4.4 A-4 ELEKTROKOVINA Elektromotorji

4.4.1 Factory Outline

1) Outline

The forerunner of this company, ELEKTROKOVINA, was established in 1948 and at its peak possessed a work force of 3,500. With the onset of organizational division and privatization following national independence, the company was split up into approximately 30 small companies and factories. The total work force now numbers approximately 600.

The factory's main products are small pumps and motors of up to 15 Kw in capacity for use in industry, works, buildings and the home. The factory produces 10,000 pumps and 47,000 motors annually, and approximately 60% of its products are exported mainly to the United Kingdom and Germany. This factory is the largest manufacturer of pumps and motors in Slovenia.

Capital	: 882,795,000 SIT
Factory complex area	: 49,412 m^2
Employees	: 252
Operating hours	: 8 hours/day
Products	: pumps, motors
Annual production	: 57,000 units

4.4.2 Water Conservation

1) Features of water use

Most of the water supply is used for cooling water in the casting process, and the total usage is 130 m^3/day.

All of the water used by the factory comes from the public water supply, and the supply system that was used from the time of the former ELEKTROKOVINA is currently used by all the companies in the group. Water is taken from the public water supply at three points each installed with water meters, and ELEKTROKOVINA TEHNIKA is currently in charge of these intake points. ELEKTROKOVINA TEHNIKA collects charges from each of the companies based on their respective water usage volumes and pays the money to the city authorities. Because the individual factories receiving the water supply do not have water meters, the water usage of each factory is estimated each month by multiplying the overall water supply by the share ratios of each factory that are determined according to factory scale. The share ratio of ELKO ELEKTROKOVINA MARIBOR is set at 37%.

2) Current condition of water conservation

① The factory possesses an idle cooling tower that was installed to circulate water for cooling purposes at the time when the factory used to produce its own aluminum alloy ingots for casting and large quantities of cooling water were required.

② Cooling water for the factory's nine casting machines is only used once, and it appears that water quantities are not adjusted at the outlets by means of water temperature control.

3) Technical comment

① Installation of a water meter at the factory entrance

The installation of a water meter for the factory is a fundamental condition for water saving. In fact, it is preferable to control daily volumes of water usage by installing a water meter on the branch pipe for water to the casting machines.

② Recycling of cooing water for the casting machines

It is possible to circulate cooling water for repeated use by means of a cooling tower, and it is thought that the existing cooling tower that lies idle can be effectively used for this purpose. This cooling tower has a capacity of 100 m^3/day, which is more than enough.

③ Potential water saving

It is normally the case to expect a water saving of more than 90% when introducing a cooling tower, however, in consideration of the high temperatures recorded in Maribor in the summer, it is considered that approximately 80% of the existing cooling water (130 m^3/day) can be saved. Thus, a water saving of approximately 100 m^3/day is considered possible.

4) Economic comment

The cost of introducing the recycled use of cooling water by means of a cooling tower is estimated to be around 30-40 SIT/m^3 following examination of the model factories and secondary beneficiary factories. Thus, comparing this with the existing cost of 200 SIT/m^3 for water supply and waste water, this proposal is thought to be highly feasible in economic terms.

4.4.3 Pretreatment and Waste Water Treatment

Waste water from washing in the machine processing process and the painting booths amounts to 10 m^3 and 34 m^3 per year respectively. The factory consigns the treatment of its waste water to the neighboring ELEKTROKOVINA SVETILKE and there are no problems with this.

4.5 A-5 HENKELZLATOROG

4.5.1 Factory Outline

Capital	:	8,317,517,000 SIT
Factory complex area	:	28,200 m^2
Employees	:	575
Operating hours	:	16 hours/day (two shifts), 249 days/year
Products	:	powder detergents, cosmetics
Annual production	:	16,000 t, 6,640 t
Annual turnover	:	130,000,000 DM (1995)

4.5.2 Water Conservation

(1) Technical comment

① Installation of water meter for river water

The estimation of water usage volumes is carried out, however, because the use and discharge of river water costs a lot (more than 100 SIT/m^3), it is necessary to carry out more effective water control by installing a water meter.

② Total recycling of cooling water for compressors and injection molding machines

In view of the fact that the said machinery is concentrated in one area and the cooling water does not need to be very cold, it would be easy to carry out the total recycling of water by means of a cooling tower.

③ Potential water saving

It is normally the case to expect a water saving of more than 90% when introducing a cooling tower, however, in consideration of the high temperatures recorded in Maribor in the summer, it is considered that approximately 80% of the existing cooling water can be saved. Thus, a water saving of approximately 220 m^3/day is considered possible.

(2) Economic comment

The cost of introducing the recycled use of cooling water by means of a cooling tower is estimated to be around 30-40 SIT/m^3 following examination of the model factories and secondary beneficiary factories. Thus, comparing this with the existing cost of more than 100 SIT/m^3 for water supply and waste water, this proposal is thought to be highly feasible in economic terms.

4.5.3 Pretreatment

1) Current conditions

① There are seven sewage discharge outlets, of which two are not currently used. Apart from an oil-water separator installed underneath the incoming truck platform, there are no other pretreatment facilities of note.

② Waste water from the manufacturing processes contains weak traces of product substances. The COD level is very high, however, because there no discharge standards for COD, this does not pose a problem at the current time. The products are composed of easily biodegradable (so-called "soft") substances which could be treated at the central treatment plan in future.

③ Foam is apt to appear in waste water from the manufacturing processes due to the influence of surface active agent, however, this is becomes barely recognizable by dilution, when the water reaches the downstream sewage pump station.

④ Regarding waste water generated in the production of hair dye planned for 1997, quality analysis was carried out on a model waste water sample.

2) Examination of pretreatment method for reducation of the pollution load

Examination shall be carried out to investigate methods to deal with the future case where sewerage charges are set based on BOD, COD and other load values.

① Regarding the washing powders, the manufacturing process can be completely closed off through making only a slight devising. In specific terms, make-up water is currently added to the recycling tanks from the city water supply, however, by lowering the make-up surface control level, it would be possible to accept around 1-2 m^3 of water that currently overflows during changeovers and other extraordinary times.

② Thickening and separation would be difficult in the case of cosmetics because of the large volumes of waste water generated (180 m^3/d), however, this would be an effective method in the case of hair dye (scheduled for production soon) because the volume of waste water generated would only be 1 m^3/d. Moreover, thickening and separation would be an effective means of indispensable dealing with the oil and fat content of the waste water.

The recycle of thickened waste water in hair dye is considered to be difficult due to the nature of hair dye products, which differs from powder detergents, and the subtle effects on function and color. Generally, thickened waste water is evaporated to dryness and the resulting solid waste is either incinerated or disposed of. If there is sufficient calorific value, the thickened liquid could be mixed with boiler fuel and combusted.

③ In the case of the cosmetics and hair dye manufacturing processes, the coagulation of waste water is difficult. Various conditions were tested in jar tests, however, no floc at all was formed in reaction to inorganic coagulant.

④ Oxidization decomposition by the Phenton method does cause a remarkable change in the apparent water color, however, there are no reductions in the measured values of absorbancy and COD. Moreover, because this method is expensive and only adds to the overall pollution, and so on, it is not appropriate for this case.

⑤ Degradation by ozone treatment would also seem to be difficult judging from the Phenton method test results.

⑥ Anaerobic biological treatment is a method worth considering in the case of cosmetics waste water treatment. If treatment results were favorable, it is thought that this method could also be applied to waste water from hair dye production.

Outline of the pretreatment system

Case 1: anaerobic biological treatment of cosmetics waste water (4a, 5)
In 4a, waste water from areas other than the cosmetics plant is included, but the waste water from 5 shall be treated together.

The aim is to reduce the extremely high levels of COD, BOD and oil and fat.

As the pH value of the raw water is practically neutral and there are no coarse suspended solids, the raw water is directly without filteration heated to 35°C and treated in an anaerobic reactor. The selected reactor type is the fixed bed system.

Table 4.5. Quality and Pollution Loads of Waste Water and Treated Water

Kind of wastewater	Quantity m^3/d	CODcr mg/L (kg/d)	BOD mg/L (kg/d)	pH ( )	SS mg/L (l/m)	t-Fat mg/L (kg/d)	t-P mg/L (kg/d)
Wastewater outlet 4a	200	660 (132)	300 (60)	9.8	130 (26)		0.6
outlet 5	100	2,400 (240)	1,400 (140)	6.7	310 (31)	900 (90)	6.3
*1 Total (4a + 5)	300	1,240 (372)	670 (200)	9	190 (57)	300 (90)	2.5
*2 Case-1 Anaerobic treated	300	370 (110)	200 (60)	8	190 (57)	< 100	< 2

(Notes) * 1: quality of cosmetics waste water

* 2: Case 1: case where cosmetics waste water undergoes pretreatment (anaerobic biological treatment)

Table 4.5. Equipment and Running Costs of the Pretreatment System

	Equipment cost SIT	Depreciation & Interest SIT/m^3	Running Cost SIT/m^3	Total treatment cost SIT/m^3
CASE-1	39,300,000	36	81	117

The total treatment cost of 117 SIT/m^3 shown in Table 4.5 is for a treatment volume of 300 m^3. When converted to the cost for a total waste water volume of 700 m^3, this will be 50 SIT/m^3.

4.6 A-6 SWATY Tovarna umetnih brusov

4.6.1 Factory Outline

Capital	: 2,124,000 SIT
Factory complex area	: 39,779 m^2
Employees	: 451
Operating hours	: 8 hours/day (two shifts sometimes), 260 days/year
Products	: revolving grindstones (diamond, ceramic, reinforced resin, resin)
Annual production	: 44,000 carat, 667 t, 1,072 t, 465 t
Annual turnover	: 25,000,000 DM

4.6.2 Water Conservation

(1) Technical comment

① Recycled use of cooling water for press machines

In view of the fact that the six large presses at the factory are concentrated in one area and the cooling water does not need to be very cold, it would be easy to carry out the total recycling of water by means of a cooling tower. However, because there are numerous other small presses, it would be difficult to circulate water for use in all the machinery.

② Potential water saving

It is normally the case to expect a water saving of more than 90% when introducing a cooling tower, however, in consideration of the high temperatures recorded in Maribor in the summer and the fact that it would be difficult to recycle water for use in all the machinery, it is considered that approximately 60% of the existing cooling water (approximately 120 m^3/day) can be saved. Thus, a water saving of approximately 70 m^3/day is considered possible.

(2) Economic comment

The cost of introducing the recycled use of cooling water by means of a cooling tower is estimated to be around 30-40 SIT/m^3 following examination of the model factories and secondary beneficiary factories. Thus, comparing this with the existing cost of 200 SIT/m^3 or more for water supply and waste water, this proposal is thought to be highly feasible in economic terms.

4.6.3 Pretreatment

① Most of the waste water is cooling water and there are no problems in terms of quality except for the mixer washing water. The volume of mixer washing water is around 5 m^3 and in terms of quality it satisfies discharge standards. Because this waste water is diluted to around a fiftieth of its original concentration within the overall waste water, there is no need to carry out pretreatment.

② Organic waste gases are generated in the manufacture of resin grindstones and there are no particular measures to deal with this at the present time. If such gases come to be regulated in the future, they could either be rendered innocuous through using after burners or water washing with scrubbers could be tried. In the case where water washing is applied, it would be necessary to deal with organic waste water.

Ⅶ. Conclusion

VII. Conclusion

The nature, society, economy, and environmental administration of Slovenia and Maribor City surveyed have been outlined. The condition of industrial water and effluent of 20 factories in the Maribor City was also surveyed. The industrial water and effluent of these 20 factories which occupy for more than 80% of the industrial wastewater of Maribor City, have been investigated. The survey results have clarified the following items:

(1) The ratio of the cost of industrial water and effluent to the shipping price is comparatively high.

(2) It is estimated that the volume of industrial water can be saved by an average of 20%.

(3) Under the current emission standards, it is more advantageous for almost all factories to discharge to the WWTP than to discharge directly to the rivers.

(4) The volume of pollutants can be reduced by applying pretreatment, but the level of reduction is closely related with the system of the rates on the discharge to the WWTP.

(5) The relation between the volume of pollutant load reduced and the discharge charging system can be obtained by setting a calculation equation of discharge rates based on pollutant load and by estimating what each factory will do about pretreatment.

(6) Administrative authorities can reflect their policies on the calculation equation of discharge rates and estimate the result. That is, it is possible to estimate the volume of pollutant load on the WWTP, rates income, total amount invested by factories, and consequently, the costs borne by administrative authorities and factories.

Moreover, recommendations were given on 1) Treatment of industrial waste water and pretreatment 2) Rationalization of water use 3) Setting of WWTP rates, and 4) Measures the administrative authorities must take. Although a number of recommendations were made to factories concerning the rationalization of water use and wastewater treatment methods in this survey, due to limitations in time, these recommendations were only very general. Detailed studies must be carried out at each factory to effectively implement our recommendations.

Throughout the course of this survey, the JICA Study Team was quite impressed by the earnest attitude and efforts taken by those concerned in Slovenia and Maribor City for the preservation of the environment. We felt everywhere an uncompromising determination to preserve the nation and its natural environment at any cost, irrespective of financially difficult circumstances. Slovenia is going to steadily carry forward its environment-preservation plan, taking the long view, backed by the long history and cultural traditions of Europe. It will be a great reward for us if our survey proves instrumental in not only preserving the environment in Slovenia, but also in imparting to other countries of Europe an understanding of the Japanese way of thinking, and Japanese techniques.

In conclusion, we would like to heartily thank all those concerned for their cooperation in this survey.

Relative Information

TABLES OF CONTENTS

Relative Information

1. Nitrogen-Phosphorus Removal Technology

1. Nitrogen • Phosphorus Removal Technology

1.1 Necessity of Nitrogen • Phosphorus Removal

Nitrogen • phosphorus removal is necessary for the following two reasons;

(1) The advance of eutrophication of closed water areas has resulted in reddish brown and greenish yellow tides and unsightly views. Therefore, the nitrogen and phosphorus in the wastewater, the cause of these problems, must be removed.

(2) If effluent containing a large amount of ammonia nitrogen enters the drinking water source, the chlorine demand increases during the purification process and the amount of TOX (organic halogen compounds • carcinogenic substances) generated also increases.

1.2 Nitrogen Removal Technology

1.2.1 Physico • Chemical Nitrogen Removal Process

Representative physicochemical nitrogen-removal methods include the break-point chlorination, ammonia stripping, ion exchanger (adsorption by zeolite), catalyst wet oxidation, and hydrochloric acid methods. Three of these methods, i.e., the break-point chlorination method, the ammonia stripping, and the adsorption by zeolite (ion exchanger) were already established technologically and put to practical use before 1993. The other two methods are still developing, but their results should be paid attention to.

In the ammonia stripping method, the wastewater is changed to on alkaline and then ammonia is volatilized into the air by aeration (in some cases ammonia is effectively volatilized with the temperature heated up by blowing steam). The adsorption by zeolite method selectively adsorbs ammonium ion by using the zeolite's cation exchangeability. In both methods, concentrated ammonia solution is further needed for treatment of the washing water for the resultant gas for the former and the regenerated water for the latter. On the other hand, in the break-point chlorination method, the ammonia in the wastewater is decomposed to nitrogen gas by interaction of the used chlorine gas (hydrochloric acid).Theoretically, when the ammonia in the inorganic wastewater is removed by using sodium hydrochlorite, three moles of sodium hydrochlorite are needed to remove two moles of ammonia theoretically. But in effect, addition of 20 % excess sodium hydrochlorite is required for many cases. All these physicochemical methods are limited only to the treatment of the ammonia nitrogen, and treatment of nitrate and nitrite sources of nitrogen.

In principle, with the physicochemical methods, the facilities are compact and easy to operate, but the operation cost is expensive compared with that required for biological nitrogen removal. Another important points to be noted is that both ammonia stripping and adsorption by zeolite methods are transfer (concentration) technologies while the break-point chlorination method is a technology based on decomposition to nitrogen gas. Therefore, these applications are limited only to the state of nitrogen i.e.,ammonia source nitrogen.

II.2.2 Biological Denitrification

Biological denitrification, a technology based on decomposition to nitrogen gas from every source of nitrogen in the wastewater through microorganics reaction, treats every source of nitrogen, including as ammonia, nitrate, nitrite, and even organic nitrogen sources. Although the wastewater is necessary for removal of the organic nitrogen, the nitrogen is decomposed mainly into ammonia at the biological treatment. Accordingly, this paragraph explains the removal of the ammonia nitrogen.

Biological denitrification is composed of roughly two processes, i.e., nitrification and denitrification, the principles of which are explained separately here. At the nitrogen removal of the organic wastewater, the decomposition of BOD should also be considered.

1) Nitrification

Nitrification is a process of oxidization of the ammonia nitrogen into the nitrate nitrogen (through the nitrite nitrogen) by microorganic reaction where the participating microorganisms are generally referred to as nitrate bacteria. More precisely, the nitrification process is composed of two processes; the nitrite process, where the ammonia nitrogen is changed into the nitrite nitrogen, and the nitrate process, where the nitrite is changed into the nitrate nitrogen. The bacteria participated in these reactions are called nitrite bacteria and nitrate bacteria, respectively.

The typical bacteria are known to be *nitrosomonas* genus for the nitrite process, and to be *nitrobacter* genus for the nitrate process. The above-mentioned reactions are expressed stoichiometrically in the following.

$$\begin{array}{llll} NH_4^+ & + 1.5\,O_2 & \rightarrow & NO_2^- + H_2O + 2\,H^+ \\ NO_2^- & + 0.5\,O_2 & \rightarrow & NO_3^- \\ \hline NH_4^+ & + 2\,O_2 & \rightarrow & NO_3^- + H_2O + 2\,H^+ \end{array}$$

As shown in the above equations, about 4.6 g of oxygen is necessary for the oxidation of 1 g of nitrogen. The nitrate reaction is a decrease in the pH reaction and then 7.14 g of alkali as $CaCO_3$ is consumed for the nitrification of 1 g of the ammonia nitrogen.

Nitrate bacteria are a type of autotroph (the so-calld autotrophic bacteria which make cell synthesis from inorganic carbon such as hydrogenbicarbonate ion. Autothopic bacteria are not able to proliferate themselves by using organic materials, due to the strictly autotrophic bacteria), characterized by a slow proliferation rate (compared with usual bacteria) and low flocculability. The optimum water temperature is about 35 ℃, and attention should be paid that the bacteria usually lose their activities above 42 ℃. Their activities are almost the same at 15 ~ 35 ℃, while the reaction rate is reduced nearly 1/2 below 10 ℃. Therefore, the treatment water temperature should be controlled above 15 ℃ since the reaction rate depends strongly on the water temperature below 15 ℃. As the optimum pH for the nitrate bacteria is neutral (6.5 ~ 7.5), the control for pH is necessary, too.

2) Denitrification

Denitrification is a process of reduction of the nitrate nitrogen (nitrite nitrogen) into the nitrogen gas by the microorganic reaction where the partic ipating microorganisms are generally named nitrogen-removal bacteria. The reaction reducing the nitrate nitrogen to the nitrogen gas is carried out through the nitrite nitrogen. It is different from the nitrate bacteria that the de-nitrification bacteria participate in both reactions, reducing the nitrate to the nitrite and reducing the nitrite to the nitrogen gas. The typical de-nitrification bacteria are pseudomonas genus, alcaligenes genus, and hyphomicrobium genus, and half the microorganisms in the soil are said to have the capacity to remove nitrogen. For the de-nitrification reaction, the materials are called hydrogen donor (electron donor. Generally the organic materials used by microorganisms. There are the de-nitrification microorganisms which use inorganic material as the hydrogen donor, but the explanation is abbreviated here.),are necessary. For example, the de-nitrification reaction used methanol as the hydrogen donor is shown stoichio metrically in the following.

$$6\,NO_3^- + 5\,CH_3OH \rightarrow 3\,N_2 + 5\,CO_2 + 7\,H_2O + 6\,OH^-$$

To remove nitrogen in organic wastewaters such as sewage and food processing wastewater, the BOD in the original water is usually used as the hydrogen donor (addition of organic reagent such as methanol as the hydrogen donor costs in excess). The denitrification reaction proceeds under absence of the dissolved oxygen (DO). In other words, at the reaction, the bacteria use the binding oxygen of the nitrate nitrogen (NO_3) for oxidizing organic substances and for their respiration if the dissolved oxygen is absent. Consequently, mixing in the de-nitrification tank must be carried out anaerobically and should not be aerated. The de-nitrification is an activated via an in increase in pH reaction and then 3.57 g alkali is formed as $CaCO_3$ by reducing 1 g the nitrate nitrogen to the nitrogen gas.

The de-nitrification bacteria are mainly heterotroph (as heterotrophic bacteria which make cell synthesis from organic substances). They have proliferation rate faster than that of the nitrification bacteria and are more flocculable. The optimum water temperature is 30 ~40 ℃, but it should be noted that the bacteria usually lose their activities above 42 ℃. The water temperature effect on their activities is almost the same as that for the nitrification bacteria , and the optimum pH is neutral to weakly alkaline(7 ~ 8).

3) De-nitrification Process

Combining the nitrification and the de-nitrification described above, the nitrogen in the wastewater is removed, and the various types of processes are employed according to the wastewater property. Depending on the form retained by the microorganisms, the processes are roughly divided into a floatation method and a biological membrane method. Here, however, the explanation will be mainly limited to the floatation method.

[The process utilized the BOD in the original water as the hydrogen donor]

This process is at present the main nitrogen-removal process employed for the organic wastewater, represented by sewage and food processing wastewater. By using the BOD in the original water as the hydrogen donor for the de-nitrification, a big reduction in operational costs may be possible. The ratio of the BOD to the nitrogen must be larger than 3 (5 is desirable) for de-nitrification using the BOD in the original water.

Fig. 1-1 shows a flowsheet for the recycling de-nitrification process. The original water is mixed with the nitrate nitrogen in the returned sludge or the recycling sludge, and then the BOD in the original water is used for the de-nitrification. Consequently, the nitrate nitrogen and the BOD (which is used for the de-nitrification) are removed.

The recycling de-nitrification process has the following advantages.

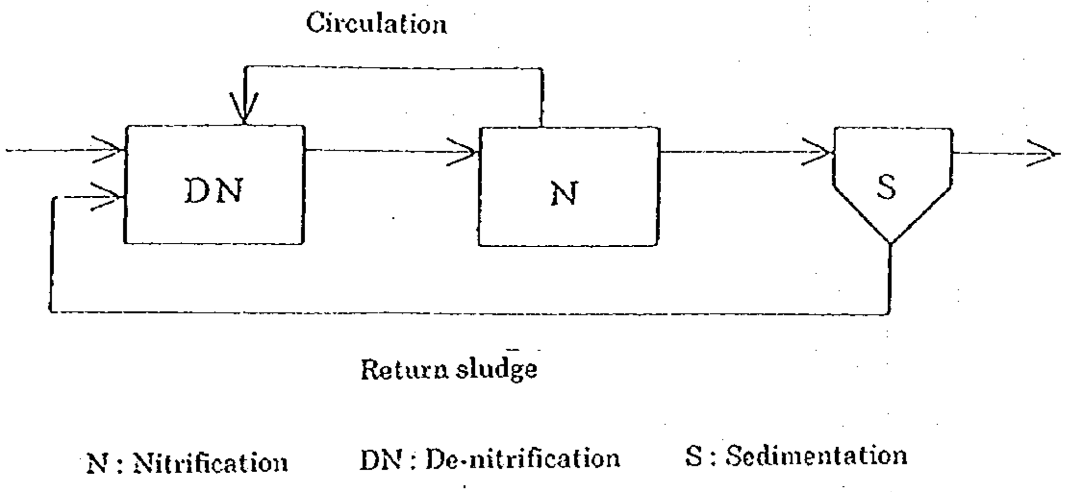
(1) Addition of the hydrogen donor is not necessary for the de-nitrification.

(2) The alkali required for the nitrification process can be used partially with that formed at the de-nitrification tank.

(3) At the de-nitrification, some of the BOD in the wastewater is also removed.

The step-denitrification method - a method in which denitrification tanks and nitrification tanks are alternately located and the raw water is divided and poured into each of the former is also an effective means of using the BOD composition in the raw water as the hydrogen donor.

Fig. 1-1 Recycling De-nitrification Process



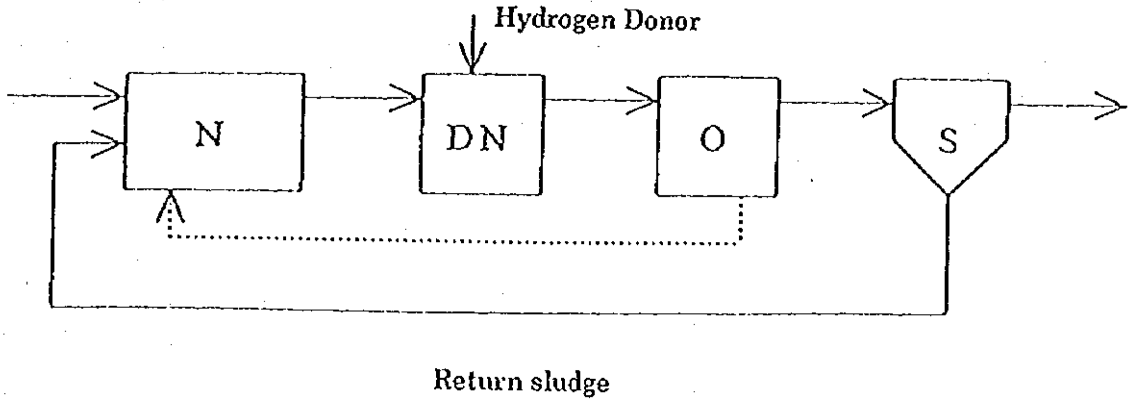
[The process added the hydrogen donor from the outside]

This process is mainly used for inorganic wastewaters such as power plant wastewater. The organic reagent is added into the wastewater because the wastewater does not contain any substances which can be utilized as the hydrogen donor. Fig. 1-2 shows a flowsheet for the representative process. After the original water is inpoured in the nitrification tank and mixed with the returned sludge, the nitrogen component in the original water is changed under an aerobic condition into the nitrate nitrogen through interaction of the nitrate bacteria. The nitrating reaction decreases in pH and then the optimum pH for the nitrating is controlled usually by adding sodium hydroxide, although this depends on the alkali contained in the original water.

Thereafter, the de-nitrification reaction is carried out in the de-nitrification tank by adding the hydrogen donor (methanol quantity is 2.5 ~3 times the nitrogen concentration: to increase in the de-nitrification rate rapidly, an extra quantity of methanol is added.), and then the excess amount of the hydrogen donor (necessary to remove it, because it is detected as BOD) is decomposed and removed at the oxidation tank.

For the organic wastewater, the addition of the hydrogen donor from the outside has been diminished after removal of the BOD in the original water and nitrification. Without addition of the hydrogen donor, a de-nitrification method using substances in the microorganisms is also known, but the process is not used so often in Japan because the reaction time required for denitrification is so long.

Fig. 1-2 Nitrification / De-nitrification Process for Inorganic Wastewate



N : Nitrification DN : De-nitrification O : Oxidation S : Sedimentation

1.3 Phosphorus Removal Technology

1.3.1 Physico・Chemical Phosphorus Removal Process

Physicochemical phosphorus removal proceses, include the coagulation and sedimentation method, crystallization method, and the adsorption method by ion exchanger or activated alumina. This section describes the most practical coagulation and sedimentation methods and crystallization methods which shared the limelight in the middle of 1980's (although practical use was infrequent).

1) Coagulation and sedimentation process

The phosphorus in the wastewater forms insoluble precipitates by reacting with the ions of aluminum, iron, calcium or other elements to form insoluble precipitates, so it can be easily removed by adding appropriate amounts of chemicals containing these elements. Table 1-1 shows the reagents suitable for this purpose, and Table 1-2 shows the conditions for selecting the reagent.

Table 1-1 Chemical Reagents Effective for Phosphorus Removal

Ferric chloride	$Fe\,Cl_3$
Ferric sulphate	$Fe_2(SO_4)_3$
Ferrous chloride	$Fe\,Cl_3$
Ferrous sulphate	$Fe(SO_4)$
Aluminum sulphate	$Al_2(SO_4)_3$
Polyaluminum chloride	$[Al_2(OH)_n\,Cl_{4-n}]_m$
Sodium aluminate	$Na\,Al\,O_2$
Pickled wastewater	$Fe\,Cl_2 + Fe(SO_4)$
Calcium hydroxide	$Ca(OH)_2$

Table 1-2 Selection Conditions of Chemical Reagent for Phosphorus Removal

Phosphorus concentration in the sewage wastewater taken in
Solid suspension and alkali in the sewage wastewater
Reagent cost included transportation fees
Reliability on reagent supply
Sludge treatment facilities
Final treatment method
Compatibility with the other processes in the treatment area
Possibility of reverse effect on the environment at the effluent

The required amounts of aluminum salt and iron salt is determined by nearly the same conditions. The most important condition is the reaction of the metallic salt with the phosphric acid ion, as shown in the following equation;

$$Me^{3+} + PO_4^{3-} \rightarrow MePO_4 \downarrow \quad \cdots\cdots\cdots\cdots ①$$

As shown clearly from the equation ①, 1 mole of phosphorus requires 1 mole of metallic salt. For example, when the metallic salt is aluminum, it reacts with the phosphorus at a 1:1 molar ratio. However, the amount of metallic salt which needs to be added increases more than the theoretical amount calculated from the equation ① because many other reactions actually take place. One of the reactions is that of the alkali in the wastewater. The metallic salt reacts with the alkali in the wastewater to form insoluble hydroxide compound, as shown in the following equation;

$$Me^{3+} + 3HCO^{3-} \rightarrow Me(OH)_3 \downarrow \quad \cdots\cdots\cdots\cdots ②$$

The hydroxide formed by reaction ② adsorbs the MePO4 formed by the equation ①, and also removes turbid substances in the wastewater. Consequently, the metallic salt consumed by the equation ② results in the effective utilization. Solubility of $MePO_4$ depends on pH. The minimum solubility of AlPO4 is at pH 6, while that of $FePO_4$ is at pH 4. Table 1-3 shows the results of phosphorus removal in the city sewage water treated using aluminum sulphate. Alum and polyaluminum chloride are usually used as aluminum salt, and ferric chloride is used as iron salt.

Table 1-3 Al : P Ratio for Phosphorus Removal

Phosphorus Removal	Al : P		Aluminum sulphate * : P
	Molar ratio	Weight ratio	Weight ratio
75 %	1.38 : 1	1.2 : 1	15 : 1
85	1.39 : 1	1.5 : 1	19 : 1
95	2.30 : 1	2.0 : 1	25 : 1

* Aluminum sulphate = $Al_2(SO_4)_3 \cdot 18H_2O$

When alum, PAC or ferric chloride is used for removing the phosphorus, the treatment cost is in the following order; PAC > ferric chloride > alum.

It should be taken into account however that PAC has better coagulability than alum at low temperatures such as in the winter, and that the treated water may become colored by using ferric chloride.

Calcium hydroxide is usually used, as calcium salt, and its addition into the wastewater, forms calcium hydroxyapatite, as shown in the following equation.

$$5Ca^{2+} + OH^- + 3PO_4^{3-} \rightarrow Ca_5OH(PO_4)_3 \downarrow \quad \cdots\cdots\cdots\cdots ③$$

As the reaction ③ depends on pH, it is necessary to increase pH 9.5 ~ 11.5 to remove the phosphorus certainly. At a constant pH, the phosphorus concentration shows hardly any change in the treated water even if the concentration in the wastewater is varied.

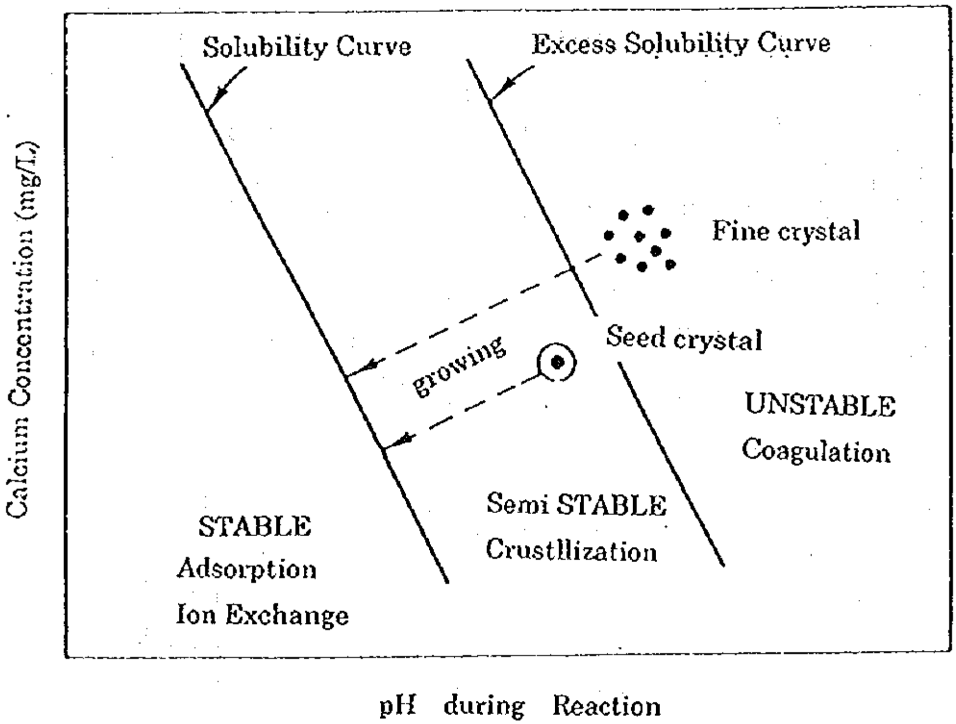
The amount of calcium hydroxide which needs to added for phosphorus removal is therefore, determined to be the quantity adjusted to the target pH, and is almost independent of the phosphorus concentration in the wastewater.

2) Crystallization method (contact phosphorus removal)

In the coagulation and sedimentation method, large quantities of sludge which is difficult to dehydrate, are generated with phosphorus removal, and the treatment and disposal of this sludge presents problems. Accordingly, another phosphorus-removal method which goes not generate sludge has been developed. By using seed crystals such as rock phosphate, the phosphate ion reacts with calcium ion in the solution to form calcium hydroxyapatite which is crystallized on the surface of seed crystals. This method is called the crystallization method.

Fig.1-3 shows the phosphorus removal mechanism of the crystallization method.

Fig. 1-3 Concept of Crystallization Method

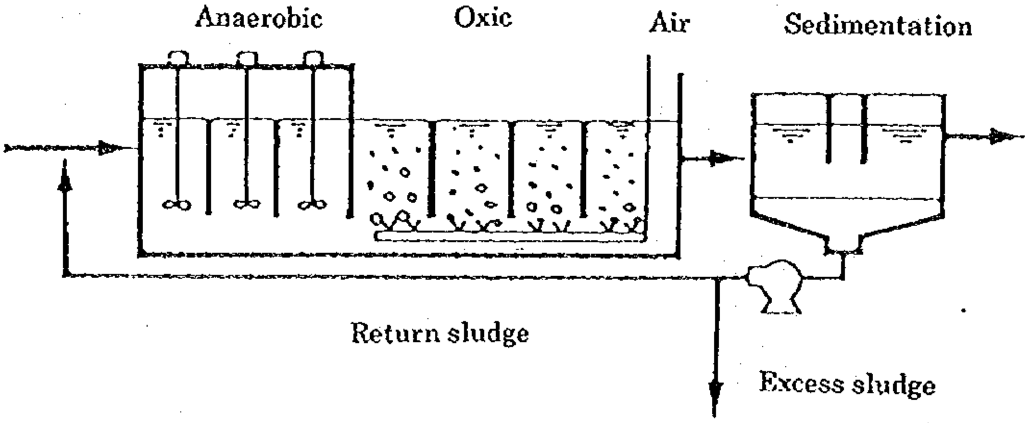


When the working concentration of hydroxyapatite goes beyond the supersaturated solubility curve, that is, when it enters the unstable domain, it enters the operating domain of coagulating sedimentation process in which the hydroxyapatite turns into fine crystals and settles (see Fig.1-3). But at a domain between the dissolved and the unstable domain, i.e., at a metastable domain, it is known that by adding the seed crystals to the solution, hydroxyapatite is crystallized on the surface of the seed crystals and the crystals grow gradually without formation of any new crystals such as seed crystals. This mechanism is applied to the crystallization method of phosphorus removal, which removes the phosphorus by flowing wastewater adjusted for pH and Ca concentration to the column filled with the seed crystals. This method was studied actively to remove phosphorus from sewage in the 1980's by a Japanese plant maker. However, this method is not yet in the actual use, because it an additional facilities after the secondary treatment and its reaction conditions are restricted.

1.3.2 Biological Phosphorus-Removal Process

The biological phosphorus-removal process removes the phosphorus in the wastewater by taking out the from the system microorganisms which ingest excess phosphorus in the wastewater and proliferate. Fig. 1-4 shows the standard flowsheet of the biological phosphorus-removal process. This process consists of two steps; the first half- the usual activated-sludge process, is kept anaerobic, and the latter half is oxic. Thus, the process is called the A/O system.

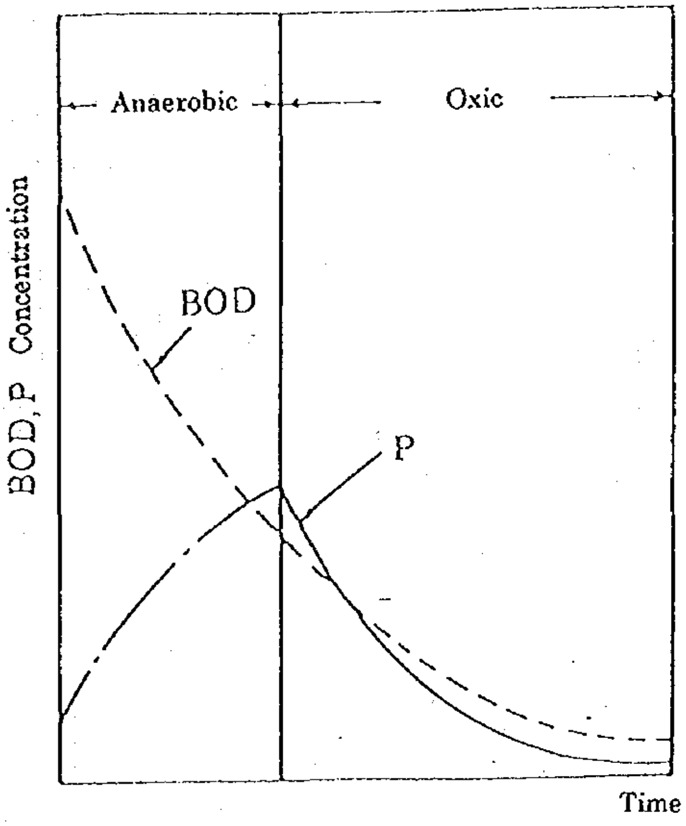
Fig. 1-4 Flowsheet of Biological Phosphorus Removal



Since Phosphorus is an essential element for microorganisms, a portion of phosphorus is removed by the usual activated-sludge method to remove BOD in the wastewater, and thos control the prol, feration of microorganisms there. This process is called the biological phosphorus-removal process since its ability to remove a lot of phosphorus in the wastewater has been confirmed by the fact that the usual microorganisms store more phosphorus in their bodies than they require for their proliferation and metabolism. Indeed, this process is known to remove large quantities of phosphorus two to four times greater than the quantities removed by the standard activated-sludge process.

As for the phosphorus behavior during the biological phosphorus-removal process, as shown in Fig 1-5, the phosphorus concentration increases due to releasing phosphorus once from the microorganisms' bodies under the anaerobic conditions, and the decreases due to the microorganisms excessive intake phosphorus under the oxic conditions. On the other hand, most of the BOD component is adsorbed by the microorganisms at the anaerobic tank and then removed further by oxidation decomposition at the oxic tank.

Fig. 1-5 Phosphorus and BOD in the Biological Phosphorus-Removal Process



The phosphorus removal quantity by the biological treatment at the steady state is expressed by the following equation.

$$\Delta P = \Delta BOD \times Y \times Ps = \Delta S \times Ps$$

where ΔP : Phosphorus removal quantity
ΔBOD : BOD removal quantity
Y : Sludge generation quantity per BOD removal
Ps : Phosphorus content in the sludge
ΔS : Residual sludge generation quantity

The phosphorus removal quantity is determined by the residual sludge generation quantity and the phosphorus content in the sludge. Therefore, the phosphorus removal is not expected to be great for processes which generate lesser amounts of residual sludge such as the oxidation ditch method and long-time aeration method.

The standard activated-sludge process generates the same quantity of residual sludge as that generated by the biological phosphorus removal. However, the phosphorus removal at the standard activated sludge is not substantial since the Ps is lower($Ps = 0.01 \sim 0.02$), than that ($Ps = 0.04 \sim 0.06$)for biological proceses.

As described above, it is confirmed that microorganisms ingest excess phosphorus by cultivating them under the condition repeating anaerobic - oxic circumstance conditions. However, the mechanism is not fully elucidated, and must be made the subject of future research.

Based on the inferences and knowledge so far, the mechanism can be explained as follows; Usual oxic microorganisms cannot ingest organic substances at all under the absolutely anaerobic condition without DO and NOx. However, some kinds of microorganisms (de-phosphrylation bacteria: not a specific bacterium, but a general name of bacteria with de-phosphrylation function) come to accumulate polyphosphoric acid in their cells by domesticating activated sludge under the anaerobic - oxic. Under the anaerobic conditions they hydrolyze the polyphosphoric acid in their cells and release phosphoric acid from their cells. Utilizing the energy generated then, they take in their bodies the organic substances (BOD). After that, under the oxic condition, the de-phosphorylation bacteria get energy by oxidizing the organic substances taken in their bodies under the anaerobic and the oxic conditions, and ingest excess phosphorus in the liquid. By cultivating the microorganisms continuously under these circumstances, the de-phosphorylation bacteria which can ingest the organic substances under the anaerobic condition proliferate more preferentially than other microorganisms with no ability to take in organic substances under the anaerobic condition, and then the biological phosphorus removal is carried out stably.

The biological phosphorus-removal process has the following characteristics;

(1) BOD removal and de-phosphorylation are carried out at the same time.

(2) In contrast physicochemical phosphorus removal process, the operational cost is not expensive since this method does not require any reagent.

(3) The de-phosphorylation bacteria which are flocculable proliferate preferentially, and then bulking of sludge can be prevented.

A large number of the real facilities are operating at the sewage plants in Japan, and at most of them this process has been adopted as the means to prevent the bulking, as described above in the third item. Moreover, at the wastewater treatment plant from the meat processing this process has been introduced to remove phosphorus and to prevent bulking.

The working range of this process depends on its application purpose. For applying the phosphorus removal, balance between the BOD and the phosphorus concentrations is important. It should be taken into account that the removable phosphorus quantity is limited within 4 ~ 5 % of the removed BOD. On the other hand, when applying this process to prevent bulking, the main target of this process is the wastewater with the original BOD concentration at 100 ~ 2,000 mg/l.

1.3.3 Biological Nitrogen • Phosphorus-Removal Process

Furthermore, nitrogen, which, like phosphorus is suggested to be a eutrophication-causing substance, can be removed with the phosphorus at the same time by using the biological phosphorus • nitrogen removal process as shown in Fig.1-6.

1) Outline

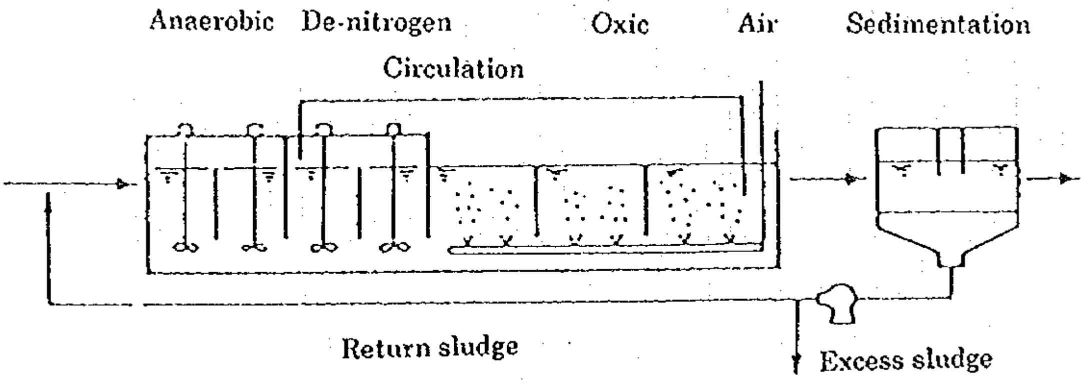
This anaerobic-oxygen free-aerobic system, a treatment process combining the biological phosphorus-removal process with the biological nitrogen-removal process, utilizes the phenomenon of excess intake of phosphorus by the microorganisms in the activated sludge and their nitrification • de-nitrification reactions.

The phosphorus-removal process applied to this system is the anaerobic-aerobic system, and the nitrogen-removal process is the circulation type of nitrification and de-nitrification methods. Reaction tanks are located in order of anaerobic tank, oxygen free (de-nitrification) tank, and aerobic (nitrification) tank. The influent water and returned sludge are flowed into the anaerobic tank, while the mixed liquid in the aerobic tank is circulated into the anaerobic tank.

The treatment performance of this system, i.e., the phosphorus removal performance, seems at times to decrease to some extent, particular on rainy days. To insure a certain of phosphorus concentration for the releasing water, physicochemical treatment, such as addition of coagulant, is necessary in most cases of complimentary facilities.

When this system is applied to a water treatment plant to remove phosphorus by adding coagulant at the end of biological reaction tank already, the amount of coagulant added is known to be saved.

Fig. 1-6 **Biological Phosphorus-Nitrogen-Removal Process**



2) Important Points to be Noted for Design and Maintenance

(1) A watercourse bypassing the primary sedimentation tank should be constructed to obtain the organic substances necessary for the anaerobic, tank (or oxygeh-free tank) on rainy days and for the startup of the equipment.

(2) For usual city sewage, there is no necessity to add methanol for nitrogen removal, or to add sodium hydroxide for pH adjustment. Chemical feed facilitates, however, may be necessary to be put on, when the alkalinity in the influent water is low, depending on the drainage area or the scale of the effect of rainfall.

(3) The nitrated liquid is circulated fundamentally by a circulation pump. The liquid is also circulated via an air-lift effect by an air-diffuser in the aeration tank.

(4) To remove phosphorus effectively, thickening of the primary sedimentation tank and the excess sludge should be carried out by separation thickener, and a sludge-treatment process with a small returned load of phosphorus from the sludge treatment system should be chosen.

(5) To insure a stable phosphorus concentration for the releasing water, the facilities adding the coagulant (PAC) should be installed at the end of the aeration tank.

1.3.4 Comparison of various biological treatment systems

Table 1-4 shows the characteristics of various biological treatment systems and the object substances to be removed. Table 1-5 shows their general comparison.

These tables are prepared for treatment of usual city sewage.

Note for Table 1.4

1. This table is prepared on the basis of water quality for usual city sewage, as shown below.
BOD 150 ～ 200 mg/L, SS 150 ～ 200 mg/L, T-N 30mg/L, T-P 4mg-L
2. ◎ indicates the main removal object, and △ indicates the incidental removal.
3. Coagulant at the A 2 O system (5) (mark※) is added for the treated water to be stabilized at the same phosphorus concentration when influent water is diluted by rain.

Note for Table 1.5

(1) *1 includes the running cost and the depreciation expenses but does not contain the sludge-treatment expenses.
(2) *2 does not contain the sludge-treatment expenses.
(3) ◎ indicates the main removal object.
(4) △ indicates the incidental removal.
(5) The numerical values at the setting up area ratio, the treating expenses, the construction expenses, and the resultant sludge are relative values against 1 for the standard activated-sludge system.

Table 1-4 Characteristics and Object Substances to be Removed of Various Biological Treatment Systems.

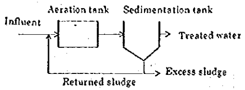
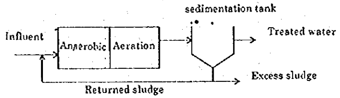
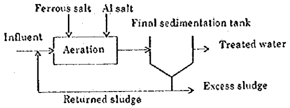
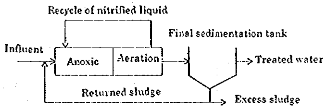
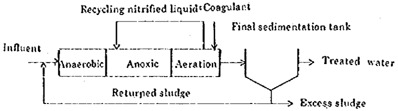
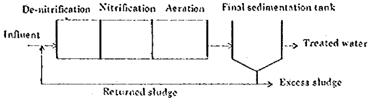
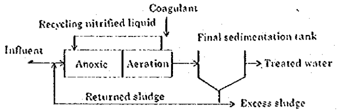
Biological treatment	Treatment process	Characteristics	HRT(hr)	BOD	Nitrogen	Phosphorus
1 Standard activated sludge		To remove mainly organic substances.	6 ~ 8	◎ 80 ~ 95	△ 30	△ 30 ~ 50
2 Anaerobic-aerobic activated sludge (A/O system)		By releasing phosphorus from the activated sludge at the anaerobic tank and taking it in excessively at the aerobic tank, the phosphorus is removed. Nitrogen is removed at the same amount as the standard activated sludge.	6 ~ 8	◎ 80 ~ 95	△ 30	◎ 70 ~ 80
3 Coagulant addition-activated sludge system		Phosphorus is removed together with BOD by adding coagulant at the biological reaction tank. Ferrous salt is added to be oxidized fully, at the first part of the reaction tank, while Al salt is added at the end part.	6 ~ 8	◎ 80 ~ 95	△ 30	◎ 80 ~ 90
4 Recycle type of nitrification-de- nitrification system		Ammoniac and oxidized nitrogen's are nitrified based on biological nitrification and denitrification reactions. To improve denitrification rate, multiple circulation combined with two or three oxygen-free and aeration tanks used, too.	12 ~16	◎ 80 ~ 95	◎ 60 ~ 70	△ 30 ~ 50
5 Anaerobic-oxygen free-aerobic activated sludge system. (A2O system)		Combining anaerobic-aerobic activated sludge with recycle type of nitrification-denitrification system, phosphorus and nitrogen are removed biologically at the same time.	13 ~17	◎ 80 ~ 95	◎ 60 ~ 70	◎ 70 ~ 80
6 Nitrification-endogenous de-nitrification system		As hydrogen donor at the denitrification reaction, organic substances adsorbed at the activated sludge and accumulated in the cells, are used.	18 ~25	◎ 85 ~ 95	◎ 70 ~ 90	△ 50
7 Coagulant addition-recycle type of nitrification-de-nitrification system		Phosphorus removal rate is improved by addingcoagulant at the aeration tank in the recycle type of nitrification- denitrification system	12 ~16	◎ 80 ~ 95	◎ 60 ~ 70	◎ 80 ~ 90

Table 1-5 General Comparison Among Various Biological Treatment Systems

Biological Treatment	HRT hr	BOD N P	removal %	System area ratio	Treatment cost *1	Construction cost *2	Chemicals used	Operation	Resultant sludge	Check points of equipment
1 Standard activated sludge	6 ~ 8	◎ △ △	80~95 30 30~50	1	1	1		Easy	1	A few
2 Anaerobic-aerobic activated sludge	6 ~ 8	◎ △ ◎	80~95 30 70~80	1	1	1.1		Quite	1	A few
3 Coagulant addition-activated sludge system	6 ~ 8	◎ △ ◎	80~95 30 80~90	1	1.8	1.2	Coagulant like PAC	Easy	1.1	Normal
4 Recycle type of nitrification-denitrification system	12~16	◎ ◎ △	80~95 60~70 30~50	1.3	2	1.6		Easy	0.9	Normal
5 Anaerobic-oxygen-free-aerobic activated sludge system	13~17	◎ ◎ ◎	80~95 60~70 70~80	1.3	2.1	1.7		Easy	0.9	Normal
6 Nitrification-endogenous denitrification system	18~25	◎ ◎ △	85~95 70~80 50	1.8	2	1.6		A little bit difficult	0.9	Normal
7 Coagulant addition-recycle type of nitrification-denitrification system	12~16	◎ ◎ ◎	85~95 60~70 80~90	1.3	2.8	1.8	Coagulant	Easy	1	Many

2. Color Removal Technology

2. Color-removal Technology

The various types of color-removal (decoloring) technology shown in Table 2.1 are currently being examined.

(1) Technology applied to the final stage of wastewater treatment as advanced treatment

Since the activated-carbon adsorption and ozonization processes are ineffective if COD and SS are still present, they are performed as the final treatment after the COD and SS are removed. Neither of these processes generate sludge.

(2) Technology applied as pretreatment

A coagulant is mixed in to form flocks and coagulate the sedimentation. As BOD, COD, SS, and P are also removed with this process, it is often applied as a pretreatment in coloring plants.

With the Fenton method, coloring matters are oxidized and decomposed with ferrous sulfate and hydrogen peroxide. Although this method removes color outwardly, in reality it increases pollutants in the wastewater. As the cost for the chemicals used in this method are high and equipment is expensive when large in size, the method is applied only for outward decoloring of thick wastewater in small quantities.

Table 2.1 Color-Removal Technology

Name of Treatment	Outline of Treatment	Decoloring Characteristics	Running Cost	Construction Cost	Sludge Disposal	Size Efficiency	Disadvantages
Activated-Carbon Adsorption	Granulated activated carbon is packed as a fixed bed or fluid bed, and the coloring matters in wastewater are removed with the physicochemical adsorbing capacity of the activated carbon.	Effective on basic and acidic dyestuffs. Removal rate on real wastewater is 90%.	In the case of self regeneration of activated carbon 1.80 In the case of outside regeneration of activated carbon 3.00	1. 00 0.83	Not required	As the technology is automated, it is suitable for large-sized equipment.	Efficiency decreases on dispersed, sulfide, and reactive dyestuffs. Running cost is high.
Diatemoceous Earth Adsorption	Particulated diatemoceous earth is mixed in wastewater, and the coloring matters are removed with the physicochemical adsorption capacity of the earth. Then, the coloring matters are separated from treated water by coagulating sedimentation.	Effective on many types of dyestuffs.	0. 59	0.27	Required	As fine particles are handled, it is not suitable for large-sized equipment.	Efficiency decreases with azo-system and reactive dyestuffs.
Coagulating Sedimentation	Coloring matters are separated from treated water through coagulating sedimentation by first mixing coagulant of the dicyandiamide system in wastewater, and then adding and mixing coagulant of the aluminum anion sulfate system.	Effective on many types of dyestuffs. Removal rate on real wastewater is 60%.	0. 66	0.27	Required	This technology is popular and suitable for large-sized equipment.	Ion concentration of the water under treatment increases. The decoloring rate is low.
Fenton Oxidation	This technology utilizes the oxidation capacity of hydrogen peroxide. Coloring matters are oxidized and decomposed by hydrogen peroxide when ferrous sulfate is included as a catalyst.	Effective on almost all types of dyestuffs. Removal rate on real wastewater is 90%.	3. 12	0.83	Required	As the reaction process is complicated, this technology is not suitable for large-sized equipment.	Ion concentration of the wastewater under treatment increases. Readjustment of pH is required. Running cost is high.
Oxidation by Ozone	Ozone containing air produced by silent discharge in the air is blown into wastewater . The wastewater is decolored by the coloring matters' reaction to the ozone.	Effective on many types of dyestuffs. Removal rate on real wastewater is 90%.	1. 00	1.00	Not required	As this technology is systematized, it is suitable for large-sized equipment.	Efficiency decreases on dispersed dyestuffs.
Electrolytic Oxidation	Using an insoluble electrode, electrolyte is generated in wastewater or is added in wasteweter to cause electrolysis. Coloring matters are decomposed by peroxide which is generated at the time of electrolysis or by the oxidation and reduction reaction caused near the electrode.	Effective on many types of dyestuffs. Removal rate on real wastewater is 70%.	0. 94	1.16	Not required	As the electrode material is expensive, this technology is not suitable for large-sized equipment	Decoloring rate is low. Generates toxic chlorine compounds as by-products. Requires high construction cost.
Electrolytic Oxidation Coagulation	Using a sacrifice electrode, electrolysis is caused by the electrolyte present in the wastewater or by adding electrolyte. Coloring matters are removed by peroxide which is generated at the time of electrolysis, by the oxidation and reduction reaction caused near the electrode, or by coagulation caused by the substance which elutes from the sacrifice electrode.	Effective on many types of dyestuffs. Removing rate on real wastewater is 90%.	0. 98	0.67	Required	As the technology is systematized, it is suitable for large-sized equipment.	Generates toxic chlorine compounds as by-products.

(Note) * : Running cost is the total excluding costs for dewatering and disposal of sludge. Values indicated as cost are comparative coefficients.

2-1 Activated-carbon Adsorption

This is a technology to decolor water with the physicochemical adsorbing capacity of activated carbon. In the original method, pulverized activated carbon was mixed into the wastewater to be treated and the coloring matters were adsorbed to the carbon. Subsequently, the coloring matters were separated after either coagulating the sedimentation or putting the carbon which had adsorbed the coloring matters in an aeration tank and separating the coloring matters in the final sedimentation basin.

Although this old method was very popular because it required only very simple equipment, it had the disadvantages of high running costs and the potential outflow and discharge of activated carbon at the time of separation failure. Therefore, this method was replaced by the adsorption tower method upon the development of high-performance granulated active carbon.

Granulated active carbon is used for both the fixed-bed method and the fluid-bed method. In the fixed-bed method, a packing method similar to that of a sand filter is applied, and a set of one, two, or three activated-carbon-adsorption towers is used in-line.

In the fluid-bed method, normally a single adsorption tower is used. Activated carbon is fluidized, saturated, discharged, regenerated, and fed back into the tower in a continuous adsorption cycle.

In addition, a back-migration-bed method midway between the fixed-bed method and the fluid-bed method is also used. At present, all three of these methods are widely applied to decoloring, deodorization and COD removal. Since active carbon accounts for most of the running costs, plants which introduce these methods are usually equipped with an activated-carbon regeneration furnace in order to decrease the quantity of activated carbon used.

For the regeneration of activated carbon, adsorbing matters in the pores of activated carbon are decomposed at a high temperature under the condition of steam saturation. Running cost can be reduced by 40% when activated carbon is regenerated with an industrial-owned activated-carbon regeneration furnace. Judging from the results of experimental application of activated-carbon adsorption to the treatment of dyeing wastewater, as well as the results of actual treatment in dyeing and paint plants, the decoloring efficiency has been shown to differ with the type of dyestuff used. The efficiency is affected by coexisting processing agents or processing aids such as surface-active agents. Some dyestuffs are difficult to remove, depending on the reaction group. It is also known that the color of the water reappears after the adsorption treatment. Therefore, it is important to check efficiency from the results of tests on real wastewater. According to the results obtained by the test on sewage after secondary treatment, removal of 100mgCOD/kg activated carbon was attained when the ratio of water and activated carbon was about 1,000:1 (quantity of discharge : quantity of activated carbon).

The advantages of activated-carbon adsorption are that it generates hardly any sludge, and that it is suitable for highly automated large-sized equipment applied to industrial uses. On the other hand, the method has the disadvantage of a high running cost compared with other methods. Thus, the method tends only to be applied to either finishing treatment after pretreatment such as coagulating sedimentation, or, to the contrary, the treatment of high-concentration wastewater (with little suspended matter).

In either case, in applying this technology, measures must be taken to control the pollution caused by the regeneration furnace and to minutely check the level of deterioration of the activated carbon.

2-2 Oxidation by Ozone

In addition to having a strong oxidizing effect in oxidative decomposition of organic matters and reduced matters in water, ozone is also known to act as a strong disinfectant. Reaction after oxidation generates oxygen and other gases and generally generates minimal levels of toxic by-products.

A silent-discharge method, photochemical method, and electrolytic method are all used for ozone production. The silent-discharge method and solid high-polymer electrolytic method using electrolytic membrane are applied for industrial use.

The silent-discharge method, an old technology put to practical use in the latter half of the 19th century, is still the most commonly applied method in current ozonizers. The method is classified into several types, i.e., the coaxial-cylindrical type, flat type, and surface-discharge type, depending on the structure of the electrode. The method is based on the principle of silent discharge, and uses oxygen or air as its raw material.

When considered in terms of its oxidation-reduction potential, ozone's oxidation effect is limited to a relatively small number of components and coloring groups in the organic matters contained in water. Its effectiveness for decoloring wastewater, however, is quite high, and an a decoloring rate exceeding 90% can be obtained on almost any dyestuff. Oxidation by ozone is accordingly regarded as a very effective decoloring treatment.

Although ozone has a relatively limited effectiveness on the dyestuff of a dispersed system, a decoloring rate of approximately 90% can be obtained. The dyestuff of a dispersed system has a low solubility in water, but it can be effectively used to dye synthetic fibers like acetyl cellulose fibers when it is dispersed with appropriate surface-active agents in the water. Decoloring by ozone in the treatment of wastewater is most widely applied in the field of treatment of human and animal excreta. The efficiency of decoloring by ozone has long been known, but its application has been hindered by its high running costs.

The concentric circular type of ionizer conventionally used for industrial applications consumes approximately 22kWh per 1kg of ozone produced using air as the raw material. The running cost, therefore, was more than double that of other oxidizers. Recently, a new technology was developed to produce air with a high oxygen concentration using an adsorbent called monocular sieve. When this technology is applied, the power required to produce 1kg of ozone is reduced to only 12kWh. Moreover, with the development of a high-performance flat-type ozonizer, the power required to produce 1kg ozone per hour is reduced to 13kWh, including what is required of peripheral equipment. In estimating the running cost of this treatment plant, removal of COD matters was taken into account on the basis of the experimental results, and the ozone injection rate was set at 35mg/l.

Decoloring via ozone oxidation is suitable for large-sized plants because no storage facility is required for storage of an oxidizer, there is no generation of toxic by-products, and the highly efficient arrangement of the method optimizes its decoloring efficiency.

3. Toxic Substance Treatment Technology

3. Toxic Substance Treatment Technology

Before an industrial plant can discharge its wastewater to the WWTP, pretreatment equipment must be installed to satisfy the WWTP's discharge standards.

3.1 Treatment of Heavy Metal

1) Coagulating sedimentation with slightly soluble salt

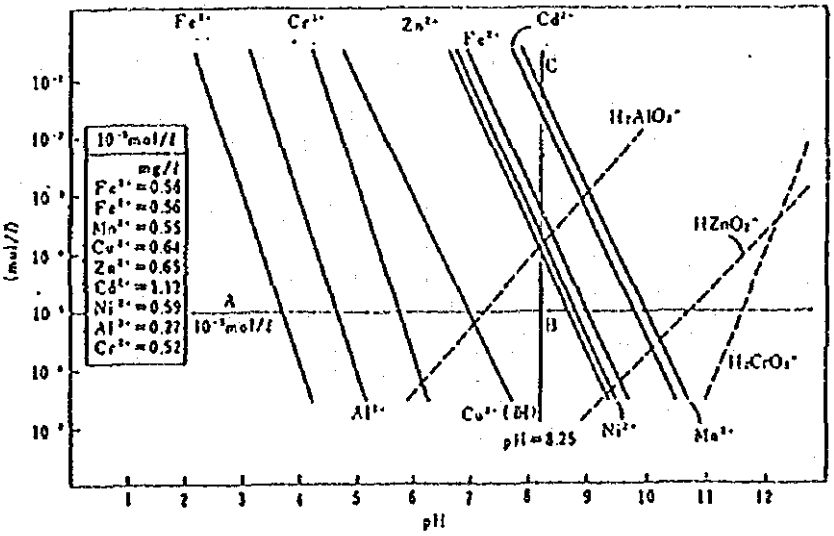
(1) Hydroxide method

In this method, an alkalizing agent like NaOH, $Ca(OH)_2$ or Na_2CO_3 is added to wastewater, the wastewater is alkalized, and heavy metal is precipitated and separated.

$$M^{n+} + nOH^- \ M(OH)_n$$

A hydroxide like Al, Pb, Zn, Ni, Cu, Mn, Sn, or Co is amphoteric, and it must be noted that under a high pH, such a compound changes to a complex ion hydroxide and remelts, reacting to the excessive ion hydroxide. Table 3.1 below indicates the relation between the solubility of a metal ion and its pH.

Table 3.1 Relation between the Solubility of a Metal Ion and its pH

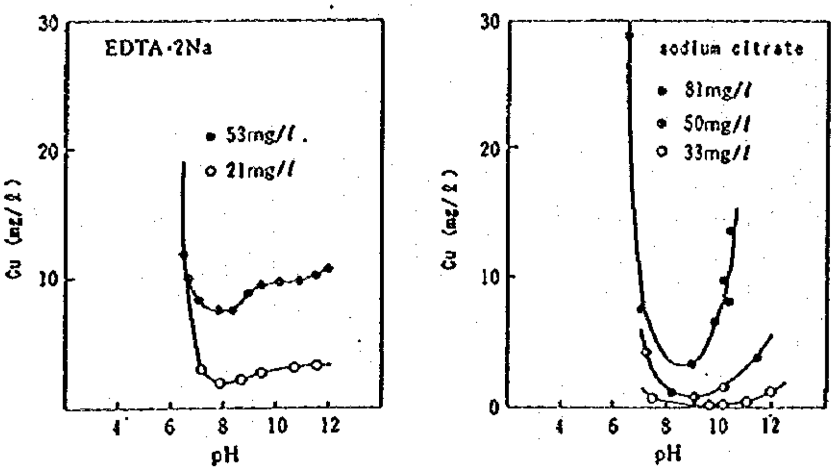


(2) Substitution method

When complex-forming compounds, for example, organic acids such as citric acid, gluconic acid, EDTA, cyanogen, amine, ammonia or phosphoric acid, are contained in wastewater, a complex with a stable structure is formed and the hydroxide method is ineffective. In such a case, the substitution method is applied. In this method, a harmless counter-ion alkaline earth metal such as Ca^{2+} or Mg^+ is added as a substitute for the heavy metal, and the heavy metal is separated as hydroxide.

Figure 3.1 indicates the influence of EDTA and citric acid on the hydroxide treatment of copper.

Figure 3.1 Influence of Chelating Agent



2) Ferrite generation magnetic separation

When alkali is added to thick wastewater containing heavy metal including Fe^{2+} for oxidation treatment, the heavy metal is taken into the crystal of ferrite, and magnetite of the insoluble magnetic substance is generated. Subsequently, the generated sludge can be separated with a magnetic separator.

Optimal magnetite generating conditions are: temperature of more than 60°C, and $2NaOH/FeSO_4 = 1$ (mole ratio).

$$(3\text{-}x)\ Fe^{2+} + x\ M^{2+} + 6\ OH^{-}\quad Fe_{3\text{-}x}Mx(OH)_8$$

$$Fe_{3\text{-}x}M_x(OH)_8 + O_2\quad M_xFe_{3\text{-}x}O_4$$

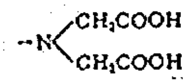
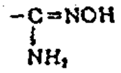
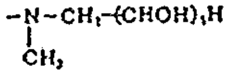
The separated sludge is a by-product of ferrite which can be used effectively as a damping material (sound and vibration insulation), as a material for magnetic indicators (indication and induction), or as a material for wave absorbers (reflection and leakage prevention).

3) Ion exchange resin method

Ion exchange resin exchanges and adsorbs the ions in the water. Positive-ion-exchange resin is used to separate positive ions (metal single ions like Pb^{2+} and Cd^{2+}), and negative-ion-exchange resin is used to separate negative ions (complex ions like $CrO4^{2-}$ and $HgCl_4^{2-}$). This method is applied to the reuse of large quantities of wastewater with a high ion concentration. The ion-exchange resin is classified as either a strong acid (strong base) resin or a weak acid (weak base) resin, depending on the solubility of the exchange base.

For advanced treatment of heavy metal and as a safety measure against imperfect treatment, chelate resin is normally installed in the final process of the wastewater-treatment equipment. Chelate resin was developed for the purpose of adsorbing metal ions selectively. Representative chelate resin is shown in Fig. 3.2 below.

Fig. 3.2 Coordination Group and Selectivity of Major Chelate Resin

coordination group	selectivity
 $-N(CH_2COOH)_2$	$Fe^{3+} > Cu^{2+} > Al^{3+} > Ni^{2+} > Pb^{2+} > Zn^{2+} > Ca^{2+}$, $Mg^{2+} > Na^{+}$
$-NH-(C_2H_4NH-)_n-H$	Au^{3+}, Pt^{2+}, Pd^{2+}
 $-C(NH_2)=NOH$	$Cu^{2+} > Ni^{2+} > Co^{2+} > Zn^{2+} > Mn^{2+}$
 $-N(CH_3)-CH_2-(CHOH)_4H$	BO_3^{3-}
$>N-CH_2PO_3H_2$	Fe^{3+}, In^{3+}, Bi^{3+}, $Sb^{3+} > Cu^{2+}$, $Al^{3+} > Cd^{2+} > Ni^{2+}$, $Zn^{2+} > Ca^{2+}$, $Mg^{2+} > Na^{+}$
$>N-CS_2H$	Hg^{2+}, Ag^{+}
$-NH-CS-NH_2$	Hg^{2+}, Ag^{+}

3.2 Treatment of Hexavalent Chromium

1) Reduction-hydroxide sedimentation method

Hexavalent chromium can exist as a stable ion in both acidic and alkaline water, and unlike other heavy metals, it cannot be removed easily with hydroxide sedimentation. Therefore, Cr^{6+} is reduced to Cr^{3+} and hexavalent chromium is sedimented and separated as hydroxide of Cr^{3+}.

$$4H_2CrO_4 + 6NaHSO_3 + 3H_2SO_4 \quad 2Cr_2(SO_4)_3 + 3Na_2SO_4 + 10H_2O$$

$$Cr^{3+} + 3OH^- \quad Cr(OH)_3$$

In the reduction of Cr^{6+}, the amount of chemicals added should ideally be controlled with an oxidation-reduction potential meter (ORP meter). If such control is performed, the pH is normally set at 2 - 2.5, and the ORP at 250 - 300mV. $Cr(OH)_3$ is generated by Cr^{3+} chromium ion when an alkalizing agent like $Ca(OH)_2$ is used and the Cr(OH)3 is then sedimented and separated.

Figure 3.3 shows the ORP curve of reduction by $NaHSO_3$. It should be noted that adding excessive amounts of $NaHSO_3$ results in the generation of a basic salt like $[Cr_x(OH)_y(SO_3)_3]^{-(3x-y-2z)}$. Figure 3.4 illustrates the influence of excessive sulfite.

Figure 3.3 ORP Curve - pH

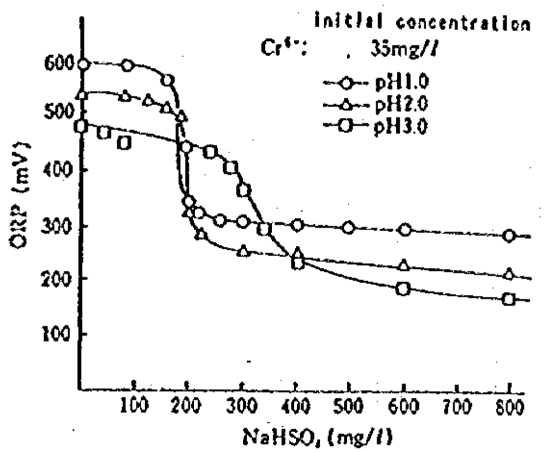
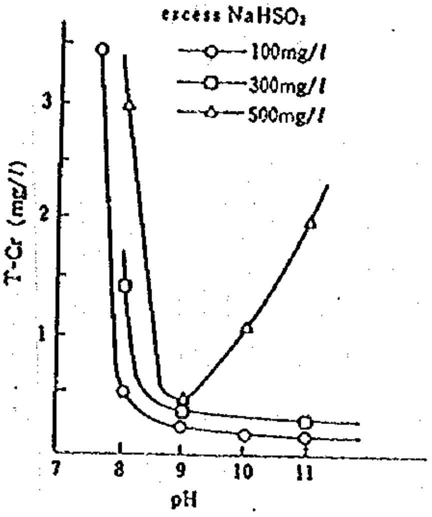


Figure 3.4 Influence of Excessive Sulfite



2) Ion-exchange method

When an exchange resin of strong base is used to remove chromic acid from wastewater, the chromic acid is adsorbed completely. To apply this method to the reuse of water, the use of an exchange resin of weak base makes it much easier to reuse the water. For the regeneration of ion-exchange resin, alkaline salt liquid is used as the regeneration liquid.

3.3 Treatment of Mercury

1) Sulfide-generation coagulating-sedimentation method

When Hg^+ reacts with S^{2-}, it generates extremely insoluble salt.

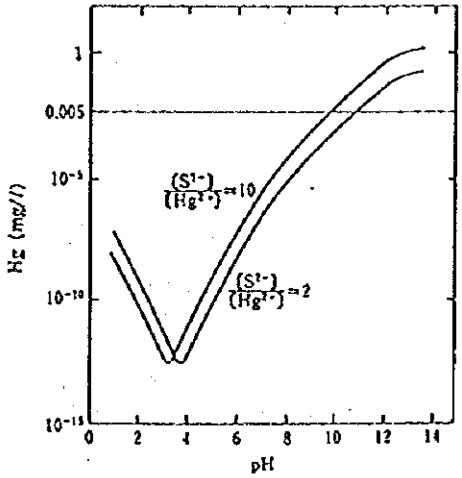
$$Hg^{2+} + S^{2-} \quad HgS \quad Ksp = 4 \times 10^{-53}$$

Complex formation caused by pH and excessive S^{2-} affects solubility. When the pH is low, the solubility product increases. It should be noted that the presence of excessive amounts of S^{2-} causes remelting.

$$HgS + S^{2-} \quad HgS_2^{2-} \qquad K = 3.3 \times 10^{-2}$$

Figure 3.5 below gives an example of a theoretical calculation carried out on the wastewater containing 15% NaCl and 5mg/l Hg^{3+}, taking into account factors such as the excessive S^{2-}, chloride complex, and OH^-.

Figure 3.5 Concentration of Dissolved Mercury after Sulfide Reaction (Calculated Value)



2) Adsorbent method

This method, which uses activated carbon as the adsorbent, is applied in combination with the sulfide coagulating-sedimentation method. Figures 3.6 and 3.7 indicate the isothermal lines of mercuric chloride and methylmercuric chloride respectively obtained in 24-hour standing contact with various activated carbons.

Fig. 3.6 Isothermal Line of Mercuric Chloride

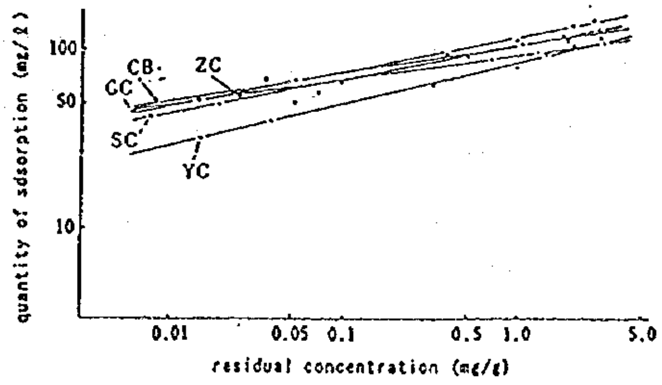


Fig. 3.7 Isothermal Line of Methylmercuric Chloride

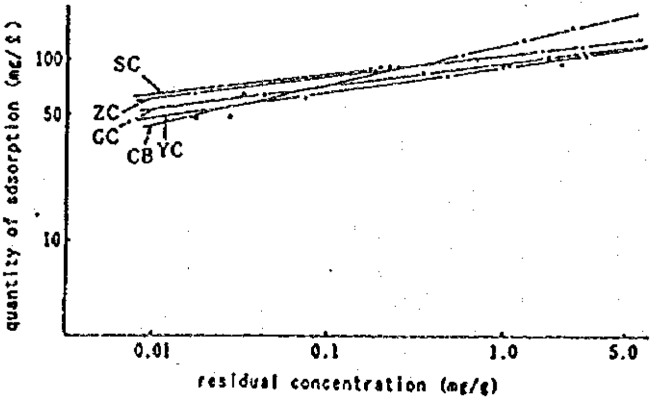
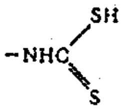
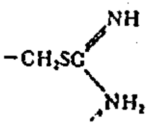
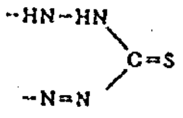
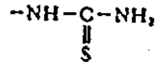


Fig. 3.8 below shows various types of mercury chelate resin. Using these resins, the mercury content can be reduced to less than 0.0005mg/l.

Fig. 3.8 Various Types of Mercury Chelate Resin

donor 子	coordination group	polymer group
S	-SH	polyacryl (DVB)VB) ethylene dimethacrylate
N S		polyacryl (DVB) phenol resin
		polystyrene (DVB)
		phenol resin
	 $-NH-\underset{\underset{S}{\Vert}}{C}-NH_2$	phenol resin polystyrene (DVB)

3.4 Treatment of Arsenic

Due to the characteristics of the sources from which it is discharged, wastewater containing arsenic usually contains various kinds of metal ions. Since arsenic naturally tends to generate slightly soluble salts with metals such as calcium, magnesium, iron, aluminum, and zinc, it can be reduced to a low concentration by treatment with the coprecipitation method. The solubility products of slightly soluble salts are indicated in Table 3.2.

Table 3.2 Solubility Product of Slightly Soluble Arsenate

Comprex	pk sp
$[Al]^3[AsO_4]^2$	20
$[Fe]^3[AsO_4]^4$	20.2
$[Cn]^3[AsO_4]^2$	18.2
$[Mg]^3[AsO_4]^2$	19.7
$[Cu]^3[AsO_4]^2$	35.1
$[Zn]^3[AsO_4]^2$	27.0
As_2O_3*	0.8

* Solubility Conduct

3.5 Treatment of Cyanogen

1) Alkaline-chlorine oxidation method

This method is widely applied to the treatment of wastewaters of the cyanogen system. Cyanogen is decomposed in two stages. In the first stage, chlorine is added to alkaline wastewater, and in the second, the pH is neutralized and chlorine is further added. Normally, sodium hypochlorite is used for this method and controlled with an ORP meter. Fig. 3.9 indicates the ORP curve of the two-stage alkaline-chlorine oxidation treatment.

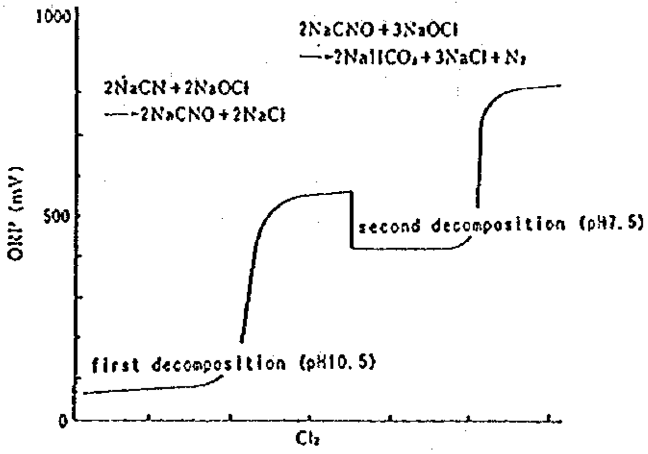
First-stage reaction: pH over 10, ORP 300 - 350mV

$$NaCN + NaOCl \quad NaCNO + NaCl$$

Second-stage reaction: pH 7 - 8, ORP 600 - 650mV

$$2NaCNO + 3NaOCl + H_2O \quad N_2 + 3NaCl + 2NaHCO_3$$

Fig. 3.9 ORP Curve of Two-stage Alkaline-Chlorine Oxidation Treatment



Cyanides which can be decomposed with the alkaline-chlorine oxidation method include free cyanide, copper cyano complex, and the cyano complex of zinc and cadmium.

2) Oxidation by the ozone, electrolytic oxidation method

The reaction of cyanide and ozone is greatly affected by pH. Generally, the best result can be obtained when the pH is 11 - 12. The advantages of this method are that no harmful pollutants are contained in the product generated after reaction, and that the reduced form of ozone (O_2) used is completely harmless. The disadvantages are that it is a gas-liquid reaction, and that it is expensive to produce the ozone. The following equations show the ozone-activated oxidation reaction.

$$CN^- + O_3 \quad CNO^- + O_2$$

$$2CNO^- + 3O_3 + H_2O \quad 2HCO_3^- + N_2 + 3O_2$$

Treatment of thick cyanide wastewater by means of oxidation with chemical addition causes various problems. As considerable heat is generated at the time of reaction, chloric acid is generated and oxidation capacity decreases, sometimes resulting in incomplete treatment. The electrolytic oxidation method is suitable for the treatment of such thick wastewater. To increase the power efficiency, sodium chloride is generally melted in the wastewater up to saturation. Concurrently, oxidative decomposition is accelerated by the hypochlorous acid generated at the time of electrolysis. The reaction at the anode is indicated in the following equations.

$$CN^- + 2OH^- \quad CNO^- + H_2O + 2e$$

$$2CNO^- + 4OH^- \quad 2CO2 + N_2 + 2H_2O + 6e$$

$$CNO^- + 2H_2O \quad NH^{4-} + CO_3^{2-}$$

3) Slightly soluble complex compound sedimentation method

When nickel, iron, or cobalt is contained in cyanide wastewater, stable complexes are formed, and oxidative decomposition with the alkaline-chloride oxidation method or electrolytic method is difficult. Such wastewasters are generally treated by taking advantage of the characteristic of complex salt using the method to generate slightly soluble salt. Once generated, the slightly soluble salt is sedimented and removed with the coagulating-sedimentation method.

For example, when excessive amounts of iron ions are present in the water, iron cyano complex ions react as depicted in the following equations, thereby generating slightly soluble salt.

$$3[Fe(CN)_6]^{4-} + 4Fe^{3+} \quad Fe_4[Fe(CN)_8]_3$$

$$2[Fe(CN)_8]^{3+} + 3Fe^{2+} \quad Fe_3[Fe(CN)_8]_2$$

$$[FE(CN)_0]^{4-} + 2Fe^{2+} \quad Fe_2[Fe(CN)_0]$$

3.6 Treatment of Organochlorine Compounds

1) Volatilization method

When wastewater containing volatile compounds is aerated, volatile compounds are volatilized and their concentration in the wastewater decreases. As organic chlorine compounds are slightly soluble, volatilization treatment can be easily carried out. For example, it is reported that by the treatment of TEC, 0.0018 - 0.002mg/l water was obtained from raw water of 0.19 - 0.23m/l by applying the volatilization method using a packed tower with a treatment capacity of 1,000m³/d and air quantity of 20m³/m³ - wastewater/hour. By the treatment of PEC, 0.001mg/l water was obtained from raw water of 0.013 - 0.061mg/l by applying a similar method using a tower with a treatment capacity of 3,000m³/d and air quantity of 120m³/m³ - wastewater/hour.

2) Activated-carbon adsorption method

The volatilization method and the activated-carbon adsorption methods are the only current methods which enable nearly complete separation of organochlorine compounds from wastewater. The disadvantage of the activated-carbon adsorption method is its small adsorption quantity. Fig. 3.3.7 in Chapter IV indicates the measured adsorption isothermal line.

3) Oxidative decomposition method

Organochlorine compounds are decomposed to carbon dioxide and chloride ions under oxidation conditions. In a decomposition experiment conducted using pergamanganate, they were decomposed under acidic or neutral pH and ordinary temperature (25°C).

A method to irradiate zinc oxide or titanium dioxide with ultraviolet light while using a catalyst is being examined. More than 90% of TEC and PEC can be decomposed by 10 - 20 minutes of irradiation.

Other methods currently under examination include decomposition by ozone, direct burning of thick waste gas, and decomposition of organochlorine compounds in liquid to ethane or ethylene gas by means of catalytic reduction.

4) Biological decomposition method

The quantity of PEC and TEC is reportedly reduced by sewage treatment and the activated-sludge treatment for industrial wastewater.

A bacterium which decomposes TEC to carbon dioxide aerobically was recently discovered, and the incubation conditions of this bacterium have been clarified. According to a recent report, TEC was decomposed to carbon dioxide by the recombination of a TEC-decomposing gene to coliform bacillus.

As for PEC, it is widely known that PEC is decomposed to TEC by microorganisms, and much research has been made in this field. A system is currently being developed to economically decompose PEC to carbon dioxide by biological treatment in combination with TEC-decomposing microorganisms. At present, however, the system is still at the beaker stage, and actual application may be some years ahead.

4. Proposals for Harmful Chemical Substances & Chemical Substances

4. Proposals For Harmful Chemical Substances & Chemical Substances

4. 1 How Industrial Effluents Affect Sewer System

1) Substances contained in industrial effluents & their effects on the sewer system

Some effluents can erode and clog up the sewer pipes and conduits when they are discharged into the sewer system without proper prior treatment. It is necessary to bear in mind that some effluents contain unacceptable substances that may cause the malfunction of the waste water treatment system of the waste water treatment plant. (See Table4.1.1)

Table4.1.1

Chemicals	How chemicals affect sewer systems
Cadmium, Alkyl mercury, Hexavalent chromium, Total mercury, Lead, Zinc, Copper, Chromium, Arsenic, Fluorine, Organic chlorine compound, PCB, Organic phosphorous compound	1. They have a toxic effect on microorganisms and cause the malfunction of the waste water treatment system. 2. Their removal at the waste water treatment plant is outside the range of possibility. 3. They form sludge on sewer sludge, which makes the treatment and disposal of the sludge more difficult.
Cyanide	1. Deadly poisonous hydrocyanic acid gas can be produced, which endangers personnel working in the conduits. 2. Microorganisms can be affected adversely even in low concentration, which causes malfunctions of the waste water treatment system.
Phenol	1.An offensive smell can be produced. 2.The malfunction of the waste water treatment system can be caused as badly as it is caused by cyanide.
Iron, Manganese	1.Unlike other metallic substances, no toxic substances are contained; however, they can clog up the diffuser tubes when they are large volumes.

Concentration of Hydrogen Ion	1.Toxic gasses or gasses with offensive smells can be produced when the waste water is mixed with other effluents. 2. Equipment and facilities made of metal or concrete can be eroded.
Biochemical Oxygen Demand	1.The treatment capacity is limited, and, when there Demand there is an overload, the quality of waste water to be treated can be deteriorated.
Floating Matter	1.It settles in and blocks up the sewer pipes and conduits, which causes offensive smells. 2. The sludge removal device must bear a heavy burden and such an overload causes the malfunction of the organism treatment system, which leads to the deterioration of the quality of waste water to be treated.
Mineral Oil, Animal & Plant Oils	1.Mineral oil which is volatile can cause fires and explosions. 2. Highly viscous mineral oil and animal and plant oils can coat and block up the sewer pipes and conduits. 3. They adhere to activated sludge, which obstructs oxygen supply, causing the deterioration of the quality of waste water to be treated.
Iodine	1.It can cause a shortage of oxygen in the sewer pipes and conduits. 2. Deadly poisonous hydrogen sulfide can be produced. 3. The aeration capacity can be affected when the volume is large.
Temperature	1.Drainage at a high temperature helps metal and concrete erode away. 2. It can cause gasses with offensive smells when it is mixed with other types of drainage.

2) Japanese effluent emission standards

Because of the above-mentioned reasons, in Japan, there are standards for discharging effluents with harmful chemical substances as shown in Table4.1.2 in accordance with the Japanese law.

Table 4.1.2

Emission Standards for Effluents

Chemical group	Emission standards
Cadmium	0.1mg/l or under
Cyanide	1mg/l or under
Organic phosphorus	1mg/l or under
Lead	0.1mg/l or under
Hexavalent chromium	0.5mg/l or under
Arsenic	0.1mg/l or under
Total mercury	0.005mg/l or under
Alkyl mercury	To be kept undetected.
PCB	0.003mg/l or under
Trichloroethylene	0.3mg/l or under
Tetrachloroethylene	0.1mg/l or under
Dichloromethane	0.2mg/l or under
Carbon tetrachloroethylene	0.02mg/l or under
1,2-Dichloroethane	0.04mg/l or under
1,1-Dichloroethylene	0.2mg/l or under
Cis-1,2-Dichloroethylene	0.4mg/l or under
1,1,1-Trichloroethane	3mg/l or under
1,1,2-Trichloroethane	0.06mg/l or under
1,3-Dichloropropene	0.02mg/l or under
Tiurum	0.06mg/l or under
Cymadine	0.03mg/l or under
Thiobenculp	0.2mg/l or under
Benzene	0.1mg/l or under
Selenium	0.1mg/l or under
Total chrome	2mg/l or under
Copper	3mg/l or under
Zinc	5mg/l or under
Phenol	5mg/l or under
Iron (soluble)	10mg/l or under
Manganese (soluble)	10mg/l or under
Fluorine	15mg/l or under

Biochemical oxygen demand (BOD)	Less than 600mg/l (Less than 300mg/l)
Quantity of floating matter (SS)	Less than 600mg/l (Less than 300mg/l)
Normal hexane extract Mineral Oil	5mg/l or under
Normal hexane extract Animal & plant Oils	30mg/l or under
Nitrogen content	Less than 240mg/l (Less than 150mg/l)
Phosphorus content	Less than 32mg/l (Less than 20mg/l)
Concentration of hydrogen ion (pH)	Above 5, under 9 (Above 5.7, under 8.7)
Temperature	Under45° C (Under 40° C)
Consumption of iodine	Under 220mg/l

Note:

1. The numerical values in the brackets are the standards for the manufacturing industry and gas suppliers.
2. Some of these standards may not apply to some chemical substances or items, depending on the volume of the effluent.

3) Adverse effects of chemical substance emission on bioligical treatment

(1) Oils & fats

Discharging into the sewage treatment plant waste water containing oil and fat not only causes the sewer pipes and conduits to be clogged up but also affects adversely the sewage treatment system of the sewage treatment plant. (Especially, that exerts a very bad influence upon biological treatment efficiency.)

Removing oils and fats along with the SS lessens a BOD load on activated sludge and eliminates obstacles clung to flocks. Ation of activated sludge is hindered by both relatively high molecular oils such as heavy oil, machine oil, mineral oil, and animal and plant oils and solvents such as carbon tetrachloride, chloroform and acetone. The following are observational facts:

(a) Oils and fats are absorbed by flocks and the surface of activated sludge bacteria is covered by oil film, which obstructs respiration.

(b) Oils, fats and hydrocarbon consume dissolved oxygen, for the aeration tank, required for the removal of the BOD on a unit of weight basis 2 or 3 times as much as carbohydrate organic protein compounds do. That is, more air than planned is required and the shortage of air is then caused by such additional oxygen supply required for the aeration tank.

(c) Although effluents from meat and fish processing factories, leather manufacturers and slaughterhouses have high oil and fat contents, they can solidify while they are aerated in the aeration tank. Solidified fats are not absorbed into activated sludge and adsorb flocks and then form floating flocks, which results in an increase in the SVI (Sludge Volume Index). The floating flocks are carried over with treated water from the sedimentation tank, which results in increases in the SS and the BOD and then deteriorates the quality of effluents discharged.

(d) Waste water with high oil and fat contents is prone to generate filamentous bacteria and even if filamentous bacteria are not generated on such waste water, the SVI is ready to rise, which usually makes the sedimentation of the sludge in the sedimentation tank difficult. In regard to waste water with a high milk content, the same sequence of affairs is observed in most cases.

When a solvent such as carbon tetrachloride and acetone is mixed with such waste water, the lipid of bacteria in activated sludge and protozoans are dissolved, causing the malfunction of metabolism. This results in the dissolution of the activated sludge.

For the above-mentioned reasons, in regard to the normal hexane extract which flows into the sewage treatment plant, pretreatment should be conducted so that the emission level can be 5mg/l or under for mineral oils and 30mg/l or under for animal and plant oils, meeting the emission standards shown in Table 4.1.2.

(2) Organic compounds & organic petrol substances

(a) Effluents from petrochemical plants

Effluents from petrochemical plants often contain quantities of floating oils and grease, chrome, H_2S and suspended solids. These effluents are composed of volatile substances and substances that react ex post facto, and the qualities of the liquids are subject to change, which may obstruct the action of the activated sludge. The degrees of difficulty in conducting biological treatment for different types of organic compounds and organic petrol substances can be briefly summarized as Follows:

① Lengthwise chain compounds are easy to treat.
② Compounds with hydroxyl radicals are easy to treat. The more hydroxyl radicals they have, the easier they are to dissolve.
③ When $-CH_3$ radicals are added, the degree of obstruction decreases.
④ Side chain compounds are difficult to treat.
⑤ Chlorine compounds and $-NO_2$ compounds are difficult to treat.
⑥ The fourth degree carbonic compounds are untreatable.

Other chemical compounds that are difficult to biologically dissolve are shown in Table 4.1.3 .

Table 4.1.3(1)
Substances Difficult to Dissolve Biologically

Chemical group	Name of compound
Nitrogen compounds	Diethanolamine, Triethanolamine, Acetyl ethanolamine, Formamide, Acrylonitrile, Dimethyl aniline, Melamine, Xylidine, Hexamethylene tetramine, Diamino pyridine, Morpholine, Acetyl morpholine, Acetoanilide
Aldehyde	3-Hydroxy butanol, Benzaldehyde
Ketone	Diethyl ketone, Methyl isobutyl ketone, Methyl-n-Amyl ketone, Acetophenone
Ether	Dimethyl ether, Ethyl ether, Diethyl ether, Isoamyl ether, Ethylene glycol dimethyl ether, Bis-2-Enoxi ethyl ether, Tetraethylene glycol, Dioxane
Alcohol	3 Butyl alcohol, Diethylene glycol, Cyclohexanol, Aryl alcohol, Pentaerythritol
Phenol	Pyrogalol, Xylenol 1.3.5
Hydrocarbon	Xylene, Naphthalene, α -Methyl naphthalene, Benzene, Ethyl benzene, n-Propyl benzene, n-Butyl benzene, 3 Butyl benzene, n-Dodecane, Ethylene dichloride, Carbon tetrachloride, Chloroform, Monochlol benzene
Carbohydrates	α -Cellulose, C.M.C.

Table4.1.3(2)

The Degree of Difficulty in Treating Activated Sludge

Name of compound	Easy/Difficult	BOD Level in g/g
Hydro carbon		
Gasoline	Difficult	0.078
Kerosene	Difficult	0.53
Benzene	Difficult	1.20
Alcohol		
Methanol	Easy	0.76
Ethanol	Easy	1.07
n-Propanol	Easy	0.47-1.5
i-Propanol	Easy	1.29-1.42
n-Butanol	Easy	1.45
i-Butanol	Easy	1.66-0.07
n-Amyl alcohol	Easy	1.50-1.61
i-Amyl alcohol	Easy	1.50-1.62
Aryl alcohol	Difficult	1.6
n-Hexanol	Difficult	0.7
Penthyl alcohol	Difficult	1.55
Glycerol	Difficult	0.83
Phenol		
Phenol	Easy	1.4-2.1
o-Cresol	Easy	1.64
m-Cresol	Easy	1.70
p-Cresol	Easy	1.40
Naphthol	Easy	1.70
Aldehyde		
Form aldehyde	Easy	1.00
Aceto aldehyde	Easy	1.27
Benzaldehyde	Difficult	1.5
Furfural	Difficult	0.77

Name of Compound	Easy/Difficult	BOD Level In g/g
Acid, Salt, Ester		
Formic acid	Easy	0.02-1.27
Acetic acid	Easy	0.34-0.88
Benzoic acid	Easy	1.34-1.40
Phenyl acetate	Difficult	
Ether		
Ethylene glycol	Easy	
Diethyl ether	Easy	
Diethyl ether	Easy	
Ketone		
Acetone	Difficult	0.21
Diethyl ketone	Difficult	1.00
Methyl isobutyl ketone	Difficult	2.14
Methyl phenyl ketone	Difficult	1.40
Cyanide		
Acryl nitrile	Easy	
Lactonitrile	Easy	
Benzonitrile	Easy	
Vinyl		
Acryl alcol polymer	Difficult	
Chlotone aldehyde	Easy	
Acriamide	Easy	
Butadiene	Difficult	
Methyl vynil ketone	Difficult	
Styrene	Easy	
Polyethylene glycol	Difficult	
Others		
Ethylene Dichloride	Difficult	
Ethylene chlorohydrin	Difficult	

(b) Other chemical compounds

Activated sludge is easily affected by either dinitro orthocresol or butadiene and dies out completely when it comes into contact with one of them. Activated sludge in industrial effluents after the pickling process reacts in the same manner if the effluents are not perfectly neutralized.

(3) Harmful substances

(a) The inflow of disinfectants, herbicides and pesticides into the aeration tank causes the activated sludge to dissolve. The maximum level of concentration is 5mg/l; however, it is desirable that no harmful chemicals should be detected anyway.

(b) Waste water containing sulfide and SO_2 converts into H2S, when it turns anaearobic. Detecting 5mg/l or more of H_2S at the mouth of the aeration tank indicates that activated sludge will dissolve.

How to handle waste water containing sulfide: Air in the places where waste water is brought to and in the stabilization tank must be kept from becoming anaearobic. Floating matter staying still in the pits and the tank must be kept in contact with air and must be stirred. This gives convection to the still waste water to eliminate any dead angles.

(c) Heavy metals

Heavy metals contained in waste water come from metal salt, acids (H_2SO4, HCL), and alkalis (NaoH) which are used in the process of manufacturing heavy metals. Even if the content of heavy metals is very low, they join bacteria of the activated sludge and build up and then become a hundredfold concentrated.

The following shows the intensity of the toxicity of metal ion:

Ag>Hg>Sn>Cu>Cd>Cr>Ni>Pb>Co>Zn

There are many reports on how heavy metals obstruct action of activated sludge and the permissive levels of heavy metals content. Different levels are given in different reports, depending on different conditions for different waste water treatment cases, the existance or absence of other chemicals that inhibit action of activated sludge, the weight of the load, and the level of the dissolved oxygen concentration. However, there are several invariable truth:

① If the content of Cu, Cr and Zn detected at the mouth of the aeration tank is only a few mg/l, no significant obstruction should be observed as long as any excess sludge is eliminated from the aeration tank regularly. But if the elimination of excess sludge is neglected, heavy metals continue to build up and they start to obstruct action of activated sludge.

② If the content of heavy metals in waste water fluctuates all the time, it affects the coagulation of activated sludge if the content fluctuates between 0 and 10mg/l, for instance.

③ It is rare that one kind of heavy metal should exist singly. When several kinds of heavy metals exist, their obstruction of action of activated sludge appears at a lower permissive level of concentration compared to a single kind of heavy metal. This is believed to agree with the fact that there is synergy among toxic effects of heavy metals.

④ When only a few mg/l of heavy metals exist at the mouth of the aeration tank, those heavy metals join or are adsorbed by activated sludge, and as high as 90% of the heavy metals are then removed. This is a remarkable characteristic of activated sludge; however, the interpretation of this fact is that the amount of heavy metals removed has been moved into the bacteria of the activated sludge because heavy metals never fly about in the air.

In this case, heavy metals have moved into the excess sludge. Therefore, it is necessary to bear in mind that the utilization of such excess sludge will be restricted because of the heavy metal content in the excess sludge.

4) Other substances requiring special attention

(1) Surface active agents

Most detergents contain surface active agents that generate bubbles in the effluent at the sewer treatment plant. This costs them extra money for preparing antifoaming agents for aeration of the activated sludge.

In Slovenia, there is a regulation that stipulates that "the use of surface active agents must be limited to a certain amount at a time, which may not affect the sewer system or the sewer treatment plant. "Where is no such restriction in Japan.

(2) Colorings used at dyeing plants & chemical plants

The volume of coloring constituents of effluents decreases after a sewer treatment process; however, if the level of coloring is significantly high, it may be difficult to meet the emission standards. In Japan, as for the level of coloring, there are no emission standards for general water areas whereas there are very strict emission standards for specified water areas. Before discharging effluents containing colorings into such specified water areas, they must be treated by activated carbon adsorption or with ozone.

In order to decrease the burden the sewer treatment plant must bear, the authorities order some of the plants that produce colored effluents to set up preliminary treatment facilities for the removal of the colors.

The use of dyes containing chemical substances such as cadmium that affects action of microorganisms is already on the decrease all over the world. Consultations with the authorities are recommended before purchasing dyes.

4. 2 Effluents & Waste From Hospitals

1) Sources of effluents & waste
Effluents from hospitals can be roughly grouped into general effluents and specific effluents. Effluents mainly come from the following places:

(1) Kitchens
There are feeding facilities for inpatients and staff and kitchens for cafeterias for visitors. Effluents from those facilities contain large volumes of solids and oils from cooking and washing dishes have the highest degree of turbidity among all effluents from the hospital.

(2) Laundries

Waste water from laundries contains effluents coming from washing linens for inpatients and white hospital frocks for staff and has a high degree of turbidity. As a matter of fact, however, it is offen that the laundry is sent out to outside cleaning agents in part or in whole these days. As for hospitals which send out the laundry, they use washing machines for inpatients' linens installed in one of the wards and the volume of waste water produced is small.

(3) Baths

Effluents from baths contain dirt from washing bodies, washing soap, detergents and scale from bathtub water. Often hot water in bathtubs is not discharged everyday but is circulated by filters for reuse. Although effluents containing washing soap and detergents have a high level of concentration, bathtub water discharged has a low level of concentration.

(4) Lavatories

Before discharging human waste from lavatories into the public sewer system, the raw sewage must be treated in a sewage treatment tank designed in accordance with the standards of the Building Standards Act. These days, the raw sewage from lavatories is often treated along with miscellaneous water from kitchens, baths, and laundries.

(5) Wards, consultation rooms, clinical examination rooms & X-ray rooms

Specific waste water from these facilities has relatively low levels of the COD and the BOD. In hospitals, disinfectants such as formaline, cresol and hibitene are used to treat effluents containing heavy metals such as chrome and mercury and so are organic solvents, for instance methanol, ethanol and chloroform and acids and alkalis. Effluents containing chemicals are often found in waste water.

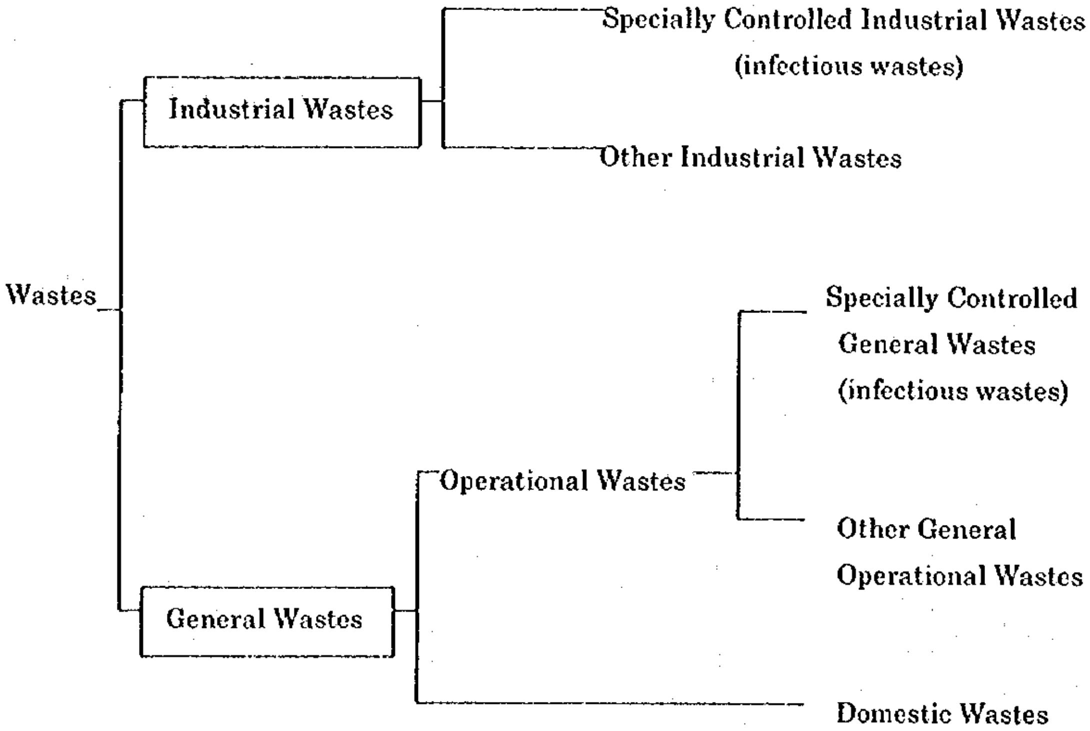
Raw sewage containing human waste, blood or harmful substances that are infectious is produced. Some hospitals even produce radioactive waste water.

In Japan, industrial wastes and effluents (solid, liquid) that are produced by hospitals dealing with infectious pathogens are designated as <u>specially controlled industrial wastes</u> and must be treated or disposed of in conformity to the law in order to prevent any possible infections.

The following is a summary of the regulations established under Japanese law:

2) Sorting out wastes

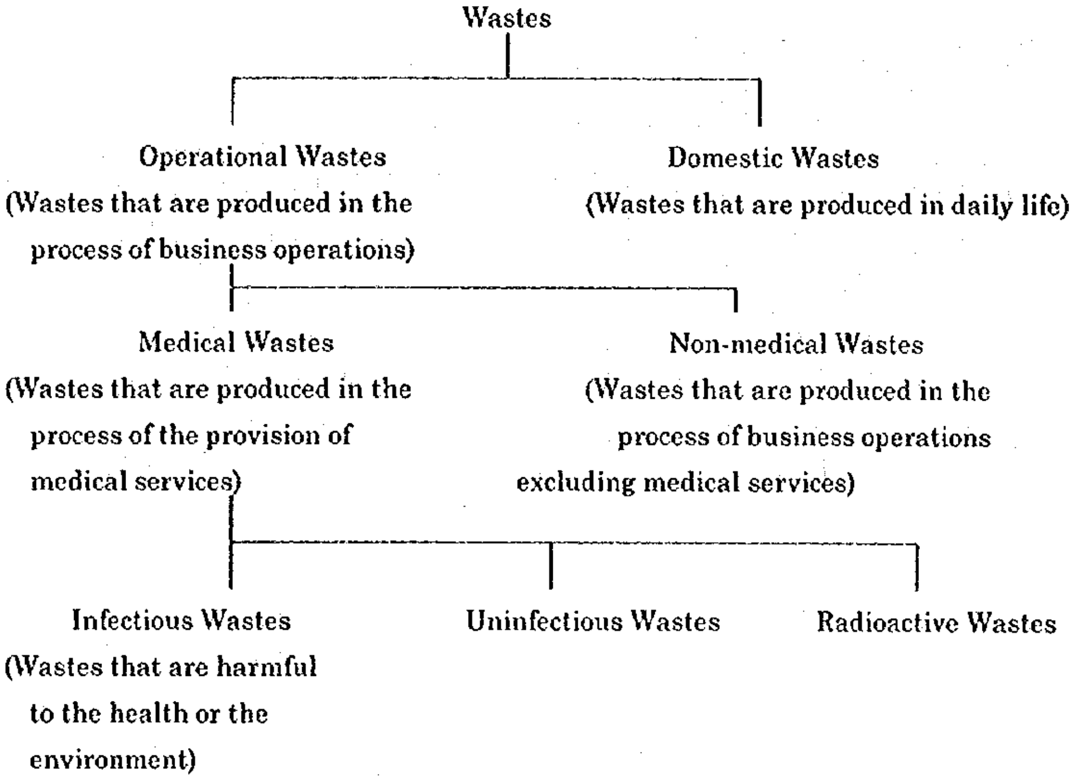
According to the Waste Disposal Law, wastes must be divided into industrial wastes and general wastes, and then further subdivided into specially controlled industrial wastes (infectious wastes, etc.) and other categories:



- Specially controlled wastes (general, industrial) are explosive, toxic, infectious or harmful to health or the environment.

3) Specially controlled wastes (infectious wastes)

(1) Wastes from medical institutions



Note: Radioactive wastes are specified under other regulations.

(2) Among general wastes (excluding industrial wastes), "specially controlled general wastes" are limited to those which are explosive, toxic, infectious or harmful to the health or the environment.

Among industrial wastes (sludge, waste oils, waste acids, waste alkalis, waste plastics, scrap rubber, scrap metals, scrap glass, etc. produced in the process of business operations), "specially controlled industrial wastes" are limited to those which are explosive, toxic, infectious or harmful to the health or the environment.

(3) Among medical wastes, the regulations prescribe that infectious wastes are those containing infectious pathogens or those which infectious pathogens are stuck on.

Infectious wastes include wastes from hospitals, clinics, sanitary inspecting offices, health centers for the aged, and other facilities' dealing with infectious pathogens. Also included are wastes from examination and reserch institutes, universities and their affiliated examination and research institutes, and other examination and research institutes involved in academic research, the manufacture of products, the improvement of technologies, the development of methods or the invention of devices or new ideas.

Types of infectious wastes and examples are shown in the following table: (Table4.1.4)

Table 4.1.4

Kind of waste	Infectious general wastes	Infectious industrial wastes
① Blood, etc.		Blood, Blood Serum, Plasma, Humor (Including Semen), Blood Products
② Pathological wastes produced by surgical operations	Organs, Tissue	
③ Bloodstained sharp medical tools		Needles, Scapels, Test Tubes, Chalets, Scrap Glass
④ Medical tools which have been used for tests or examinations in relation to peccant microorganisms	Midiums and Dead Bodies of Test Animals which have been used for tests or experiments	Test Tubes and Chalets which have been used for tests or experiments
⑤ Other bloodstained things	Bloodstained Scrap Paper, Flocks (Sanitary Cotton, Gauze)	Bloodstained Gloves for surgical operations and experiments
⑥ Contaminated substances or things on which contaminated substances are or may be stuck and which do not come under ① through ⑤	Scrap Paper and Flocks on which contaminated substances are stuck	Scrap Plastics on which contaminated substances are stuck

Note: With regard to ⑤ and ⑥, it is considered that the relative risk of infecting unrelated people differs with the extent to which the waste is stained with blood or contaminated with other substances, as well as the shape and properties of the waste. Therefore, if it is judged by the doctor that there is very little risk of infecting unrelated people, the waste does not have to be treated as infectious waste.

4) Controlling infectious wastes at medical institutions

(1) Assignment of persons in charge of controlling specially controlled industrial wastes

<Hospitals, Sanitary Research Institutes, Examination & Research Institutes>
The responsibilities of the persons in charge of controlling specially controlled industrial wastes at medical institutions cover the prevention of nosocomial infections and the treatment of infectious wastes in proper ways.

<Clinics>
Doctors can assign themselves to be in charge of controlling specially controlled industrial wastes.

Persons in charge of controlling specially controlled industrial wastes at hospitals, sanitary research institutes and examination and research institutes must work out plans in detail for the discharging, sorting out, packing and intermidiately treating of infectious wastes and make them known to everybody in their clinics without exception.

(2) Qualifications of persons to be in charge of controlling specially controlled Industrial Wastes

- Through sessions of the course approved by the Minister of Health and Welfare
- Doctors, dentists, veterinarians, pharmacists, health nurses, midwives, clinical inspectors, and sanitary inspectors

(3) Duty of persons in charge of controlling specially controlled industrial wastes to report

Persons in charge of controlling specially controlled industrial wastes at medical institutions must submit reports specified under the regulations to the authorities on a regular basis.

5) Sterilization of wastes

Specially controlled general wastes and specially controlled industrial wastes which are produced within the premises of medical institutions must be treated by sterialization using one of the following methods specified under the regulations.

(1) Complete incineration by the with an incinerator
(2) Complete disolution with a dissolving device
(3) Sterilization by the use of either a high pressure steam sterilizer or a dry sterilizer

4.3 Toxicological Tests

Volumes of harmful chemical substances and environment-friendly chemical substances in waste water are indexes for the determination of the quality of the waste water. However, with further industrial development bringing about more advanced technologies, it is anticipated that wholly new chemical substances will be developed and used, and, then, effluents containing these chemical substances will be discharged into the sewer system. Therefore, more chemical emissions may be added to the list of chemical substances for emission control in the future.

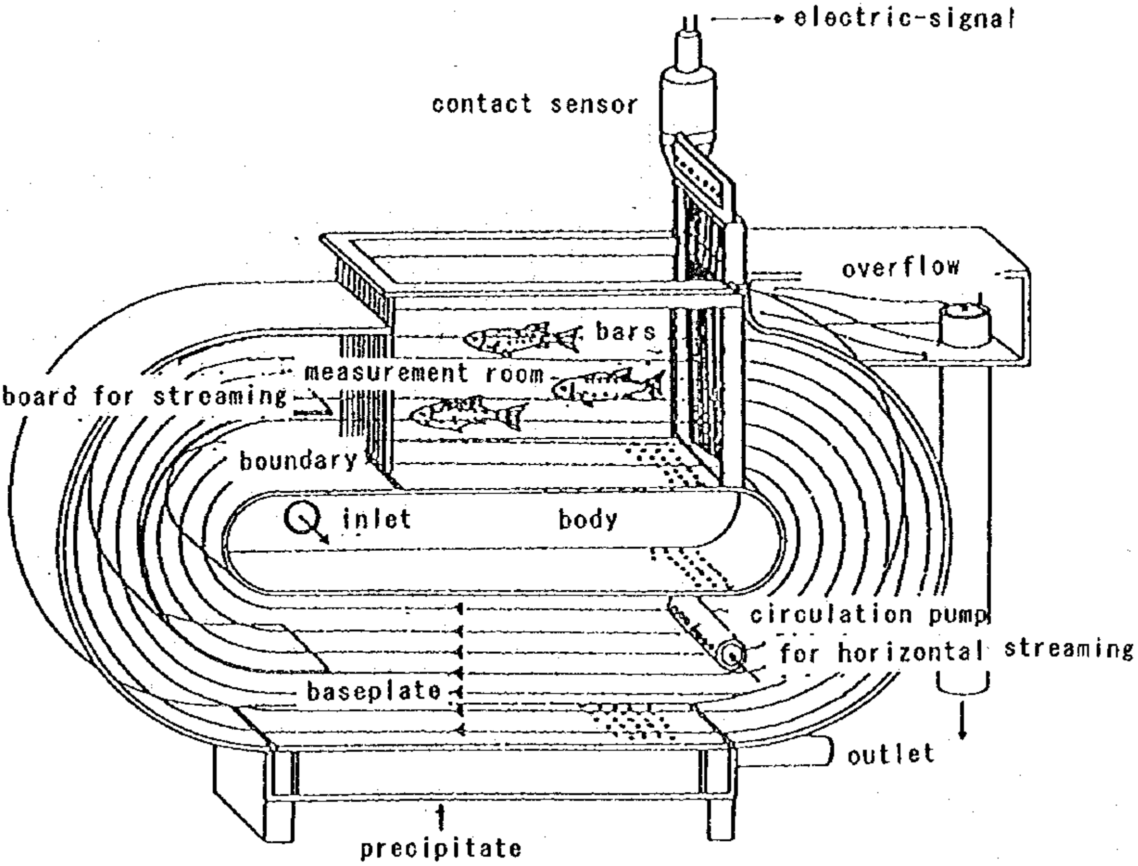
In most cases, chemical analyses for industrial effluents and sewage with complex composition cannot give us sufficient information on how those effluents affect the rivers into which they flow. This is because the toxicity of individual constituents of effluents and various chemical compounds with different compositions is unidentifiable in most cases. Change in the toxicity of effluent largely depend on the interaction between individual constituents of the effluent and dissolved chemical substances in the river into which the effluent flows. The addition of more chemical substances to the group of controlled chemical substances for the purpose of emission control leads to an increase in analysis costs. Thus, bioassays have drawn attention as a method of identifying and controlling toxic chemical substances contained in effluents on a day-to-day basis.

The toxicity of specified substances toward aquatic life is usually expressed in TLm. This is a method of determining the degree of harmfulness of acute toxicants in pollutants to aquatic life. However, it would be premature to use this method to find the safety level of concentration for the survival of aquatic life. The fact that no aquatic life dies at a certain level of concentration does not mean that no aquatic life is affected at all by the level of concentration. Therefore, to set the impermissible level of concentration to the level at which animals start to die is likely to disastrous consequences. The impermissible level of concentration should be the level at which physiological or biochemical abnormalities are induced. There are many kinds of methods of finding the level of concentration which are based on changes in indexes. Those indexes are based on the determination of evasion reaction level, the findings of pathological studies, the identification of opening and closing movement and the heart rate of sea shells, the analysis of the zymogram of serum protein, the determination of the RNA content of tissue sections, dehydrogenase reactions, etc.

In Japan, effluents produced through industrial activities and those discharged through sewer pipes which have already been treated are diverted into a stream or a pond located within the premises of the sewer treatment plant to keep aquatics in there. This is for the purpose of ascertaining that the treated waste water is safe and showing a convincing approach to environmental protection at the sewer treatment plant.

The following is a bioassay unit used to monitor the quality of the water of the Rhine, as a method of monitoring WWTP treated water. Harmful chemical substances may affect life or death, growth, breeding and behavior of aquatics and behavior is most easily affected at a lower level than any higher levels all the others are affected at. This unit is useful in obtaining information on how aquatics are affected in real time. The introduction of such a unit is relatively easy. For example, when harmful substances flow into the measuring compartment as shown in the figure below, fish show unusual behavior. In such a case, fish begin touching the reaction bars frequently and this is automatically monitored by the sensor. In other words, the unit provides information on environmental changes automatically and responsively.

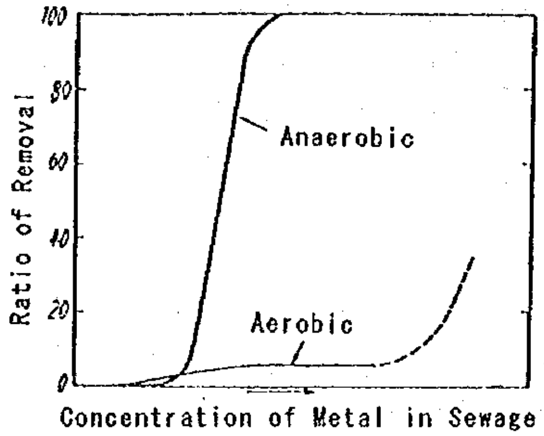
Fig. 4: Bioassay Unit Used For Monitoring Water Quality of The Rhine



4.4 Heavy Metals

Biological treatment conducted for sewer treatment is a treatment process using a metabolic function of microorganisms. Metallic substances that inhibit action of enzymes of microorganisms and toxic chemical substances such as cyanide never be contained in the effluent to undergo biological treatment. In the event that one of these substances is contained in the effluent, the microorganisms' function of resolving and synthesizing organic matter does not operate properly and treatment efficiency will be affected as shown in Fig. 4.4.1.

Fig. 4.4.1 Change in Treatment Efficiency During Sewer Treatment Process



The main active inhibitors that give serious damage to purified microorganisms at a very low level of concentration are some heavy metals. The following shows a correlation between how the activation of respiration is affected by representative heavy metals and the volume of organic matter decreased. (The volume of organic matter decreased is measured in the same manner as BOD is measured.)

(1) Chrome

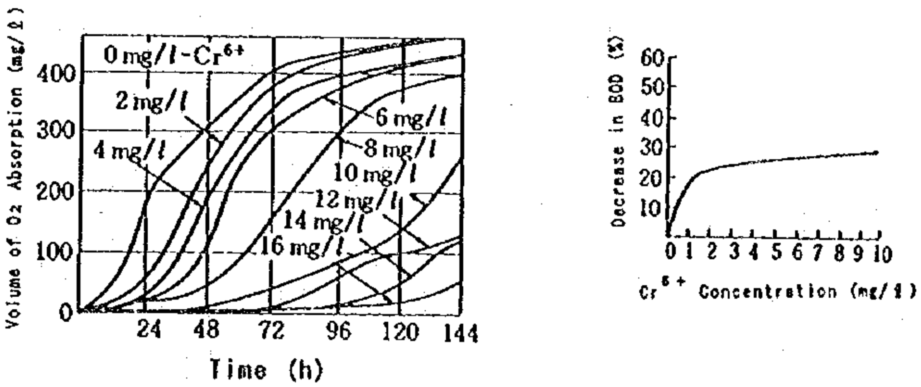
Waste water containing chrome which flows into the metropolitan sewer systems is produced by the leather industry or produced through the surface finishing process using Cr^{6+}, and, chrome is also contained in aluminum electrode waste water.

When Cr^{6+} is contained in waste water, nitrification is suspended for a short period of time. When the Cr^{6+} content is 0.5 mg/l or below, Cr^{6+} is adsorbed by activated sludge and is not found in treated waste water while it is found when the content is 2.0 mg/l or above.

It has been reported that while the biological reduction or removal of Cr^{6+} is being conducted, the chrome content of the activated sludge remains as high as 18.4% of the dry solid weight. Even if the chrome content of the solid is as high as 3.5%, the activated sludge digesting tank should normally operate.

Fig. 4.4.2 shows effect on oxygen respiration of Cr^{6+} & BOD decrement rate.

Fig. 4.4.2 Effect on Oxygen Respiration of Cr^{6+} & BOD Decrement Rate



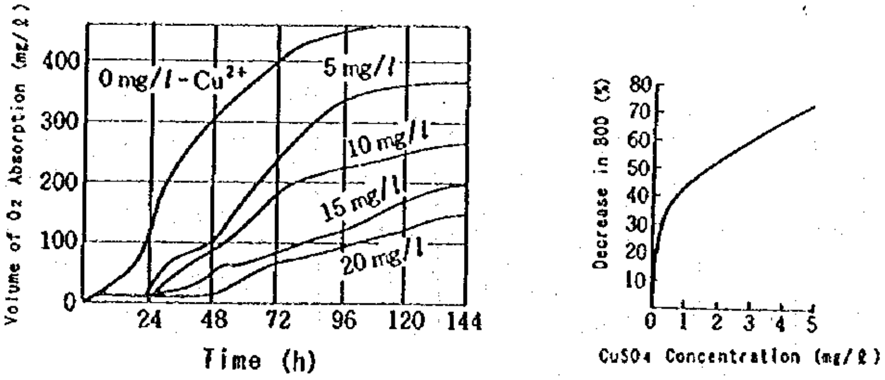
(2) Copper

Waste water containing copper which flows into the metropolitan sewer systems is produced mainly by the electro- copper-plating industry. Such waste water usually contains chemical substances that compose complex ion of copper.

The maximum level of copper concentration which does not affect sludge treatment efficiency is 1 mg/l. For a short time load at a high concentration level, the maximum level of copper sulfate concentration is 50mg/l while that of cyanide copper is 10 mg/l. Digestibility remains affected by the sludge produced by sewer treatment until the copper sulfate concentration reaches 410 mg/l.

Fig. 4.4.3 shows. effect on oxygen respiration of Cr^{2+} & BOD decrement rate.

Fig. 4.4.3 Effect on Oxygen Respiration of Cr^{2+} & BOD Decrement Rate



(3) Zinc

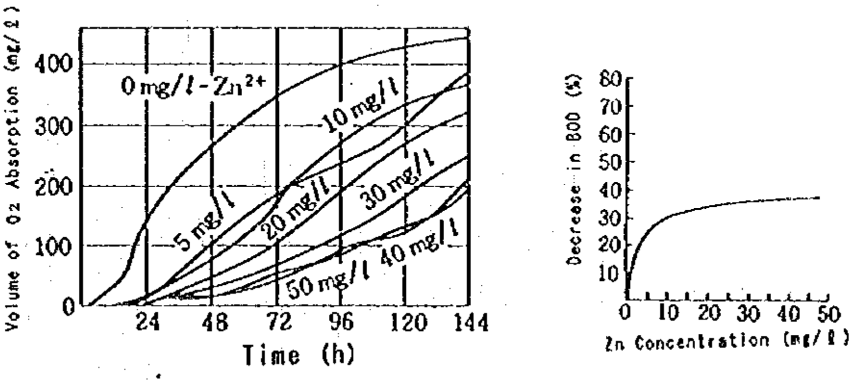
Sewage containing zinc which flows into the metropolitan sewer systems is produced mainly by the electro-plating industry; however, such sewage is also produced by organic synthesizing plants for acrylic fibers, rayon, cellophane and special synthetic rubber, etc.

The maximum level of zinc concentration which does not affect sludge treatment efficiency is 2.5 to 10 mg/l. It has been reported that a 4 hour load of 160 mg/l zinc concentration on sludge seriously affects sludge treatment efficiency for a whole day; however,the efficiency returns to normal in 40 hours.

Zinc sulfate with 20 mg/l of zinc concentration causes a digestive malfunction in no time. The maximum zinc concentration level must be kept between 10 mg/l and 20 mg/l in order to maintain the normal digestion of primary sedimentation or mixed sludge.

Fig. 4.4.4 shows effect on oxygen respiration of Zn & BOD decrement rate

Fig. 4.4.4 Effect on Oxygen Respiration of Zn & BOD Decrement Rate

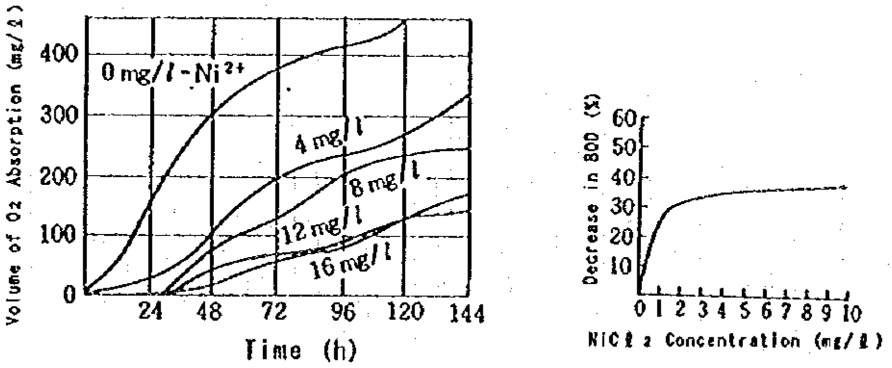


(4) Nickel

Waste water containing nickel which flows into the metropolitan sewer systems is produced mainly by the plating industry. The most remarkable influence of nickel is an increase in turbidity of sewage at a final treatment stage. The maximum nickel concentration level which does not affect sludge treatment efficiency is between 1 mg/l and 2.5 ml/l. A 4 hour load of 200 mg/l nickel concentration on sludge seriously affects sludge treatment efficiency for several hours; however, the efficiency returns to normal in 40 hours. Mixed sludge from the sewage treatment unit which receives waste water containing 10 mg/l of nickel can be adequately digested. Sludge from primary sedimentation formed out of sewage containing 40 mg/l of nickel can also be adequately digested.

Fig. 4.4.5 shows a correlation between how oxygen respiration is affected by Ni and the rate of BOD decrement.

Fig. 4.4.5 Effect on Oxygen Respiration of Ni & BOD Decrement Rate



4.5 Comments on Nitrogen & Phosphorus Removal Technique

Emission Standards for T-P in effluents are very rigorous: up to 1 mg/l for the textile industry and up to 2 mg/l for other industries. Among the factories which were visited this time, it was found that although the majority of them discharge more than 1 mg/l of T-P, very few discharge double figure volumes and most discharge single figure volumes.

This fact indicates that the level of phosphorus concentration in the effluents discharge by the entire city of Marie-Paul should be even lower.

It would be very expensive for the factories that discharge exceeding volumes of T-P to set up preliminary treatment facilities for the removal of phosphorus, as indicated by the conceptional designing conducted for each model factory. It is hence economical for them to have their effluents treated at the waste water treatment plant collectivery. (The current waste water treatment process used at the waste water treatment plant is designed to remove phosphorus, also.)

For the treatment method, please refer to " Nitrogen & phosphorus Removal " in the appendix attached to the text.

5. Application Examples of Waste Water Treatment Systems in Japan

5. Application Examples of Wastewater-treatment Systems in Japan

5.1 Metal Machining Industry

1) Outline of the plant

When crystal clocks became popular, the main manufacturing plant of a Japanese clock manufacturer, S, extended its operations from the production of precision instrument parts to the production of precision electronic parts such as printed boards, crystal oscillators, crystalline liquid panels and IC's. With the introduction of new manufacturing equipment; the company took several measures to protect the environment, including rationalization of water use, drastic improvement of the galvanizing wastewater-treatment system, measures for the prevention of water and noise pollution, and the treatment of offensive odors.

2) Wastewater treatment by semi-closed system

There are 500 sources of wastewater. Before discharge, wastewater is roughly fractionated to the circulatory system, which requires ion-exchange treatment, and the discharge system, which requires chemical treatment.

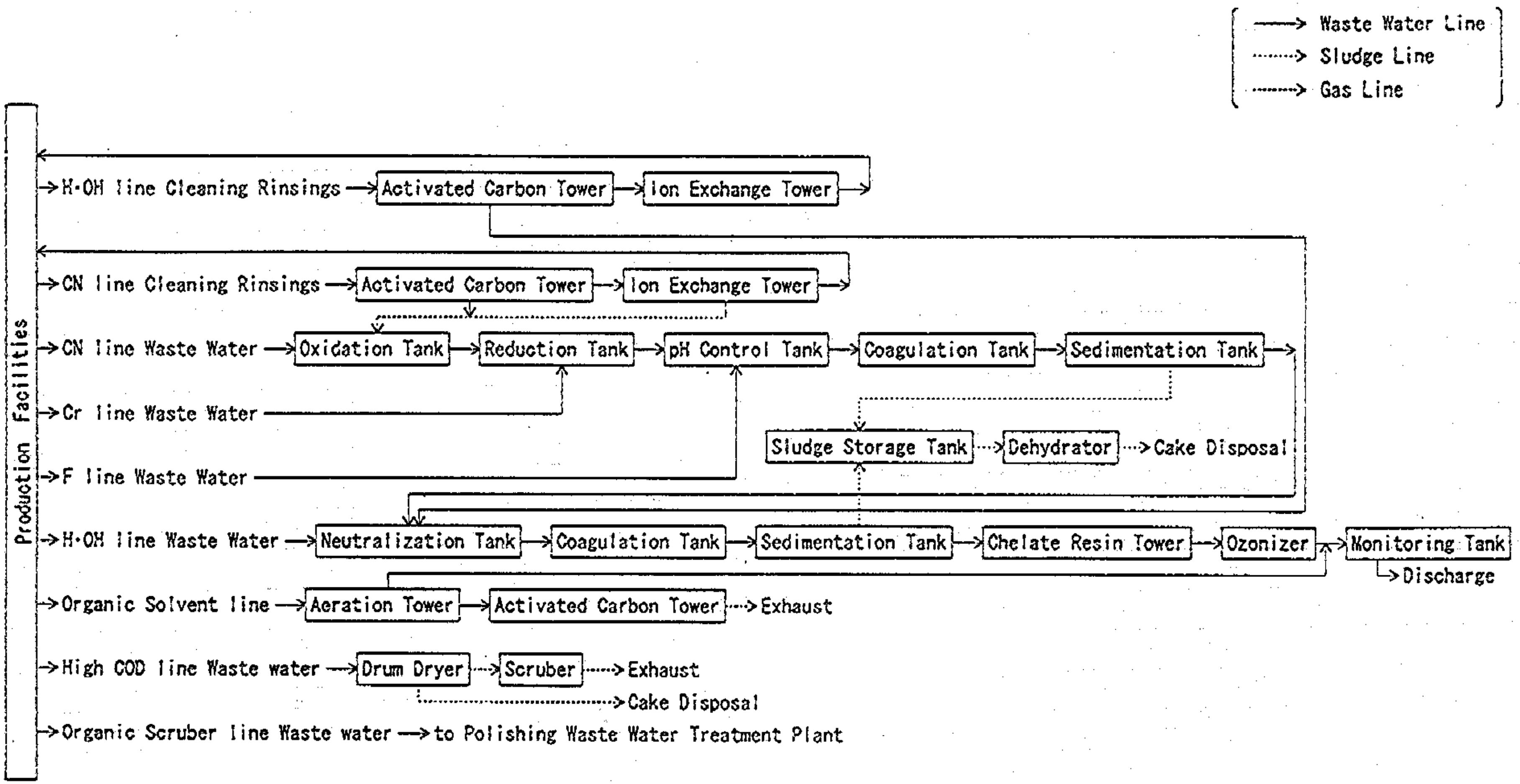
The design standards of this system are indicated in Table 5.1.1, and the flow sheet, in Fig. 5.1.1.

Table 5.1.1 Design Standards

	Water System	Water Quantity (m^3/day)
Circulatory	Acid-alkali circulatory system	570
System	Cyanogen circulatory system	100
	Cyanogen system	11.4
Discharge	Chromium system	7.0
System	Fluorine system	4.2
	Acid-alkali system	73.7
	High-COD system	2.9
	Solvent system	11.7
	Organic system	42.3

The circulatory system is composed of two systems; i.e., cyanogen-system washing wastewater, and acid-alkali-system washing wastewater. Water of both systems is reused. The discharge system is composed of four systems; i.e., cyanogen-chromium-fluorine system, acid-alkali system, solvent system, and high-COD system.

Fig. 5.1.1 Wastewater-treatment System



After organic matters are removed from the acid-alkali-system washing wastewater with an activated-carbon adsorption tower, the washing water is desalinated with an ion exchange resin tower and reused as acid-alkali washing water.

Organic matters are also removed from cyanogen-system washing water with an activated-carbon adsorption tower, and after desalination with an ion exchange resin tower, the water is reused as cyanogen-system washing water. With treatment of 570m^3/day of alkali-acid-system water and 100m^3/day of cyanogen-system water, a total of 670m^3 of reused wastewater is treated per day.

Cyanogen of cyanogen-system wastewater is first oxidized and decomposed, and then the water is treated together with chromium-system wastewater.

Specifically, heavy metal in cyanogen and chromium-system wastewater is precipitated and coagulated by means of chromium reduction and pH control, and the solid and liquid are then separated in the sedimentation tank. The supernatant is retreated with acid-alkali-system wastewater.

Fluorine-system wastewater is put in the pH control tank for the cyanogen-system wastewater and treated together with cyanogen-system wastewater.

The heavy metal in the acid-alkali-system wastewater is precipitated and coagulated by pH control, and then solid and liquid are separated in the sedimentation tank. The supernatant is chelated in the chelate-resin tower to treat the remaining heavy metal, the COD is oxidized by ozone with the use of a tank for monitoring water quality, and the water is discharged. Treated water of stable quality can be obtained by oxidizing the COD contained in galvanizing or etching wastewater with ozone.

Solvent-system wastewater is led to a tank for monitoring water quality after aeration in an aeration tower. Solvent contained in aeration gas goes through adsorption treatment in the activated-carbon adsorption tower and the gas is then exhausted into the air.

COD components of high-concentration COD-system wastewater are dried and solidified by a drum dryer and separated. Scattered substances contained in the evaporated gas are removed with a scrubber and the gas is exhausted into the air.

As a measure against offensive odors given off during wastewater treatment at the time of the reaction or the replenishment of chemicals, the sites giving off the odors are closed off and treated with a scrubber.

As a measure against underground water pollution caused by earthquakes, etc., all of the underground tanks and chemical tanks are designed with a double-walled structure.

The quality of the discharged water is shown in Table 5.1.2.

3) Treatment facilities

The treatment facilities are composed of complicated treatment systems which are comprehensively managed and controlled almost automatically from the central managing room. Maintenance of all facilities is conducted by 5 persons (four in the daytime, and one at night).

As the area of the site, 760m^2, is comparatively small for the quantity of wastewater treated, the facilities are constructed vertically extending from the third floor of the basement to the roof.

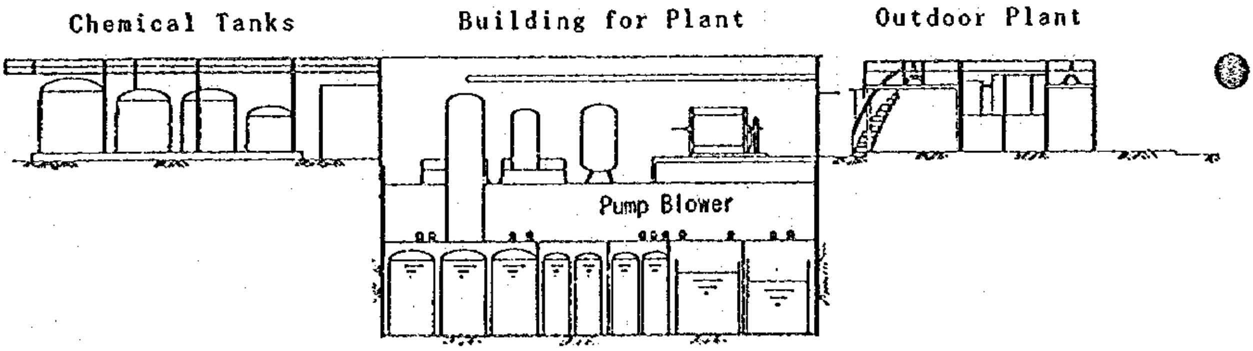
As measures against noise, the pumps are all installed on the second level of the three-floor basement, and the pump room is surrounded with 100mm-thick sound-proof walls. Consequently, the noise generated at the power source, 100 phon, is reduced to 45 phon at the border of the site. A low-noise motor which is used as the power source of the solvent tank, the only outdoor noise source, is covered with a sound-proof box with 100mm-thick walls.

The outlined section of the facilities is shown in Fig. 5.1.2.

Table 5.1.2 Quality of the Water Discharged

Item		Treated Water	Regulation Value
COD	(mg/l)	4	20
SS	(mg/l)	<1	40
F	(mg/l)	1	15
CN	(mg/l)	<0.01	1
Cu	(mg/l)	<0.05	3
Cr	(mg/l)	<0.05	2
Mn	(mg/l)	<0.01	10

Fig. 5.1.2 Outline of the Facilities



5.2 Fiber and Dyeing Industry

1) Outline:

This is a dyeing plant which exclusively dyes cloth linings made from polyester fibers. To construct a new plant on a new site, it was necessary to take measures to meet stricter effluent standards. As a specific measure to meet the coloring rate standards, an activated-carbon adsorption treatment is introduced. Slovenian trainees visit this plant for inspection.

(1) Production capacity:

Total workdays:	22 days/month Monday - Saturday (three shifts)

9 workers/night duty
+ 10 inspectors working in the daytime

Monthly production: Approx. 50,000 units a unit = 50m

Monthly production value: Approx. 100 million yen
(processing cost base due to transaction in a group)

(2) Production equipment:

Tube-type high-pressure jet dyeing machine:	8 (3 for 2,500m, 5 for 5,000m)
Alkali volume reduction line:	1
Drying line:	1

(3) Auxiliary equipment:

Boiler and industrial-owned power generator (provides 80% of the required power)
Runs all equipment

(4) Quantity of industrial water:

630m³/day 3/4 for dyeing and washing 1/4 for washing and reduction of alkali volume

(5) Heat recovery:

Recovery up to 50°C Heat exceeding 50°C has no use.

Effluent is atomized and cooled with air.

2) Wastewater-treatment system

(1) Outlined flow

Neutralization -> Activated-sludge aeration -> Contact aeration -> Coagulating sedimentation -> Sand filtration -> Activated carbon

For activated-sludge aeration, a special air mixer is used.

After dewatering, the sludge is taken out as a cake with a moisture content of 80%.

(2) Water quantity: Average 630m³/day 24 hour inflow

(3) Example of water quality record

	Raw Water	Primary	Secondary	Treated Water	Effluent Standards
		Sedimentation			
pH	10.2			7.9	5.8 - 8.6
BOD mg/l	1,100	2.7	0.8	< 0.5	Below 12
COD mg/l	550	120	51	15	-
SS mg/l	92	50	19	7	Below 20
Coloring rate			450	45	Below 80
t-P mg/l	86				-
t-N mg/l	32				-

(Note)

COD is CODmn. No standards are set on water discharged to rivers.

Coloring rate: when water is diluted by the multiples of the values of the coloring rate, its appearance is exactly the same as that of distilled water.

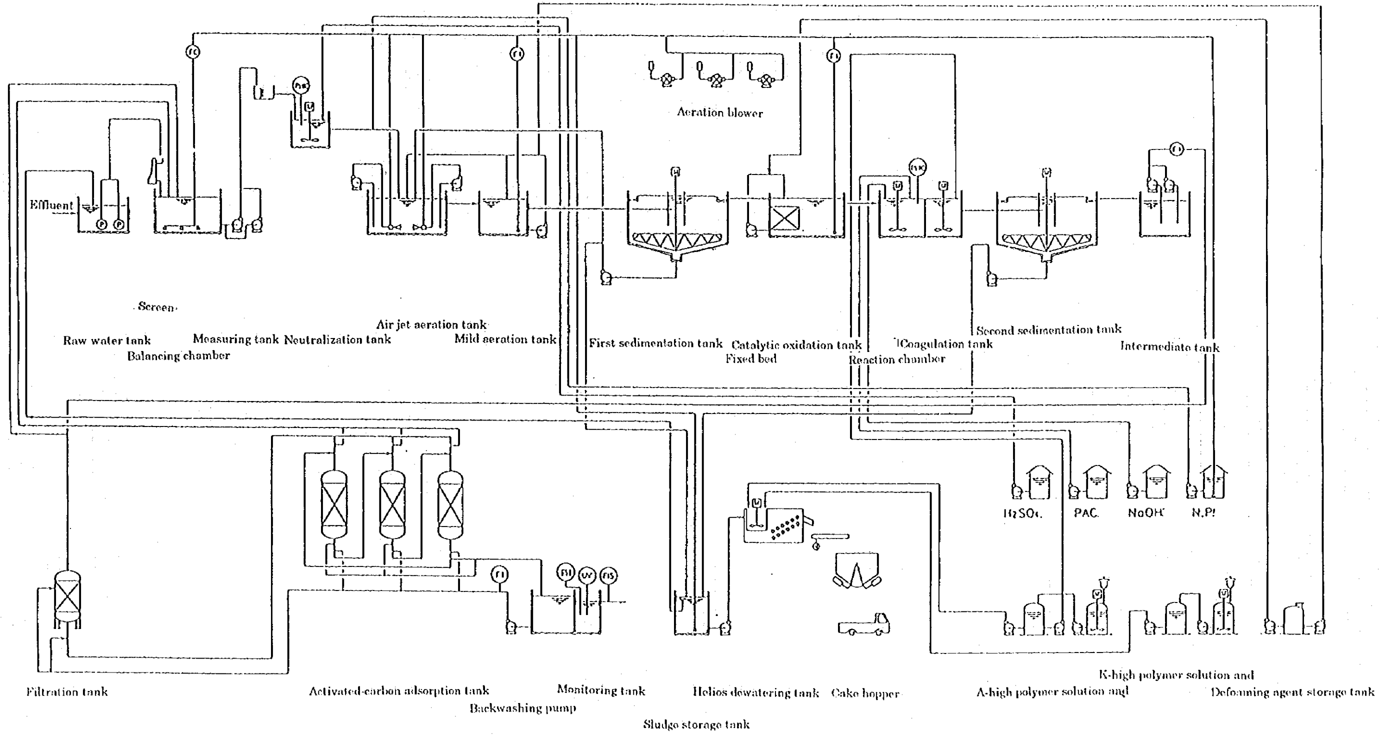
(4) Total equipment cost: Approx. 300 million yen

(For reference, total plant equipment cost is 2 billion yen, and the total amount invested, including the land cost, is approximately 2.4 billion yen.)

(5) Running cost:

Activated carbon replacement:	1.5 x 12 months = 14 million yen/year	1 tower/month
Sludge-disposal cost:	20	4t/day x 250 days
Others:	11	
Annual total:	45	depreciation cost not included
Cost per unit quantity of water:	300 yen/m^3	

Fig. 5.1.3 Flowsheet of Wastewater Treatment System at a Textile Dyeing Factory



5.3 Beer Brewing Industry

1) Outline

Although this plant used to process all of its wastewater with aerobic biological treatment, a recent renovation has made it possible separate high-concentration raw water for exclusive aerobic biological treatment. As high-concentration wastewater contains a large quantity of organic SS content, the organic SS content is solubilized and reduced in volume in an acid fermenter. Subsequently, the water goes through centrifugal separation and coagulating sedimentation, and is then passed on to the UASB stage.

The water treated with the UASB process is mixed with low-concentration wastewater and put through aerobic biological treatment. Biogas generated in the UASB process desulfurized and recovered as steam-producing energy.

Note UASB: Upflow Anaerobic Sludge Blanket

2) Treatment system (refer to the wastewater-treatment flow sheet.)

3) Quantity of wastewater

High-concentration wastewater: Squeezed barley juice and the waste liquid of waste yeast 150m^3/d

Low-concentration wastewater: 5,000m^3/d

4) Water quality

(1) Quality of high-concentration wastewater

pH : 3.5 - 5.2
SS : 35,000mg/ℓ
BOD : 38,700mg/ℓ
CODcr : 75,600mg/ℓ

(2) Quality of high-concentration wastewater after coagulating-sedimentation treatment

SS : 300mg/l
BOD : 1,940mg/ℓ
CODcr : 7,560mg/ℓ

(3) Quality of low-concentration wastewater

BOD : 1,000mg/ℓ
CODMn : 300mg/ℓ

(4) Quality of the water after final treatment

BOD : 1.0mg/ℓ
CODMn : 6 - 8 mg/ℓ

5) Quantity and Composition of Generated Biogas

Quantity Generated : Average 1,200m^3/d
Composition : CH_4 70 - 80%, CO_2 17 - 24%,

H_2S 320 - 600ppm

6) Designed load of UASB

CODcr load : 9 - 11kg/m^{3}d

BOD load : 6.5 - 7.7kg/m^{3}d

7) Economy

Following is an economic comparison between the plant's former system of aerobic biological treatment of all wastewater and the newly introduced anaerobic biological treatment:

(1) Calculation standard

① Power cost : 15 yen/kWh

② Sludge-disposal cost : 7,000 - 7,500 yen/ton -DS

③ Chemical cost : 25%NaOH 22.6 yen/l

Desulfurizer : 140 yen/kg

Polymer : 1,050 yen/kg

④ Steam-recovery cost : 2,360 yen/ton - steam

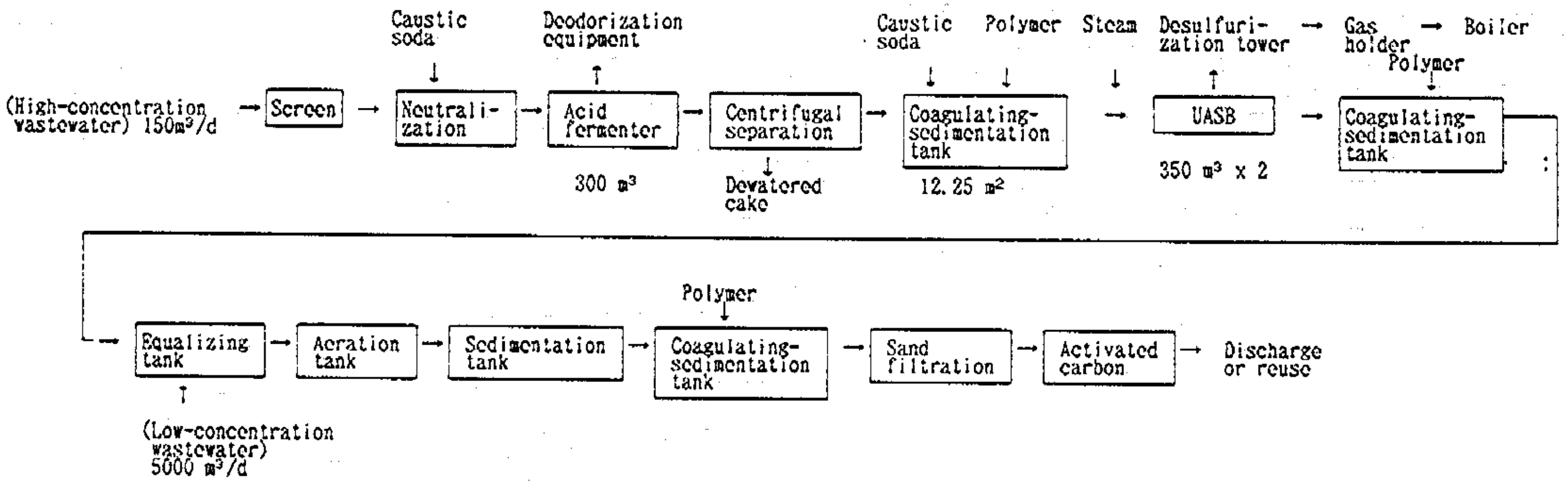
(2) Running cost: Unit: Yen/removed kgBOD

	Aerobic Biological Treatment	Anaerobic Biological Treatment + Aerobic Biological Treatment
Power cost	48	4
Chemical cost	7	18
Sludge-disposal cost	47	5
Steam-recovery cost	-	-8
Total	102	19

The running cost of anaerobic biological treatment is 102 yen/kgBOD. On the other hand, when equipment for anaerobic biological treatment is introduced, the recovered steam, which is about 1/5 of that in anaerobic biological treatment, reduces the cost to 19 yen/kgBOD. On an item-by-item basis, while the power cost and sludge-disposal cost account for more than 90% of the running cost for aerobic biological treatment, they account for only about 30% after the introduction of anaerobic biological treatment.

As anaerobic biological treatment generates small quantities of sludge and requires no oxygen-supplying power, the running cost can be reduced somewhat. On the other hand, however, the chemical cost required for anaerobic biological treatment is 18 yen/kgBOD, 2.6 times higher than that required for aerobic biological treatment (7 yen/kgBOD). This cost is driven up primarily by the requirement for caustic soda for neutralization after acid fermentation.

Fig.5.1.4 Flowchart of Wastewater Treatment System at a Beer Brewing Factory



Flowsheet of Wastewater Treatment System

5.4 Meat Industry

1) Outline:

The government and private companies invest jointly in this meat plant. The nation, the prefecture (Chairman), the city (President), Japan Agricultural Cooperatives, and related companies bear the plant's working expenses, which total 8.57 billion yen. As the plant was constructed in a new industrial park, measures had to be taken to meet much stricter standards. Activated-carbon adsorption was adapted in the plant primarily to meet the extremely strict COC standards. Slovenian trainees visit this plant for inspection.

(1) Production capacity:

Total workdays	:22 days/month (Monday - Saturday), 6 hours/day
Daily production capacity	:50 cows and 1,000 pigs

(2) Employees: 130 man-days

There is a center for the maintenance and management of the facilities and the guidance and superintendence of business. There are also outside workers for butchery and dismantling, meat processing, and operations at wholesale markets. There are even prefectural inspection and grading agencies.

(3) Facility costs: A large ratio of the facility costs goes towards protection of the environment.

Total cost for acquisition of the facilities	: 4,392,835,000 yen
Total cost of facilities for the protection of the environment	: 1,286,614,000 (29%)
Wastewater treatment There is a special water quality agreement):	906,656,000
Incineration Building (Use is suspended due to its offensive odor)	: 247,282,000
Building for sick cattle	: 23,152,000
Tree planting (29% of the site)	: 109,524,000

2) Wastewater-treatment system

(1) Treatment method (refer to the flowchart)

Treatment process:	Treatment method
Primary treatment:	Solid and liquid separation screen, pressure flotation of oil
Secondary treatment:	2-stage oxidation-type activated sludge
Advanced treatment:	Nitrification, denitrification, oxidation, coagulating sedimentation, sand filtration, activated carbon
Sludge treatment :	Mechanical dewatering (taken out as a cake of 80% moisture content)

(2) Designed water quantity and water quality:

Water quantity 1,440m³/day 6 hour inflow, 24 hour treatment

Water quality	Raw water	Treated water	Record (96 Jan.)
BOD mg/l	1,300	8	< 1
CODmn mg/l	500	8	3.6
SS mg/l	900	8	< 1
Oil mg/l	200	5	< 1
T - N mg/l	210	7	1.8
T - P mg/l	70	1	< 0.1

Blood is separated and specially treated outside the plant.

In addition to a biannual inspection of water quality by the administration, a monthly inspection is also conducted on a voluntary basis.

(3) Reuse of treated water

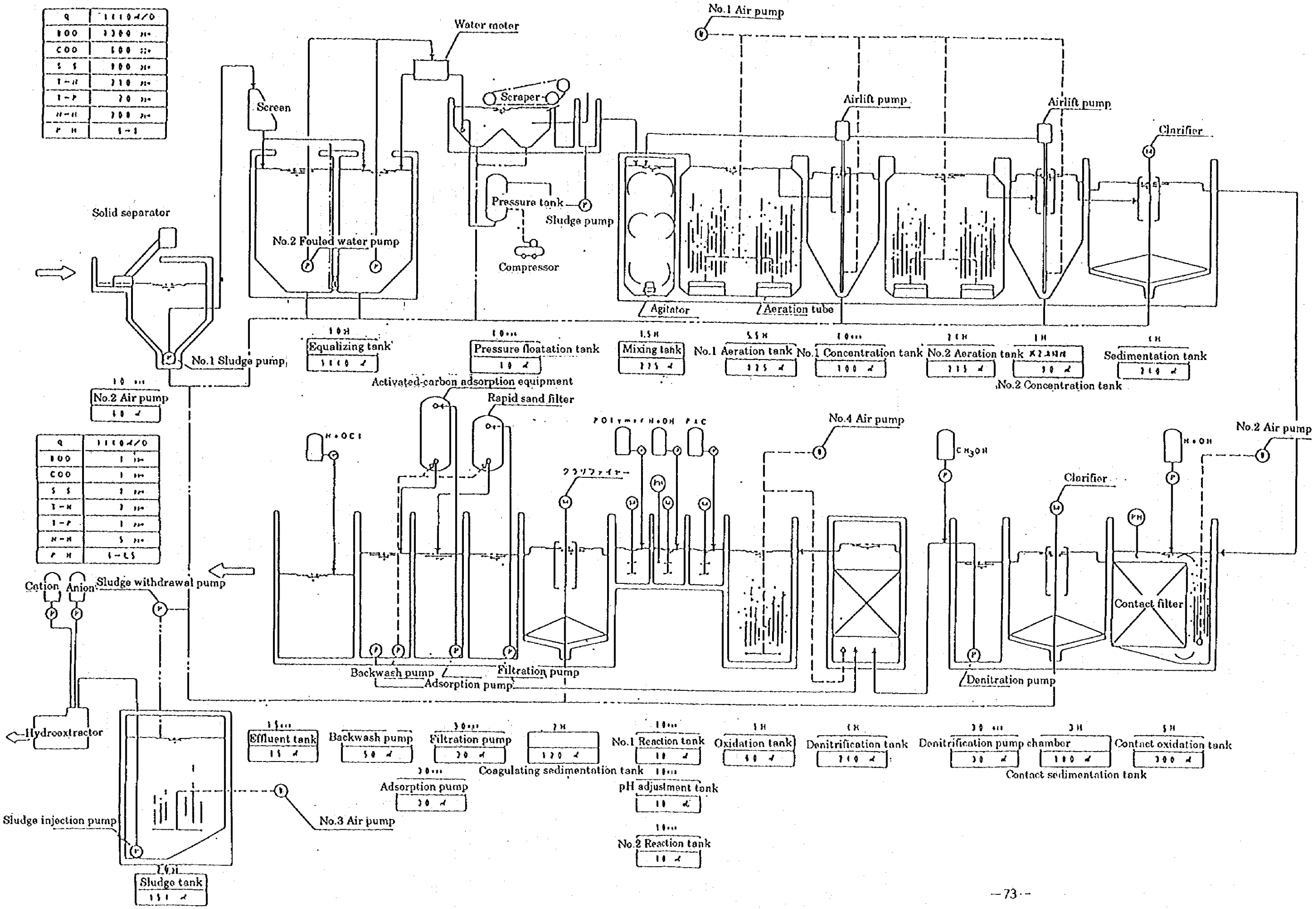
The quality of the treated water is very good. Approximately 170 - 180m³/day of the treated water is used for washing cars, cleaning floors, and watering trees. This means that the amount of water actually discharged equals the amount of water treated minus the amount of water reused.

(4) Running cost:

(According to the record of 1995)		Per unit quantity of water
Chemicals	: 4,930,000 yen	
Power	:12,837,000	
Sludge disposal	:15,290,000	
Analysis	: 288,000	
Sub-total	:33,343,000	159 yen/m³
+Personnel	:15,108,000	231
+Depreciation	: 7,107,000	265
(excluding subsidies, fixed rate)		
Total	:55,560,000	655

As the industrial water costs 120 yen/m³, the total cost of water is 775 yen/m³.

Fig. 5.1.5 Flowsheet of Wastewater Treatment System at a Meat Factory



6. Guideline for Conservation of Industrial Water

6. Guideline for Conservation of Industrial Water

Conservation of industrial water means the effective use of the minimum required amount of water. It does not mean to reduce the amount of water to less than that which is needed. However, as explained below, it is very difficult to reduce the amount consumed to the minimum required volume, and the required level of water quality is often unclear. In promoting water conservation, these basic questions should be answered.

6.1 Preconditions for water conservation

There are several aspects of water conservation, each with its own preconditions. Several of these preconditions are enumerated below.

(1) Water use costs

The following four costs are included in the total cost for water use. The reduction of these costs is sometimes necessary for effective use.

① Water intake cost

This cost includes the charges for industrial water supply, potable water supply, surface water intake, pumping for well water, etc.

② Water treatment cost

This cost is applied when the water intake cannot be used without further treatment (e.g., the removal of iron, manganese, suspended solids, etc.).

③ Wastewater treatment cost

This is the cost of treating wastewater until it can be discharged without any problems. Public sewerage charges are also included in this cost.

④ Recycling cost

Various facilities will be needed in order to recycle water for reuse after it has been used once. Construction and running costs for power, chemicals, etc., are incorporated in this cost.

(2) Water supply quantity

If the water supply quantity is limited, there will be an even greater need for conservation of the available water.

The following cases are believed to constitute limitations in the water supply.

① The water supply from the industrial water system, surface water, river-bed water, etc., is limited.

② The pump-up quantity of groundwater is restricted due to lowering of the groundwater level, land subsidence, salination of well water, etc.

③ The increased demand for water supply to meet increased production is not satisfied because of the poor water resource.

(3) Environmental protection

Restrictions in the quality and quantity of wastewater will differ with the direction in which the wastewater is discharged. However, the primary restrictions will normally apply to the quality of water, i.e., levels of COD, BOD, etc.

On the other hand, if the wastewater is to be discharged to the closed water area, the total emission control (ex. COD x wastewater quantity) will be applied. In this case, the effluent volume will have to be reduced to the maximum possible extent through water conservation, and reductions in the concentrations of pollutants will also be needed. In Japan, the total emission control has been applied for closed water areas such as lakes, marshes, and the closed sea area (e.g., the Tokyo Bay and the Seto Inland Sea).

6.2 Water-Conservation Procedure

Water conservation simply means saving water, but practical application of the procedure will be limited. In very broad terms, the procedure can be classified as saving water, recovery use, and wastewater reclamation.

6.2.1 Saving water

(1) Thorough control of water usage

The objective of water usage control is to control and reduce the amount of water flowing which is never used. The control procedure itself will differ from factory to factory, and will fall under the following three categories.

① Improving awareness of water saving

If this approach involves only efforts to reduce water consumption on an individual level, it will be difficult to obtain thorough effects through simple training alone. However, if thoroughness is planned through a refined operational manual, a major effect could be expected.

② Accurate measurement of the quantity of water usage

Water usage control would not be possible without accurate knowledge of the water flow rate at each usage point. However, as the installation of flowmeters at each point would be impractical, expedient procedures such as the following will be applicable.

a) Install a meter at each main water usage block.

b) Install meters at main water usage points within each main water usage block.

c) Estimation of flow rate at other points based on pipe size, valve openings, etc.

d) Drawing up of Table and Figure.

Examples are shown in Tables 6.1 & 6.2 and Figures 6.1 & 6.2.

③ Preparation of the operational manual based on the minimum requirement of each water usage point

It is extremely difficult to ascertain how much water needs to be used for a particular purpose. For cooling water, the quantity is normally determined by the design specifications for the equipment and devices, but these specifications often allow for considerable surpluses in the amounts of water to be used, and the quantities the equipment and devices require vary with water temperature and years of service.

Amounts of washing water used are often determined by experience, and, since they often have a bearing on product quality, limits are difficult to investigate experimentally. Nevertheless, even though the usage cannot be reduced to a minimum level, an operational standard for the amount of water needed under the present level of technology will certainly have to be determined.

(2) Application of water-saving-type devices

The water-saving-type devices are defined as devices which have been especially designed and manufactured to perform all of their intended functions with minimized usage of water. As it is particularly difficult to save washing water, most water-saving-type devices are used practically in the field of washing processes. The following four types of water-saving-type devices are classified according to their water-saving principles.

① Systems to eliminate usage of water when it is not required

a) Automatic water supply control system

A solenoid valve installed in a water supply pipe switches on and off automatically when the production equipment goes into operation or is stopped. Although this type of system is not efficient for devices which are operated continuously over long periods, it can be effective in lines which are used intermittently.

b) Automatic urinal flusher

A device which supplies water to flush a urinal during service time or in accordance with the number of users. The former type is based on a time switch, and the latter, on a detector. Examples are shown in Figure 6.3.

c) Hand control valve

A valve mounted at the end of a water hose to allow an operator to freely control the water discharge at hand.

When washing is carried out with a water hose, water is discharged wastefully during the moments after the operator turns on the main valve, and before he turns it off. In addition, the operator often moves to another work for brief periods without bothering to close the main valve. Therefore, the use of the hand control valve is expected to conserve a considerable amount of water.

An example is shown in Figure 6.4.

② Countercurrent multistage washing system

This is a widely used and extremely efficient washing system which requires reduced amounts of water for the same washing effects. Typical examples of washing devices which incorporate this system include bottle washers in the food industry and metal plating equipment in the metal product industry.

An example of this system is shown in Figure 6.5.

③ Local recycling use

This system is incorporated into processes such as waste gas scrubbing, etc. An example is shown in Figure 6.6.

④ High-pressure washing system

In high-pressure spray washing systems, spray nozzles are used to reduce water consumption but the water pressure is increased to maintain the washing effect. High-pressure jet washers are used for washing the insides of tanks and floors.

6.2.2 Recovery Use

Recovery use means the re-use of water which has already been used. The method can be classified as cascade use and recycling use.

(1) Cascade use

Water which has been used for some applications can be used for other applications without treatment. This is known as "cascade" because of its similarity to the successive flow of water from upstream to downstream. If this system can be implemented, no costly installation will be required and running cost will be low. Although this would comprise an extremely effective water-saving system, the following items require investigation for adaptation.

① Quality and temperature of the used water must be suitable for the intended application.
In the case of a typical cascade use, the use of indirect cooling water (e.g., compressor cooling water) effluent for other purposes, high temperature of the cooling water effluent (35 to 40 °C) often precludes its use for other purposes which require cooling. However, if it is used for washing (for washing textiles after dyeing, for example), the high temperature could be an advantage.

② The quantity of used water should be about the same as the quantity of water to be used for the intended application.
One of the main conditions for cascade usage is that the water quantities required by both users are roughly the same.

③ Operating conditions on the discharge side should be similar to operating conditions on the usage side.

Even if the daily quantities of usage are roughly the same, cascade usage will be difficult if the operating periods on both sides are substantially different or the operating times are not coordinated.

(2) Recycling use

In a broad sense, recycling use and recovery use are about the same, but here, in a narrow sense, recycling means the repeated use of untreated effluent from a certain application in the same application. The most typical example, shown in Figure 6.7, is a system using a cooling tower for the recycling use of indirect cooling water from a compressor, air conditioner, etc. Assuming that the water flows into the inlet of the tower to be cooled at 40 °C and flows out at the outlet at 30 °C (a temperature difference of 10 °C), the flow in each section is proportional to the ratios shown in Figure 6.7, and a supply of about 5% of the recycling water volume would be sufficient.

6.2.3 Reclamation of Wastewater

Reclamation use is the reuse of wastewater after appropriate treatment for the improvement of its quality. With the exception of some very rare types of wastewater, the use of recent technology enables water of any quality to be obtained from wastewater. Consequently, the question of whether or not to reclaim wastewater is purely an economic one. Three general types of reclamation systems are enumerated here.

(1) Local reclamation system

This is a system in which wastewater is taken from one specific process, given appropriate treatment, and reused for the same purpose in the same process. The system is shown in Figure 6.8.

(2) Factory reclamation system

This is a system in which the water discharged from various processes within a factory is collected, given reclamation treatment, and reused in the same factory. The system is shown in Figure 6.9.

(3) Regional reclamation system

In this system, which is applied in areas such as an industrial estate where a number of factories are located together, wastewater from each factory is treated collectively and resupplied as industrial water. The system is shown in Figure 6.10.

Although all three of these systems have their own advantages and disadvantages, the local reclamation system and factory reclamation systems are considered more economical and readily implementable.

Table 6.1 Water Consumption and Equipment Data Sheet

Place	Use	No.	Process or Equipment Name	Water Consumption in Operating Day classified to source 1) (m^3/d)					Op Hr (h/d)	Op Day (d/y)	CW Temp. at Out let (°C) 6)	Specification of Equipment and Operating Method	Remarks
				WW 2)	PW 3)	OW 4)	RW 5)	Total					
Total													

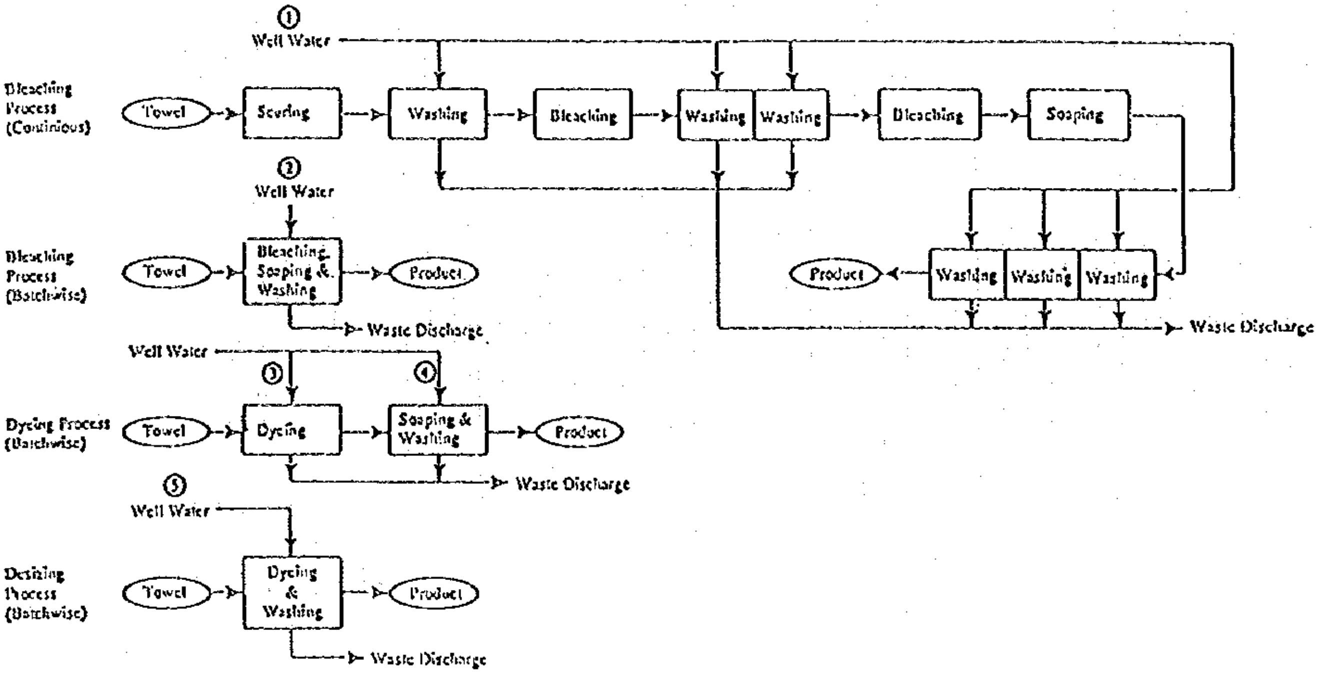
Note : 1) Please fill in annual average quantity of operating day.
Please fill in additionally peak quantity in ( ) if seasonal change is high.
2) WW = Well water. 3) PW = Potable Water. 4) OW = Riverbed and/ or Surface Water. 5)RW = Recycling Water.
6) CW = Cooling Water.

Table 6.2 Water Consumption and Equipment Data Sheet

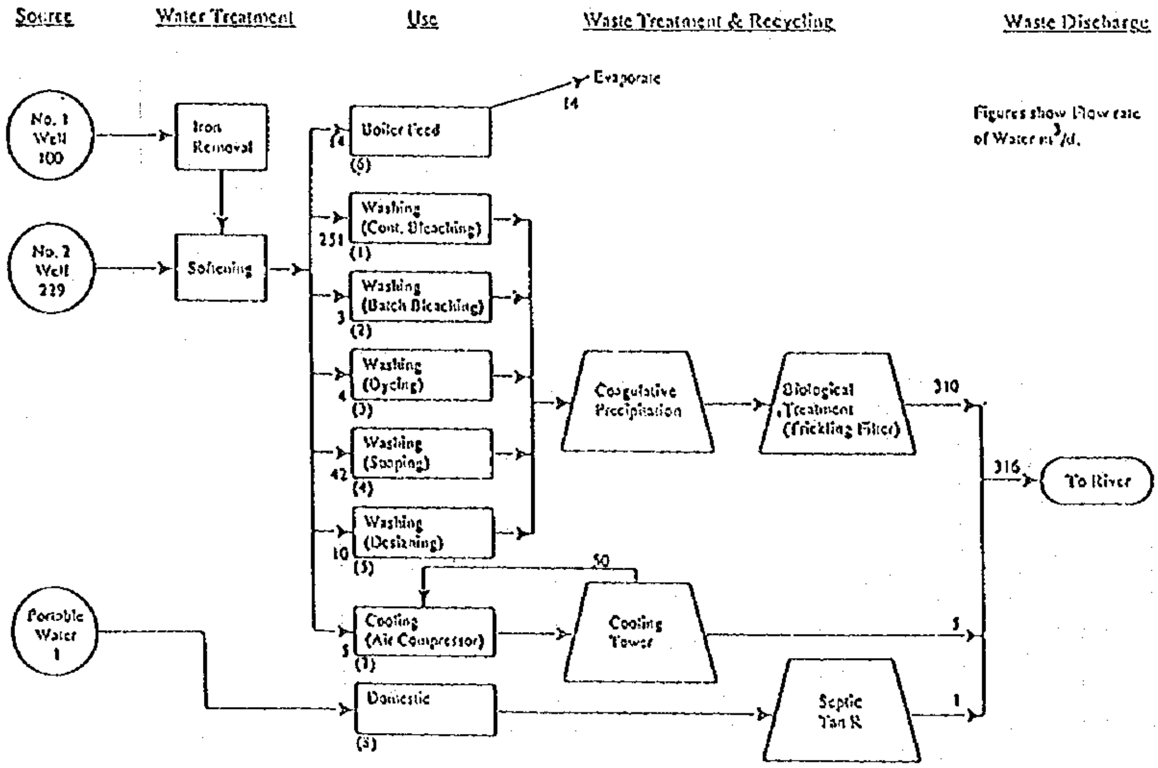
Place	Use	No.	Process or Equipment Name	Water Consumption in Operating Day classified to source [1] (m³/d)					Op Hr (h/d)	Op Day (d/y)	CW Temp. at Out let (°C) [6]	Specification of Equipment and Operating Method	Remarks
				WW [2]	PW [3]	OW [4]	RW [5]	Total					
Plant A	Washing	1	Continuous bleaching	251				251	7	291		1 unit	
	do	2	Batch bleaching	3				3	4	291		Winch type 1 unit	
Plant B	do	3	Dyeing	4				4	7	291		Overmyer type 4 units	
	do	4	Soaping	42				42	7	291		2 units	
	do	5	Desizing	10				10	6	291		Winch type 1 unit	
Plant C	Boiler Feed	6	Boiler	14				14	9	291		Max. Capacity 4 tons/hr	
	Cooling	7	Air-Compressor	5			50	55	9	291	35	Recycling use 42 °C to 35 °C	Cooling Tower
Office	Domestic	8	Drinking Toilet, etc		1			1	9	291			
			Total	329	1		50	380					

Note : 1) Please fill in annual average quantity of operating day.
Please fill in additionally peak quantity in ( ) if seasonal change is high.
2) WW = Well water. 3) PW = Potable Water. 4) OW = Riverbed and/ or Surface Water. 5)RW = Recycling Water.
6) CW = Cooling Water.

Fig.6.1 Flow Diagram of Water Supply and Water Discharge



Process Diagram of Production Line



Figures show Flow rate of Water m³/d.

Fig.6.2 Drawing of Factory Layout

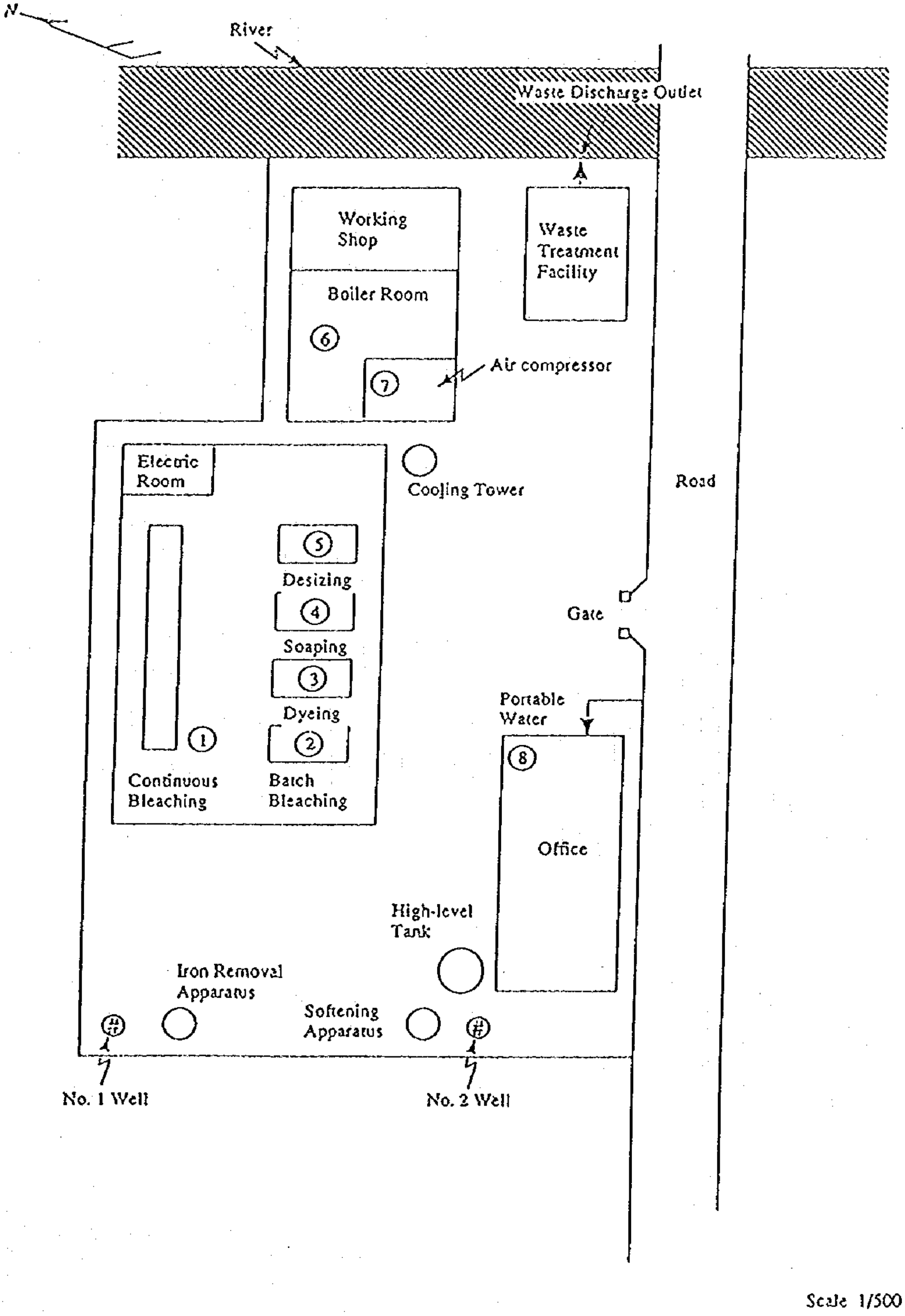
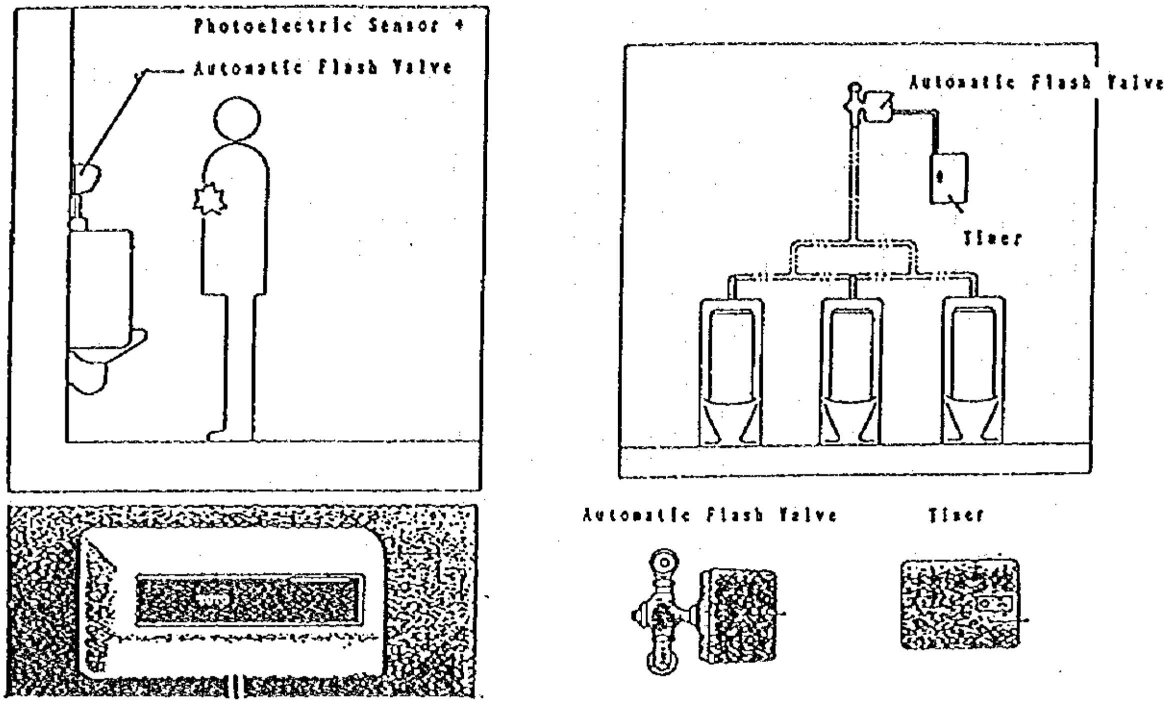


Fig.6.3 Automatic Urinal Flusher



(1)Detector Type

(2)Timer Type

Fig.6.4 Hand Control Valve

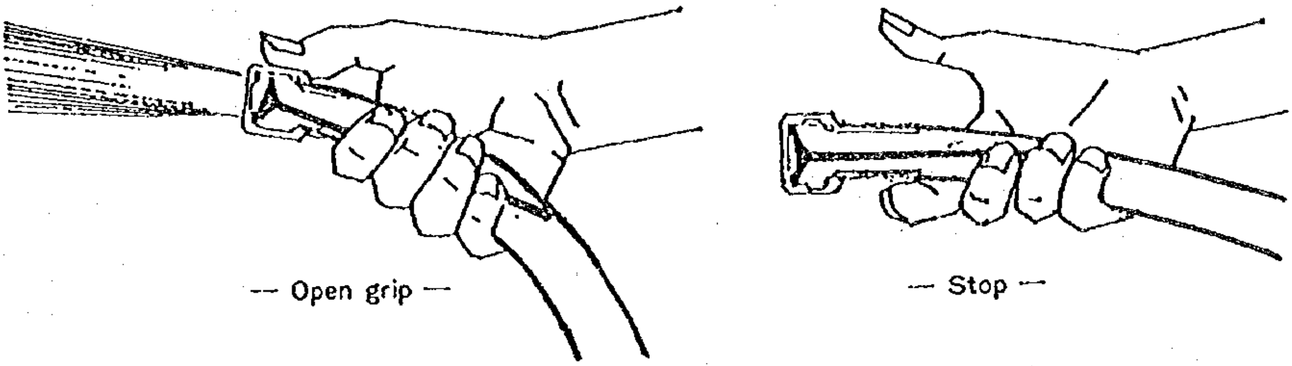


Fig.6.5 Example of Counter-Current Multistage Washing System

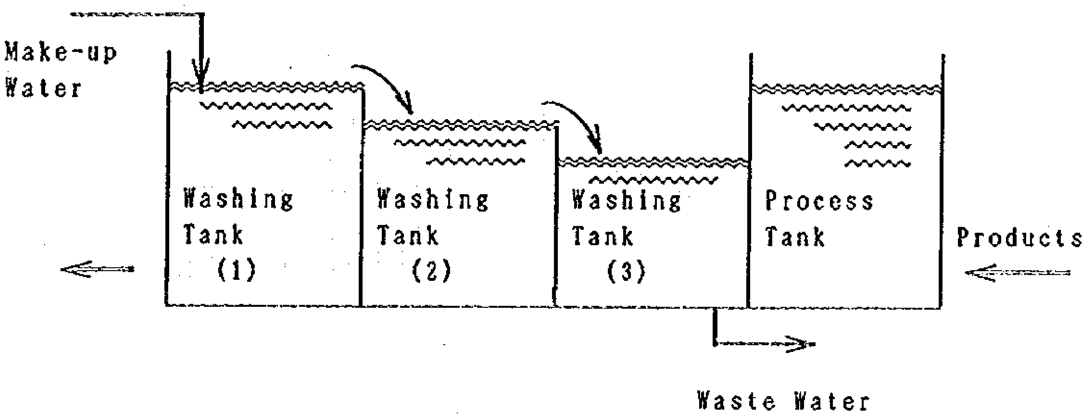


Fig.6.6 Waste Gas Scrubber

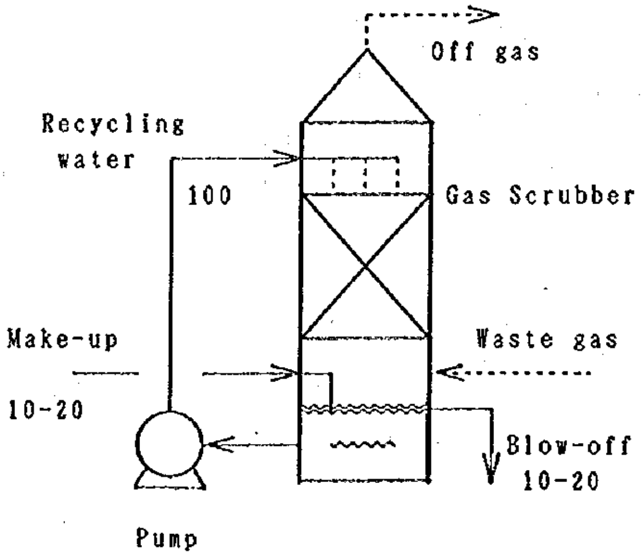


Fig.6.7 Recycling Use with Cooling Tower

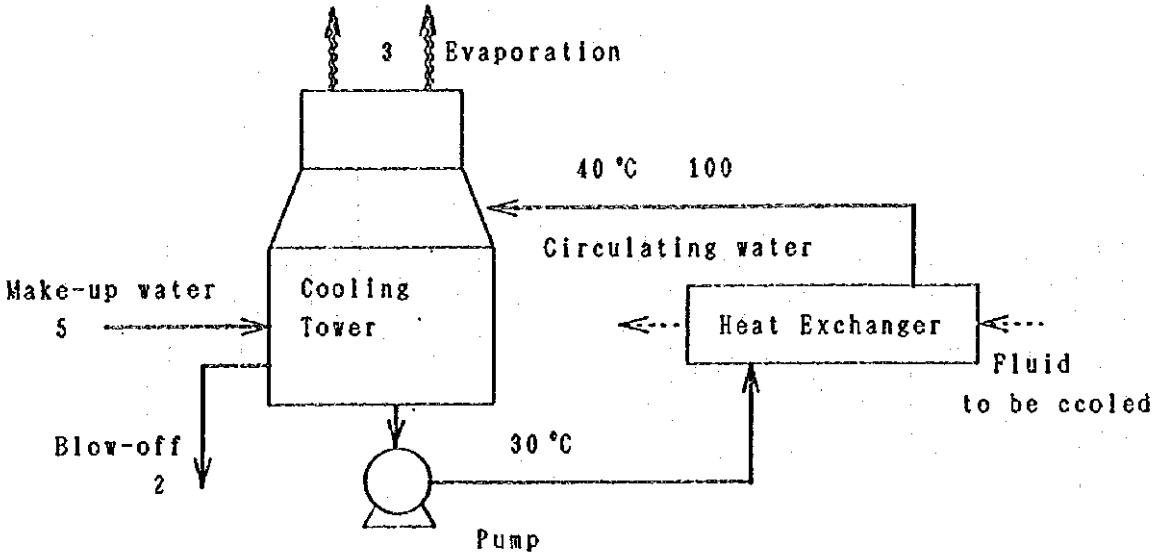


Fig.6.8 Local Reclamation System

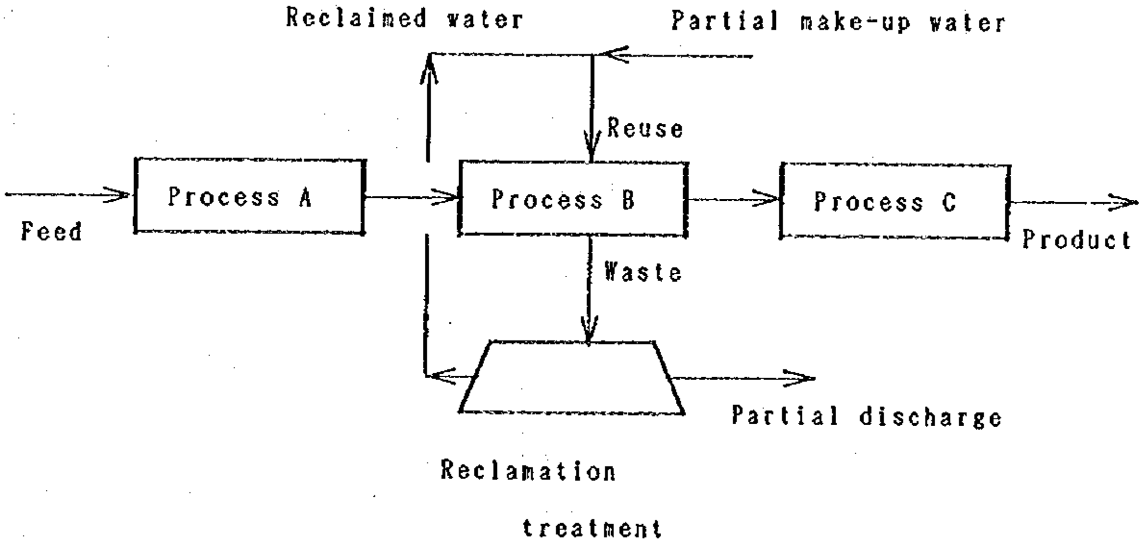


Fig.6.9 Factory Reclamation System

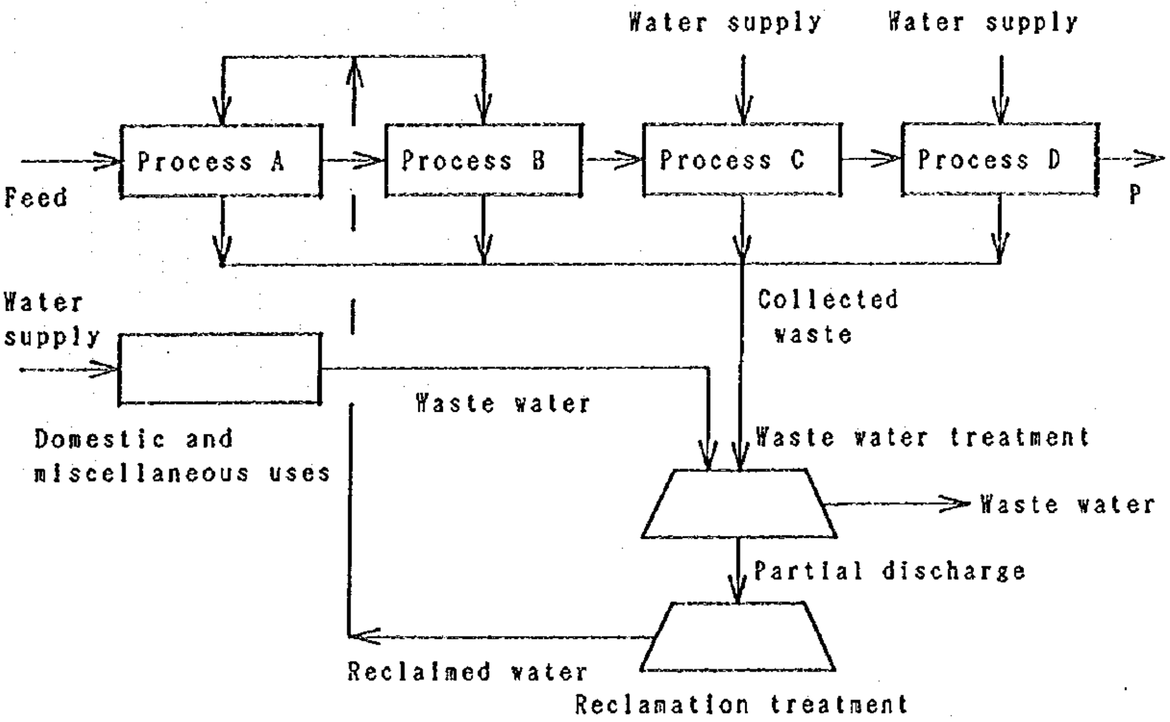
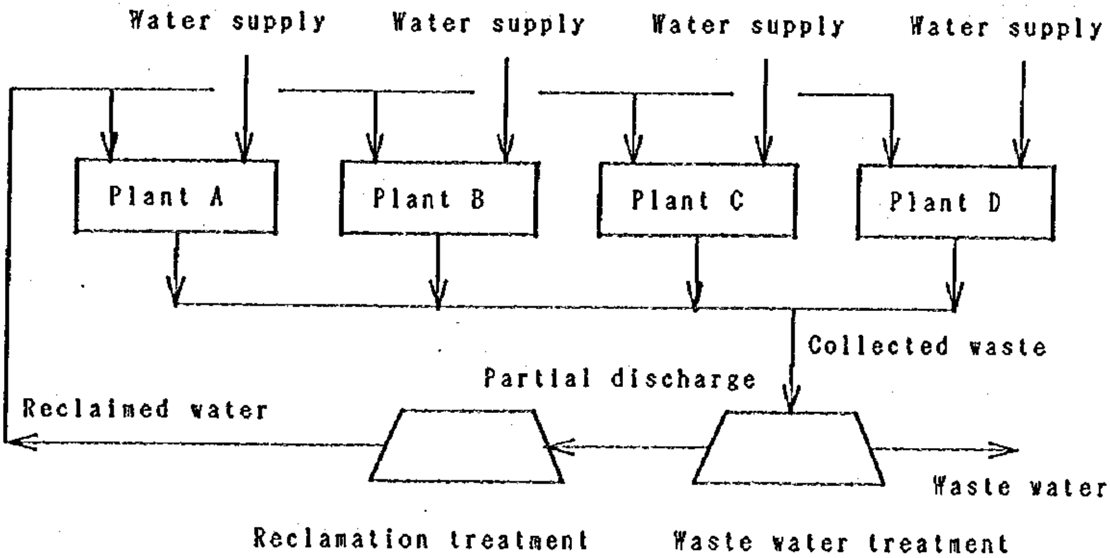


Fig.6.10 Regional Reclamation System



7. Japanese Environmental Administration

7. Japanese Environmental Administration

7.1. Transitions in Environmental Administration

7.1.1. Japanese Environmental Problems

In the years between 1950s through to the 1970s, Japan experienced serious environmental problems in the form of industrial pollution, such as air pollution, water pollution, and noise problem. It is thought that the following characteristics, which are unique to Japan, contributed to such.

① The promotion of high economic growth policies, the modernization of industrial structure, and the industrialization of heavy chemicals were essential after the war due to the fact that Japan has few natural resources.

② Production and consumption activities are concentrated in certain areas due to the fact that a mere quarter of the total land area (370,000km^2) is habitable, while the rest is mountainous.

③ Inadequate preparation of public funds for living environment-related facilities contributing to the reduction of pollution.

In the midst of this, pollution problems became a serious social issue, and in the 1960s there were four major pollution-related court cases. In response to the increasing awareness of pollution-related problems, it became necessary for the government to strengthen pollution-related regulations.

An outline of the four major pollution-related court cases is shown in Table 7.1.1. Three of these were related to water contamination. The cause of such problems was the ingestion of drinking water and fish contaminated with heavy metals over extended periods of time.

Table 7.1.1 Outline of Four Major Pollution Suits

Case	Brought before the court	Judgement delivered	Outline
Niigata Minamata Disease Suit (The Agano River Mercury Poisoning)	June, 1967 (The first phase)	September, 1971	Poisoning incident caused by ingesting fishes contaminated by organic mercury discharged from a chemical plant.
Yokkaichi Asthma Suit	September, 1967	July, 1972	Respiratory disease incident caused by emission from six petrochemical plants.
Itai-Itai Disease Suit (Remark)	March, 1968 (The first phase)	June, 1971 Judgement by the appeal court August, 1972	Cadmium poisoning incident caused by ingesting agricultural products, fishes and water contaminated by Cadmium discharged from a mining plant.
Kumamoto Minamata Disease Suit	June, 1969	August, 1973	Poisoning incident caused by ingesting fishes contaminated by organic mercury discharged from a chemical plant.

(Remark) Itai-itai disease: otherwise called "Ouch-ouch disease."

7.1.2. The History of Environmental Administration

In Japan, industrial pollution problems became a social issue during the period of high economic growth during the latter half of the 1960s. Many environmental-related laws were promulgated and amended by the pollution diet of 1970, which continue to become more strict and comprehensive as time goes by. Some of the main points are listed below.

① The enactment of the basic law for environmental pollution control of 1967. The introduction of serious pollution control regulations.

② The pollution diet of 1970. The approval and enactment of 14 pollution-related laws.

③ Drastic amendment of the basic law for environmental pollution Control and the enactment of the environmental basic law (1993) in order to cope with new environmental problems on a global scale.

Fig.7.1.2 Legal Related to Pollution and the Environmental