

Fig. 3.4.1 Propagation and transition in population size of various microorganisms in the course of the stabilization of wastewater ⁴³

Depending on concentration levels of various components of the designated raw wastewater, it may be required to dilute it before treatment. Some references on the use of seawater as diluting water are as follows: "On the Treating Ability and the Microflora of the Sea-Water-Activated Sludge under Various Treating Conditions" and "On the Microflora of the Sea-Water-Activated Sludge, Especially on the Resident Microflora Investigated through a Conventional Method".

(2) The Basic Treatment Process

The treatment of organic wastewater by means of the activated sludge process is carried out as a combination of the stages shown in Fig. 3.4.2⁴⁴. Before entering the activated sludge process, the wastewater is subjected to physical treatments such as screening, sedimentation and skimming in order to separate and remove suspended and floating matter as well as isolated oil components. This is a preliminary treatment stage called the primary treatment. The effluent from the primary treatment stage is then fed to the next stage called the secondary treatment where the wastewater is treated with the activated sludge process, thereby removing organic matter as a BOD-causing component.

The incoming wastewater from the primary treatment stage is led into an equalization tank where the water is homogenized in quality, diluted, given a pH adjustment or nutritious salts such as nitrogen and phosphorus added, as is necessary. Since the equalization tank is given the role of controlling the supply of wastewater to the aeration tank, it must be large enough to cope with fluctuations in quantity.

The wastewater stored in the equalization tank is continuously sent to the aeration tank at a constant rate to be mixed with activated sludge which has previously been propagated and cultivated with the same wastewater. This mixed liquor is aerated for a fixed period of time so that the organic matter will be oxidized and decomposed by the sludge, which simultaneously also adsorbs other contaminants such as fine sand.

The mixed liquor is gently led to the settling tank by natural flow and is left undisturbed for 2 - 3 hours so that the sludge separates out of the mixture and settles. The supernatant liquid (treated wastewater) is then usually released as effluent but is sometimes subjected to a further treatment called the tertiary treatment, which is aimed at removing nitrogen and phosphorus, as well as remaining BOD and COD.

Part of the sludge which settles at the bottom of the settling tank is continuously returned to the aeration tank (return sludge) and mixed with the newly introduced wastewater. The rest of the sludge (excess sludge), which has increased in volume after decomposing organic matter, is taken out of the system to be processed separately and disposed of. More than 90% of the BOD possessed by wastewater is removed by a treatment system with this activated sludge process.

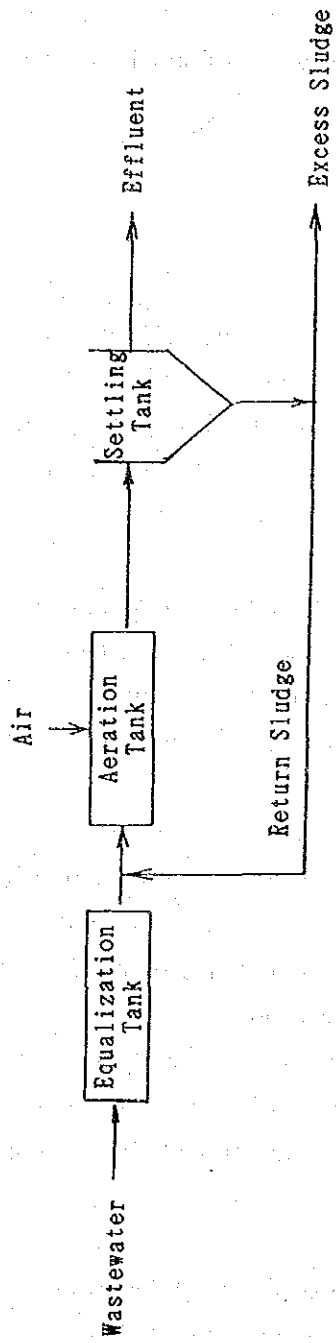


Fig. 3.4.2 A flow diagram of the standard activated sludge process ⁴⁴

(3) The Propagation and Acclimatization of Activated Sludge

It is an indispensable condition for obtaining high quality treated wastewater to produce activated sludge well acclimatized with the same raw wastewater as that to be treated. One of the processes to propagate and acclimatize such sludge is to aerate the designated wastewater, thus creating a sludge culture naturally, and to propagate it. However, since this process takes too long to generate the required quantity of sludge, the usual process is to transfer the bulk of excess sludge from an existing treatment plant (with an unspecified type of wastewater) and then use it.

In this case the sludge acclimatizing period is generally five to 10 days but it may take as long as 30 to 50 days if the decomposition of synthetic organic compounds such as alkylbenzene sodium sulfonate, polyvinyl alcohol etc. is required.

A reference for the effects of surface active agents involved in the dilution of wastewater with seawater is: "Employment of Some Detergents as Circumstance-Restricting Agent in the Sea-Water-Activated Sludge-Process".

(4) BOD Load

BOD load is a concept based on the ratio (F/M) of BOD (F) to activated sludge (M) which could be expressed in volumetric and sludge load.

BOD volumetric load represents the daily intake in weight (kg) of BOD generating matter into a unit volume (1m^3) of the aeration tank and is expressed as follows:

$$L_v = L_f Q/V$$

Where L_v : BOD Volume load ($\text{kg-BOD}/\text{m}^3 \text{ day}$)
 L_f : BOD Concentration of incoming wastewater (kg/m^3)
 Q : Volume of incoming wastewater (m^3/day)
 V : Capacity of aeration tank (m^3)

On the other hand, BOD sludge load represents the daily intake in weight (kg) of BOD generating matter per kg of MLSS and has the following expression:

$$L_s = L_f Q/V S$$

Where L_s : BOD Sludge load ($\text{kg-BOD}/\text{kg-MLSS day}$)
 S : MLSS Concentration (kg/m^3)

Thus, the relationship between L_v and L_s is given as:

$$Lv = Ls S$$

Fig. 3.4.3⁴⁵ shows the relationship between BOD sludge load, decomposition of organic matter and the propagation of sludge.

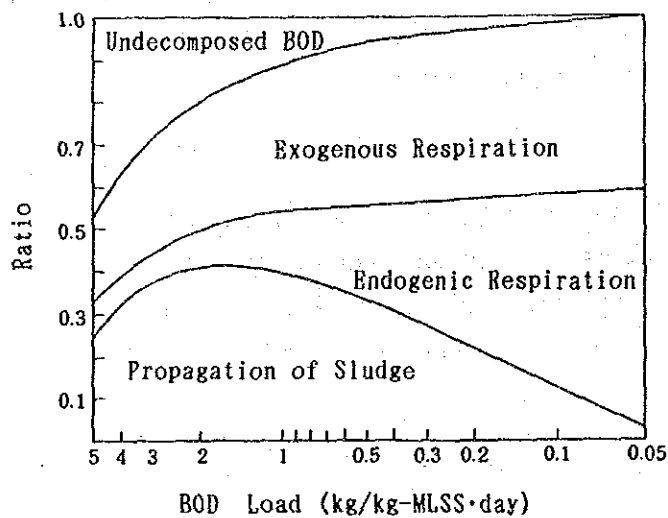


Fig.3.4.3 BOD load's relationship with organic matter decomposition and sludge propagation⁴⁵

As BOD sludge load increases, the quantity of undecomposed BOD generating matter also increases, thereby causing a deterioration in the quality of the treated effluent. In addition to this problem, when the BOD sludge load is raised to a 1 kg-BOD/kg-MLSS day or so level, sludge develops so-called filamentous bulking and exhibits difficulty in separation and settling, jeopardizing the entire stable treatment operation of the plant.

For BOD loading, the following figures are generally employed:

- a. BOD Volume load: 0.5 to 1 kg-BOD/m³ day
- b. BOD Sludge load: 0.2 to 0.3 kg-BOD/kg-MLSS day

(5) Sludge Volume Index

One of the sludge's indispensable conditions is good settling characteristics, thereby ensuring easy separation with the supernatant liquid in the settling tank, and as a measure for how well sludge settles sludge volume index (SVI) is often used.

SVI represents the volume (ml) which 1g of activated sludge takes up after aeration-tank mixed liquor, while placed in a measuring cylinder, 100 to 1000 ml in volume, is left undisturbed for 30 min. to let the sludge component settle and is expressed as follows:

$$SVI = SV/S$$

Where SVI: Sludge volume index (ml/g)

SV : Sludge volume after 30 min. settling

S : MLSS concentration (%) (In this case, a volume ratio (%) of the sludge to the liquor is denoted as SV₃₀)

Because SVI is not intended to show any basic physical property of the sludge its values for the same sludge differ greatly as MLSS varies.

Normal sludge has its SVI value within the range of 50 to 100 and exhibits good settling characteristics. When the SVI value under the plant's stable operation condition is known SV₃₀ may be used in place of SVI.

(6) Quantity of Recycled Sludge

In order to keep the BOD sludge load in the aeration tank constant, MLSS must be adjusted by feeding back some sludge from the settling tank.

The following formula is generally used to find the quantity of sludge to be recycled:

$$S = S_r R / (1 + R)$$

Where S_r: The SS concentration of recycled sludge(mg/l)

R : Sludge recycling ratio

The sludge recycling ratio is the volume ratio of the recycled sludge to the incoming wastewater. On the other hand, the volume of the recycled sludge can also be found using the following formula:

$$S \leq 10^6 / \text{SVI} R / (1 + R)$$

Where S : MLSS concentration (ml/l)
 SVI: Sludge volume index
 R : Sludge recycling ratio

Furthermore the sludge recycling ratio can conveniently be obtained from SV_{30} using the following formula:

$$R = SV / (100 - SV)$$

Where R : Sludge recycling ratio
 SV : Sludge volume after being set still for 30 min. (%)

(7) Oxygen Demands

The oxygen consumed by the activated sludge process microorganisms inside the aeration tank is the sum of the portions of the removed BOD used by the microorganisms for oxidation decomposition action to obtain propagation energy and internal respiration, and is calculated by the following formula:

$$X = a' L_r + b' S'$$

Where x : Volume of oxygen demanded (kg/day)
 L_r: Amount of BOD removed (kg/day)
 S': MLSS Value (kg)
 a': Ratio of the removed BOD portion used to obtain energy for sludge propagation (1/day)
 b': Ratio of the removed BOD portion used for sludge internal respiration (1/day)

The values of a' and b' generally fall within the ranges of 0.35 to 0.55 and 0.05 to 0.24 per day, respectively although they do vary with wastewater type and sludge conditions.

It is one of the necessary conditions of plant operation to always keep the amount of dissolved oxygen (DO) within the range of 1 to 4mg/l. Plant operation at a DO value 0 means wastewater is not adequately treated, thus enhancing the BOD of the treated effluent. On the other hand, a plant operated at high DO values, although BOD is treated, microorganisms lose cohesion and become deflocculated due to self-oxidation, resulting in an insufficient separation

by sedimentation of the sludge and its subsequent discharge in the form of suspended solids (SS). Furthermore, wastewater produces ammonia which is then nitrified into nitrous or nitric acids by action of nitrifying bacteria in the sludge, causing a fall in pH or rise in COD.

(8) Analysis and Measurement Involved in the Operation Management of a Treatment Plant

The main concern of the operation management of an activated sludge process plant is the management of the aeration tank. In the aeration tank activated sludge microorganisms multiply and propagate using wastewater as nutrients, thus holding together as coherent sludge. With excess sludge subsequently taken out of the system, a desirable balance between the sludge and organic matter is maintained so as to ensure the quality of the treated effluent. Since the collective properties of activated sludge microorganisms vary with the nature of the wastewater, sludge with distinctive characteristics most suited to each wastewater treatment plant exists. The activated sludge process consists of two stages, biological action and separation of solid and liquid, with its treatment effectiveness depending on the following factors:

1) External factors

- (i) The properties of the incoming wastewater: Water temperature, components, concentration, and affinity for biological treatment**
- (ii) Fluctuations in the quantity and quality of the wastewater**

2) Internal factors

- (i) Plant operation (conditions for treatment): Resident time, supplied air volume (dissolved oxygen concentration), MLSS concentration, BOD load, and the management of sludge in the settling tank.**
- (ii) Characteristics of sludge (activity level, SVI, etc.)**
- (iii) Variant operation methods such as anaerobic and aerobic**
- (iv) Effluent from the sludge processing stage as load**

Parameters for water quality management are as follows:

- (i) Appearance, water temperature and transparency: Color, smell, foaming, SS and sediments,**

and oily appearance

- (ii) pH: This is a parameter for nitrification and denitrification reactions.
- (iii) MLDO: While DO of more than 0.3 mg/l is generally regarded as satisfactory, the rule of thumb for DO at an aeration tank outlet is usually above 2 – 3 mg/l.
- (iv) SV: 30 – 80% is regarded as satisfactory.
- (v) MLSS: While the accepted ratio MLVSS to MLSS is generally taken as 75 to 85%, the share of VSS tends to be high for organic wastewater.
- (vi) Activated sludge microorganisms: Water quality management using microorganisms requires experience but nevertheless is accurate.

Regarding the content of general management involved in the operation of an activated sludge process plant, examples of a log book and weekly report are shown in Tables 3.4.1 and 3.4.2⁴⁵, respectively.

3.4.2 Other Variant Processes

Since the activated sludge process was developed, a system called the standard activated sludge process, as described above, has customarily been employed. Today, however there are various processes, taken as variations of the activated sludge process, which have also been put to practical use.

As examples of aerobic treatment processes, those using biological membranes and special bacteria are discussed.

(1) Variant Activated Sludge Processes

1) Step aeration

This is a process in which the incoming wastewater enters from several inlets provided along the flow direction of the mixed liquor while the recycled sludge is returned to the tank's main inlet. The advantages of this method are: (i) the possibility of making the oxygen consumption level uniform throughout the aeration tank, (ii) the ease of managing the MLSS level even if BOD load changes (iii) the ease of taking a countermeasure to an increase in SVI.

Table 3.4.1 Log book ⁴⁵

date		weather temp. °C	terms of seeding				name				
measure	items	time	9:00					standard of operation condition	BOD/COD		
	equalization tank	quantity							aeration tank pH		
		volume							aeration tank DO		
	water to aeration tank	quantity							MLSS		
		dilution							volumetric load		
	return sludge	(%)							sludge load		
excess sludge	extrac-tion										
analysis	items	items of measure	temp.	pH	BOD	COD	T-N	NH ₃ -N	T-Cl	SS	oil
	equalization	9:00									
	aeration tank	9:00									
	treated wastewater	9:00									
	removal ratio (%)	9:00									
aeration tank	item	temp.	pH	DO	SV ₃₀	MLSS	MLVSS	MLVSS/MLSS (%)	return sludge		
	time	9:00							SS (mg/l)		
calculation	SVI	$\frac{SV_{30}}{MLSS} = \frac{\quad}{\quad} = \quad =$									
	BOD volumetric load (kg/m ³ ·d)	$\frac{C \times Q}{V} = \frac{\quad \times \quad}{\quad} =$									
	BOD sludge load (kg/kg·d)	$\frac{C \times Q}{V \times MLSS} = \frac{\quad \times \quad}{\quad \times \quad} =$									
MEMO									sketch of sludge under microscope		

Table 3.4.2 Weekly report ⁴⁵

items of measure		date					
condition	weather						
	air temp. (°C)						
	WS, WD (m/sec)						
wastewater	volume (m ³ /d)						
	water temp. (°C)						
	TS		SS				
	BOD ₅	mg/l	kg/d				
	COD _{Cr} (or TOD)	mg/l	kg/d				
	BOD ₅ /COD _{Cr} (TOD)						
	COD _{Mn} (mg/l)						
	oil (mg/l)						
	treated wastewater	temp. difference between influent and effluent					
TS		SS					
BOD ₅		mg/l	removal ratio				
COD _{Cr} (or TOD)		mg/l	removal ratio				
BOD ₅ /COD _{Cr} (TOD)							
COD _{Mn}		mg/l	removal ratio				
NO ₂		NO ₃					
oil		mg/l	removal ratio				
operating conditions for aeration tank	transparency (cm)						
	BOD sludge load	BOD ₅	COD (or TOD)				
	volumetric load	BOD ₅	COD (or TOD)				
	temp. difference between influent and effluent						
	DO (mg/l)						
	MLSS (or MLVSS)						
	MLVSS/MLSS						
	quantity of spray						
	return sludge						
	hydraulic retention time						
	SV ₃₀						
	aerobes						
	foaming						
operation conditions for settling tank	water space load						
	sludge retention time						
	concentration of sludge						

2) Contact stabilization

While the organic content of the wastewater entering the aeration tank is adsorbed by the sludge microorganism within a relatively short period of time, it takes these microorganisms a long time to sufficiently digest (assimilate) it. As a result, the following method has been devised: the sludge and wastewater are mixed and aerated for about 30 to 60 min. in the aeration tank; after adsorbing organic matter, the sludge is separated out by sedimentation in the settling tank; it is then sent back to the deaeration tank where it is aerated again to recover its coagulating, adsorbing as well as floc-forming abilities.

3) Extended aeration

This is a process in which the BOD load is kept at about 1/10 that of the standard activated sludge process, thereby reducing the volume of the excess sludge.

4) Oxidation ditch

This is a variation of the prolonged aeration process with a modification in the construction of the aeration tank. Wastewater and activated sludge are mixed and aerated in an endless ditch 1- 3m deep. This method may be seen as the fully-mixed-type prolonged aeration and has an added feature of using a stirrer as a means of supplying oxygen.

5) Sequencing batch activated sludge process

This is a process in which a series of wastewater treatment actions, consisting of the intake of wastewater, aeration, sedimentation and the release of the treated effluent, take place in succession in a single reaction tank, with two variations of its own: intermittent and continuous intake types.

Its advantages include: simple plant design because of the dual use of a single tank for aeration and sedimentation purposes; the prevention of bulking; high removal ratios for nitrogen and phosphorus; ease of maintenance management.

6) Oxygen aeration

While at present the activated sludge process is considered a rational organic wastewater treatment process, it has a limitation to its high load operation due to the possibility of bulking. To overcome this there is a process which achieves an increase in load level by raising the oxygen supply level during aeration by using pure oxygen instead of air. However, this accompanies an increase in running cost.

7) Anaerobic/Oxic Process

This is a process which incorporates a phosphorus removing function by installing an anaerobic tank prior to the aeration tank. As a hypothesis puts it, it is understood that the activated sludge releases phosphorus in the anaerobic tank (while simultaneously adsorbing BOD sources), and adsorbs it in excess in the aeration tank. A strict condition is applied to the anaerobic tank such that it must be absolutely anaerobic, so that it is operated in the presence of neither dissolved nor bonded oxygen.

8) Denitrifying activated sludge

In the treatment of wastewater with the activated sludge process, the nitrogen content of the wastewater is considered to be a necessary nutrient for the sludge and its ratio to BOD of 5:100 is generally accepted as indicating its adequate supply level. Therefore, if nitrogen supply is less than this, additional nitrogen should be introduced, while in the opposite case some nitrogen must be removed instead.

This process eventually discharges various nitrogen compounds present into the air after converting them into nitrogen gas by rationally combining the metabolisms of nitrifying and denitrifying bacteria both naturally present in the activated sludge.

9) Selector-based system

This incorporates an aeration tank designed to create a time gradient of the matrix concentration in it, higher at the start of the treatment and lower at the end. The system is also provided with a means of manipulating the mixing characteristics of the aeration tank and the recycling of the sludge in a well balanced manner, thereby increasing the effectiveness of the matrix concentration gradient.

(2) Biological Membrane Processes

1) Trickling filter

Basically this relies on the same biochemical principles as those of the activated sludge process and decomposes organic matter in the wastewater using the biochemical action of the aerobic bacteria present on the surface of a biological membrane.

The filter bed is composed of crushed rock, ceramics and molded resins, layered in that order, and the wastewater is made to flow through it. The biota of the biological membrane has a heterogeneous continuous structure, from the anaerobic layer on the filter material surface to the aerobic layer in contact with the wastewater, with a food chain occurring within the membrane such that the microorganisms consume organic matter in the wastewater while protozoa and metazoa, in turn, catch these microorganisms. It exhibits an excellent treatment effect with such well-balanced environmental conditions.

2) Rotating disk

This is a variation of rotating filter beds and incorporates a disk which is partially submerged in a tank and rotates at a low speed so that the biological membrane formed on the disk surface will adsorb and decompose the organic matter.

With the rotating disk filter, the wastewater flows horizontal, unlike the trickling filter which causes it to flow vertically. Similar to the trickling filter, the biological membrane is fixed to the disk and consists of bacteria, fungi and protozoa, constituting a self contained biota with a relatively long food chain. This is one of the common features of biological membrane processes including the rotating disk. The biological membrane regularly breaks away from the disk, falls down into the treated water, and is separated in the settling tank. The biological membrane is aerobic on the surface and anaerobic at deep sublayers, with the latter understood to exert denitrifying action.

3) Fixed bed (contact aeration)

Fixed beds, composed of a base material fixed to and immersed in the aeration tank, purify the wastewater using the action of microorganisms adhering to the base material and propagating there. Working as filters, these fixed beds have traditionally been constructed from plastic honeycomb, fabric materials, etc. In recent years, however, the biological membrane filter technique, as distinguished from fluid beds, has been in wide use. This technique achieves efficient treatment by incorporating biological membranes with large surface areas provided by granular media such as sand, light aggregates, granular activated carbon, plastic balls and ceramic granules. These are immersed in the aeration tank so that microorganisms will coagulate on their surface.

4) Fluidized bed

In contrast to the trickling filter, rotating disk and contact aeration processes where membranes are held by some kind of support, microorganisms reside on granular media with the fluid bed process and are carried around in the aeration tank by these media. These media, as carriers of microorganisms, are the same as those mentioned in (3) 'Fixed bed' and the energy necessary to agitate and stir them is obtained from the air which is, in turn, supplied from the bottom of the fluid bed tank. Microorganisms which separate from media are separated in the settling tank in the subsequent stage and discharged outside the system as excess sludge.

5) Bio-film filtering

This process uses a configuration similar to that of a gravity filter where wastewater enters the top part of the tank, filled with granular media, and the treated effluent is taken out of

the bottom part, from which air diffusion also occurs. While the wastewater passes through granular media, the microorganisms coagulated on the media surface decompose the organic matter in the wastewater using dissolved oxygen.

As the treatment process described above are all variations of the activated sludge process their basic principles of treatment, and therefore their operation management methods, are the same as those of the standard activated sludge process.

3.5 General Matters Concerning Measurement and Analysis at Research Institute⁴⁶

The following are to be excluded from the discussion presented in this chapter as they are considered to be part of common administrative matters at a research institute although they do have some direct impact on analytical tasks: the management of laboratory supplies including replenishment for the sample storage room, and spare parts for laboratory equipment and apparatuses; the maintenance of laboratory facilities and safety measures including fire prevention and safe handling of potentially dangerous items such as deleterious materials, high pressure gases, electricity and radioactive isotopes.

3.5.1 Management of Measurement and Analytical Tasks

(1) The Maintenance and Management of Laboratory Records

1) Recording Measurements

It is important to keep a detailed record of the entire process involved in preparing a report so as to establish a standard for the reliability of its raw measurements, in case the content is ever disputed or a comprehensive evaluation of the already-submitted analyzed data becomes necessary.

2) Organizing Data

<1> Instrumental analysis

When many samples are subjected to instrumental analysis, it is cumbersome to record the same measurement conditions each time. Avoiding this, the following method will make the organizing of data easier: a calculation procedure is prepared in order to convert raw measurements into formatted data with a predetermined format; raw measurement, in the form of charts or analytical curves, are attached to the records of formatted data; the measurement conditions are printed on each chart paper strip with a rubber stamp pre-impressed with them while other necessary information is entered.

<2> Solid samples

When conducting composition analysis of solid samples, the following items must be

recorded with the type of weight, i.e. wet weight, dry weight or ash weight, clearly stated:

- a. Sample collection method
- b. Sample drying method
Type of drying method; temperature, duration, container, etc.; dry weight
- c. Sample pretreatment
Decomposing and ashing methods; handling method; quantities of reagents used; ashing temperature, duration, container, etc.; ash weight in case of ashing; dilution ratio of sample preparing solution
- d. Method of measurement for analysis sample
pH or acid concentration; handling method; kinds and quantities of reagents used such as solvents; analytical curves; standard addition method; internal standard method; and others
- e. Standard solution
Kind and purity of standard reference materials; manufacturers, batch numbers, etc. of standard reference materials; preparation operation

<3> Recording items at sampling

The following items should be recorded at sampling.

- a. Name of sample;
- b. Sampling location and its conditions;
- c. sampling method;
- d. date and time;
- e. weather (on the day of sampling and previous);
- f. air and water temperatures;
- g. PH;
- h. sample's appearance;
- i. presence of odor; other useful information

For RO and wastewater treatment plants, operating condition should also be recorded. For recording during field investigations, the preparation of a field book, a pocket-size note book protected with a hard cover, will facilitate the work.

3) Data Sheet Management

While measurements are often rearranged for reporting and other purposes, analysis

results, even if already submitted, should never be left loose. Bearing in mind that these results may be referred to in the future as valuable data, they should be well maintained and managed so that will not be scattered and lost.

For their maintenance and management, it is convenient to use book binding kits which enable documents and reference material to be bound easily and quickly.

It is recommended that raw data such as recording charts be stored in storage bags with a label carrying relevant information such as the measurement data, content and conditions on their surface.

(2) Management of Samples, Chemicals and Standard Reference Materials

1) Sample Management (ASTM, JIS K 0094 'Sampling method for Industrial Water and Industrial Waste Water')

In water quality analysis, collected samples should promptly be tested. The sample water should also be given pretreatment since some of its components such as organic matter, suspended substance, phenols, cyanide compound, sulfides, heavy metals and nitrogen compounds are susceptible to change due to biodegradation, hydrolysis, volatilization, adsorption, etc.

2) Reagent management (JIS K 8001 'General Rules of Testing Method for Reagents', JIS K 0050 'General Rules for Chemical Analysis, JIS K 8002 'Methods of preparing Solutions for Reagent Test, JIS K 8003 'Methods of Preparing Undiluted and Limit-Indicating Reference Solutions for Reagent Test', JIS 8004 'General Reagent Test Methods' JIS K 8005 'Standard Substances for Volumetric Analysis, JIS K 8006 'General Matters for Reagent Test'-section for titration).

Reagents are guaranteed high quality chemicals intended for testing purposes and are widely used in the areas of scientific education, testing and research, analysis and experiment and special industries. In Japan they are classified in terms of quality (reagent special class and reagent first class) and usage (for quantitative analysis of alkali metals, drying, etc.). Purpose-specific reagents are chemical testing of agricultural chemicals residue, atomic absorption analysis, absorptiometric analysis, fluorometric analysis and chromatographic analysis. There are also other standard for reagents such as ACS, based on 'Reagent Chemicals', 5th ED (1975) prepared by the US Chemical Society's committee for Analytical Reagents(USA); Merck (Germany); and Analar R (UK). The reagents prescribed by these standards do not have a quality classification and are mostly of a similar quality to JIS's special class. Care in the handling of reagents is provided with a label which shows one of the following:

a. Deleterious materials (specified by the Ordinance on Industrial Safety and Hygiene):

A directive/warning message

b. Hazardous materials: hazardous material classification specified by the Fire Prevention Law

c. Toxicants/deadly poisons (specified by the Poisonous and Deleterious Substances Control Law): Message 'NOT MEDICINE' as well as characters signifying 'Toxicant' in white against a red background for toxicants or those signifying 'Deadly Poison' in red against a white background for deadly poisons, on both containers and packages. Among reagents those used as indicators require special attention since the same indicators can produce different indications under different conditions for example, use after a long storage time or being taken from different production batches. In case there is a possibility of this happening, analytical curves must be re-examined. Also, storage periods must be 10-20 days even for relatively stable reagents.

During metal component measurement, if large quantities of high concentration acids are used for acid treatment etc., small amounts of heavy metals such as Pb, Cu, Cd and Hg are detected even when these acids are of the highest quality. (The levels of impurities such as Pb, Fe, and Cd contained by aqueous ammonia, hydrochloric acid, nitric acid, sulfuric acid, etc. are far from negligible, with for example, the Pb level reaching 0.2 - 0.5 ppm.) Since there is a possibility that these metals are treated as contaminants in the process of elution or concentration, it is a safe practice to use a high-purity special-purpose reagent suitable for ultramicroanalysis (one for precision analysis, class extra special, etc).

Although distilled water or desalted water (water purified with ion exchange resins) is generally regarded as satisfactory for analytical purposes it is recommended that desalted water be used after distilling it.

3) Standard Material Management

<1> Standard reagents for volumetric analysis (JIS K 8005 'Standard Reagents for Volumetric Analysis')

Standard reagents must be desiccated before use. Once opened, they must always be placed in an empty desiccator (i.e. without desiccating agents) and stored in a cool, dark place avoiding outside air.

<2> Standard reagents for analytical curves (JIS K 0102 'Testing Methods for Industrial Wastewater') Standard reagents for analytical curves, when used for inorganic components, are regarded as satisfactory if they are more than 99.5% pure as well as exhibiting qualities similar to that of reagents for volumetric analysis.

The undiluted solutions (stock solutions) of inorganic standard reagents should be about 1

mg/l in concentration and be stored in such a state as to be free from precipitation or decomposition (e.g. acidity or alkalinity higher than 0.1N). When diluted solutions are required, it is necessary to prepare them each time by diluting the undiluted solution with water or diluted acid or base).

4) Management and Storage of Dangerous Chemicals

As a research institute handles numerous dangerous chemicals, measures such as appointing a person responsible for managing chemicals to each set of facilities are desirable (if possible). On the basis of awareness and knowledge as a scientist, it is necessary to fully grasp the characteristics of the chemicals being used and understand relevant laws/regulations so as not to cause an accident.

In general large quantities of dangerous chemicals should be stored in a lockable chemicals depot chemicals storage room, with only limited quantities kept in the laboratory. When stored, it is desirable that they be classified into suitable groups according to the nature of the danger involved, such as toxicity, mixing hazard and flammability, and that these groups be separated from each other by placing them in different cabinets or on different shelves.

The Japanese Chemical Society Classifies a variety of dangerous chemicals into the following 11 danger categories with easy-to-identify disaster prevention label specified for each of them: ignitability, flammability, combustibility, explosibility, oxidizability, hydrophobicity, strong acidity, corrosiveness, toxicity, deleteriousness and radioactivity.

On the other hand, it is also necessary to prevent chemical bottles from falling or clashing due to vibration, and for that purpose various products have recently been marketed including special cabinets specifically aimed at the safe handling as well as orderly storing and classifying of chemicals; earthquake-proof bottle trays; and magnet-attached fall-preventing cups.

(3) Analytical Instrument Management

The maintenance and improvement of analytical accuracy relies not only on the ability of the technician who carries out the analysis but also on the accuracy and stability of the analytical instrument and the reliability of its maintenance.

When using the instrument, location conditions of installation are also important. Although these conditions, including the absence of vibration or direct sun light, a thermostatic chamber and low humidity, vary depending on the type of instrument, where microanalysis is required the possible presence of background noise at the instrument location should be given special attention. At locations where noise is present in the power source or equipment which generates high frequency radio waves is installed nearby, it is important to investigate whether these have any effect on the measuring instrument.

For the management of instruments, it is essential to carry it out with the research institute's basic approach towards management and its 'Instrument Management Standard' established. It is desirable that frequently used common instruments (such as pH meters, small spectrophotometers, and chemical balances), which are used by an unspecified number of researchers, be maintained and managed in such a manner that services and inspections are provided in accordance with the management manual prepared in advance with utmost care. An example of management standard models is shown in Table 3.5.1⁴⁷. While it is common that large pieces of equipment (mass spectrograph, X-ray analyzer, etc.) are each managed through an exclusively appointed person with advanced specialist knowledge and technical skills, it is also desirable that they be each operated by an exclusively appointed operator.

In general, measuring instruments and analytical equipment which measure chemical quantities such as the concentration of a specified substance differ greatly from those measuring physical quantities in that the former are not necessarily based on the absolute measurement principle. These types of measuring instruments require some sort of material which serves as a standard and indicates the quantity of the material being measured as a value relative to the quantity of the standard material. This necessitates confirmation of the position of the zero and span point on the scale as part of maintenance work, constituting a marked difference from absolute measurement in terms of maintenance requirements. For this work a standard material is indispensable and therefore, it is an important aspect of the maintenance activity to maintain the performance, especially the accuracy, of the measuring instrument using the correct standard material.

When maintenance is carried out, measuring instruments are often found to be out of order due to faulty parts or minor damage. It is therefore, important to keep spares for parts with high break-down rates and to obtain technical skills for instrument hardware so that repairs can be made in-house. This is necessary because it is often the case that some measurement instruments are out of order for a prolonged period of time due to difficulties in obtaining spare parts.

3.5.2 Management of Measurement and Analytical Techniques

(1) Gravimetric Analysis

Gravimetric analysis in analytical chemistry is a method to find the share of a target component in a sample by separating it from others in a pure compound or a simple substance and measuring its weight.

Microanalysis by instrumental analysis is a comparison method of measurement, as discussed in the previous section, and its standard material is accurately adjusted by the gravimetric method. (JIS K 0050 'General Rules for Chemical Analysis' Gravimetric Analysis)

Table 3.5.1 Model of management standard for spectrophotometer ⁴⁷

(○ : checking, □ : exchange)

checking items		standard	starting	management interval					operation	note	
				daily	weekly	monthly	each 3 months	each 2 halfyear			yearly
light source portion	subjects	items									
	source of light	1. lighting 2. position	light up normal position	○						watching instruction manual	
	condensing mirror	1. dirt 2. position	non dirt and deterioration			○				watching instruction manual	
	sample box	dirt, corrosion	non dirt and corrosion	○						watching	
	cell holder	1. dirt, corrosion 2. position of cell	non dirt and corrosion, good reproducibility	○						watching confirm reproducibility	
	window	dirt	non dirt	○						checking, sensitiveness for UV portion	
	silica gel	deterioration	good ability in hygroscopicity		○					watching exchange	
	wavelength accuracy		within limits					○		instruction manual or JIS K 0115	
	beyond lights		within limits							JIS K 0115	
	measuring lights accuracy		within limits							JIS K 0115	
synthetic quality	lenearity of absorbance to concentration of Abs0		within limits							○	measure the same sample on range of transmittance and absorbance. check lenearity of absorbance to transmittance using table of numerical value.
	0,100% stability of Abs0		within limits								

1) Separation (JIS K 0050 'General Rules for Chemical Analysis')

Depending on the principles involved, separation methods are classified into the following variations: sedimentation, gas generation and electrolysis.

2) Desiccation (JIS K 0050 'General Rules for Chemical Analysis')

Desiccation refers to the operation to remove water content from substances containing water but more precisely it includes the removal of not only water but also dampness from volatile matter. The desiccation of solids is generally more complicated than that of gases or liquids. The following are methods of desiccating solid substances.

- a. To leave the solid alone while the water content evaporates
- b. Desiccation on filter paper or a porous sheet
- c. Desiccation by compression
- d. Desiccation in a desiccator containing a desiccating agent
- e. Desiccation by heating
- f. Desiccation by congelation
- g. Desiccation by sedimentation

3) Constant Weight (JIS K 0050 'General Rules for Chemical Analysis')

To measure the mass of a substance is called weighting and a precision or a chemical balance is in wide use in usual gravimetric analysis, while a microbalance (lower reading limit 1 microgram) is used for micromasurement.

The following are to be noted in conjunction with weighting:

- a. Desirable conditions of the balance room are a temperature of 20 -25°C with a humidity of approx. 60%.
- b. The balance base must be stable and must not transmit vibration.
- c. During measurement, the operator must stay seated in the correct manner and when reading the measurement must not go closer to the balance than necessary.
- d. Ultramicromasurement should be carried out by placing the sample in a glass weighting bottle, platinum dish or crucible made of a metal such as platinum.

(2) Volumetric Analysis (JIS K0050 'General Rules for Chemical Analysis', JIS K 8005 'Standard Substances for Volumetric Analysis' and JIS K 8006 'General Matters for Reagent Tests' - sections for titration)

Volumetric analysis is also called titration analysis and together with gravimetric analysis

is one of the most fundamental and widely used of quantitative analysis methods.

There are two ways of classifying titration methods: one based on the chemical reaction involved and another according to the manner of detecting the end point. The former includes

- a. Neutralization titration or acid–base titration,
- b. oxidation–reduction titration,
- c. precipitation titration,
- d. complexometric titration;

while the latter involves

- a. the indicator method,
- b. precipitation formation or dissipation,
- c. potentiometric titration,
- d. conductometric titration,
- e. amperometric titration,
- f. photometric titration, and
- g. others such as high frequency titration and thermometric titration.

The following are to be noted:

- a. A point reached, as the standard solution is added to the sample, where the amount of the titration reagent in the standard solution is equivalent to that of the titrant in the sample, is called the equivalence point. (For neutralization titration it is the neutralization point.) Points reached in actual titration experiments are called end points and are not necessarily identical to theoretical equivalence points and these differences constitute quantitative errors.
- b. Character E (Einguess) marked on some measuring flasks signifies 'incoming' and the volume indication of a solution at the standard temperature is given as its incoming quantity when poured into the flask up to the level shown by the marked line. On the other hand, character A (Ausguess) signifies 'outgoing', and the volume indication of a solution at the standard temperature is given as its outgoing quantity when poured out of the flask from the level shown by the marked line.
- c. The volume of a drop of a solution is usually 0.03 ml.
- d. After recording the quantity of the solution at the end point, it is recommended that another 1/2 – 1 drop of the standard solution be added so as to confirm the end point.

(3) Absorptiometer (JIS K 0115 'General Rules for Molecular Absorptiometric Analysis')

This is a method to find the concentration of the target component in a sample as follows: a suitable reagent is added to the sample material or its content so as to cause its coloration; the absorbancy of the solution is measured using a photoelectric spectrophotometer or photoelectric photometer and this, in turn, gives the concentration of the target component.

The following are to be noted:

- a. It is most important to obtain a suitable coloration reaction.
- b. This is usually used to analyze solutions with a concentration less than 1 %.
- c. It is unavoidable that measurement is accompanied by errors, the causes of which lie either with the instrument or the sample solution. When it is required to obtain the same measurement results using different instruments, it is necessary to give careful consideration to the instruments' spectral widths and wavelength accuracies, and whether the sample emits fluorescence or is turbid.

(4) Ion Electrode Method (JIS Z 8802 "Methods for Determination of pH of Aqueous Solutions", JIS K0122 "General Rules for Ion-Selective Electrode Method")

The ion electrode or ion selective electrode is an electrode which develops a potential in response to the presence of a specific ion in the solution. Since this electrode potential is linked to the activity (or concentration) of the specified ion, it is possible to selectively measure the concentration of this ion in the solution. The analysis method using this kind of electrode is called the ion electrode method.

There are various types of ion electrodes:

- a. Solid membrane electrode
- b. Liquid membrane electrode
- c. Enzyme electrode
- e. Gas responsive electrode.

It is also important to measure the electrode potential while the sample solution is being stirred with a stirrer.

In case a target component of a diluted solution is to be measured within a short time, it is recommended that the standard addition method be used combined with the Grand's plot method.

(5) Atomic Absorption Photometry (JIS K 0121 "General Rules for Atomic Absorption Spectrochemical Analysis")

This is a method to find the concentration of an element in a sample as follows: using a suitable method the sample is dissociated into vaporized atoms; a light ray with its wavelength

adjusted to the specific wavelength of the target element is passed through this vapor; the target element's atoms in the basic state absorb the light, with the element exhibiting a level of absorbancy depending on the concentration of these atoms; this absorbancy is measured by means of photoelectric photometry, etc. to obtain the concentration of the element.

The followings are possible causes of measurement errors:

- a. Inappropriate choice of standard sample and error in its preparation.
- b. Inappropriate treatment and dilution of analysis sample.
- c. Discrepancy in composition as well as physical and chemical characteristics between the standard solution and the analysis sample solution.
- d. Interference from concurrent substances.
- e. Drifting and degradation of the lamp used as light source lamp.
- f. Faulty adjustment to the optical systems of the light generation and wavelength selection modules.
- g. Instability of or faulty adjustment to the light measurement module.
- h. Contamination and blocking of the atomizer and burner.
- i. Fluctuations in flow and pressure of combustible gas and combustion assisting gas.
- j. Faulty adjustment to the positioning of light beams penetrating the flame.
- k. Error in preparation of analytical curves.

(6) Emission Spectroscopic Analysis (JIS K 0116 "General Rules for Emission Spectrochemical Analysis")

This is a method to measure the intensity of light as follows: High temperature argon plasma is generated using high frequency energy and the solution sample is injected into the central part of the plasma so that it is ionized and emits light; from the spectral lines of this light, the component with the specific wavelength of the target element is isolated with a diffraction grating and then its intensity measured. ICP-MS has combined this with a gravimetric analyzer, capable of analyzing ions generated by plasma with a high sensitivity, and can analyze various elements to trace regions.

Since its detection sensitivity is greatly affected by the properties of the sample and operation conditions of the equipment, it is necessary to provide some kind of pretreatment according to the target element, concentration range for quantitative analysis, and major components. Depending on the kind and concentration of the target element, if sufficient sensitivity cannot be obtained or interference from the sample's major component elements is anticipated, it may be necessary to carry out such operations as separation from the main component and concentration, as well as readjustment of the chemical and physical properties before quantitative

operation can be started.

(7) Infrared Spectrophotometry (JIS K 0117 "General Rules for Infrared Absorption Photometric Analysis")

This is a method for carrying out qualitative and quantitative analysis of components of a sample, using its absorption spectra, a set of lines with their lengths representing the absorbed quantities of infrared light at frequencies where absorption occurs.

The followings are to be noted:

a. Phase of the Sample

The spectra of a substance changes slightly depending on the phase it is in at the time of measurement – gaseous, liquid or solid.

b. Solvent

Absorption characteristics fluctuate depending on the type of solvent used in the measurement of the sample solution.

c. Concentration and Temperature

Even if the solvent is unchanged, the spectra shift as the concentration and temperature change due to an accompanying change in association conditions.

d. Internal Structure of Molecules

The electronic state of an atomic group changes with the types of adjoining atoms or atomic groups and accordingly the position of its absorption characteristics changes somewhat. It is also affected by the mass of atoms within an atomic group or the coupling effect between atomic groups within a molecule.

(8) Ion Chromatography (JIS K 0124 "General Rules for Analytical Methods in High Performance Liquid Chromatography")

This is a method to quantitatively measure concentrations of component ions in a sample. The solution sample is passed through a separation column filled with an ion-exchange resin and its component ions become separated due to a difference in their affinities to the resin. Each ion is then dissolved in a solution and its conductivity (alternatively absorbancy or oxidation-reduction currents) measured, thus determining the concentration of the ion.

(9) Gas Chromatography (JIS K 0114 "General Rules for Gas Chromatographic Analysis"; ASTM "Index of Mass Spectral Data")

This is a method for carrying out qualitative or quantitative analysis of components of a sample. A gaseous or gasified liquid sample is diffused inside a separation column with a carrier

gas such as high purity nitrogen gas and fillers acting as the moving and fixed phase, respectively. As the sample moves along, its components develop a difference in moving speed due to a difference in their affinity for the fixed phase (distribution coefficient etc.), thereby allowing it to be separated and then detected with a detector. By choosing appropriate fillers and detector, this method can be applied to many organic and organometallic compounds.

A gas-chromatograph-mass spectrometer (GC-MS) combines this gas chromatograph with a mass spectrometer. After being concentrated at the interface between these two, each component of the sample, previously separated by the separation column of the gas chromatograph, is then led into the mass spectrometer, where it is ionized in an ionizing chamber under vacuum conditions and formed into an ion beam to produce its mass spectrum, thereby allowing it to be identified as a substance. The analysis of the spectrum is cumbersome and in order to process it quickly and effectively the use of a computer is indispensable, thus turning a GC-MS into a GC-MS-COM. The US Environmental Protection Agency (EPA) has developed a typical GC-MS-COM system which prints out a report on the analysis results using so-called similarity indices (0-1) in the order of higher probability.

3.5.3 Evaluation of Measurement and Analytical Results

(1) Collaborative Experiment

Collaborative experiment refers to an arrangement where more than one research organization engage in measurement of the characteristics of the same sample in order to reach an objective and reliable judgment. Collaborative experiment has the following three objectives:

- a. Establishment of measurements.
- b. Establishment of measurement methods and investigation of accuracy they produce.
- c. Improvement of measurement skills of people carrying out measurement.

1) Unified Accuracy Management Investigation

This involves simultaneously sending the same standard sample to a number of designated research organizations which will then analyze it, and is the most effective method of comparative examination of analytical results.

2) Cross-Checking

This is a method of checking if measurement and analysis results are reasonable by putting part of the sample aside so that it can be used for repetition of the experiment by the original experimenters themselves or by two or three commissioned third party organizations.

(2) Self-Management

Self-management refers to the voluntary management of the accuracy of measured data at the research institute. The three main elements of management are:

a. Reference (goal)

To identify the objectives clearly and define them concretely, scientifically and quantitatively.

b. Input (observation)

To grasp the present situation and identify the means to achieve the objectives.

c. Control (action)

To devise actual methods to achieve the objectives and implement them.

1) Total Accuracy Management

<1> Establishment of Standards and References

a. Materialistic Standardization

Management of standard reference materials, and standard and reference samples.

b. Technical Standardization

Actions and steps involved in technical tasks other than those standardized as part of measurement methods must be standardized. For example, automatization and instrumentation are incorporated into each stage of a measurement process – sample collection, chemical pre-treatment and measurement.

c. Administrative standardization

This is the standardization of the formats of written communication media. The standardized communication media should be used for the entire process of analysis report preparation, from sample admittance through measurement and analysis, to report writing, while integrating various component tasks. These media also facilitate staff action and interaction such as requesting, communicating, directing, recording and reporting.

<2> Identification of Variable Factors

In order to make accuracy management effective, it is necessary to grasp comprehensively where variable factors lie and to take action with a clear understanding of the most dominant factor.

<3> Error Control System

It is desirable that accuracy management be based on self-management and individual initiative, thereby encouraging active staff involvement. For this purpose, a recognition of errors based on the statistical way of thinking and an understanding of their variation are necessary.

2) Statistical Accuracy Management (JIS Z8402 "General Rules for Permissible Tolerance of Chemical Analysis and Physical Test")

<1> Statistical Expressions of Measured Data

Statistical expression provide a common language and measure for both those taking measurements and using them; those supervising and supervised, through data.

<2> Statistical Recognition of Measured Data

It is a fallacy to consider valuable data as being those without errors, because such measurements do not exist. Rather, the true value can only be estimated by examining the actual condition of change in measurement, i.e. errors.

<3> Statistical Processing of Measured Data

The basis of statistical processing is testing and estimation, which could be taken as equivalent to qualitative and quantitative analysis.

a. Processing of Measurements

Methods of rounding numerical values, and provisions for rounding of measurements.

b. Evaluation of Measurement

Provisions for allowances and invalidation of measurements.

c. Indication of Measurements

i) In case the limit of determination is specified.

- When a measurement is smaller than the limit of determination, the indication will be "Not detected".
- When a measurement is greater than the limit of determination, the indication will give the reading down to the same decimal place as that of the limit of determination.
- The number of significant digits above the decimal place of the limit of determination should in principle be two.

ii) In case the limit of determination is not specified.

- The indication is given in figures of multiple of 1 or divisor closest to the standard deviation

of the measurement.

- The number of digits to be indicated will in principle be two.

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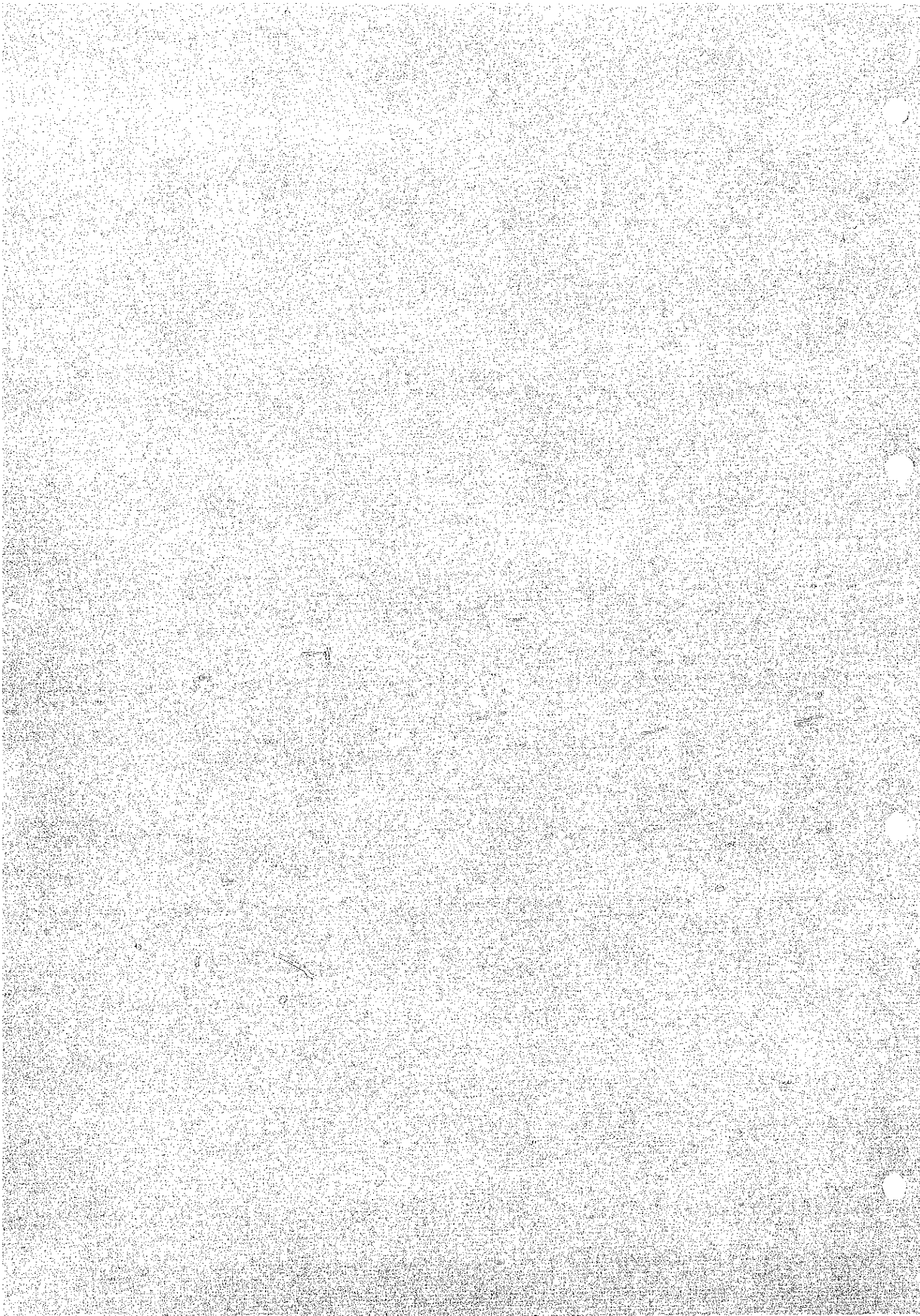
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Chapter 5 Summary



Chapter 5. Summary

Since the signing of R/D in January 1982, considerable cooperation was carried out by providing both hardware and software in order to improve the developing ability of seawater desalination technology at SWCC. In particular, many fruitful results were obtained by collaborative work such as experimental research and literature survey between the specialists of JICA and SWCC since October 1991. The results are summarized as follows:

5.1 MSF Process

M-1 Laboratory Experiment on Scale Prevention

The literature survey shows that the effect of oil on the functions of a scale inhibitor has not been studied yet. Consequently, a laboratory experiment was performed to determine the effect. It was found that the presence of oils in seawater reduces the capacity of the scale inhibitor. Elaborate discussion is necessary before making a decision about further experiments with an MSF test plant because a large amount of used oil-contaminated seawater must be treated before discharge.

M-2 Corrosion Tendency for Some Kinds of Materials

A literature survey was carried out on the corrosive characteristics of metallic materials (copper alloys, titanium and titanium alloys, aluminum alloys and stainless steels) and non-metallic materials which were used for MSF plants. Research and development themes to be studied in the future have been proposed, based on the survey results.

M-3 Study on Some Materials by Corrosion Measurement Apparatus

Concerning the corrosion-measuring apparatuses for metallic materials of MSF plants, the latest information on test equipment in laboratories, monitoring equipment and test systems for practical plants have been provided by a literature survey. In addition to that, proposals have been made for the systems and methodology of estimation tests on metallic materials.

M-4 Analysis of Oil Dispersed in Raw Seawater at the Heat Rejection Section of MSF Plants

The results of the literature survey showed that there is only a little information on the

behavior and chemical analysis of oil when oil-contaminated seawater is used for feed of an MSF process.

Assuming an accident of crude oil spill, a laboratory experiment on evaporation of oil-contaminated sea water was performed in order to predict the contamination of the product water and to find an analytical method for oil. It was found that the amount of water transferred to the product water was highest at the deaerator, and decreased from higher temperature stages to lower ones in turn. GC/MS and IR are suited to the analysis of oil.

However, more accurate, detailed experiments will be necessary, because the above experiment had not perfectly simulated the actual performance of plants in operation.

5.2 Reverse Osmosis Process

R-1 Sterilization

The literature survey shows that the most popular method of sterilization is the chlorine process, but that this process is not always the best because of recent organic contamination of feed seawater. Some new processes other than chlorine sterilization are being searched for to settle environmental problems. It is necessary that the most suitable process for local conditions be established for each plant.

R-2 Pretreatment of Seawater

It is found that a pretreatment process for oil-contaminated seawater has not been established yet. The laboratory experiment revealed the possibility of removing dispersed oils considerably from seawater by precipitation with a coagulant. It is advisable to experiment on oil removal further, based on the results of the experiment.

R-3 Pollution Effect of Membrane Cleaning Discharge

Summarization was made for the quantity and quality of various kinds of waste water which might be discharged from a reverse osmosis plant with a capacity of 200,000 m³/d fresh water. The laws and regulations on waste water discharges in Japan have been reviewed to plan a treatment system for the waste water. The waste water does not raise environmental problems for the time being because there are a few large scale plants. However, there will probably be more public debate when a considerable number of plants with large capacities are in operation in the future.

R-4 Selection of Membrane

A systematic literature survey was carried out to review the characteristics of reverse osmosis membranes. They are summarized in tables. As regard to potential membranes to be used for seawater desalination in the Arabian Gulf with high salinity and temperature, much attention will be paid to the three types of membrane. The research themes in future will be: Evaluation of Membranes or Modules Resistant to Higher Pressure, Higher Temperature and Higher Oxidation, Establishment of the Optimum Operation Conditions Fitted to Higher Temperature and Salinity, etc.

R-5 Chemical Cleaning of the Fouled Module

Technology on membrane fouling and cleaning has been investigated by a literature survey. It was found that few systematic studies have been made in the field of reverse osmosis membranes for sea water desalination. The membranes are usually cleaned according to the instruction manual provided by the membrane manufacturers. How to estimate a membrane cleaning process was summarized and presented.

R-6 Selection of Membrane for Hybrid RO Process

Only a little information on membranes suitable for a hybrid process is available, although the process of seawater desalination has a considerable number of advantages. Therefore, fundamental experiments were performed with flat membrane test equipment on membranes that were expected to perform well. The results obtained showed that some membranes were found suitable for the hybrid process because of high flux rates. Further detailed experiments will be needed for practical purposes.

R-7 Standardization of the Main Analytical Method

The items of analysis necessary for the reverse osmosis process are classified into two groups; one is concerned with water and another is related to membranes. The standard methods of analyzing water developed in the U.S.A. and in Japan, were given and compared with each other. Some comments to be taken notice of, were presented in standardizing the analytical procedures.

In addition, the methods required for analysis of membrane fouling were also reviewed with some examples of membrane fouling.

