assistant. UPJN staff looks after both the STP and the pumping stations.
- Contractor (STP) : 1 Engineer, 2 supervisors, 1x 3 fitters, 1 x 3 electricians, 10 x 3 operators and 6 sweepers /sewerage workers deployed over three shifts (Total 45 workers).

The strength of supervisory staff is rather large.

Training

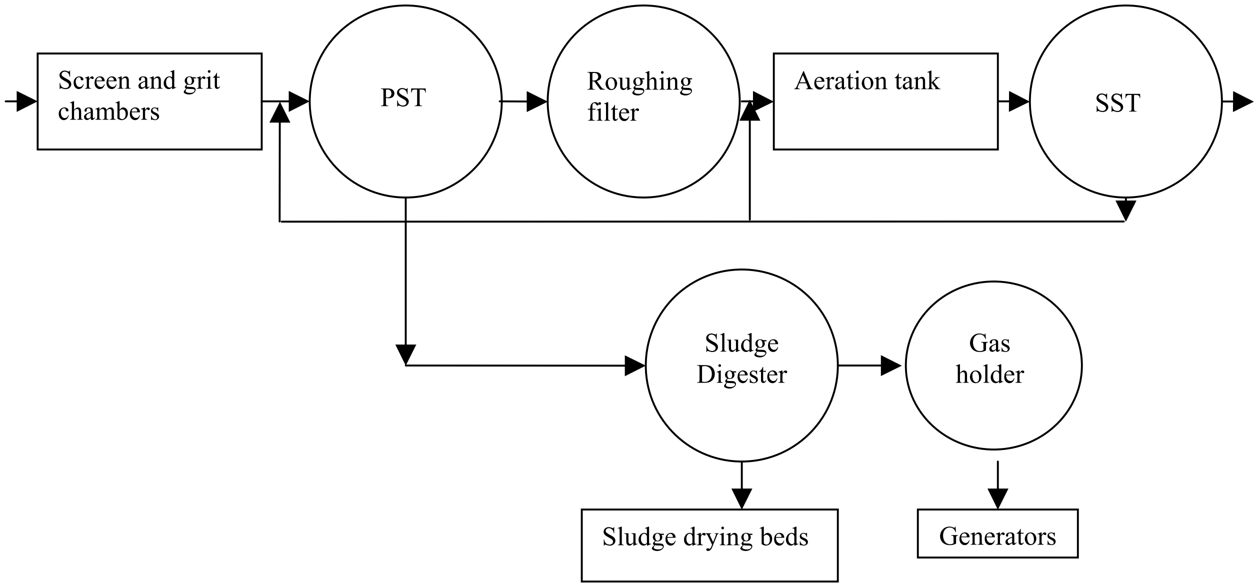
- No special training has been imparted to Engineers and operators at this STP.
- Contractor staff lacks background understanding of wastewater treatment especially on the biological processes of activated sludge technology and sludge digestion.

Box 2 : Profile of the RF/AS plant at Dinapur, Varanasi

Plant capacity : 80 mld
Year of commissioning : 1991
No. of streams : 2 each of 26.7 mld
Components : Coarse screen and grit chamber at Konia pumping station
Coarse screen, primary sedimentation tank
Roughing filter, aeration tank, secondary sedimentation tank
Digesters, biogas holders, duel fuel generators(no sludge thickeners)
Treated effluent pump, return sludge pump, raw sludge pump, filtrate pump, etc.

The roughing filter is designed for a hydraulic loading of 68 m/d, has a relatively much larger size of the media between 7 – 10 cm and shorter depth of media bed of 1 m.

Flow scheme



Performance

	Influent			Effluent			Removal		
	BOD	TSS	F. Coliform	BOD	TSS	F. Coliform	BOD	TSS	F. Coliform
	mg/l	mg/l		mg/l	mg/l		%	%	%
Range	55-208	253-792	2.90E+05 - 1.60E+09	13 – 77	25-121	2.3.00E+05 - 5.00E+08	49-86	57-97	6 - 99

(Source : CPCB, November 2001)

Power requirement

- Load during average flow conditions : 600 kW
- Plant consumption : 12,000-14,000 kWh/d
- Average duration of power cut is 3-5 h/d, during which time raw sewage is not received however during normal circumstances plant is operated by running the duel fuel engines to maintain aerobic conditions in the reactors.

Biogas generation

- Biogas generation : 2000-2500 m^3/d
- Provision for heating of sludge to 37º C through cogeneration system, however due to operational

difficulties this has been abandoned
- Gas leakage reported from digesters and gas holders due to corrosion of structural elements

Biogas composition

- Methane : 65%
- Carbon dioxide : 25%
- Other gases : 10%
- Hydrogen sulphide : traces
- Calorific value : 5500 kCal/m^3 = 6.4 kWh/m^3

Resource recovery – Biogas to energy

It is possible to generate about 3200 kWh of electrical energy from biogas. To this effect four duel fuel engines each of 400 kW were installed. However, due to current resource constraints, procurement of diesel has become difficult and therefore the engines have not been running for last four-six months. Currently entire biogas is flared. There is no incentive for maximising biogas generation or utilisation due to following reasons :

(a) minimum electricity charges have to be paid any way
(b) budget for diesel purchase is very limited
(c) cost of own generation is only 20% lower than the grid supplied energy
(d) excess electricity if any, can not be transmitted to Konia sewage pumping station

A cogeneration system was installed for heat recovery and heating of sludge to 37º C, however, the heating coils are clogged due to scale formation and the system is dysfunctional. A gas desulpherisation unit was not provided as H_2S concentration is in traces.

Resource recovery – sludge

Over the years several local micro-enterprises have evolved which are involved in collecting, processing sludge and blending with other mineral additives. This value added product is then sold as a soil conditioner to tea plantations in north-east state of Assam. Estimated revenue from sale of sludge is about Rs. 1.24 million/annum.

Resource recovery – treated effluent

Although the treated wastewater is extensively utilised by the farmer community over 1600 ha. along the effluent channel, no significant revenue has accrued from this activity. Net revenue in year 2002-03 was Rs. 95,000. Notional resource recovery in the form of use of nutrients for increased agriculture produce and economic benefits to farmer community are significant, however these have not been quantified.

Total resource recovery

Total resource recovery in year 2002-03 was as follows :

Electricity + Sludge + Effluent + Floriculture = Rs. 1.36 million + 1.24 million + 95,000 + 7000)
= Rs. 2.7 million

Total resource recovery as a percentage of current capital cost (Rs. 173.4 million) is an insignificant 1.6%. With respect to original capital investment of Rs. 80 million the recovery is about 3.4%.

With respect to the current actual annual O&M cost (Rs. 32 million) the resource recovery amounts to 8.4%.

O&M aspects

- Introducing secondary sludge into primary settler is ineffective in solids removal
- High energy costs due to excessive drop in hydraulic profile and multiple pumping stages
- Wear and tear of turntable in roughing filter. Currently one of the filters was out of operation due to this fault
- Cleaning of filter media once in 7-8 years
- Unlike most other STPs in UP, the Dinapur STP is operated and maintained by UPJN staff. This is because of large size of existing workforce which was inducted back in 1991. However works of small quantum are given out on short term job work basis.

- O&M manual is available and a variety of plant performance data are monitored and meticulously processed.

Manpower

UPJN supervisory staff : 1 PM (E&M) – 1 PE (E&M) – 4 APE (E&M)
1 PM (Civil) – 1 PE (Civil) – 4 APE (Civil)

The plant is under day to day supervision of Project Manager (E&M) and according to him, 50% of the current strength at APE level (both civil and E&M) is sufficient.

Operating staff (inclusive of work charged personnel) :

Position	**NRCD Norm**	**Actual**
Chemist	1	1
Lab attendant	2	2
Operator	31	26
Attendant	6	2
Electrician	4	2
Mechanic	4	2
Welder/Black Smith	1	0
Labour	54	18
Miscellaneous	9	18
Total	112	71

(Source : UPJN, Dinapur STP)

Training

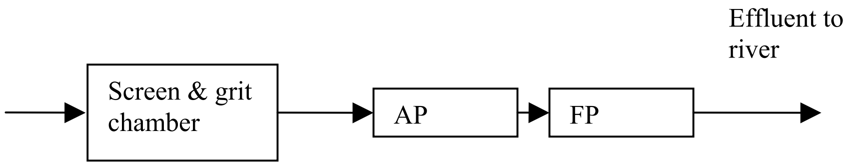
NEERI provided training to engineers at Nagpur and to the operating staff at the plant site. However, this was done in the early stage of commissioning of the plant. Subsequent refresher trainings have not been provided. Old staff has been transferred or retired and new staff as well as contract workers will have special training needs. However, these have not been assessed.

Appendix D

PROFILES OF WSP BASED STPs COVERED UNDER THE STUDY

Box 1 : Profile of WSP at Kaliadeh, Vrindavan

Plant capacity : 0.5 mld (1998 population load)
Year of commissioning: 2000
Current flow : 0.8-0.9 mld
No. of streams : 1 stream
Components : Manually cleaned bar screen and grit chambers, 1 anaerobic pond and 1 facultative pond. The schematic is shown below:



Hydraulic retention time : 1 day in anaerobic ponds and 4 days in facultative ponds.
The DPR of the project mentioned that thin population existed around the site prior to construction of the plant. Over the years it is now surrounded with residential localities and there is no scope for capacity expansion, although the plant is almost 60-80% overloaded.

Performance of the plant

Representative influent and effluent quality data is as follows :

	BOD (mg/l)			SS (mg/l)			F. Coliform (MPN/100 ml)		
	Inlet	Outlet	% rem	Inlet	Outlet	% rem	Inlet	Outlet	% rem
January	105	79	24.8	174	57	67.2	4.3E+07	1.7E+06	96.047
February	na			na			na		
March	145	41	71.7	311	70	77.5	6.0E+06	1.0E+06	83.333
April	92	46	50.0	191	63	67.0	2.3E+07	1.1E+06	95.217
May	158	40	74.7	671	54	92.0	6.3E+08	3.0E+06	99.524
June	107	79	26.2	158	139	12.0	7.3E+08	3.4E+08	53.425
Average			49.5			63.1			85.5

(Source : MOEF, 2003)

Power requirement

Running of the plant : nil

Resource recovery – Aquaculture

Not feasible as there is no maturation pond or aquaculture pond; besides, the demand for fish in general in Vrindavan is expected to be low.

Resource recovery – sludge

Nil

Resource recovery – treated wastewater

Nil

Total resource recovery

Nil

O&M aspects

- UPJN has given the O&M work of the WSP along with the connected sewage pumping stations to a contractor on an annual contract.
- Rest of the points are same as described in case of STP at Mathura

Manpower

- UPJN supervisory staff : Common with the STP at Mathura
- Contractor : 1 supervisor, 6 unskilled workers deployed in two shifts of 12 hours each
- Skill level : low skill level required

Box 2 : Profile of WSP at Masanighat nala in Mathura

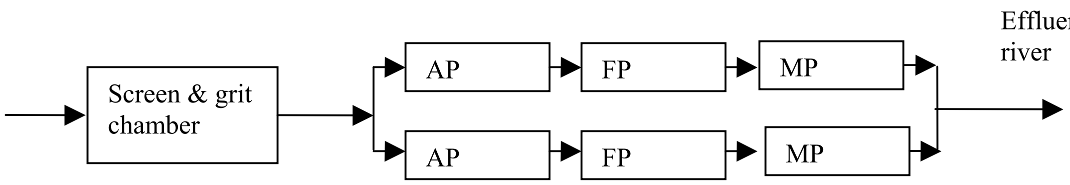
Plant capacity : 12.5 mld

Year of commissioning : 2000

Current flow : 16 mld

No. of streams : 2 streams

Components : Manually cleaned coarse screen and grit chambers, 2 anaerobic ponds, 2 facultative ponds, 2 maturation ponds. The flow scheme is as shown below:



Hydraulic retention time : 1 day in anaerobic ponds, 4 days in facultative ponds and 3 days in maturation ponds

Aquaculture was initiated in facultative and maturation ponds, however due to reported incidents of fish kills, this has been discontinued

Performance

Representative influent and effluent quality data is as follows :

	BOD (mg/l)			SS (mg/l)			F. Coliform (MPN /100 ml)		
	Inlet	Outlet	% rem	Inlet	Outlet	% rem	Inlet	Outlet	% rem
January	na			na			na		
February	102	30	70.6	121	62	48.8	9.1E+08	2.2E+08	75.824
March	308	29	90.6	1058	44	95.8	1.3E+08	2.0E+06	98.462
April	192	28	85.4	313	70	77.6	6.4E+07	6.0E+05	99.063
May	152	21	86.2	324	46	85.8	2.5E+08	3.0E+07	88.000
June	174	25	85.6	739	69	90.7	8.7E+08	8.1E+07	90.690
Average		27	83.7		58	79.7			90.4

(Source : MOEF, 2003)

The above data indicate that the plant is performing well and the effluent is within desired quality standards. However, during a visit to the plant it was learned that the influent BOD is in the range of 250-450 mg/l and the plant was receiving 30-40% extra flow. Organic overloading was attributed to discharges from industrial units. Treated effluent BOD is reported to be around 100 mg/l which is attributed to sustained hydraulic and organic overloading. Although the above tabulated results for BOD and SS present a normal working plant, the faecal coliform values do not confirm the same trend. In a normal and well functioning WSP the faecal coliform removal efficiency is expected to be over 99.99% with effluent concentrations in the order of 10^3 to 10^4/100 ml

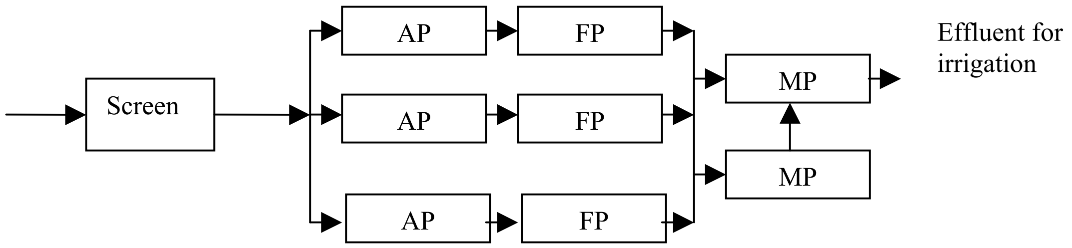
Power requirement

Running of the plant : nil

Resource recovery – Aquaculture
Discountinued due to reported cases of fish kill.
Resource recovery – sludge
The WSP was commissioned in year 2000. Recently sludge was removed from anaerobic ponds in year 2003. However, the operating agency has not been able to sell the sludge to farmers in the region. Therefore no recovery is attributed on this account. Estimate of volume of generated sludge in not available.
Resource recovery – treated wastewater
In absence of separate irrigation infrastructure for conveying treated wastewater to agriculture fields, it is drained into a nalla. As a result there is no recovery from this account as well.
Total resource recovery
- Nil
O&M aspects
- The plant is operating in 30% over loaded conditions - Bar screens at the pumping station are manual and are found to be not effective in removal of plastic bags. Often functioning of even the non-clogging vertical pumps is affected - Bar screens at the STP are also unable to remove plastic bags and pouches which float in the ponds. These are then removed manually through improvised screen on long bamboos. This practice causes disturbance in the settling regime of the anaerobic pond - Grit removal is done manually once in 10 days. - Grit storage volume is low, which causes overflow into anaerobic ponds - STP workers are exposed to infectious wastewater at the bar screen and grit chamber stage which could be a concern from occupation health point of view. - Disposal arrangements for screenings and grit are inadequate - Sludge removal from anaerobic pond is supposed to be once in 6 months, however longer intervals are common. - Manual sludge removal entails emptying of the pond and thereby shutting off 50% part of the plant. - In absence of a separate storage facility e.g., a sludge storage lagoon, the sludge is stacked along the boundary of the plant which leads to unaesthetic surroundings. - UPJN has given the O&M work of the WSP along with the connected sewage pumping stations to a contractor on an annual contract. - The contractor has divided operations into two shifts of 12 hours rather than three shifts of 8 hours each which could be a concern from occupational health and labour practices point of view. - Wastewater samples are collected by a separate agency on weekly basis and analysed at an outside laboratory
Manpower
- UPJN supervisory staff - Contractor : 1 supervisor, 6 unskilled workers deployed in two shifts of 12 hours each - Skill level : low skill revel required

Box 3 : Profile of North Howrah WSP plant

Plant capacity : 30 mld
Year of commissioning : 1995
No. of streams : 3 streams each of 10 mld merging into two of 15 mld at maturation stage
Components : Coarse screen, 3 anaerobic ponds, 3 facultative ponds, 2 maturation ponds in series.



Hydraulic retention time : 1 day in anaerobic ponds, 4 days in facultative ponds and 3 days in maturation ponds. Aquaculture is being practiced in facultative and maturation ponds

Performance of the plant

All India Institute of Hygiene and Public Health carries out the performance monitoring of the plant. Representative influent and effluent quality data is as follows :

Parameter	Unit	Influent	Effluent
BOD_5	mg/l	64	13
SS	mg/l	315	39

DO at the outlet of facultative pond is 11.4 mg/l and after maturation pond it is 5.2 mg/l. Data on removal of Faecal Coliform is not available.

Power requirement

Power requirement for running of the plant : nil

Resource recovery – Aquaculture

Lease agreement signed with a fishermen's cooperative in 1997 for 7 years with royalty of Rs. 0.2 million pa for first two years, Rs. 0.3 million pa for next two years and Rs. 0.45 million pa for the remaining period.

Resource recovery – sludge

Untill 1998 the ponds were not desludged and therefore there was no recovery from this possible line of revenue.

Resource recovery – treated effluent

Although the treated wastewater is utilised by the farmer community, no tangible revenue has accrued from this line as well. Notional resource recovery in the form of use of nutrients for increased agriculture produce and economic benefits to farmer community are significant, however these have not been quantified.

Total resource recovery

- No estimate of the total income to the fishermen's cooperative is available, however it pays a royalty of around Rs. 0.34 million pa to the Calcutta Metropolitan Water and Sanitation Authority.
- Recovery to CMWSA as a percentage of original capital cost is an insignificant 0.65%.

O&M aspects

- The implementing agency Calcutta Metropolitan Water and Sanitation Authority has given the

O&M of the WSP on contract to a fishermen's cooperative for a long term lease of 7 years. - No major O&M problems are stated, however special security guards have been included in the O&M team to prevent theft of the aquaculture stock.
Manpower - CMWSA : Supervisory staff - Contractor : The cooperative has employed 18 fishermen and 12 guards who are involved in aquaculture from facultative and maturation ponds.
Training The CMWSA has an interface with AIIHPH, Kolkata, which is understood to have imparted training to its engineering staff. Information regarding training to the operators / workers of the cooperative is not available. However, the latter are adept in aquaculture and have evolved traditional practices for aquaculture in domestic wastewaters.

(Source : Calcutta Metropolitan Water and Sanitation Authority, 1998)

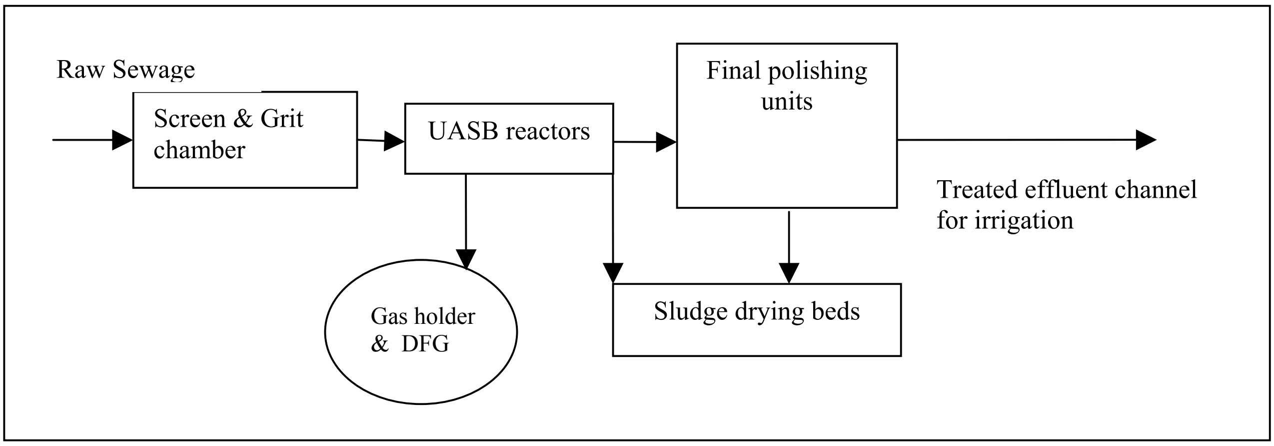
Appendix E

PROFILES OF UASB TECHNOLOGY PLANTS

Box 1 : UASB plant at Agra

- Plant capacity : 78 mld
- Average flow : 65 mld = 2708 m^3/h
- No. of streams : 6 streams each of 13 mld
- Components : Manually operated bar screens and grit chamber;
  UASB reactor, final polishing units;
  Biogas holders, duel fuel generators;
  No thickeners but sludge is sent directly to drying beds
- Hydraulic retention time in UASB reactor : 8 h
- Hydraulic retention in FPU : 1 day

Schematic



Land requirement

- Plant area : 20 ha.
- Unit land requirement : 0.26 ha/mld

Note : The area represents land requirement for the STP as well as ancillary facilities and future capacity expansion. Net unit area for the current capacity will be approximately 0.16 ha/mld.

Performance

STP influent volume is 64% of the designed load.

	Raw sewage	UASB outlet	FPU outlet	% Removal
1st set of monitoring (May 13, 2002)				
BOD (mg/l)	262	83	55	79
SS (mg/l)	461	145	89	81
1st set of monitoring (May 24, 2002)				
BOD (mg/l)	264	77	50	70
SS (mg/l)	444	133	111	75

(Source : IIT Roorkee, 2002)

The influent quality parameters are higher than the designed values which are attributed to discharges from industries e.g., tanneries and petha manufacturing. Higher outlet BOD can also be attributed to solids overflow from the combined UASB-FPU system. However, the plant personnel informed that current effluent values for BOD and SS are 28-31 mg/l and 48-51 mg/l respectively.

Power requirement

- Total load : 56 kW including screens, sludge pumps, filtrate pumps, office, lab, borewells, staff quarters etc.
- Consumption during average flow conditions: 825 kWh/d (approximately)

- Average power cut : 4-5 h/d

Biogas generation

- Biogas generation : 1700 m^3/d as per design, however current generation is 1000-1200 m^3/d
- Design rate 0.08- 0.1 m^3/kg of COD removed

Biogas composition

- Not available

Resource recovery – Biogas to energy (refer Box ** on biogas exploitation at 78 mld UASB at Agra)

- Possible electrical energy from biogas : 1000 m^3/d x 5 kWh/m^3 x 25% = 1250 kWh/d
- Generators : 2 nos. duel fuel engines of 64 kW each
- Fuel consumption : 13 l/h diesel and 33 m^3/h biogas in each engine on duel fuel mode
- Generation from duel fuel generators : Specific energy generation values are not available as the system has not been run for past several months
- The system does not have a desulpherisation and cogeneration facility
- System is run only during prolonged power cuts. Otherwise almost entire biogas is flared.

Resource recovery – sludge

Sludge generation : 70 cum/day/reactor = 420 cum/day
Almost 2500 cum of dried sludge is accumulating on the sides of the drying beds for last three years as there is no demand for sludge in an area of over 80 km radius. The agencies have been unable to provide necessary marketing inputs. In the meanwhile about 800 cum of sludge was lifted by the UP Forest Department at a rate of Rs. 38/cum, giving a recovery of Rs. 30,400 only over a period of 3 years which is insignificant in comparison to the capital investment and annual O&M costs.

Resource recovery – treated effluent

Although the treated wastewater is extensively utilised by the farmer community along the effluent channel, no significant revenue accrues from this activity. Notional resource recovery in the form of use of nutrients for increased agriculture produce and economic benefits to farmer community are significant, however these have not been quantified.

Total resource recovery

- Since commissioning, Rs. 30,400 over last 2 years

O&M aspects

- O & M of the plant is still by default with the construction agency without a formal contract as it has not been taken over by UPJN apparently due to disagreement on quality of construction.
- O&M of electrical and mechanical components has been sub-contracted to another agency
- A manual on O&M of the plant has been provided by the contractor.
- Screen and grit chambers are operated / cleaned manually, thereby exposing the workers to bacterial and viral infection.
- Bar screens installed at the pumping station and the STP are unable to remove floating matter e.g., plastic bags, pouches etc.
- Raw sewage carries high suspended solids due to discharges from tanneries and 'petha' (sweet meat) industry. In addition there are floating object such as plastic pouches, bags etc. which are not removed in the bar screens. As a result, problem of choking of distribution system of the UASB reactor is being experienced at this plant.
- Separate manpower is deployed for removing floating matter from the UASB reactor, which adds to the cost of operation as well as causes disturbance in the settling zone of the reactor.
- Accumulation of large quantity of sludge on the sides of drying beds is causing difficulties and long lead times.
- In addition, there is large quantity of sludge (40 cm depth) accumulated in FPUs which has not been removed since commissioning apparently due to paucity of funds. As a result there is likelihood of solids overflow from the FPU as well
- The O&M contractor is also given the charge of laboratory and carries out wastewater sample analysis. Apparently there is conflict of interest as it is the contractor himself who is also responsible for adhering to discharge quality specifications.

Manpower

- UPJN : 1 JE (full time) supervising the contractor; 4 support staff
- O&M Contractor : 1 Plant Engineer, 1 Supervisor (E&M), 1 Chemist, 1 Foreman; Unskilled workers : (2 as screen operators, 6 as reactor monitor, 4 for sludge withdrawal) x 2 shifts
- Manpower is deployed in two shifts of 12 h each instead of 3 shifts of 8 h each

Training

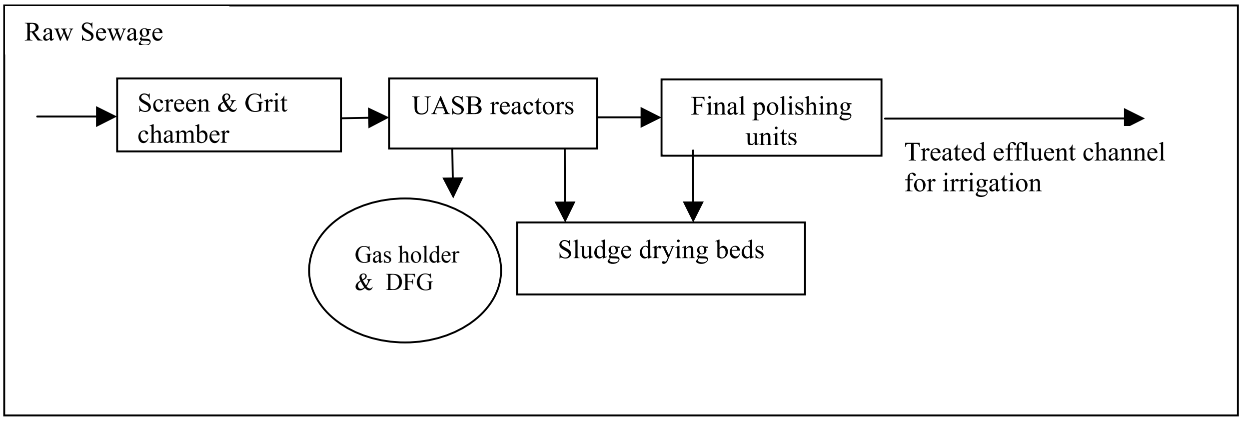
- The supervising engineers and the operating staff have not received formal training
- The supervising JE has developed understanding based on the manual and on the job training from the construction contractor

(Source : Personal discussions with YPCU, UPJN Agra)

Box 2 : Profile of the UASB plant at Faridabad

- Plant capacity : 20 mld
- Average flow : 16-18 mld
- No. of streams : 2 streams each of 10 mld
- Components : Mechanical and manual bar screens, manually cleaned grit chambers;
  UASB reactors, final polishing units,
  biogas holders, duel fuel generators;
  No thickeners, instead sludge goes directly to drying beds
- Hydraulic retention time in UASB: 8 h
- Hydraulic retention in FPU : 1 day
- Flow breakers in effluent channel of UASB reactors have been constructed subsequently by the PHED to create turbulence with the objective of augmenting reaeration

Schematic



Land requirement

- Plant area : 5.8 ha.
- Unit land requirement : 0.29 ha/mld

Note : The area represents total plant area including land requirement for sewage pumping station and ancillary facilities

Performance

STP capacity utilisation is around 80-90%.
Long term wastewater quality data is as follows :

Month	Raw sewage (mg/l)		UASB Outlet (mg/l)		FPU Outlet (mg/l)		% Removal	
	BOD	SS	BOD	SS	BOD	SS	BOD	SS
Jan 03	184	268	74	85	30	44	84	84

Feb 03	183	220	74	83	30	38	84	83
March 03	183	207	76	77	29	45	84	78
April 03	190	202	72	73	28	32	85	84
May 03	184	216	57	59	27	29	85	87
June 03	194	215	62	64	29	26	85	88
July 03	180	212	59	64	28	25	84	88
Aug 03	185	242	73	67	29	31	84	87
Sept 03	197	289	74	75	30	34	85	88
Oct 03	196	304	70	89	29	32	85	89
Average	187.6	237.5	69.1	73.6	28.9	33.6	85	86
Std. dev.	6.1	36.7	7.0	10.1	1.0	6.9	0.6	3.4

(Source : Contractor's/PHED Haryana monitoring records at the STP)

It should be noted that while there is good deal of scatter in the raw effluent data, the treated effluent data appears to have high consistency with the BOD values having a standard deviation of only 1. This level of consistency in the time series appears less probable. Moreover, it is understood that typically performance of anaerobic processes is adversely affected during winter conditions. However, this aspect is not reflected by the BOD time series for FPU effluent.

Moreover the corresponding COD values (not shown above) indicate an average reduction of 206 mg/l, and therefore the corresponding biogas generation should be in the range of 380 m^3/d (under 90% flow conditions). It is to be noted that theoretical biogas production for given influent and effluent characteristics is estimated to be 532 m^3/d. In comparison to these values, the reported biogas generation is only 280 m^3/d which is only 74% and 53% respectively of the two bench marks referred above. This cross check does not enable to place a higher degree of reliability on the reported effluent quality data.

Composite samples collected and analysed by CPCB provide following results

	Plant influent (mg/l)		Plant effluent (mg/l)		BOD Removal
Month	BOD	SS	BOD	SS	%
April 02	117	209	33	42	72
May 02	83	165	23	32	72
June 02	69	149	8*	18*	88

(Source : CPCB monitoring report obtained from PHED Haryana, Faridabad)
Note * : Values are abnormally low and should be ignored

Faecal coliform in influent and effluent of the STP are in the range of 10^6-10^7 and 10^5 MPN/100 ml respectively. However, in the month of April-June effluent concentrations in the range of 7000 to 30,000 MPN/100 ml have been reported. The latter results need to be treated with caution as they may be due to abnormal weather or other conditions prevailing on the day of the sampling.

Power requirement

- Plant load during average flow conditions : 15 kW including screens, office, laboratory, staff quarters etc.
- STP power consumption : 360 kWh/d
- Average power cut : 4-5 h/d

Biogas generation

- Biogas generation : 532 m^3/d as per design, however actual current generation is 280 m^3/d
- Design rate between 0.08-0.1 m^3/kg of COD removed

Biogas composition

- Not available
- Calorific value : 5 kWh/m^3 (assumed)

Resource recovery – Biogas to energy

- Possible electrical energy from biogas : 280 m^3/d x 5 kWh/m^3 x 25% = 350 kWh/d
- Generators : 1 DFG, 40 kW 1 DFG, 160 kW
- Fuel consumption : 3.5 l/h diesel, 22 m^3/h biogas; 17 l/h diesel, 55 m^3/h biogas
- Running of the DFG : 40 kW set only during power cuts to meet STP load
- Quantity of biogas utilised : 88 m^3/d while the rest of 200 m^3 biogas is flared.
- Quantity of electricity generated from duel fuel generators : 160 kWh
- The system does not have a desulpherisation and cogeneration facility
- Low incentive for maximising biogas generation or utilisation due to the same reasons as cited under the profile for Agra plant

Resource recovery – sludge

The O&M contractor has been given the responsibility of selling or disposing off the dry sludge. The mode of disposal is not defined and under the assumption that the sludge is being sold to agriculture farmers, PHED is deducting Rs. 1 Lakh pa from the fee of the contractor.

Resource recovery – treated effluent

Although the treated wastewater is utilised by the farmer community along the nalla, no revenue accrues from this activity. Notional resource recovery in the form of use of nutrients for increased agriculture produce and economic benefits to farmer community are significant, however these have not been quantified.

Total resource recovery

- Rs. 1 Lakh pa

O&M aspects

- O & M of the plant has been given to a contractor for a period of three years
- Manual operations of screen and grit chambers are a cause of concern from the point of view of occupational health of the workers who are directly exposed to raw sewage
- Bar screens installed at the pumping station and the STP are unable to remove floating matter e.g., plastic bags, pouches etc. problem of choking of distribution system of the UASB reactor is being experienced at this plant.
- Inadequate stilling volume in the mechanical screen chamber causes high hydraulic pressure on the bar screens and leads to their deformation/damage
- Separate manpower is deployed for removing floating matter from the UASB reactor, which adds to the cost of operation as well as causes disturbance in the settling zone of the reactor.
- The O&M contractor is also given the charge of laboratory and carries out wastewater sample analysis. Apparently there is conflict of interest as it is the same contractor who is also responsible for adhering to discharge quality specifications. This aspect is reflected by narrow range of effluent BOD and SS values which fall close to the respective discharge limits.

Manpower

- Supervisory staff from PHED : 1 EE, 1 AE, 1 JE, 1 Supervisor
- O&M staff from Contractor : 1 Plant Engineer, 1 Chemist, 1 Mechanic, 1 Electrician, 3 Operators, 12 Unskilled workers/Sweepers, 5 Gardeners, 1 Watchman.
- The Contractor work force is distributed over three shifts

Training

- The Engineering personnel from PHED have undergone short term training on wastewater treatment and operation of UASB plant at IIT Kanpur
- Level of training among contractor personnel is not known

(Source : PHED, Faridabad)

Box 3 : Biogas exploitation at 78 mld UASB at Agra

An UASB technology based STP has been commissioned at Agra in 2001-02. At designed loading rate, the plant is expected to produce 1700 cum of biogas per day. However, current biogas generation is between 1000 to 1200 cum/day. To utilise the biogas to a limited extent, a power generation unit comprising duel fuel engines has been installed. Particulars of the unit are as follows :

- No. of duel fuel engines = 2
- Capacity of duel fuel engines = 64 kW
- Total installed capacity = 128 kW
- Diesel consumption per engine = 25 l/hr while operating in diesel mode
- Diesel consumption per engine = 13 l/hr while operating in duel fuel mode
- Biogas consumption = 33 cum/hr while operating in duel fuel mode

The system works either on diesel mode or on duel fuel mode. It does not run on biogas alone, for which special engines are required which can sustain combustion of a fuel gas which has low energy content.

The full STP load is around 70 kW and by excluding certain non-essential components, one engine is able to serve the entire plant. Second engine has been installed to take care of the power requirement of fire fighting pumps. However, the latter are seldom used and therefore most of the time only one engine is operated during power failure. Typical duration of power failure is 2 hr/day.

Considering energy content of biogas @ 5 kWh/cum and diesel @ 11 kWh/lit, the duel fuel engine system efficiency is worked out as follows :

- Energy available from biogas = 33 cum/hr x 2 hr/day x 5 kWh/cum = 330 kWh
- Energy available from diesel = 13 lit/hr x 2 hr/day x 11 kWh/lit = 286 kWh
- Total energy available in 2 hours = 330 + 247 = 616 kWh
- Electrical energy generated by 1 engine = 64 kW x 2 hr = 128 kWh
- Efficiency of the generation system = 128 / 616 = 21 %

The thermal energy produced in the process is not utilised and therefore the net efficiency of the system is only 21 %.

Considering the price of diesel @ Rs. 22/lit., cost of running the generation system on duel fuel mode is Rs. 286 per hour. If maximum utilisation of available gas were to be made in running the entire STP for 24 hours, the monthly cost of running the power generation system would be :

= 13 lit/hr x 24 hr/day x 30 days/month x Rs. 22/lit
= Rs. 2,06,000 /month

In comparison to this, the average monthly electricity bill for the STP as reported by UPJN is around Rs. 36,000. Therefore the cost of generating electricity from biogas is almost six times higher than the cost of grid supplied electricity. Moreover, when one accounts for the fact that the electricity cost is not paid by the operating agency at all (as per the arrangement between GoUP and UP State Electricity Board, the former pays directly to the latter), the cost of diesel is considered a 100% additionality. In view of this, it is found that the operating agency keeps the running of the generation system to a minimum and operates it only during extended periods of power failure.

In this context, other aspect to be considered is that the operating agency has to bear a minimum cost of electricity as per the contracted load. This acts as a disincentive for reducing the consumption of grid supplied electricity by substituting with biogas derived electricity.

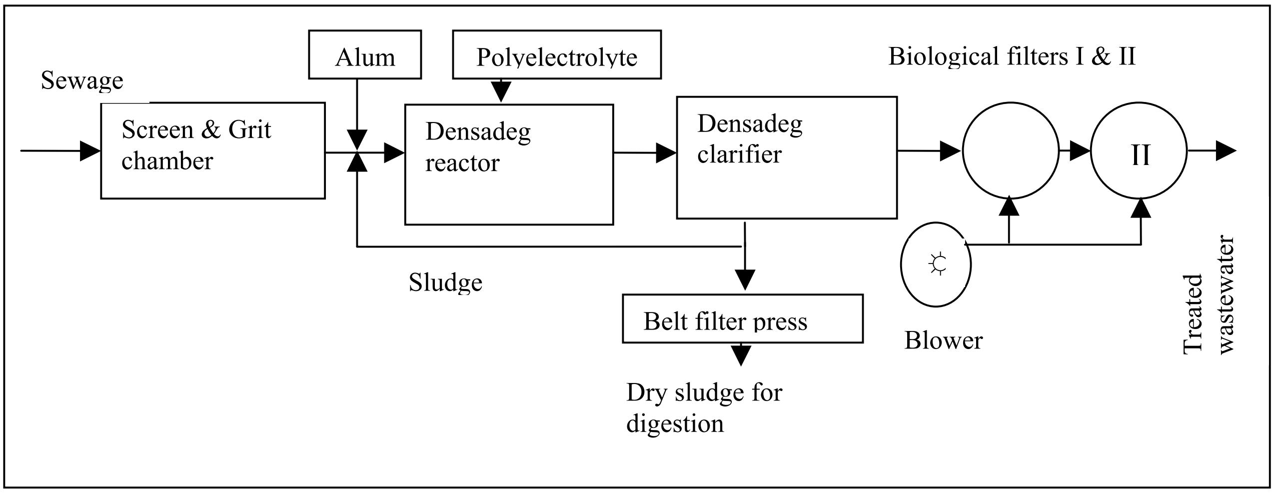
It is also pertinent to mention here that a desulphurisation unit for cleaning the biogas has not been incorporated in the overall scheme for bioenergy extraction. It is quite likely that over time the corrosive biogas can cause irreversible damage to the engines and put them out of operation.

Appendix F

PROFILE OF BIOFOR BASED STP AT DR. SEN NURSING HOME NALLA

- Plant capacity : 10 mld
- Components : Three stage screening, aerated mechanical grit chamber with classifier;
  Flash mixer, coagulation and flocculation chamber, clarifier cum thickener;
  Double stage fluidized bed aeration;
  Sludge pit, sludge recirculation, sludge press

Schematic



Key features of the plant

- Enhanced primary treatment with addition of coagulants and flocculants
- High rate primary tube settlers and integrated thickening offering space economy
- Two stage high rate biologically enhanced filtration with external aeration
- Co-current upflow movement of wastewater and air in the biofilter enabling higher retention and contact time
- Treatment scheme excluding secondary sedimentation but recycling of primary sludge
- Deep reactors enabling low land requirements
- A compact and robust system

Chemical requirements

- Alum as coagulant @ 60 ppm
- Polyelectrolyte for high rate sedimentation @ 0.2-0.3 ppm
- Polyelectrolyte for sludge dewatering (~ @ 3 kg/t of dry solids)

Land requirement

- Plant area : 0.4 ha. (excluding sludge treatment component)

Performance

Very high quality effluent with BOD < 10 mg/l and SS < 15 mg/l

Sludge production

- Thickened sludge generation @ 1 t/mld or 14.5 m^3/mld
- After further treatment in filter press the sludge is sent to the drying beds at Okhla STP

Power requirement

- Total load : approximately 92 kW including office, lab, ancillary equipment etc.
- Consumption during average flow conditions: 2200 kWh/d

Biogas generation

- Not applicable

Resource recovery – Biogas to energy

- Not applicable

Resource recovery – sludge

Separate estimates are not available as the sludge is first sent to Okhla STP for drying and then sold along with digested sludge of that STP. However this being a physico-chemical process, the sludge contains higher proportion of alum and polyelectrolyte and may not fetch high value a manure.

Resource recovery – treated effluent

Notionally a very high level of recovery in terms of monetary value as the effluent is bartered with free electricity from the power utility. Considering price of electricity at Rs. 4.8/ kWh this is estimated to be around Rs. 3.85 million per annum. This is a unique case and may not be applicable at other locations.

Total resource recovery

- A notional amount of Rs. 3.85 million per annum

O&M aspects

- Multi stage screens are effective in removal of floating objecting including plastic bags and pouches etc.
- Though grit chambers are mechanised, screens are still cleaned manually, thereby exposing workers to bacterial and viral infection
- Aerated grit chambers with classifier are mechanically cleaned and minimise occupational health hazards typically seen in other STPs
- High though optimised dosage of alum and polyelectrolytes
- Cleaning of tube settlers, sludge withdrawal and recirculation
- Sludge drying is not provided due to space constraints and therefore it is transported every day to another STP
- O & M of the plant is given on a contract to the construction agency / technology provider
- O&M is supervised by the power utility
- A manual on O&M of the plant has been provided by the contractor

Manpower

- Power utility : Supervisory staff
- O&M Contractor : 1 Plant Engineer, 1 Supervisor (E&M), 1 Chemist, 1 Foreman; Unskilled workers : (3 screen operators, 6 reactor monitor, 4 for sludge withdrawal) x 3 shifts (Total 43)
- Skill level : High skill level is required for operating the plant

Training

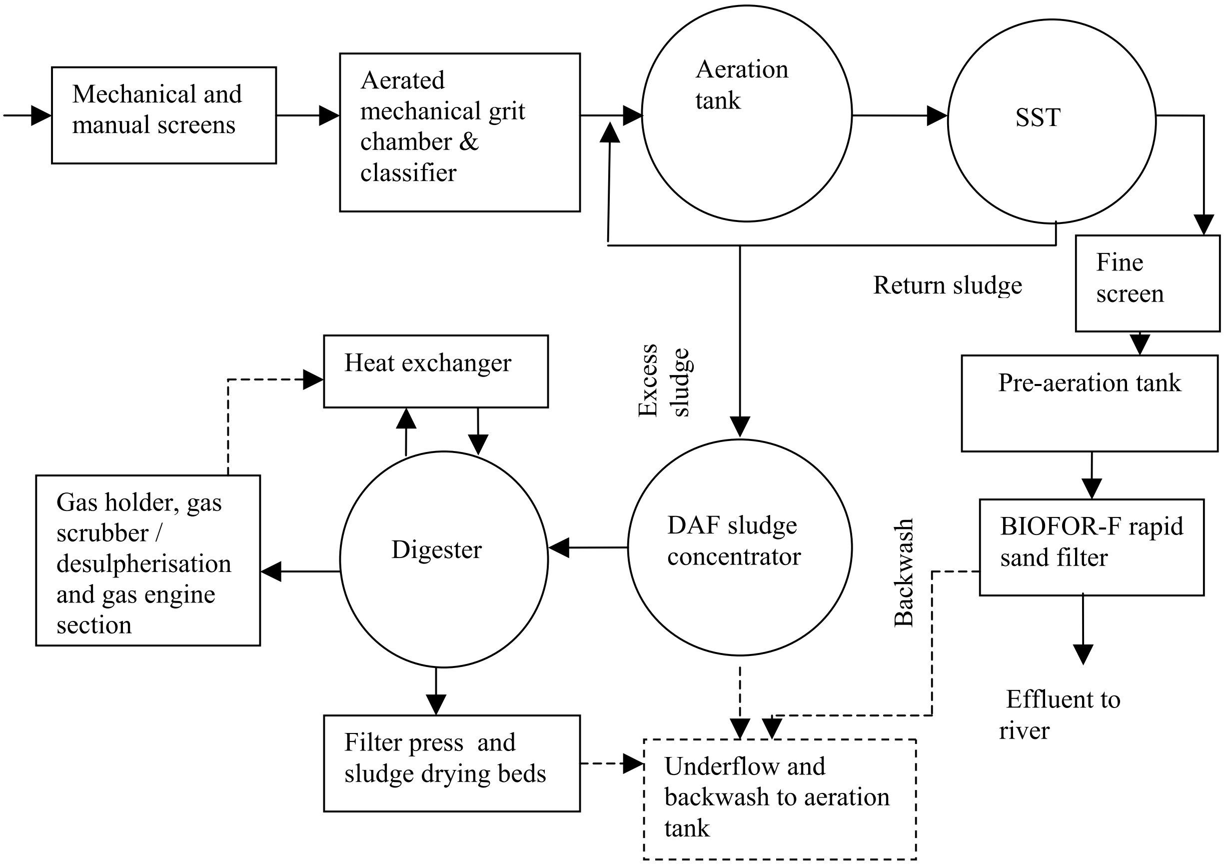
- The contractors' personnel are well trained and conversant with the technology
- The supervising engineering staff from DJB has developed understanding based on the manual and on the job training from the contractor.

Appendix G

PROFILE OF THE HIGH RATE ACTIVATED SLUDGE - BIOFOR - F BASED STP AT RITHALA, DELHI

Plant capacity : 182 mld
Year of commissioning : 2001
No. of streams : 4 streams each of 45 mld up to secondary settling stage

Flow scheme



Notes :
1. DAF : Dissolved air floatation system for sludge concentration
2. BIOFOR-F : Multimedia down flow rapid sand filter
3. In addition, a 1 mld polishing plant is installed for meeting the service water requirements

Land requirement

- Plant area : 13.8 ha. (could be less if sludge drying beds are excluded)

Plant performance

As per the technology provider the plant is guaranteed to deliver effluent BOD and SS under 15 mg/l and 20 mg/l respectively for corresponding influent values of 200 and 410 mg/l respectively. Under current hydraulic loading of 88% it is consistently achieving the designed effluent quality. Information on coliform removal is not available as the parameter is not monitored.

Sludge production - Current volume of sludge generation after anaerobic digestion is about 1280 m^3/d on 3% dry solid basis. This corresponds to 8.1 m^3 per million litre of sewage treated. At designed flows of 182 mld, the total volume is expected to be 1760 m^3/d . - Sludge is either dewatered in a filter press or dried on sludge drying beds. 43 sludge drying beds of 30 m x 30 m have been provided for this purpose. - Post sludge drying beds at current loads the sludge volume reduces to 96 m^3/d with dry solid at around 40%. At this stage the unit volume of sludge generation is approximately 1.5 m^3 per million litre of sewage treated. - Sludge disposal handled by DJB, however looking at the large volumes it is a matter of concern
Power requirement - Load during average flow conditions : 1300 kW - Average energy consumption : ≈ 32,500 – 36,000 kWh/d - The operator is authorised to draw only 5000 kWh/d from the grid - Non-technology consumption including street lighting : 700 kWh/d supplied from the grid - The plant is meeting its almost entire STP (technology) energy requirements from the biogas cogeneration system. The state-of-the-art dynamic power control system on the biogas engines ensures adequate generation corresponding to the load on the STP at a particular point of time.
Biogas generation - Biogas generation from sludge digestion : 14,000 m^3/d - As per the original design of the STP and as per the contract, biogas production was supposed to take care of almost 85% of the energy requirement of the plant. In view of this, the digesters have been designed for high and year round consistent performance. - The digesters are operated under mesophilic conditions with temperature control and sludge heating arrangement. The heat available from the biogas cogeneration system is utilised for this purpose and the sludge temperature is maintained at 24º - 27ºC. Though this is not the ideal mesophilic temperature, maintaining it within this narrow range at least ensures continuation of methanogenic bacterial activity consistently under winter and summer conditions. - During monsoon season, due to dilute wastewater the quantum of sludge generation and as a consequence the biogas generation is reported to go down.
Biogas composition - Exact analysis is not available, although the biogas quality in terms of its calorific value is understood to be very high and close to the maximum possible at 6 kWh/m^3. - The gas cleaning system comprises of an alkaline scrubber for removal of hydrogen sulphide. The underflow is further treated in a bioreactor for sulphur recovery in mineralised form.
Resource recovery – Biogas to energy - Possible electrical energy from biogas : 14,000 x 6 kWh/m^3 x 40% = 33,600 kWh/d (net electrical energy yield @ 2.2 -2.4 kWh/ m^3) - Generators : 3 nos. of biogas engines of 1 MW each (2 working + 1 stand by), make : Jenbacher, Austria - Cost of complete bio-energy system : Rs. 18 Crore (1996) - Electrical energy generation from the biogas cogeneration system : Varies between 23,000 to 33,000 kWh/d depending on the STP load and quantity of available biogas. - Thermal energy recovery (approximate) : 14,000 x 6 kWh/m^3 x 50% = 42,600 kWh/d (equivalent to about 3650 lit of diesel/d) which is utilised for heating of sludge
Resource recovery – sludge - Revenue from sludge : nil
Resource recovery – treated effluent - Nil
Total resource recovery - Total resource recovery in terms of savings due to captive bio-energy (electricity) generation is

estimated to be Rs. 56.6 million pa.
- (@ Rs. 5/ kWh of grid supplied electrical energy)
- In addition, there is considerable notional resource recovery from cogenerated thermal energy corresponding to the equivalent quantity of diesel which is internally utilised for heating of digesters
- Total resource recovery as a percentage of current capital cost (Rs. 938 million) is 6%. With respect to original capital investment of Rs. 805 million the recovery is 7%.
- Recovery as a percentage of current O&M cost (Rs. 31.9 million) : 177 % i.e., savings made by generation of bio-energy is almost 77% more than the rest of the O&M costs of the plant.

Capital costs
- Indexed capital cost of the plant in year 2001 for 182 mld : Rs. 914.7 million (excluding cost of land)
- Capital costs (2003) : Rs. 938.2 million

Annual O&M costs
- O&M cost for the STP (2003) including surplus electricity costs: Rs. 31.86 milion pa

Life cycle cost
- Capitalised cost (2003) over 35 years : Rs. 4274.33 million

O&M aspects
- Mechanical bar screens installed at the STP have improved performance with regard to removal of plastic bags and pouches, however further improvements would still be desirable
- Aerated and mechanical grit chamber and grit classifier is an effective system which minimises manual handling and risk to occupational health of workers
- Screenings and grit collection and disposal system is found to be efficient and effective
- The activated sludge process is operated as a high rate aeration process with volatile suspend solids in the range of > 4000 mg/l and DO around 2 mg/l
- Circular aeration tanks with tapered arrangement for submerged diffused aeration enable efficient control over oxygen demand - supply conditions
- Sludge recirculation and wasting is continuous which provides consistency in the operation of aeration tanks as well as the digesters
- Sludge thickening through dissolved air floatation enables 4 fold increase in dry solids concentration
- Severe frothing problem is experienced in downstream units e.g., aeration after secondary settling tank, BIOFOR-F, conveyance channels etc.
- Gas availability is crucial for cogeneration system and therefore it is typically not flared.
- Eventual sludge disposal is done in the form of land filling. However considering the quantities involved and low off-take for manure purposes, improved systems would be required for safe disposal in future
- The plant is well planned and designed for continuous and smooth functioning with lesser degree of manual labour involvement
- However, high skilled manpower is required for operation of different reactors, digesters, gas cleaning system and cogeneration system.
- O&M of the plant has been given on contract to the technology provider which takes care of the process management aspects. In addition a separate agency is appointed by the technology provider for labour works. The bio-energy cogeneration system has also been given on annual maintenance contract to a specialised agency. Supervisory inputs from DJB are minimum.
- A log book is maintained for various operations e.g., operating process parameters, running of electrical equipments, sludge heating system, bio-energy generation, plant power load etc.
- Wastewater samples are collected on daily basis
- Laboratory facility is provided by the Delhi Jal Board where the O&M contractor caries out its sample analysis and DJB also collects and analyses a separate set of samples on its own.
- A high level of plant upkeep is observed.

Manpower - Plant Manager – 1 Production Manager, 1 Process Manager, 3 Sr. Engg. (Mechanical), 1 Sr. Engg. (Electrical), 2 Engg. (Electrical); 1 Administration Officer - 11 operators, 9 skilled workers, 30 unskilled workers - 6 skilled workers at the cogeneration system - Skill level : high level of skill required for operating the plant
Training - The personnel from the technology provider are well trained and conversant with the technology/process. - Similarly the personnel of cogeneration O&M agency are well trained and efficient. - The workers deployed on labour contract have been trained on respective job functions as well as on occupational health and safety aspects.

Appendix H

VISIT TO STPs IN WEST BENGAL

1. After the completion of the main case study on STPs constructed under YAP and GAP in northern India, a short visit to selected STPs in West Bengal was made. It is reported that the STPs constructed in West Bengal during GAP-I are functioning well both from technology and institutional arrangement point of views. In this context, this visit was made with the objective of assessing the factors behind their successful performance.

2. During the course of this visit, the following three plants were covered :

a) Chandan Nagar STP	18 mld	Trickling filter
b) Panihati STP	12 mld	WSP
c) Bangur STP	45 mld	ASP

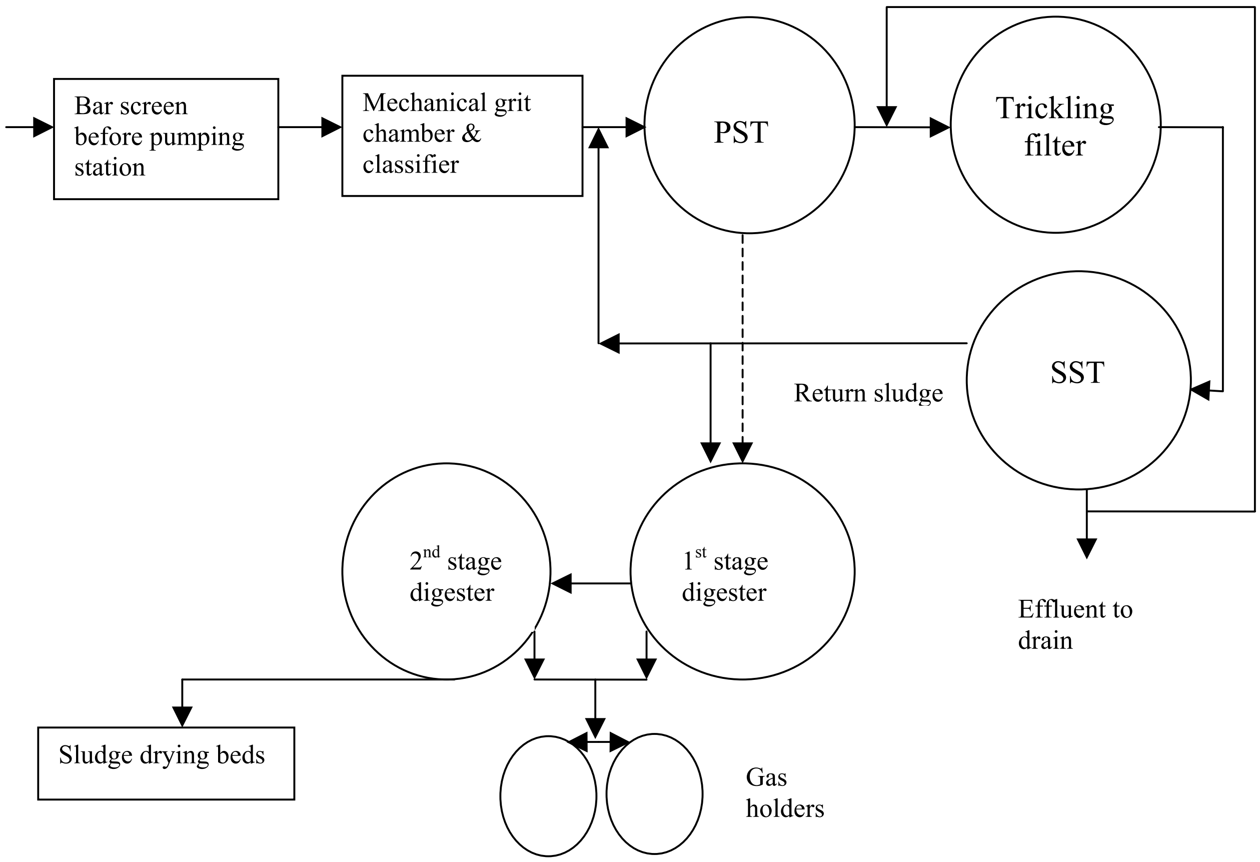
3. Chandan Nagar is a separate municipal town which is located about 50 km from Kolkota. It has a semi-urban setting and does not have a sewerage system. Individual houses have septic tank and the overflow joins open drains. Majors nallas in turn convey the combined wastewater to the river. These nallas have been intercepted and the flow has been diverted to the STP.

4. Panihati is one of the suburbs of Kolkota and it has similar wastewater flow situation (characterised by lack of sewerage) as described above. The STP is located outside the municipal limits, in a rural area which is administered by a separate local governing body called Panchayat.

5. Bangur STP is receiving sewage from the Cossipore and Chitpur sewerage zones of Kolkota Municipal Corporation. These zones are covered by a sewerage system and unlike the above two STPs the flow reaching this STP is characterised by consistent hydraulic and organic loading which is as per the original design estimates.

6. The first two plants were covered in detail while third plant was visited to make a rapid assessment of institutional arrangements and key technology constraints, if any. Profiles of the first two plants are presented in Box 1 and Box 2 and their life cycle cost analysis is presented in Annex 1 of this appendix respectively. Key conclusions on respective plants related to planning, technology, plant management etc. are discussed after each box.

BOX 1 : PROFILE OF THE TRICKLING FILTER BASED STP AT CHANDAN NAGAR, WEST BENGAL
Plant capacity : 18 mld Year of commissioning : 1991 No. of streams : 1 Plant area: 4.9 ha (unit land requirement 0.27 ha/mld) Cost of the plant : Rs. 21 million (1988-1991)
Flow scheme



- Trickling filter appears to have been designed as a roughing filter
- Note the abnormal recirculation of settled sludge to PST

Plant performance

The STP is receiving wastewater from intercepted nallas. Current hydraulic loading is only 55% of the designed capacity. Moreover, the nalla flow being dilute, the influent BOD concentration is as low as 60 mg/l.

Parameter	Influent	Effluent
BOD (mg/l)	60-70	22
COD (mg/l)	100	35
TSS (mg/l)	175-220	25
Average faecal coliform	Not monitored	
Effluent aesthetics	Dark grey and odorous wastewater	Colourless, odourless and clear effluent. Overall aesthetics is good.

Power requirement

Installed load : 200 kW
At average flow : 85 kW
At peak flow : 120 kW

Component	Power rating	Average	Remarks
Grit chamber motor	1.75	18	
Vacuum pump	0.75	18	Withdrawing settled grit
Grit classifier	0.746	18	Dry grit separation

Grit classifier	0.746	18	Dry grit separation
Recirculation pump	18.65	18	3 + 3 stand by
Sludge pumps	3.75	5	1 + 1 stand by
Dewatering pump	2.25	3	
PST motor	1.5	20	
SST bridge	1.5	20	
Filtrate pump house	2.25	6	(1 + 2 stand by)
Digester	7.5	0	4 mixers, not in use

- Estimated energy consumption based on above data and operating schedule : 34,935 kWh/month
- Actual monthly average consumption as reported by KMDA : 11,500 kWh/month
- Unit energy consumption (as per above operating schedule) : 116 kWh/mld at current flow of 10 mld.

Actual unit consumption (as per KMDA data) : 38 kWh/mld at current flow of 10 mld. This is a very low value and does not represent realistic operating conditions. The deviation could be due to power cuts if any, non-operation of electric drives etc.

Biogas generation :

Although the tender document specified influent BOD of 180-250 mg/l the nalla flow has a BOD of only 60 mg/l. Because of this low organic loading, sludge generation is less and the digesters are not put to effective use. Biogas production is insignificant in economic terms or virtually nil.

Biogas composition :

NA

Resource recovery – Biogas to energy

While some capital cost was blocked in two large digesters and gas holders, no such investment was made in installing the duel fuel generators. As the biogas generation is insignificant, the resource recovery in the form of bio-energy is not feasible.

Resource recovery – sludge

Data on quantum of sludge generation is not monitored. The sludge is dried in drying beds and then disposed off in ‘low lying areas’. While Chandan Nagar is a well known horticulture belt, demand for sludge as a soil conditioner or as a manure has not been created. As a result, there is no meaningful resource recovery from sludge.

Resource recovery – treated effluent

The treated effluent is not pumped to agriculture fields and thus there is no associated revenue flowing from this component. However, there could be some notional ‘resource recovery’ as the wastewater may be picked up by farmers from the drain on the downstream.

Total resource recovery

The combined resource recovery from biogas, sludge and effluent is nil.

O&M aspects

Trickling filter

- The trickling filter unit is well maintained and found to be functioning smoothly
- The problem of floating objects (e.g., plastic bags) is less or absent at this plant therefore the operation of the trickling filter is not affected adversely.
- The rotating distribution arms are kept perfectly levelled in a horizontal plane by giving adequate tension to the tie rods and wire ropes. As a result, wear and tear of the ball bearings is minimised. The distribution arms rotate due to the available hydraulic head of the effluent.
- The distribution arm has wide and square cross section and the opening at its far end allows flushing of any solid deposits at regular interval

- The turn table is well maintained. It is oiled/ greased once a week and since commissioning i.e., for last 13 years it has not given any major problems.
- Average size of the filter media is 7.5 to 10 cm, corresponding to a roughing filter. Since commissioning the media has never been taken out for cleaning as a need for such type of maintenance was not felt.

Others

- Mechanical grit chamber with a suction pump is found to be effective and well maintained. The grit removal operation requires minimal manual handling / cleaning and thereby reduced risk to occupational health.
- The chain and bucket type grit classifier is found to be effective in separation of solids from concentrated stream of wastewater. The unit is well maintained and functioning.

Agencies running the plant

Kolkota Metropolitan Development Authority (KMDA) is the PIA. However, as the local municipality has expressed inability to take over the responsibility of O&M of the plant even after over 13 years of commissioning, KMDA is still responsible for this task.

Almost since commissioning, KMDA has adopted the practice of engaging a contractor for O&M of the STP. The contracts are awarded on an annual basis to a local contractor. Over the years the same agency has been retained for annual contracts and it has developed good deal of expertise in running of the plant.

As a laboratory has been established at the plant, a separate contract is awarded annually for carrying out the routine monitoring of the biological wastewater treatment process. In this instance the same agency has also been given the contract of management of laboratory. Under such an arrangement where the same agency is responsible for O&M of the plant as well as for reporting the final effluent quality, an element of bias in the monitoring data can not be ruled out. However, on the other hand it helps in better process management as coordination for monitoring and adjusting reactor performance is improved.

In addition to the conventional 18 mld STP, the complex also has a 4.5 mld oxidation pond which was constructed some time in late 1970s in pre-GAP period. This plant has been given on an annual contract to an agency traditionally involved in fishing and fish trading business. The contractor has engaged a group of fishermen for operating the oxidation pond and maturation pond and carrying out aquaculture activities. In addition he has also established his own hatcheries outside the plant complex to meet the seedling requirements. In return for the fishing rights, the agency gives Rs. 100,000 per annum to KMDA.

While the oxidation ponds are of conventional type, it must be noted that it is very much under loaded (perhaps only 30% of the designed hydraulic capacity). The effluent after grit chamber from the main plant is sent to the OP. As a result of these factors, there are no complaints of odour etc. typically associated with overloaded or poorly maintained wastewater lagoons.

KMDA has also developed the surplus land at the STP complex as a public park with fountains, slides, swings and landscaping etc. Moreover, as the apparent water quality in the oxidation pond lagoons is not objectionable, they are used for boating. As a result of these features, the park attracts large number of visitors and the agency has been able to generate revenue of over Rs. 30 lakh/annum from this activity. In order to take care of the entire complex three separate contractors have been appointed for horticulture, sweeping and security cum entry ticket vending. A small cafeteria has also been set up and given on contract.

Thus, in all seven different annual contracts are awarded at Chandan Nagar STP viz. (i) O&M of STP, (ii) management of laboratory, (iii) O&M of oxidation pond, (iv) horticulture operation, (v) sweeping operation in park, (vi) security of the complex cum vending of entry tickets and (vii) running of cafeteria.

Manpower

The team of STP O&M contractor comprises 1 supervisor, 8 skilled workers and 10 unskilled workers. For the laboratory activities, the contractor has engaged one Chemist (retired from AIIHPH) and one Lab Assistant. Manpower details of other contractors are not available.

To supervise the operation of the contractor, KMDA has deputed one Technical Assistant (Civil) and one Technical Assistant (Electrical) on a full time basis at the plant. In addition, officers of the rank of AE (Elect. and civil), EE and SE give proportionate part time supervisory inputs.

Sampling and monitoring

Daily one sample of influent and effluent is collected and analysed inhouse.

Surveillance

In addition, on behalf of the NRCD a sample of influent and effluent is collected on a monthly basis by Kalyani Agriculture University.

Training

Under an NRCD sponsored training programme, the contractor has also been trained at AIIHPH, Kolkota in O&M of STPs. Moreover, the KMDA officials have received training at various levels both at AIIHPH, NEERI and overseas. Higher level of training inputs are reflected in better functioning of the STP

Role of the PIA

Continues to provide supervisory inputs.

Expenditure and revenue

Activity head	**Value, Rs. Lakh**	**Remarks**
Expenditure		
O&M of STP	8.5	
Management of laboratory	1.9	
Horticulture	7.0	
Sweeping of park	2.5	
Security	6.0	
Electricity	6.6	@ Rs. 40,000 pm for STP and Rs. 15,000 pm for the park
Sub-total	32.5	
Revenue		
Oxidation pond	1	From aquaculture in OP
Sale of entry tickets	30	@ Rs. 5 per ticket. KMDA is considering to increase the price to Rs. 10 per ticket.
Sub-total	31	
Surplus / deficit	(-) 1.5	A notional loss.

Key observations on Chandan Nagar STP

7. The Chandan Nagar STP is found to be working satisfactorily on various counts. Key conclusions are presented below.

Planning and load assessment

- Unlike in YAP, for STPs constructed in West Bengal during GAP-I a design period of 15 years was adopted.
- As a result, while the Chandan Nagar plant is nearing its design life, the hydraulic and organic loadings are still below the designed capacities.
- Some of the other reasons for low organic load are (i) absence of sewerage system and prevalence of septic tank arrangement in most part of the town and (ii) dilution of wastewater in nallas as a result of combined discharge of sewage and sullage.
- Over-estimation of the organic load at planning stage has led to provision of excessive capacity for sludge digesters which is lying unutilised.
- However, a cautious phase-wise approach towards exploitation of bio-energy has saved the capital expenditure on duel fuel engines.
- The plant has a compact layout and the unit area requirement is 0.27 ha/mld.

Technology

- The mechanical grit chamber and grit classifier /detritus are robust, effective and pose least occupational health risk to operators.
- The plant is well designed and has robust mechanical and electrical equipment.
- The trickling filter is working smoothly as distribution arm is well maintained and the problem of floating plastic objects is almost absent or well taken care of.
- The average technology energy consumption of the STP is 116 kWh/mld which is way below the average of 180 -220 kWh/mld for activated sludge process based plants (additional energy input for pumping of raw sewage at a higher level is not reflected in this figure, however that would represent a significant fraction of the total energy requirement towards meeting the oxygen transfer requirements).
- An abnormal return sludge scheme of introducing it into the PST is found which could lead to overloading and under performance of the latter.
- Although a two stage sludge digestion process has been provided, unless the digesters are designed for high end performance and monitoring, resource recovery in economically significant terms does not seem to be feasible.

Plant management

- Innovative approach of developing the surplus land as a public park has enabled the managing agency to generate sizable revenue and offset over 90% of the operating expenses.
- Appointment of a local knowledgeable contractor for O&M of the plant over a long time horizon has brought stability in the plant performance.
- Training of the contractor has led to an improvement in his knowledge, aptitude and skills and this is demonstrated through better leadership over the team of operators and consistent plant performance.

Life cycle cost

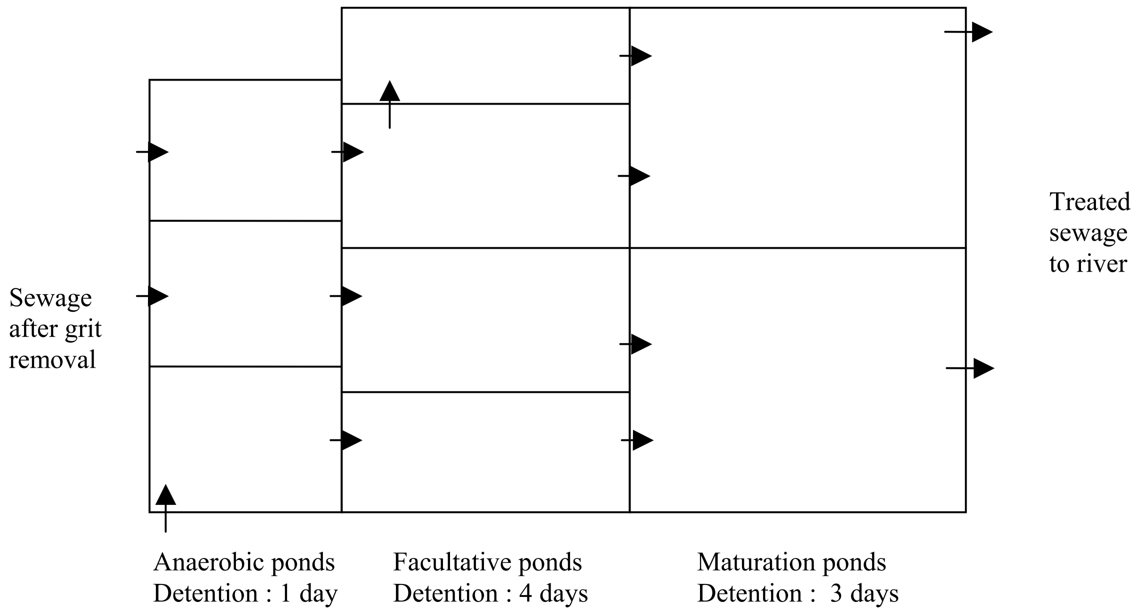
8. Based on the same criteria as adopted earlier during the main study, the unit life cycle cost (excluding land cost) is computed to be Rs. 9.5 million/mld. This is about 30% lower than that of ASP and close to that of UASB. It will be noted that energy costs are not fully represented in the

current computation as the raw sewage has to be pumped to an additional height for oxygen transfer through the trickling filter media. However, this is comparable to other technologies and thus would not make significant difference in final values.

BOX 2 : PROFILE OF OXIDATION POND BASED STP AT PANIHATI, KOLKATA

Plant capacity : 12 mld
Year of commissioning : 1993
No. of streams : 3
Plant area: 8.3 ha
Cost of the plant : Rs. 23 million (1993)

Flow scheme



Plant performance

The STP is receiving wastewater from intercepted nallas. Current hydraulic loading is only 60% of the designed capacity. Moreover, the nalla flow being dilute, the influent BOD concentration is as low as 60 mg/l.

Parameter	Influent	Effluent
BOD (mg/l)	60-70	21
COD (mg/l)	-	-
TSS (mg/l)	233	45
Average faecal coliform	Not monitored	
Effluent aesthetics	Dark grey and odorous wastewater	Colourless, odourless and clear effluent. Overall aesthetics is good. There is no odour at the STP.

Power requirement

Nil, except at the raw sewage pumping station

Biogas generation : NA

Biogas composition : NA

Resource recovery – Biogas to energy : NA

Resource recovery – sludge Nil as there is no demand creation among farmers
Resource recovery – aquaculture As the lagoons are hydraulically and organically under loaded it has been possible to carry out aquaculture cultivation in both facultative and maturation ponds. Unlike other WSPs constructed under YAP, the incidence of fish kill is not experienced at this plant which shows that nitrogen (and the organic) loading is not excessive. About 100 kg of fish is harvested every day and this is possible for about 300 days in a year. The contractor has agreed to give Rs. 200,000 per annum to KMWSA as royalty.
Resource recovery – treated effluent Nil or notional
Total resource recovery The combined resource recovery is Rs. 200,000.
O&M aspects While lining of pond embankments was carried out couple of years after commissioning of the plant, the bottom was left out deliberately as it is not conducive for aquaculture. It is said that a bottom layer of soil and sediment offers a favourable environment to the fish. (incidentally, the problem of ground water contamination through of seepage from WSP has not been reported in the area) There is good demand for small fish in the local market and accordingly the harvesting pattern has evolved. The fishermen release seedlings on a regular basis and also harvest regularly (almost daily) the moderately grown fish. Excessive body weight growth is not allowed and therefore harvesting over long interval is not practiced. Sludge removal from anaerobic pond is the responsibility of KMWSA. Recently after 8 years the ponds were desludged by engaging a separate contractor. After drying, the sludge was disposed off for land filling. Apparently there were no takers among farmers or it was not marketed adequately among the target population. The anaerobic ponds were found to be remarkably well functioning as there was no odour, scum layer or gas bubbles. This can be attributed to fact that the plant is not overloaded either from hydraulic or organic load point of views. The dykes are found to be getting eroded due to the wave action. Strengthening has been carried out in sections and especially in maturation pond this has been done by placing wooden logs. Trees on the dykes have been allowed to attain a height of 5-6 m which is not desirable as they prevent solar radiation and act as wind barrier.
Agency running the plant Kolkata Metropolitan Water and Sanitation Authority (KMWSA) is the PIA and as the local municipality has expressed inability to take over the responsibility of O&M of the plant, it is still under the control of KMWSA. For last seven years, KMWSA has adopted the practice of aquaculture in both the facultative pond and maturation pond by engaging a contractor. KMWSA makes a fair assessment of aquaculture potential and sustainable returns there from. Against this expected yield and market price, open bids are invited from interested parties in the village where the STP is located. Highest bidding contractor is selected, however recommendation of the Village Panchayat is sought on the matter. To start with the contract was given for 2 years. Subsequently the same agency was engaged for 3 years

and then 2 years. Now it is proposed to lease out the ponds for 20 years. Local fishermen are engaged by the contractor in this activity who bring traditional knowledge of fishing in inland water bodies.
Manpower The team of contractor comprises 1 supervisor (leaseholder), 1 skilled worker and 20 unskilled workers. To supervise the operation of the contractor, KMWSA has deputed one Junior Engineer on part time basis. **Sampling and monitoring** Effluent sample is collected once a week by AIIHPH Kolkota. **Surveillance** None
Training No formal training was given to the contractor or local fishermen as they are well versed in traditional method of aquaculture in inland water bodies and shallow ponds.
Role of the PIA Besides the routine supervisory inputs, all repairs including dyke protection, desludging and other civil works are carried out by KMWSA.
Expenditure and revenue Except for the supervisory inputs KMWSA does not incur regular expenditure. However, it incurred a cost of Rs. 300,000 after 8 years for desludging of anaerobic ponds. This approximates to Rs. 35,000 pa. On the other hand it earns revenue of Rs. 200,000 pa from the aquaculture operations.

Key observations on Panihati STP

9. The Panihati STP is found to be working satisfactorily and smoothly. Key observations are listed below.

Planning and load assessment

- The plant has been designed for year 2016 (design period ≈ 25 years) and thus the current loading in way below the designed capacity.
- The land acquirement has been accordingly for the final requirement. However currently only 75% of land has been used for pond construction.
- The plant has a compact layout and the unit area requirement is only 0.7 ha/mld.

Technology

- As a result of absence of overloading :
    - the plant performance is found to be smooth
    - there is no odour from the anaerobic ponds
    - let alone the maturation ponds, even the facultative ponds are also being used for aquaculture
    - although there is abundant algal growth in facultative ponds, fish kills are not reported

Plant management

- Traditional knowledge of local fishermen is gainfully utilised for sustainable aquaculture.

- Long term lease arrangement for O&M with a group of fishermen under the supervision of a local contractor is apparently found to be a win-win solution

Life cycle cost

- Based on the conventional approach the absolute life cycle cost is found to be Rs. 64 million/mld and unit life cycle cost is 5.34 million/mld (excluding the land cost)
- However, in reality this would be much less as the PIA is not incurring any expenses on manpower, instead it is earning a revenue from aquaculture. A rough estimate puts this revised cost at Rs. 46 million and unit cost at Rs. 3.84 million/mld

Key observations on Bangur STP

10. In absence of detailed data, a thorough analysis as in case of the previous two plants has not been done. However, key observations are presented below

Planning and load assessment

- The 45 mld conventional ASP based STP is fully loaded in terms of organic and hydraulic load, apparently due to adequate coverage by a sewerage system in the area being served.
- Not being sure of the quantum and quality of biogas, duel fuel engines were not installed at the outset.
- Due to space constraints, the option of centrifuge along with storage sheds has been adopted. As a result the unit land requirement is 0.12 ha/mld as against the typical norm of 0.2-0.3 ha/mld.

Technology

- Single stage ASP followed by sludge digestion has been adopted for this plant
- As in case of STPs in UP, here also the abnormal feature of recycling the settled secondary sludge into PST is observed with accompanying adverse effects.
- Sludge thickeners have been provided for improving the solid content of the sludge
- Unlike the conventional approach of single stage sludge digestion, two stage digesters have been provided. However, either due to design limitations or inadequate organic loading, biogas formation is not significant.
- Closed screw pumps have been provided for transferring thickened sludge into the digesters. However choking is reported to be a frequent problem.

Plant management

- The O&M of the plant has been given to a local agency on annual contract. Over last four years the same agency has been retained and it has developed an adequate level of expertise in operating the plant.
- The technical staff of the contractor has been trained at AIIHPH and NEERI.
- The responsibility of disposal of dried sludge rests with KMDA and not with the contractor.
- Same contractor is responsible for running of the laboratory.
- KMDA has deputed two full time technical staff at the plant for supervising the operations of the contractor.

FINANCING OF O&M OF STPs IN WEST BENGAL

11. The Ministry of Urban Development, Govt. of West Benagal created a separate budget head for O&M of GAP-I works. The funds received under this head by KMDA / KWMSA go directly for meeting the O&M costs of STPs and PS.

12. The establishment costs of the PIAs are met through the non-planned grant received from the State Govt. Besides this, KMDA has its own sources of revenue through property development which enables it to meet about 20% of the establishment costs. Of late it has also adopted an innovative approach of park development on surplus land of STP to meet the O&M costs to a certain extent.

ANNEX 1 : CASE STUDY AND LIFE CYCLE COST COMPUTATION OF STPs IN WEST BENGAL

Assessment parameter		TF at Chandan Nagar	OP at Panihati
River action plan		GAP-I	GAP-I
Capacity	**mld**	18	**12**
Hydraulic loading	%	55	60
Plant Area	ha	4.9	8.30
Area per mld	ha/mld	**0.27**	**0.69**
Performance			
Effluent BOD	mg/l	22	21
Effluent COD	mg/l	35	
Effluent DO	mg/l		5
Effluent SS	mg/l	23	46.0
Effluent faecal coliform	MPN/100 ml		1.E+04
Sludge digestion		yes	na
Biogas generation	m^3/d	nil	na
Bio-energy generation	kWh/d	nil	na
Resource recovery - biogas	Rs. pa	nil	na
Resource recovery - sludge	Rs. pa	nil	na
Resource recovery - effluent/aquaculture	Rs. pa	nil	200,000
Total resource recovery	Rs. pa	nil	200,000
COMPUTATION OF LIFE CYCLE COST			
Contract Value of Plant Civil + E & M	Rs. million	21.0	23.0
% of Work Civil Works		65%	95%
	Rs. million	13.7	21.9
% of Work oE & M Works		35%	5%
	Rs. million	7.4	1.2
Year of construction		1991	1993
Whole sale price index			
WPI : Year Of construction		73.7	92.3
WPI : (Dec 2003 estimated)		159.7	159.7
Unit cost of STP			
Cost of Plant (as in Dec 2003)			
Civil Works	Rs. million	29.6	37.8
E & M Component	Rs. million	15.9	2.0
Total Cost of Plant	Rs. million	45.5	39.8
Unit cost of STP	Rs. million/mld	2.5	3.3
Operation & Maintainance Costs			
Technology Power Requirement	kWh/d	1164	nil
Non Technology Power Requirement	kWh/d	180	nil
Total Daily Power Requirement	kWh/d	1344	nil
Unit power requirement	kWh/mld	136	nil
Daily Power Cost @ Rs 4.80/ KWhr	Rs.	6451.2	nil
Annual Power Costs	Rs. million	**2.35**	**0.00**

Assessment parameter		TF at Chandan Nagar	OP at Panihati
Manpower Cost	Cost/MM		
Manager	18000	1/2	½
Chemist / Operating Engineer	8500	3/4	0
Operators	5000	2	4
Skilled Technicians	6500	3	1
Unskilled Personnel	3000	9	12
Cost of manpower	Rs. million	**0.86**	**0.86**
Repairs cost			
Civil Works per Annum as % of Civil Works Cost		0.2%	0.2%
E&M Works as % of E&M Works Cost		3.0%	3.0%
Civil Works Maintainance	Rs. million	0.06	0.08
E & M Works Maintainance	Rs. million	0.48	0.06
Annual repairs costs	Rs. million	**0.54**	**0.14**
Total annual O&M costs	Rs. million	**3.75**	**0.99**
Unit O&M costs	Rs. million/mld pa	**0.21**	**0.08**
Uniform present worth over life cycle of plant of 35 years @ 5% rate of interest			
Uniform present worth factor		16.37	16.37
Capatalised O&M Cost over 35 Years	Rs. million	125.17	24.23
Capital cost of plant (2003)	Rs. million	45.5	39.8
Land Cost @ Rs 5 mill / ha	Rs. million	24.50	41.50
Life cycle cost (excluding land) (2003)	Rs. million	**170.68**	**64.03**
Unit life cycle cost (2003)	Rs. million/mld	**9.48**	**5.34**

Notes

1. For the sake of comparison with previous STPs included in the main study, same rates for electricity and manpower have been used
2. In case of Panihati WSP, the revenue from aquaculture and savings on manpower costs have not been factored in calculation of the life cycle cost.
3. Rest of the considerations remain same as for the STPs included in the main study.