REPORT BY THE COMMITTEE ON EXAMINATION OF DYE WASTEWATER ADVANCED TREATMENT TECHNOLOGY

1975

JAPAN ENVIRONMENT CORPORATION

This Research studied and surveyed the dye wastewater advanced treatment technology and has been discussing the method four times since the 1st discussion held on July 24, 1974.

Since then, the attached intern report was submitted based on which the study and research on the dye wastewater advanced treatment technology was conducted .

This is to report the vesults created based on the survey and reseabch.

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1. Necessity of Establishing the Dye Wastewater Advanced Treatment Technology

1.1 preface

In manufacturing textile goods, dyeing processing is a significant stage for raising raise their commercial value. Specialization in this specific stage has improved in the textile industry, and, in many cases, dyeing and its related stages are independent in terms of the form of the company. Dyeing arrangement is an industry (that consumes) large amounts of industrial water which is mainly composed of chemical substances. The type of fabric are diverse, and the number of kinds of raw materials, including dyes and the number of types of necessary materials, are large. In addition, dyeing methods and processes are complex and adopt diverse unit operations, and it may safely be said that the number of types of products is infinite. Locations of the companies are widely distributed nationwide. Many of the companies have developed as local industries, and their growth is supported by an abundant supply of good quality industrial water.

There are very few cases in which hazardous substances are contained in the wastewater, but the wastewater is diverse in terms of components. In addition, , there are many components, such as dyes and surfactants, which are difficult to treat, and so advanced treatment is required and the treatment costs tend to be higher. Furthermore, the quality and amount of wastewater greatly change with the passage of time and are not uniform. Therefore, it is difficult to lay out a treatment plan.

It is not only technically difficult but economically difficult to implement the dye wastewater treatment because the management scale of the dyeing arranging companies is small, and many of them are subcontractors.

If roughly observed, the state and problems of the dyeing arranging industry are as follows. Of the enfire 526 companies concerned in the textile machinery dyeing arranging industry and woolen textile dyeing arranging industry, the number of companies with a capital of 10 million yen or less is 246, accounting for 46.8%. In particular, of the 1,200 companies inrolved in the dyeing arranging industry for thread and knitted goods, the number of companies with a capital of 10 million yen or less varies from 1,140 to 1,150, accounting for 95 to 96%.

1.2 Wastewater Problem in the Dyeing Arranging Industry

1.2.1 Actual conditions of the wastewater treatment

Although the actual conditions of the wastewater treatment in the dyeing arranging industry are not well understood under the present circumstances, large-sized companies and some medium-sized ones adopt such methods as the activated sludge method and the coagulating sedimentation method, etc. Of the 188 factories in the textile machinery dyeing arranging industry which are the subjects of investigation, 164 factories, which account for 87.7%, provide the wastewater treatment or discharge the wastewater into public sewage.

As a result of the investigation made by the Wool Arrangement Association, 95% of the factories in the woolen textile dyeing arranging industry establish a wastewater treatment facility or discharge the wastewater into public sewage. In the dyeing arranging industry for thread and knitted goods in particular, there are many small businesses, so that the realities of the industry are not clear. It is presumed that some companies do not set up a sufficient treatment facility on the grounds that there are many small businesses in the dyeing arranging industry in general, the amount of water is 50 m^3/day or less, selection of an applicable treatment method is difficult because the amount and quality of water change greatly, and acquisition of land for a treatment facility is difficult. There are also economic reasons, including construction costs, maintenance costs, and so on.

1.2.2 Dye wastewater and water pollution

In general, discharge of untreated industrial wastewater can affect people, other industries, sewage treatment, etc. according to the amount and quality of the water and the destination of the discharged wastewater.

For instance, discharge of industrial wastewater into rivers and seas consumes DO, causes a shortage of DO, and sometimes leads to the death of fishes. Furthemore, special components of wastewater sometimes have a bad influence on drinking water, industrial water, agriculture, fisheries untreated and the like.

Like the wastewater produced in other industries, discharge of wastewater produced in the dyeing arranging industry can cause problems depending on the to conditions of the destination of the discharged wastewater. Moreover, even though the wastewater is treated, if the treatment is not sufficient, the same problems can occur.

The pollution of Miyata industrial water once damaged agriculture in the areas of Onishi City and Ichinomiya City which are major woolen textile-producing centers. In particular, in the case of dye wastewater, there are many cases where a visual hatred for coloring, foaming, and so forth becomes a problem.

1.2.3 Outline of the law and regulation concerning dye wastewater

Due to the Water Pollution Control Law, the water quality of the wastewater produced in the dyeing industry has been controlled in conformity with the Order of the Prime Minister's Office No.35 since June 24, 1971.

Under this rule, the regulatory value varies with the type of industry, and a postponement of five years is granted, but some regulatory value is uniformly determined in the same type of industry throughout the country. The uniform standard concerning the dyeing arranging industry is shown in the following table. (specifically the items which become problems in dyeing)

UNIFORM STANDARD

Item	Uniform Standard	Provisional Standard
pH	5.8～8.6 (To be discharged into public water other than sea areas) 5.0～9.0 (To be discharged into sea areas)	——— ———
BOD (mg/ℓ)	160 (Daily Average 120)	260 (Daily Average 200)
COD (mg/ℓ)	160 (Daily Average 120)	260 (Daily Average 200)
SS (mg/ℓ)	200 (Daily Average 150)	———
n-Hexane EXTRACT (mg/ℓ)	30 (Animal and vegetable oils and fats) 5 (Mineral oil)	——— ———
PHENOL (mg/ℓ)	5	———
CHROME (mg/ℓ)	2	———
COPPER (mg/ℓ)	3	———

Until June 23,1976

Concerning the dyeing arranging industry, the provisional standard for the period of five years is determined only for BOD and COD. However, in the case where the national uniform standard is insufficient in preserving the environment according to the peculiar characteristics of the water area, a more stringent standard (strict standard) is determined by a prefecture or a particalar city. Currently, the regions that do not enact the strict standard are Yamanashi prefecture and Okinawa prefecture only, but Yamanashi is making preparations to start applying a strict standard by revising its bylaw.

Of those regions, especially in the areas where the dyeing industry is thriving, considerably strict regulatory value is decided on so that the environmental standard can be achieved by providing a more stringent standard. Above all, Osaka prefecture needed to alleviate the pollution of Osaka Bay and proceeded with the revision of its bylaw to decide on a more stringent wastewater standard in accordance with the "Law Concerning Provisional Measures for Conservation of the Environment of the Seto Inland Sea" (Law No. 110, October 2, 1973) which took effect in November, 1973. The standard related to dyeing processing is shown in the following table.

Osaka Bay water area strict standard

1) Osaka Bay Special Conservation Water Area (Type 2 Water Area)

Area	Item / Amount of wastewater	COD (mg/ℓ)	SS (mg/ℓ)	Chorme (mg/ℓ)
Existing plant	30m³/Day 30m³/Day or more	20 (Daily Average 15)	30 (Daily Average 25)	1
Newly Established plant		20 (Daily Average 15)	30 (Daily Average 25)	1

2) Osaka Bay Water Area

Area	Item / Amount of wastewater	COD (mg/ℓ)	SS (mg/ℓ)	Chorme (mg/ℓ)
Existing plant	30～1,000m³/Day	50 (Daily Average 40)	100 (Daily Average 80)	1.9
	1,000～5,000m³/Day	30 (Daily Average 25)	80 (Daily Average 65)	1.5
	5,000m³/Day or more	20 (Daily Average 15)	50 (Daily Average 40)	1
Newly Established plant	30～1,000m³/Day	25 (Daily Average 20)	40 (Daily Average 30)	1
	1,000m³/Day or more	20 (Daily Average 15)	30 (Daily Average 25)	0.6

As a result, the wastewater control has become strict. In the dye wastewater containing large quantities of COD components in particular, observing the wastewater standard is regarded as difficult, and remarkable efforts are required to achieve this goal.

Furthermore, this kind of concentration control method can not control the discharge of polluted substances produced in a type of industry with a large amount of wastewater, and so the indication of progress of the pollution in specific water areas (especially in stagnant inner bays, lakes, and marshes) is yet to emerge.

The opinion that the introduction of the method of regulating the total volume of wastewater should be examined to cope with the current situation is expressed in every field. Restrictions on the discharge of polluted substances by the total volume will inevitably enable an industry consuming large amounts of industrial water to keep the concentration of the wastewater extremely low and require further advancement of the wastewater treatment .

On the other hand, the supply of industrial water is reaching its limit, and so the use of industrial water is expected to be drastically restricted in the near future. In these circumstances, regeneration and reuse of the wastewater are indispensable, and in this respect, further advancement of the wastewater treatment is required.

As for the dye wastewater, color and temperature are regarded as subjects of the restrictions in an extremely small number of areas by but they are not yet regulated in general. However, since the actual conditions of the problem of thermal effluent are being clarified, some measures will probably to be worked out in time. Color, it causes local residents to complain, so some measures must be hammered out immediately. In addition and detergents, surfactants can not be overlooked.

1.3 Points at Issue of the Dye Wastewater Treatment

Factors which make the treatment of the wastewater produced in the dyeing arranging industry difficult are divided into economic facters and technical Poctois. The economic(include the fokowing:) factors involve;① The management scale of the businesses is relatively small. ② The form of dyeing processing is subcontracted processing on commission. ③ The processing stage is situated in the middle of the processing of the final products (merchandise). ④ It is difficult for existing factories and small-to-medium-sized factories to acquire land for a treatment facility. ⑤ Due to a small number of employees, the personnel necessary for the wastewater treatment can not be secured. ⑥ It is difficult to secure technical experts and to acquire knowledge regarding the wastewater.

In terms of the technical points, as already stated, there are such problems as (the fact) that the quality and amount of wastewater are not consistent, the number of pollution components is large, and there are many cases where the quality and amount of wastewater mutually prevent each other from showing their effects on treatment. Nneedless to say, the problems are derived from the characteristics of dyeing processing, and therefore, wastewater treatment can not be considered without understanding the stages of the processing.

1.3.1 Processing stages and wastewater

The stages of the processing vary with the material and use. The stages where the wastewater is discharged are those of decizing, scouring, bleaching, dyeing, and finishing.

1) Deciging stage

This is a stage where the starch adhering to threads and cloth is removed as a pretreatment of the dyeing processing. Starch, CMC, PVA, etc. are hydrolyzed by enzymes, weak acids, oxidation, decizing agents, etc. to become water-soluble and are washed without using soap.

2) Scouring stage

This is the stage where such impurities as wax, oils and fats, pectin, nitrogenous compounds, etc. are removed by alkalis, soap, surfactants, etc.

3) Bleaching stage

This is the stage where naturally-colored substances are removed by hypochlorite, chlorite, hydrogen peroxide, alkalis, etc.

4) Dyeing stage

This is the stage where dyeing is carried out by using dyes and dyeing auxiliaries. Besides various dyes, surfactants and dyeing auxiliaries, inorganic salts, acetic acid, etc. are employed.

5) Finishing stage

This is the stage where such properties as crease-proofing and shrink-proofing are applied to the textiles. Such processing agents as melamine resin, urea-formaldehyde resin, and surfactants as aids are used. Ia addition, the processing covers which fat addition and starching, which is necessary for the spinning stage and cloth manufacturing which follow the dyeing processing, is carried out in some cases.

Recently, processing which includes insect-proofing, mold-proofing, deodrization, water-proofing, dirt-proofing, water repellency, prevention of electrification, incombustibility, flexibility, etc. is carried out in compliance with the use. Chemicals used in the processing are greatly increasing in number and kind.

1.3.2 Pollution components of the wastewater

In the decizing, scouring, and bleaching stages to pretreat raw fibers, since foreign bodies or miscellaneous matter mixed in the manufacturing processes are removed and washed, impurities are contained in the wastewater since they have different shapes due to their decomposition.

Chemicals used in the processing, such as detergents for washing, alkali agents, and enzyme agents for decizing, are also contained. As a result, high pH and BOD, and large quantities of SS and n-Hexane extracts are sometimes detected in the wastewater.

In the dyeing stage, although there is a difference according to the degree of dyeing power, residual dyes are discharged. Mordant dyes and auxiliaries are also discharged white hardly being adsorbed by the fibers.

The number of kinds of dyes is countless, but they can be classified roughly into 5 to 10 categories in terms of the relation between raw fibers and their dyeing affinity. Recently, the use of mixed dyes in response to mixed spinning has become more popular. In many cases, about 90% of the dyes used are adsorbed by fibers, but the adsorption rate in the case of direct dyes is only 60 - 80%, and only 40 - 60% in the case of sulphur dyes. In terms of dyeing methods, in the case of yarn-dyeing, dyeing is attained more easily, and consequently the amount of polluting components contained in the wastewater is small. In a dye bath, in order to achieve the goal of dyeing, many kinds of chemicals are added besides dyes. Many of the chemicals have the purposes of humidification, emulsification, solubilization, dispersion, permeation, uniform dyeing, color development, etc., and large amounts of surfactants are used together with inorganic salts, organic acids, sodium salt organic acid , alkali agents, etc. Dyeing does not reduce the quantity of those chemicals, and some of the chemicals are discharged with the wastewater, which makes the dye wastewater treatment difficult.

The polluting components are those related to pH (Acidity, alkalinity), BOD, COD and n-Hexane extracts, while chrome and copper are rarely detected.

In textile printing, the use of printing starch results in high BOD, COD, and SS. Thus, dyeing methods, types and forms of raw materials (such as the states of cotton, threads, and cloth), and the dyes and chemicals used are all diverse, and consequently the wastewater is also diverse. Since giving a detailed account of those matters is not possible, explanation is limited to a summary of them.

1.3.3 Selection of a wastewater treatment method

Taking into account the water quality of dye wastewater, treatment methods which might possibly be effectiveness effective and their characteristics are to be summarized.

1) Screening and sedimentation (Grit chamber)
   In most cases, polluting components of the dye wastewater are all dissolved or colloidal. Consequently, screening and sedimentation are not effective in reducing the polluting components. In order to maintain a wastewater treatment facility and to remove ravelings, foreign bodies, earth and sand, etc., they, are indispensable.
   A grit chamber may also serve as a storage tank to normalize the quality and amount of water. The aim of a grit chamber is to remove SS.

2) Coagulating sedimentation or coagulating pressure flotation
   In many cases, polluting components of the dye wastewater are colloidal or water-soluble high polymers, and they are hydrophilic in general. The aims of the coagulating sedimentation method or coagulating pressure flotation method are as follows: to coagulate this kind of component with a chemical, to make them hydrophobic, to improve their quality so that solid-liquid separation can occur easily, and to separate the components by sedimentation, flotation, and filtration. Both methods are effective in removing SS, BOD, COD, and color.

3) Biological treatment (The activated sludge method and the trickling filter method.)
   The chief aim of biological treatment is to remove COD. Although the COD removal rate is low, components of COD common to those of BOD can be removed.

4) Neutralization
   PH control is significant in treating wastewater which shows extremely high or low pH value by neutralization so that the effluent standard can be satisfied. However, pH control should be used to determine appropriate conditions for coagulation treatment, biological treatment, and other types of treatment. Consequently, neutralization is an indispensable unit operation.

5) Clarifying filtration or coagulative clarifying filtration
   The above methods, 1 through 4, are effective in treating the wastewater with relatively high BOD, COD,

and SS, and in achieving the national uniform standard. In addition to these methods, clarifying filtration or coagulative clarifying filtration is used as a method which removes trace amounts of SS and stabilizes the water quality of effluent at 100 ppm or less. Rapid filtration equipment or a microstrainer is employed.

6) Activated carbon adsorption

Activated carbon adsorption is effective in removing dyes, BOD, COD, etc.
Because of the characteristics of activated carbon and economic efficiency, this method is applied to wastewater with a low concentration which has been fully clarified by removing turbidity, oil content, and so on.

7) Absorptive bubble separation

This is a method which adsorbs the polluting substance on the gas-liquid interface and separates it by introducing bubbles. The method is effective in removing trace amounts of organic matter such as dyes and detergents.

8) Reverse osmosis

This is a method which produces concentrated solutions and diluted solutions by using a semi-permeable membrane. The method can be widely applied to organic matter and ionic and nonionic matter. It is applicable in the range of extremely low concentration. The water must be fully clarified, and so a special filter, in addition to sand filtration, is used as pretreatment .

9) Ion exchange (Ion exchange resin, ion exchange membrane, electrodialysis)

This is a method which is effective in desalination. Electrodialysis is not economical since its efficiency is lowered when the concentration of salts is 200 ppm or less.

10) Oxidative decomposition

Oxidative decomposition is effective in removing components that can not be decomposed by biological treatment, specifically residual COD. Care must be given to the toxicity of products by oxidation. There is room for the examination of types of oxidizing agents and economical efficiency. This method is also effective in removing color, odor, and the activity of active material.

11) Concentration by evaporation

In the case of thick liquid waste, removal of polluting matter, chemical analysis, etc. , the cost is high. If the concentration is high, proceeding with treatment is sometimes difficult. In this case, a method of discharging water is more efficient, and there is some possibility that treated water of good quality is obtained by this method. Furthermore, if components of the liquid waste can be recovered and reused, this method is also easily realized in terms of economical efficiency.

An example of this case is spent lye produced by silk cotton processing. For reuse of the components of the spent lye, some measures must be taken in order not to increase the number of kinds of polluting components.

The above is a summary of the applicable treatment methods according to the type and concentration of polluting matter. It is desirable that methods 6 through 10 are used after the concentration is lowered by methods 1 through 5, or that it is applied to wastewater with low concentration.

1.3.4. Points at issue of the wastewater treatment

1) Change in the amount and quality of water

Processing stages, dyes, and auxiliaries used vary with the type of processed goods (raw materials), so that it is difficult to grasp the amount and quality of water. Since operation of a stage generally adopts a batch method, the amount and quality (concentration) of water greatly change with the passage of time. During a year, the color of water varies with the season. Moreover, in the long run, the fashion and development of a new product affect the amount and quality of water.

2) Effluent temperature

The effluent tenperature from a dyeing processing facility is sometimes as high as 60 ℃ or more, which affects the wastewater treatment.

3) Nutrient salt

Since the wastewater generally contains only a little nitrogen and phosphorus the supply of nutrient salt must be considered when biological treatment is adopted.

4) Disposal of produced sludge

Since secondary treatment produces large quantities of sludge, a treatment and disposal method for the sludge must be considered beforehand.

5) Form of companies

Many of the companies concerned in the industry are small businesses, and consequently a treatment facility which is small-scale and effective is desirable.

6) Facility operation and management technology

Since there are many small businesses, it is necessary to make the operation and management technology for facilities easy.

7) Facility construction cost and running cost

Since there are many small businesses, economical construction cost and running cost must be examined.

1.4 Necessity of Establishing the Advanced Treatment Technology

Since most traders concerned in the dyeing arranging industry are currently located in the interior of Japan, BOD is regulated. Many of the traders adopt activated sludge and coagulating sedimentation and some of them have a trial of activated carbon adsorption and oxidation by ozone. in order to improve the results of decolorization. However, in the case where the wastewater is discharged into sea areas, COD is regulated, and its regulatory value is 15 mg/ ℓ on a daily average in the Seto Inland Sea areas. Accordingly, as measures to deal with the regulation, advanced treatment technology which can be realized both technically and economically needs to be established.

2. Progress of Examination by the Committee on Dye Wastewater Advanced Treatment (Outline)

This committee has successively conducted examinations four times to establish the dye wastewater advanced treatment technology to cope with the effluent control aimed at conserving the environment of Seto Inland Sea (which should mainly satisfy the strict standard for the Osaka Bay special conservation water area [Type II water area]) .

An outline of the progress of the examination is below.

The committee decided to set limits on the subject of its investigation and research since an overall research study on the dyeing arranging industry is difficult due to restrictions of time, geographical features, budget, etc.

As the interim report (Attached Paper) shows, as a result of the examination, the selected wastewater as a subject of the research study was mainly composed of wastewater discharged from factory A affiliated with factory J's housing complex cooperative. Actual wastewater, to which wastewater from other factories using dyes that are not used at factory A was added, was also selected as the subject. The selected treatment methods are as follows: (i) activated sludge →coagulating sedimentation →filtration →contact oxidation, (ii) oxidation of wastewater treated by filtration by ozone→activated carbon adsorption, (iii) oxidation by light and chlorine.

The committee examined the results of the research commissioned which had been conducted according to the interim report in various aspects, and made this report.

2.1 The First Meeting

2.2.1 State of the dyeing arranging industry

1) Companies concerned in the dyeing arranging industry are widely distributed throughout Japan.
2) The scale of the companies varies from small and medium to large, and particularly the number of companies with 100 employees or less is large.
3) Processes are subdivided into production of many kinds of goods in small quantities, grouping of factories, and subcontracting .

2.1.2 Examination of the problem of wastewater produced by the dyeing arranging industry

1) The uniform standard will take effect on June 24, 1976, and a more stringent standard will be put into effect.
2) Establishment of the treatment technology and treatment facilities to satisfy the strict standard is urgently required at present.

2.1.3 Examination of the dye wastewater treatment

1) Although the companies generally hope to set up an effective treatment facility, the fact is that they can not afford such a sufficient wastewater treatment facility since they are pressed with their investment in plant and equipment.
2) A factory site is small, and a company holding the factory lacks the capability of shouldering economic burdens.
3) Taking into account the existence of the small businesses, an economical method that does not require high construction costs or running costs needs to be examined.

2.1.4 Contents of the research commissioned

1) Whose dye wastewater should be used for the research?

Mixture of wastewater discharged from several factories is desirable, keeping the joint treatment in mind due to the characteristics of the corporation. On the other hand, it appears that wastewater discharged from a single company may indicate that obtained data can also be utilized for other types of dye wastewater. An experiment space or a laboratory should be considered.

2) What target treatment value should be aimed at?

The target should be aimed at up to 15mg/ ℓ for COD and 25mg/ ℓ for SS on a daily average, both of which are the standards for the Osaka Bay special conservation water area. As for BOD and pH, the uniform standard is to be adopted.

3) What treatment method should be adopted?

Since the restrictions are tight, the treatment procedure to be adopted should be as follows: (i) activated sludge method→coagulating sedimentation method→filtration as the primary and secondary treatment, (ii) oxidation and adsorption methods as the tertiary treatment.

Three types of oxidation methods currently intended are as follows: (i) oxidation method by light and chlorine, (ii) oxidation method by ozone→activated carbon adsorption method, (iii) contact oxidation method. As for the scale of an experiment, a capacity which can be scaled up technically should be allowed.

2.2 The Second Meeting

2.2.1 Location for the research study and raw water

1) Location for the research

A 100 m^2 a rea which is situated in factory A affiliated to factory J's housing complex cooperative is to be used. (Of the total 100 m^2, approx. 40m^2 is occupied by a building.)

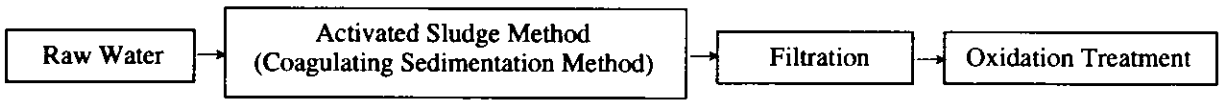
2) Raw water

The raw wastewater necessary for an experiment is to be mainly composed of wastewater discharged from factory A, taking into account the location for the research. As for special dyeing (sulphur dyes), wastewater from factory B is to be carried in and mixed with the raw wastewater.

2.2.2 Contents of the research commissioned

The treatment which satisfies or falls below the effluent standard for the Osaka Bay special conservation water area or below is to be aimed at.

A method currently considered for satisfying the above-mentioned effluent standard is mentioned below. This research puts particular emphasis on oxidation treatment.



2.2.3 Contents of the research and party to which the research is entrusted

1) The activated sludge method, the coagulating sedimentation method, filtration, and the contact oxidation method

The Activated sludge method, coagulating sedimentation method, and filtration, which are stages preceding oxidation treatment, are to be carried out. Wastewater treated by these methods is to be oxidized by chlorine. The contact oxidation method by chlorine is to be entrusted to Kurita Water Industries, Ltd.

2) Oxidation by ozone and the activated carbon adsorption method

Wastewater treated by the methods up to filtration of 1 is to be used. In oxidation adsorption treatment, the treated wastewater is to be oxidized by ozone with strong oxidizing power and finally adsorbed by activated

carbon. The oxidation adsorption treatment is to be entrusted to Orugano, Ltd .

3) The oxidation method by light and chlorine

Wastewater treated by the methods up to filtration of 1 is to be used. In this method, the treated wastewater is oxidized by adding chlorine and irradiating light. The method is to be entrusted to Toray Engineering Inc.

2.2.4 The interim report (see Appended Paper) examined by the committee was submitted.

2.3 The Third Committee

The Contents of each report of the research commissioned that were conducted in accordance with the interim report were examined.

2.3.1 Report of the research commissioned

1) Kurita Water Industries, Ltd.

After filtration, the amount of COD_{Mn} of the wastewater was on the order of 40ppm on average. Each company decided to conduct oxidation treatment by using this treated wastewater. Treatment effects of the contact oxidation treatment were not observed.

2) Orugano Ltd.

Effects of oxidation by ozone on COD removal were not particularly remarkable. In this research, treatment which could attain only COD_{Mn} of 15 ppm or less by activated carbon adsorption was possible.

3) Toray Engineering Inc.

Treatment which could attain COD_{Mn} of 15 ppm or less was possible.

3. Contents of the Research Commissioned

3.1 Subjects of the Research Entrusted to Kurita Water Industries, Ltd.

3.1.1 Operation of the activated sludge method, coagulating sedimentation method, and filtration

The activated sludge method, coagulating sedimentation method, and filtration are to be carried out as pretreatment for such advanced treatment as oxidation and adsorption. Effects of these methods are to be verified.

3.1.2 The contact oxidation method

Conditions are to be determined by a batch type experiment which uses treated wastewater obtained by treatment 3.1.1. A relation between current velocity and COD_{Mn} removal is to be investigated by a continuous type experiment.

3.2 Subjects of the Research Entrusted to Orugano Ltd.

3.2.1 Examination of changes in the quality and amount of water with the passage of time

3.2.2 Research on the amount of ozone added and properties of treated wastewater

3.2.3 Research on properties of wastewater treated by granular activated carbon adsorption

3.2.4 Research on optimum treatment facilities for oxidation by ozone and the granular activated carbon adsorption method

3.2.5 Research on recovery of granular activated carbon's capability after regeneration of granular activated carbon

3.3 Subjects of the Research Entrusted to Toray Engineering Inc.

3.3.1 Relation between COD removal and necessary amount of chlorine

1) Changes in the amount of COD with the passage of time during a reaction and changes in the amount of chlorine consumed with the passage of time are to be studied. ($\triangle Cl_2$ / $\triangle$COD is to be understood.)

2) A difference in the above-mentioned $\triangle Cl_2$ / $\triangle$COD according to the COD component is to be studied.

3.3.2 Relations between COD removal and irradiation time

With reference to 3.3.1, a relation between the COD removal rate and light irradiation time is to be be studied.

4. Results of the Research

4.1 Analysis of Source

The following is a summary of the results of the examination of the dyeing processing stages which are sources of the wastewater.

4.1.1 Raw fibers and materials

1) The diffecrent types of raw fibers are wool, cotton, rayon, polynosic, nylon, acryl, vinylon, polyester, etc. These kinds of fibers are dyed when they are in the states of stock, top, threads for a kimono with splashed patterns, processed threads, filaments, textiles, etc.

2) In this research, wastewater produced by the dyeing of wool, cotton, chemical fibers, and synthetic fibers was sampled as raw wastewater. The following are dyes and auxiliaries used.
Dyes - acid dyes, cationic dyes, dispersed dyes, reactive dyes, fluorescent dyes, chrome dyes (Use of chrome dyes will not continue in the future.), etc.

Acid agents - acetic acid, formic acid, oxalic acid, sulfuric acid, etc.
Alkali agents - caustic soda, ammonia, soda ash
Inorganic salts - mirabilite, salt, ammonium sulfate, sodium bichromate, sodium chlorite, hydrosulfide, aluminum sulfate, etc.
Auxiliaries (compound chemical) - for acryl, for nylon wool, for ester
Oily agents (compound chemical) - for acryl, for nylon, for wool, for ester
Others - detergents, insecticides, starch agents, fixing agents fix, etc.

4.1.2 Stage of processing

An outline of the processing stage is shown in a chart.

In the dyeing processing, batch operations are applied to most yarn-dyeing. In the case of this experimental

factory, continuous operations by using a wool dyeing machine, were adopted.

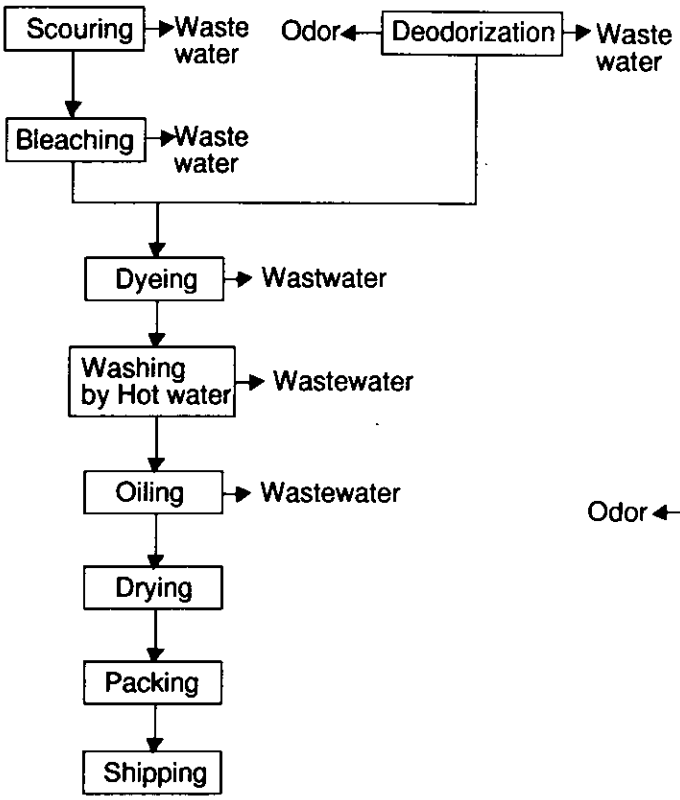
Apart from the continuous operations, a batch system wool dyeing machine was also used, and consequently changes in the wastewater with the passage of time were considerably large. Moreover, in some cases it took 48 hours to transport the wastewater from the dyeing machines and other facilities discharging it to a wastewater treatment facility in some cases. Accordingly, it is difficult to clarify a relation between the wastewater provided for the experiment and the wastewater at the source (operation conditions).

4.1.3 Wastewater samples

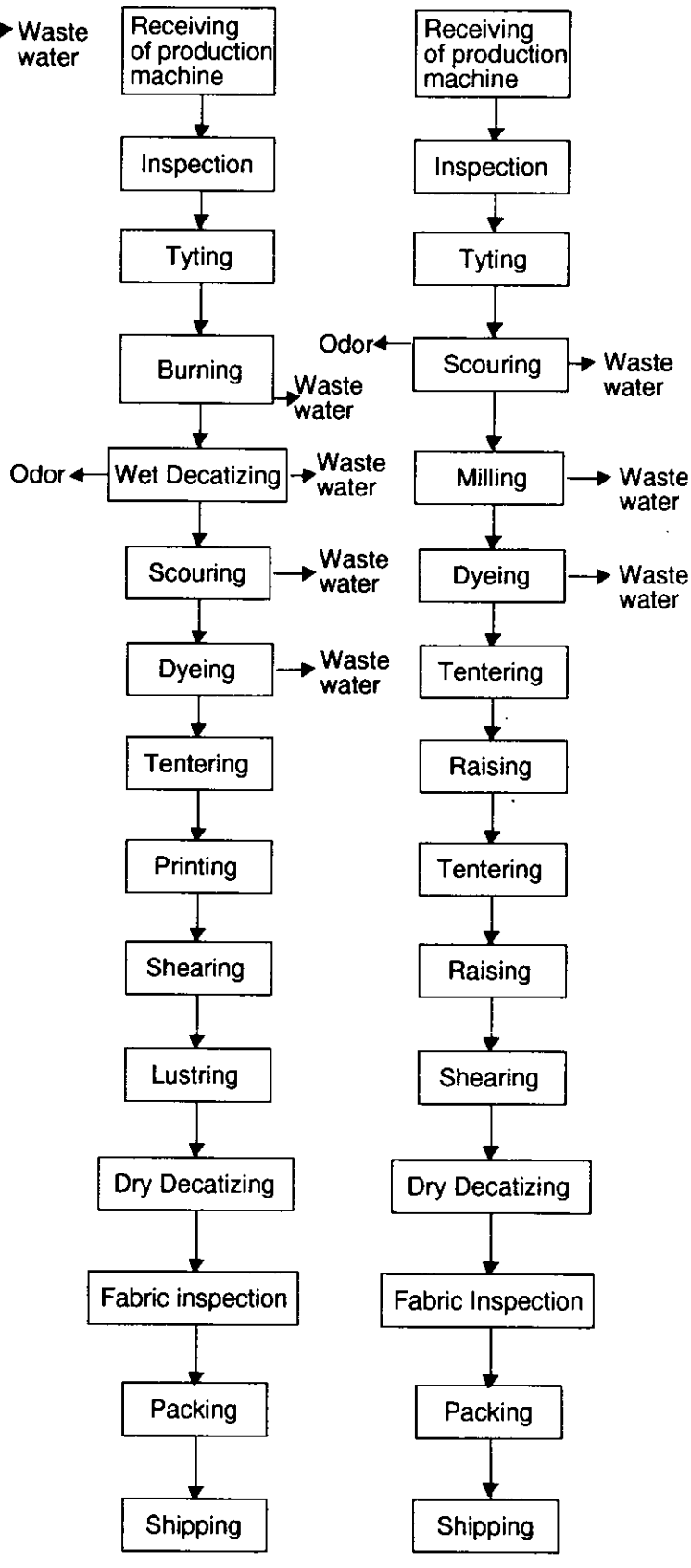
Wastewater samples were collected on the condition that operations at the factory were not changed, and that wastewater discharged was not divided according to the factory's own operation plans.

A portion of integrated wastewater was collected as a sample (raw wastewater).

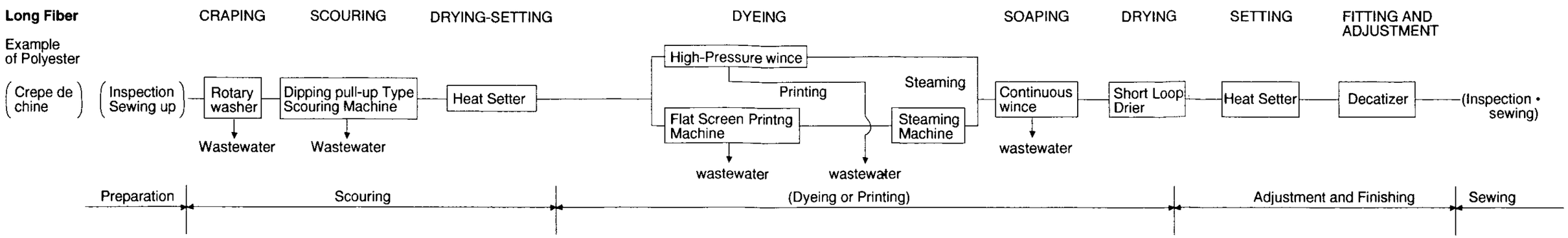
EXAMPLE OF THREAD DYEING PROCESSING PROGRESS

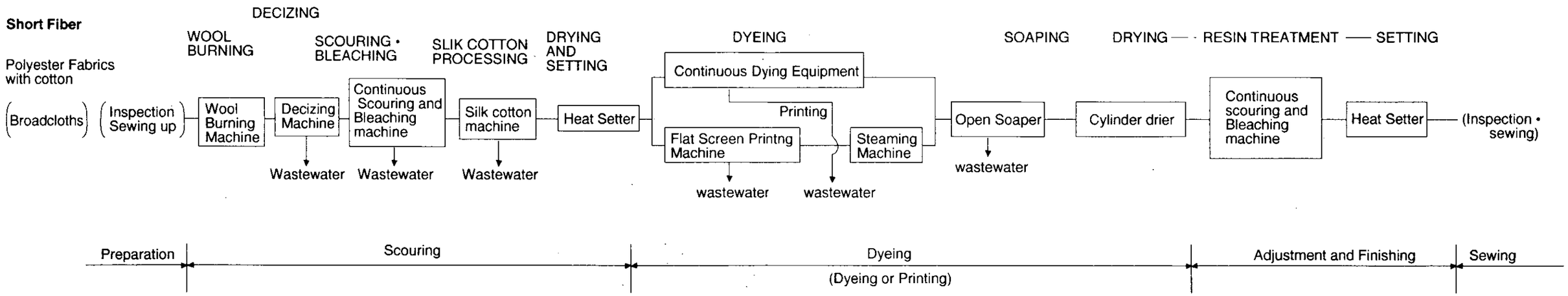


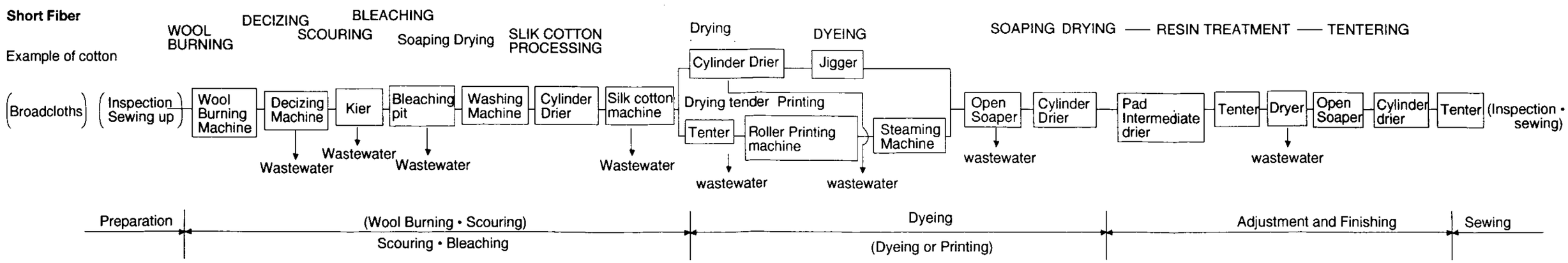
EXAMPLE OF WOOLEN TEXTILE PROCESSING PROGRESS



An Example of Dyeing and Processing Progress







4.1.4 Research planning schematic flow

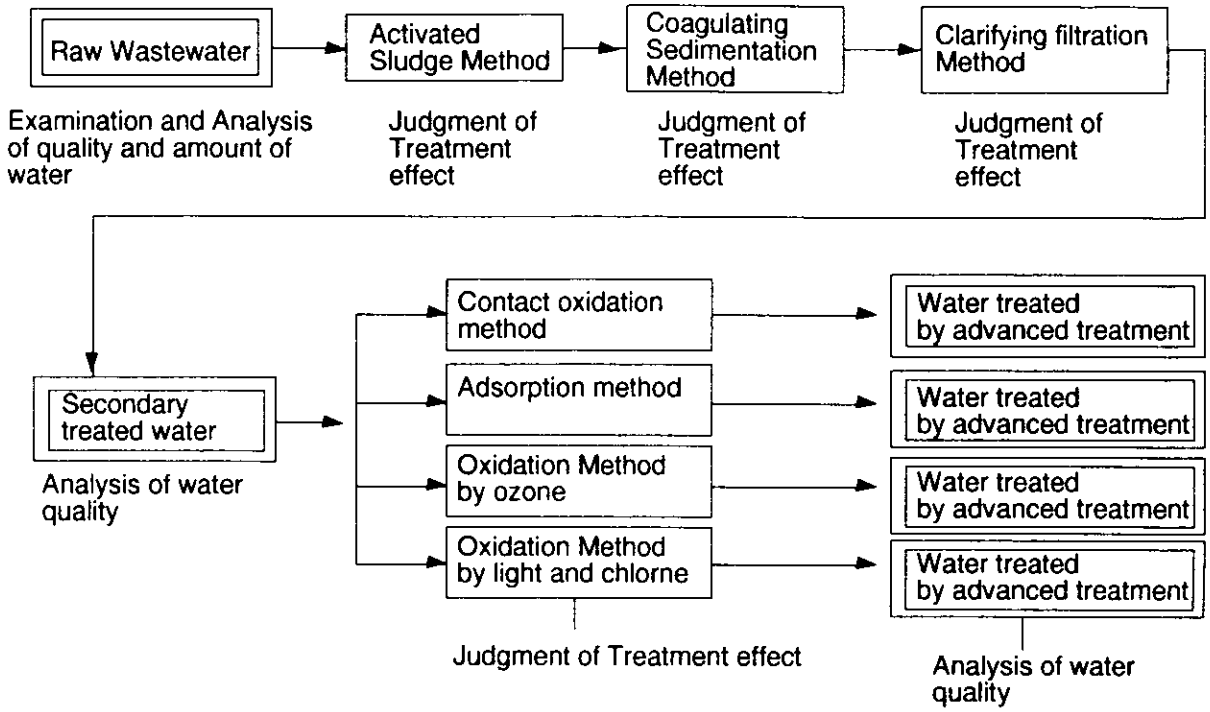


Fig. 1 SCHMATIC FLOW

The research was planned as shown in Figure.1 with the assumption of a rational treatment system flow by combining various prospective treatment methods.

4.2 Outline of Results of the Research

4.2.1 Quality and amount of wastewater

1) Since batch type operations are applied to many of the processes, the amount of wastewater is expected to change greatly.
In order to stabilize the quality of wastewater so that the water quality control can always be observed, it is necessary to operate a whole treatment facility regularly.
To this end, first of all, the amount and quality of raw wastewater to be treated should be kept uniform as much as possible. They should also be homogenized by providing a holding tank (a temporary storage tank) in the middle of a drainage canal, or by returning a portion of the wastewater towards its source from the end of a drainage canal.
2) Changes in the quality of wastewater are extremely great as shown in Table T-1, Attached Tables T1-4 (Attached Tables 1-4 in Table-1 of a report made by Toray Engineering Inc.), Table K-3 (Table-3 of a report made by Kurita Water Industries, Ltd.), Tables O-3, 4, 7, 8 (Tables-3, 4, 7, 8 of a report made by Orugano, Ltd.) , Figures K1-5 and Figures O-5, 6, 10. There are cases where a few peaks are observed during daily operation hours.

① pH: Throughout the research period, pH varied from 4.7 to 10.4, and it was generally situated on the side of alkali. pH of wastewater was obviously situated on the side of acid only for 2 days, on November 7 and 13.

② Water temperature: The temperature of the wastewater is characterized as follows: (i) A range of its variation is wide. (ii) It changes very easily. (iii) Changes take place quickly. As Table K-4 shows, on November 13, the temperature rose to 42℃ from 34℃ and then went down to 34℃ within 2 hours.
③ COD: As Tables O-3,4,7,8 show, the amount of COD ranges between 70.6 and 180 mg/ℓ. Although it was measured at the same time and on the same day, there is a slight difference according to the table. However, the difference in the measured value appears to have been caused by a slight time lag in wastewater sampling. As shown in Figure O-6, concerning the hourly variation on November 21, the value of COD varied from 90 to 155 mg/ℓ, and the maximum value and the minimum value were detected by hourly water sampling. This supposedly explains that the mixing and homogenization of wastewater is difficult since production adopts batch type operations and wastewater is moved by piston flow in a drainage canal.

3) Correlation between BOD and COD

Results of simultaneous measurement of BOD and COD are extracted from Table K-3 to form Table-1. As for raw wastewater, the value of COD_{Mn} is smaller than that of BOD as a whole. The value of BOD is 1.2 to 2.0 times that of COD_{Mn}, and consequently the value of BOD appears to be about 1.5 times that of COD_{Mn}. Since COD is detectable from not only organic matter but inorganic reducing substances, it is not believed that the correlation always complies with a fixed rule. However, in the case where the value of BOD is higher than that of COD_{Mn}, it is generally believed that biological treatment can be carried out effectively and easily.

Although biological treatment is effective in reducing BOD, it is not regarded as remarkably effective in removing COD. Also, in this case, the amount of BOD of treated wastewater is smaller than that of COD_{Mn} as a whole. The value of BOD is 0.3 to 0.9 times that of COD_{Mn}, so that it is adequate to consider that the value of BOD is about 0.5 times that of COD_{Mn} on average.

This is also obvious in terms of the COD_{Mn} and BOD removal rates.

Although there are some exceptional results, it may safely be stated that the BOD removal rate varies from 80 to 90%, while the COD_{Mn} removal rate varies from 60 to 70%.

If the contents of polluting components are qualitatively fixed, the value of BOD/COD should be definite showing a strong correlation, and the correlation can be indicated by the formula, BOD = a ×COD + b (a, b: fixed numbers). However, in terms of the contents of the dye wastewater, its components and constitution are individually different, so that strong recurrence can not be expected.

4) Color, SS, etc. of raw wastewater

Since dyeing processing is mainly composed of thread and cotton dyeing, and dipping is adopted in most cases, the coloring, SS, turbidity, transparency, etc. of the wastewater show lower value than other types of wastewater. Accordingly, polluting components appear to be mainly composed of dissolved matter.

4.2.2 The activated sludge method

Taking account of the properties of raw wastewater, especially in the case where the treatment system which can attain the target water quality is assumed, it is reasonable to adopt the activated sludge method in order to remove most portions of BOD and COD. This was also proved by the results of the activated sludge treatment. Since raw wastewater was generally situated on the side of alkali, it was treated by controlling pH and by adding a proper quantity of urea and dipotassium phosphate as the need arose. Results of the treatment are as shown in Table K-11.

1) The space loading varied from 0.5 to 1.0 Kg/m^3 per day, which was a favorable result.

2) In the case where the operation was carried out on the condition that MLSS ranged between 3,000 and 4,000ppm, the amount of BOD of treated wastewater ranged from 10 to 85ppm. Accordingly, the amount of BOD was 44 ppm on average, and the BOD removal rate was 73.9%. In the case where the amount of MLSS varied from 5,000 to 5,800ppm, the amount of BOD of treated wastewater ranged between 9 and 32ppm. In this case, the amount of BOD was 20ppm on average, and the BOD removal rate was 88.7%. On the other hand, the average amount of COD was 46ppm in the former case and 66 ppm in the latter case, and the COD removal rates were 64.3% and 57.9%, respectively. As a matter of course, the COD removal rate was lower than the BOD removal rate, but results were rather favorable, although the experiment was

conducted on site in the file.

3) A water temperature of around 30℃ was maintained throughout the period of the experiment, so that conditions were good.

4) As shown in Table K-4, the SV value of 30 to 40% and the SVI value of 100 or less were maintained. Consequently, the settling efficiency of activated sludge was satisfactory.

5) The amount of DO inside an aeration tank ranged between 2.0 and 4.0ppm all the time, so that there were no problems with it. However, the amount of DO was reduced from 0.2 to 0.5ppm when sulphur dye wastewater flowed in. Since the reduction of the amount of DO appears to be caused by sodium sulfide, more ventilation should be allowed, or advance oxidation needs to be considered.

6) In the case where sulphur dye wastewater flowed in, the amount of BOD of treated wastewater was 53ppm, the amount of COD was 73ppm, the BOD removal rate was 75.0% , and the COD removal rate was 52.6%, on the condition that tank space loading was 0.5 Kg/m^3 per day, and that the amount of MLSS ranged from 5,000 to 6,000ppm at the time of operation. Thus, the quality of treated wastewater was slightly deteriorated. It appears that this happened because an outflow of activated sludge could not have been avoided. However, wastewater treated by coagulating sedimentation and filtration showed no differences from other types of wastewater.

7) Production of excess sludge varied from 0.23 to 0.28 Kg per 1 Kg of BOD in dry weight.

8) As a result of the measurement, sludge settling velocity appears to range between 1 and 2m/hr. However, since an inflow of sulphur dye wastewater reduces the sludge settling velocity to 0.2m/hr, it is better for the water surface loading to be 17.8m^3/m^2 per day or less.

9) Activated sludge treatment requires a long retention time and has the strong merit of absorbing changes in the raw water concentration through the working of organisms. Consequently, treated wastewater of stabilized quality can be obtained.

4.2.3 The coagulating sedimentation method

It is difficult to predict which will be more effective, carrying out the coagulating sedimentation method before or after the activated sludge treatment, especially in terms of the functions and roles of the coagulating sedimentation method. In this research, emphasis was put on removal of COD components and SS which remained after activated sludge treatment.

As coagulants, 100 to 150ppm of aluminum sulfate or 100 to 200 ppm of polyaluminum chloride (PAC) was used together with 1 ppm of polymer coagulants (KURIFLOC PN 133) .

1) Even if the SS (100ppm and more) value and COD (100ppm and more) value are high as in the case of wastewater treated by activated sludge through which sulphur dye wastewater passes, use of about 200ppm of PAC and polymer and about 1ppm of coagulants are sufficient.

2) The amount of COD_{Mn} of wastewater treated by coagulating sedimentation was on the order of 45ppm. The COD removal rate varied from 40 to 45%. The coagulating sedimentation method is relatively effective in removing BOD if the value of BOD remaining after the activated sludge treatment is high. However, removing the residual BOD is difficult if the activated sludge treatment goes smoothly.

3) Production of sludge in the case of coagulating sedimentation was 0.1 Kg (dried sludge)/m3 (wastewater). If activated sludge is added, 0.15 Kg/m^3 of dried sludge should be produced in the case where the amount of BOD of raw water is 180ppm.

4.2.4 The clarifying filtration method

The filtration method has the follwing aims : to remove minute SS running out due to coagulating sedimentation, to reduce the amount of COD, to remove obstacles following advance treatment, and to reduce the load imposed

on advanced treatment. Consequently, the clarifying filtration method is an indispensable operation according to the advanced treatment in many cases.

In this research, the effects of rapid sand filtration (filtration rate: 2.6m/hr) were studied, and wastewater treated by filtration was offered as sample water for oxidation treatment and adsorption treatment.

1) The amount of COD_{Mn} of wastewater treated by filtration was about 40ppm. Since the target was not achieved, more appropriate treatment must be added.

2) Since the amount of SS appears to vary from 15 to 20ppm by coagulating sedimentation, equipment which is capable of capturing a large amount of SS is suitable. The filtration rate should be aimed at 10 to 15m/hr.

3) After filtration, the amount of SS was 5ppm or less all the time, but COD_{Mn} could not be removed. Rather, BOD showed a tendency to decrease a little. Accordingly, it is believed that dissolved COD can not be removed, and that the causes of BOD exist not only in dissolved substances but in activated sludge which flows out.

4.2.5 The contact oxidation method

It is possible to secure 20ppm or less of BOD and 10ppm or less of SS by the activated sludge, coagulating sedimentation, and filtration methods. However, it is evidently difficult for the amount of COD_{Mn} to be 40ppm or less. Residual COD_{Mn} is thought to be a substance which does not decoupese or which requires a very long time for its biological decomposition even if decomposition is possible. Hence, it was belived that there were no methods except for chemical oxidation, and so this research was mainly aimed at the examination of the contact oxidation method. In the contact oxidation method, spherical oxidizing catalysts (CN balls) were used, and the effects of oxidation by chlorine on COD removal were studied.

1) Sodium hypochlorite was used as an oxidizing agent, and the influences of pH on oxidative reaction were investigated. As a result, as shown in Table K-8, although the tendency was slight, the lower the pH value was, the lower the treated wastewater's COD_{Mn} value was. However, in this experiment, the amount of residual COD_{Mn} was 30ppm and more. Furthermore, when the residual COD_{Mn} was reacted by acidity, nickel in the catalysts eluted, and highly concentrated nickel was detected. There was even a fear that wastewater exceeding the regulatory value of nickel would be discharged depending on the location of the experiment.

2) CODMn was studied by changing the amount of sodium hypochlorite, which was an oxidizing agent to be used from 600 to 1,500ppm. As a result, although the amount of residual COD decreased when the amount of the oxidizing agent increased, a difference was hardly observed. (Table K-9)

3) Although effects of the catalysts were verified by the water passage method, effects of applying the CN balls were not observed, as Table K-10 shows. Effects of applying the chlorine agent independently were recognized.

4) As a result of the above, in the case where the amount of COD_{Mn} is 40ppm after filtration, it is difficult to reduce the amount of COD_{Mn} to 15ppm or less by oxidation by chlorine.

4.2.6 The oxidation method by ozone

A method which treats water by the oxidizing power of ozone is widely applied to the treatment of service water in Europe. Since ozone remaining in treated wastewater returns to molecular oxygen gases, there is no need to take account of hindrances, unlike the case of residual chlorine. Thus, this method is regarded as useful if care is paid to the use of ozone.

This method is regarded as effective in the decolorization of dyes.

1) Oxidation of wastewater treated by filtration by ozone

The reasults of oxidation of wastewater treated by filtration (The amount of COD_{Mn} is about 40ppm: this is called secondary treated wastewater.) by ozone are shown in Table O-1.

As the table shows, although a decrease in the amount of COD is recognized, it is difficult to attain the

wastewater with 15ppm of COD_{Mn}, which is the target. Results that show that the amount of COD_{Mn} varies from 30 to 35ppm and that the COD_{Mn} removal rate ranges between 20 and 30% can only be expected. However, it was found that a decrease in the average absorbance was striking, and the color removing effects varied from 50 to 90%. As Table O-2 also shows, although oxidation by ozone did not show any effects in removing n-Hexane extracts and SS, the amount of surfactants was reduced from 30 to 50%.

2) Oxidation treatment of dye raw wastewater by ozone
Secondary treated wastewater appeared to be wastewater from which easily oxidizable substances by activated sludge were removed. Furthermore, it appeared that only the matter that was stable against oxidation remained behind in the secondary treated wastewater. Consequently, direct ozonization of raw wastewater was put to the test. Table O-3 shows the results of the test. Although a decrease in the amount of COD_{Mn} was recognized in all experiments, it was extremely small, and, consequently, the effects of ozonization on COD_{Mn} removal fell short of those of activated sludge treatment. According to Table O-4, removal of BOD, n-Hexane extracts and SS by ozonization can hardly be expected. Oxidation, however, was sometimes effective in removing surfactants.

3) As a result of this research, it was found that no remarkable effects of ozonization on COD_{Mn} removal could be anticipated.

4.2.7 The oxidation method by light and chlorine

In the case where organic matter contained in wastewater is oxidized by an oxidizing agent, factors which prompt a reaction are pH, temperature a co-existing substance (catalyst), etc. Irradiation of lights, ultraviolet rays, γ rays, x rays, etc. are method which prompt the reaction. This method is similar to the case where discoloring of the dyes is promoted by rays. The research was aimed at a decrease in the amount of COD_{Mn} through this method.

1) This experiment adopted batch treatment and continuous treatment. Under appropriate conditions, the amount of COD_{Mn} could be 15 ppm or less.

2) Table T-2 shows the results of the batch treatment, in which the amount of wastewater with COD_{Mn} ranging between 25 and 70ppm that had been treated by filtration was used as sample wastewater. As in the case of experiment No.8, a decrease in the amount of COD_{Mn} by an irradiation reaction was smaller than that by a dark reaction in some cases. Accordingly, in this case, if the amount of COD of raw water is 40ppm, the amount of COD_{Mn} can not be expected to be 15ppm.

3) The value of COD_{Mn} of raw water flowing in and that of treated wastewater are not completely proportional. This is considered to be caused by the substance contained in wastewater that has difficulty in being oxidized, and the fact that the content of the substance varies with the type of wastewater.

4) In the batch treatment, as shown in Table 2, treated wastewater of good quality was obtained on the condition that the COD removal rate varied from 60 to 90%. As Table T-4 shows, in every item, wastewater of target quality which was worth being put to practical use was also obtained.

5) Concerning the continuous treatment, as Table T-3 indicates, the same results as those of the batch treatment were obtained.

6) Mixing of sulphur dye wastewater did not affect the treatment.

7) Colorless treated wastewater was obtained, and it was found that decolorization effects were high.

8) Compared with the amount of COD removed, the amount of chlorine consumed was larger. About 17ppm of Chlorine(about twice its theoretical value) was consumed in order to remove 1ppm of COD_{Mn}, and, consequently, the utilization rate of an oxidizing agent was not very high.

9) There is a direct relation between reaction time and the consumption of chlorine. The time necessary for the amount of COD_{Mn} to reach 15ppm or less is considered to range between 40 and 60 minutes on average.

4.2.8 The activated carbon adsorption method

It is known that the activated carbon adsorption method is effective in removing coloring substances and organic matter. In the recent industrial wastewater treatment, attention has been paid to activated carbon and it has come into wide use. In this research, adsorption treatment was conducted after various sorts of treatment, and effects of the treatment were studied.

1) Granular activated carbon adsorption treatment

① Pittsburgh granular activated carbon CAL was used as activated carbon. The equilibrium adsorption test and the packed column water passage test were conducted at a temperature of 25℃.

② Results of direct treatment of wastewater treated by activated sludge, coagulating sedimentation and filtration (secondary treated wastewater) by activated carbon are shown in Table O-5 and Figure O-7 (2). On the condition that the amount of COD_{Mn} of raw water flowing in varied from 30 to 45ppm, and that the water passage time was 90 hours, the amount of COD_{Mn} of effluent of the first tower was 17ppm. It was in excess of 20ppm when the water passage time was about 100 hours. The amount of COD of treated wastewater which had passed through the second tower varied from 10 to 15 ppm, and the amount of COD of treated wastewater which had passed through the third tower varied from 5 to 10ppm.

③ Results of water passage of the secondary treated wastewater which was oxidized by ozone are shown in Table O-6 and Figure O-7 (1). In the case of ozonization, the amount of COD_{Mn} ranged between 25 and 35ppm, and it was about 30ppm on average. In the case where the treated wastewater had passed through the activated carbon column, the amount of COD_{Mn} was 13ppm when the water passage time was 90 hours. Then, the COD_{Mn} value of 21ppm was detected after the water passage time exceeded 105.5 hours. Although the amount of COD_{Mn} was once in excess of 20ppm when the water time passage was approaching 150 hours, it was 20 ppm or less up until the time reached 135 hours. The amount of COD_{Mn} was 10ppm at the outlet of the second tower, and it was 2 to 8 ppm at the outlet of the third tower all the time.

④ Methods of directly treating dye raw wastewater by activated carbon were examined.
Since raw wastewater could not pass through the column without being treated, it passed after SS had been removed by filtration. Results of this treatment are as shown in Table O-7 and Figure O-9 (2). Since the wastewater was filtrate of raw wastewater, its water quality varied greatly, and the amount of COD_{Mn} ranged between 70 and 140ppm. The amount of COD_{Mn} at the outlet of the first tower varied from 35 to 90ppm. At the first tower, the COD removal rate was about 50% on average, and the fluctuation in the concentration at the inlet and outlet of the first tower was almost parallel. The amount of COD_{Mn} removed gradually decreased as the wastewater passed through the following columns, namely the second and third towers. The removal rate was 40 to 50% at the second tower, and 10 to 20% at the third tower. The amount of COD of the wastewater which had passed through the third tower varied from 15 to 40ppm. Accordingly, it is difficult to achieve the target value of 15ppm or less at all times.

⑤ Results of oxidation of raw dye wastewater by ozone which had been carried out before the raw wastewater was treated by activated carbon are shown in Table O-8 and Figure O-9 (1).
Due to the influences of a change in the raw wastewater concentration, there was a variation in the quality of wastewater, which has the same tendency as the direct treatment of wastewater by activated carbon . Although the concentration of wastewater and treated wastewater was slightly reduced by ozonization, it was 10ppm at both the inlet and outlet of the first tower. A difference in the concentration was hardly recognized between the second tower outlet and the third tower outlet. Even if ozonization is added, it is difficult to attain the COD_{Mn} value of 15ppm or less by treating raw wastewater by adsorption.

⑥ In the case where adsorption treatment is mainly carried out, although ozonization is employed as well, effects of ozonization on COD removal are not as great as expected. This can also be explained by the results of the direct treatment of secondary treated wastewater conducted in the case where sulphur dye wastewater was mixed, and by those of the equilibrium adsorption test carried out with ozonization. (Figure O-11)

⑦ Effects of ozonization on activated carbon treatment indicate that since a water passage cycle was prolonged by ozonization, the load imposed on activated carbon was reduced.

⑧ The amount of wastewater treated is thought to roughly vary from 2.0 to 2.5m^3 per activated carbon of 1Kg.

⑨ After an activated carbon regeneration test, the efficiency of activated carbon was recovered, and it was almost as good as that of the brand-new one.

2) Powdered activated carbon adsorption treatment

① Table T-5 shows the results of direct treatment of secondary treated wastewater by activated carbon. It appears that activated carbon of about 200ppm is required in order to attain the treated wastewater's COD_{Mn} value of 15ppm or less on the condition that the value of COD_{Mn} of wastewater is 42.5ppm.

② The amount of COD_{Mn} was reduced from 41.1ppm to 24ppm by oxidizing secondary treated wastewater by light and chlorine. In the case where activated carbon of 50ppm was used in addition to the oxidation, the amount of wastewater's COD_{Mn} was 19.2ppm. The weight of COD_{Mn} that activated carbon of 1g adsorbs is equal to 96mg. (Table T-6)

③ As shown in Figure T-10, there is a difference in the inclination of the adsorption isotherm between the cases in which oxidation by light and chlorine is carried out and the cases in which where it is not. This indicates that after oxidation, the amount of adsorption is easy to control by equilibrium concentration. Oxidation developed a tendency to make adsorption treatment difficult.

As the above indicates, the effects of oxidation by light and chlorine on activated carbon adsorption showed a different tendency from those of ozonization. This is caused by the fact that a degree of oxidation in the oxidation process differs between the two methods.

Comparison between Table T-6 and Table O-1 shows that a decline in the value of COD_{Mn} is more remarkable, and oxidative degradation advances further in the case of oxidation by light and chlorine than in the case of ozonization. Accordingly, it appears that there is a considerable difference in the constitution of residual adsorbed matter (COD).

The above is a summary of the experiments conducted in this research on the treatment of actual wastewater discharged from a dyeing factory. For details, refer to reports made by persons in charge of the research which are attached at the end of this volume.

5. Conclusion

This committee has done the research study on the dye wastewater advanced treatment technology. During the period of the research study, an interim industrial test which would be put into practice on site was planned, and a study was made of the application of various types of treatment. The following is an outline of the study.

5.1 Outline of Results of the Research and Comprehensive Evaluation

1) Since the amount and quality of wastewater both change greatly, it is important to try to equalize them in terms of treatment.

2) The following is the average water quality of raw wastewater.

BOD	200mg/ℓ
COD_{Mn}	170mg/ℓ
SS	50mg/ℓ

3) Although a strong correlation is recognized between COD_{Mn} and CODCr , such a strong correlation is not present between COD and BOD.

4) The following is the average water quality of wastewater treated by activated sludge, coagulating sedimentation, and sand filtration.

BOD	20ppm or less
COD_{Mn}	40ppm or less
SS	5ppm or less

5) The effects of the contact oxidation method and the oxidation method by ozone were not as good as expected. It was difficult to attain treated wastewater with COD_{Mn} of 15ppm or less by those methods.

6) It was possible to attain the target COD_{Mn} value of 15ppm by the oxidation method by light and chlorine which irradiated x~rays to carry out oxidation by chlorine.

7) Activated adsorption was effective in removing COD_{Mn}. Direct application of adsorption to raw wastewater, however, did not achieve the goal.
The following are further summaries of the above.

① The activated sludge, coagulating sedimentation, and sand filtration methods are indispensable as treatment. Since the treatment methods produce sludge, sludge disposal must be considered.

② Activated carbon adsorption and oxidation by light and chlorine can both achieve the goal as advanced treatment.

③ In terms of economic efficiency, it is more favorable that adsorption treatment is carried out after oxidation treatment.

④ Although oxidation is effective in decolorization, care must be given to the toxicity of oxidative products.

⑤ Activated carbon treatment also has effects on decolorization. In terms of economic efficiency, application of oxidation as well as the regeneration of activated carbon must be considered.

5.2 Dye Wastewater Advanced Treatment System and Points at Issue

An optimum treatment system which would satisfy the strict effluent standard applied to Osaka Bay by dye wastewater advanced treatment (target water quality: COD_{Mn} of 15ppm or less) was examined.

A research schematic flow sheet is shown in Figure 1.

By making a flow sheet for treatment which can be put into practice according to Figure1, the points at issue can be clarified.

According to Figure 1, four types of treatment flow are available: (1) oxidation by ozone → activated carbon adsorption, (2) activated carbon adsorption only, (3) oxidation by light and chlorine only, (4) oxidation by light and chlorine → activated carbon adsorption. In all types of flow, as stated earlier, wastewater which has been treated by activated sludge, coagulating sedimentation, and sand filtration, in this order, are to be treated further. If these four types of methods are to be simplified, in methods (1) and (2), activated carbon adsorption has remarkable effects on the removal of COD_{Mn}; on the other hand, in methods (3) and (4), oxidation by light and chlorine is strikingly effective in removing COD_{Mn}. If costs and secondary effects are to be excluded, oxidation by ozone in (1) and activated carbon adsorption in (4) can be eliminated.

Consequently, in order to reduce the number of treatment steps as much as possible and to simplify a facility, either activated carbon adsorption or oxidation by light and chlorine must be selected.

In the case where many types of components are contained in such wastewater as dye wastewater, and where the method must cope with the quantity ratio of the components and a difference in the processing lot, it is difficult to determine which is superior by selecting either of them.

As yardsticks for selecting treatment processes, not only the merits and demerits of each treatment method, but other factors covering management basis, technical levels, locational conditions (This is related to acquisition

of materials.), securement of land, operational conditions, prediction of future plans, etc. at a company must be considered. In consequence, advanced treatment is not to be limited to only one system at this point. Any effective method is to be picked out, and points at issue are only to be indicated.

1) Pretreatment-related matter

If the raw wastewater is limited to process wastewater only, there are few cases where foreign bodies are mixed. However, removal of coarse SS by screening and such pretreatment as neutralization and grit removal are required wherever they are suitable. A somewhat big-scale storage is preferable, not merely a pump pit.

2) The activated sludge method

Within the range of this research, no notable obstacles were found. However, when the proportion of sulphur dye wastewater was large, treatment tended to be hindered, which requires attention.

3) Coagulating sedimentation - sand filtration

Within the range of this research, there can be no great obstacles. However, according to the raw wastewater, activated sludge treatment can be impeded, the amount of SS can increase, and the state of flocculation can be deteriorated. Consequently, care must always be paid to the management of equipment.

4) Granular activated carbon adsorption

Regeneration of spent activated carbon must be considered.

Regeneration of activated carbon by heating in a regenerative furnace is favorable. It is significant that this process is to be scaled up as much as possible in cooperation with other companies, and that the operation rate of a regenerative furnace is to be raised.

5) Oxidation treatment

① The effects of ozonization were not remarkable. The addition of ultraviolet rays irradiation should be examined.

② Concerning oxidation by light and chlorine, methods For raising the rate of using oxidizing agents should be investigated. For the purpose of rationalizing management, application of Toko test type chlorine consumption measurement should be studied.

6) Differences in treatment effects according to the polluting component

In this test, attention was paid to influences of sulphur dye, but no great obstacles were observed in general. However, since many other components which can not be dealt with by this test only are expected to exist, further care must be taken. In particular, attention must be paid to the existence of surfactants, oily agents, inorganic salts (ammonia and phosphoric acid, in particular), etc.

5.3 Concluding Remarks

In terms of the diversity of dyeing processing, the results of this on-site experiment deal with only a part of the whole dyeing industry, and, accordingly, it is difficult to regard them as sufficient data which can be applied to other types of dye wastewater. Furthermore, the period of the experimental research was limited, and a factory was not entirely covered. However, data obtained by this research still provide valuable results which are applicable on site and are unique design materials which can be put into practice. It is desirable that the technology to develop the results further is to be explored, and pilot research aimed at the technology development is to be conducted. As a matter of course, all possible measures must be taken for the purpose of maintenance and management of a facility after the treatment facility actually starts operating. It is also strongly desired that data are to be accumulated as much as possible, and that efforts are to be made so that the utilization of technology can be established.

Table 1 Result of activated sludge treatment and raw wastewater measured value

Measurement date	Raw wastewater				Treated water				COD Mn Removal rate	BOD removal rate	Remarks
	Measured value			BOD/COD Mn	Measured value			BOD/COD Mn			
	COD Mn	COD Cr	BOD		COD Mn	COD Cr	BOD				
	ppm	ppm	ppm		ppm	ppm	ppm		%	%	
9.24	92	403	135	1.47	32	94	21	0.66	65.2	84.4	
27	105	454	147	1.40	43	206	56	1.30	59.0	61.9	
10.4	135	586	175	1.3	35	106	22	0.63	74.0	87.4	
8	118	661	201	1.70	33	113	85	2.58	72.0	57.7	
15	106	396	101	0.95	48	178	81	1.69	54.7	19.8	
18	142	518	97	0.68	70	210	50	0.71	50.7	48.5	
22	122	594	176	1.44	27	145	10>	0.37>	77.9	94.3	
25	142	613	273	1.92	140	404	52	0.37	1.4	81.0	
29	126	526	-	-	47	150	-	-	62.7	-	
11.1	113	568	252	2.23	46	145	32	0.7	59.3	87.3	
7	128	516	170	1.33	76	277	26	0.34	40.6	84.7	
8	148	556	120	0.81	52	124	9	0.17	64.9	92.5	
12	122	588	164	1.34	43.5	182	14	0.32	64.3	91.5	
20	116	417	126	1.09	62	247	44.5	0.72	46.6	64.6	
22	178	697	298	1.67	71	315	60.8	0.86	60.1	79.6	
26	162	588	198	1.22	114	507	169	1.48	29.6	15.2	
27	132	574	157	1.19	98	517	83	0.85	25.8	47.1	
29	128	506	174	1.36	74	299	66.8	0.90	42.2	75.7	

The measured values are extracts from table K-3.

Table 2 Result of oxidation treatment by lihgt and chlorine

Experiment No.	Date	COD Mn before treatment COD_{Mn}	COD Mn after treatment COD_{Mn}	COD removal rate
		ppm	ppm	%
1	10.16	70	56	20.0
2	〃	68	9	86.8
3	〃	70	11	84.3
4	17	65	9	86.2
5	18	25	16	36.0
6	22	35	3	91.4
7	23	30	12	60.0
8	24	36	24	33.3
9	26	68	14	79.4
10	28	54	5	90.7
11	29	44	12	72.7
12	30	31	6	80.6
13	11.5	38	10	73.7
14	6	45	12	73.3
15	7	41	14	65.9
16	21	29	9	69
17	22	25	8.5	66.0

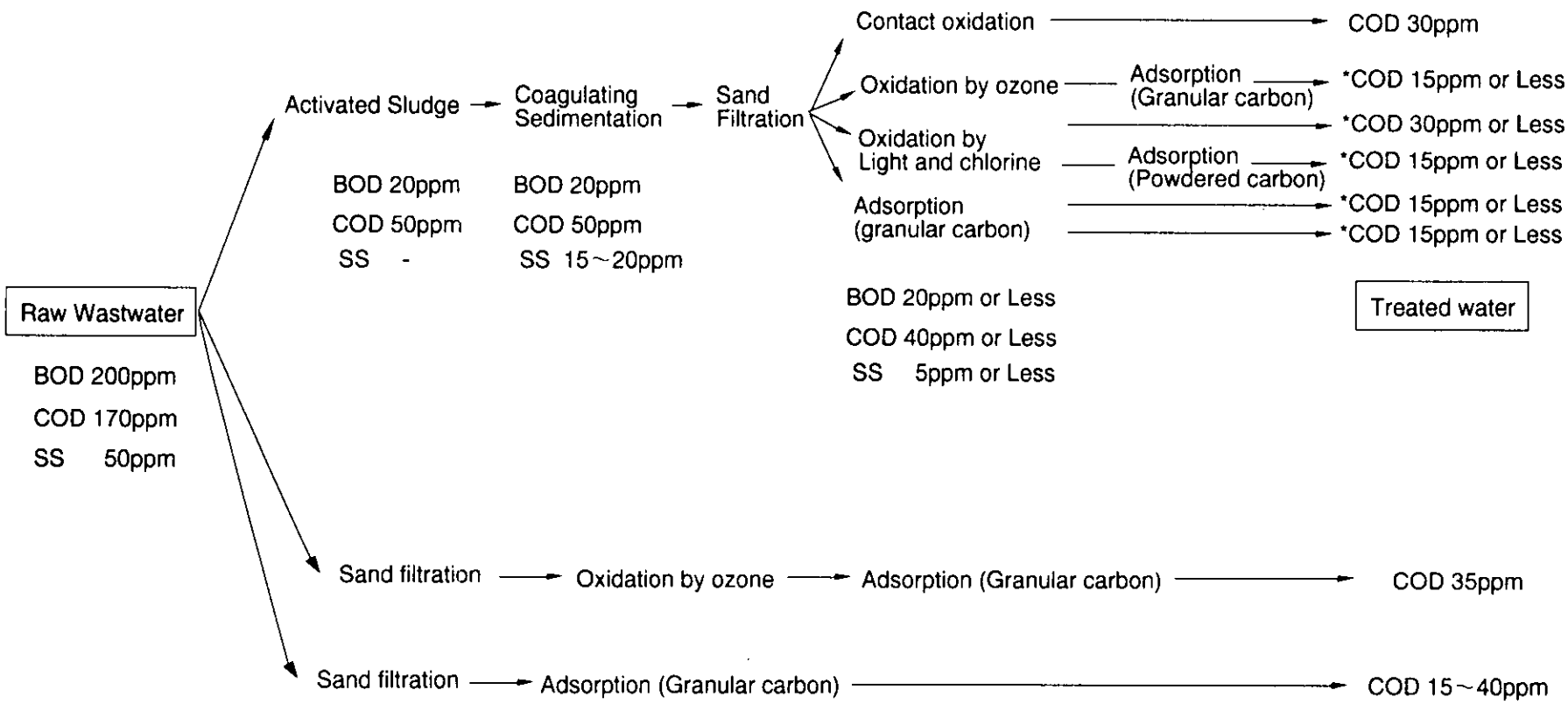


Fig 2 DIAGRAM OF ADVANCED TREATMENT TECHNOLOGY RESEARCH SYSTEM FOR DYE WASTEWATER

(Attached Paper)

August 12, 1974

Mr. Toshio Eguchi
Chief Director
Environmental Pollution Control
Service Corporation

Minoru Tanaka
Chairman of the Committee
Committee on Examination of Dye Wastewater
Advanced Treatment Technology

Interim Report on the Dye Wastewater Advanced Treatment Technology

As a result of our examinations of the above issue, it is has been deemed appropriate that a research study on the following methods selected from various types of dye wastewater advanced treatments currently carried out is to be done. Consequently, we ask you to conduct the research commissioned according to the attached outline.

As for the results of the research, we ask you to report them to us by January 10, 1975.

Description

1. **The activated sludge, coagulating sedimentation, filtration and contact oxidation methods**
2. **The oxidation method by ozone and the granular activated carbon adsorption method**
3. **The oxidation method by light and chlorine**

(Attached Paper)

Outline of the Research Study Commissioned

1. Treatment methods commissioned

(1) The activated sludge, coagulating sedimentation, filtration and contact oxidation methods

In order to conduct the tertiary treatment effectively, it appears to be necessary to sufficiently carry out the activated sludge, coagulating sedimentation, and filtration methods which are conventionally used. However, it is still difficult to satisfy the strict standard by the conventional methods. Accordingly, it is to be determined whether the contact oxidation method is applicable economically and technically as the tertiary treatment, and if it is, what kind of treatment process is available.

a.Outline of the research

1. Scale of an experimental plant

(i) Capability

Activated sludge equipment	$10m^3$/day
Contact oxidation equipment	experimental scale

(ii) Necessary area Approx. $20m^2$

2. Experiment method (Details are to be discussed with a party entrusted with the research.)
3. Experiment period
   September 20, 1974 - December 20, 1974

b. Equipment layout

Appended Figure 1

(2) The oxidation method by ozone and the granular activated carbon adsorption method

Wastewater pretreated by the activated sludge method and ozone with strong oxidizing power are to be used. It is to be determined if the activated carbon adsorption treatment process is applicable economically and technically as the tertiary treatment for dye wastewater.

a.Outline of the research

1. Scale of an experimental plant

(i) Capability 50 ℓ /H - 100 ℓ /H - 200 ℓ /H

(ii) Necessary area Approx. $30m^2$

2. Experiment method (Details are to be discussed with a party entrusted with the research.)
3. Experiment period

   September 20, 1974 - December 20, 1974

b. Equipment layout

Appended Figure 2

(3) The oxidation method by light and chlorine

Wastewater pretreated by the activated sludge method is to be used. Chlorine with oxidizing power and light which accelerates oxidation are also to be used. It is to be determined if the oxidation method by light and chlorine is applicable economically and technically as the tertiary treatment for dye wastewater.

a. Outline of the research

1. Scale of an experimental plant

(i) Capability 40 - 120 ℓ /H

(ii) Necessary area Approx. 20m²

2. Experiment method (Details are to be discussed with a party entrusted with the research.)

3. Experiment period
September 20, 1974 - December 20, 1974

b. Equipment layout

Appended Figure 3

2. Outline of the location for the experiment

Location for the experiment : Factory A located in Sakai City, Osaka Prefecture

For a site background drawing , see Attached Figure 4.

Sakai City is studded with lots of small and medium-sized dyeing factories.

There are many dyeing factories related to interior decorations in particular. Dyes and auxiliaries, etc. used differ with the fashion in color and the types of fibers, so that a change in wastewater is striking. Consequently, it is extremely difficult to grasp the average quality and amount of water.

Vacant land (approx. 100m²) located in factory A which carries out many kinds of processing and uses many types of fibers and dyes. is available for use and is to be used as a site for the experiment.

Wastewater discharged from the factory is also available and is to be used as raw water.

3. Contents of the research study

In this research, according to the matters for investigation shown in 3-1, items to be studied mentioned in 3-2 are to be examined. On the assumption that there are three cases in terms of the amount of wastewater: 1,000m³/day, 3,000m³/day and 6,000m³/day, data corresponding to the following items are to be submitted.

(1) Flow sheet

(2) Construction cost

(3) Running cost

(4) Construction area

(5) Number of operator

(6) Others

3-1 Matters for investigation

(1) Types and amount of processing at the factory

(2) Work processes and amount of wastewater according to the process

(3) Properties and water temperature of raw water

(4) Quality and water temperature of treated wastewater

(5) Other necessary items

3-2 Outline of items to be studied

a. The activated sludge method (the coagulating sedimentation method) and filtration (pretreatment process)

(1) The temperature of wastewater and BOD load are to be parameters, and removal of COD and BOD is to be investigated. (conditions for coagulation)

(2) Production of excess sludge

(3) Offensive odor and external appearance

(4) Other items considered to be necessary

b. Oxidation treatment (tertiary treatment process)

(1) Conditions for oxidation (oxidation effects)

(2) Other items considered to be necessary

4. Parties which are entrusted with the research (scheduled)

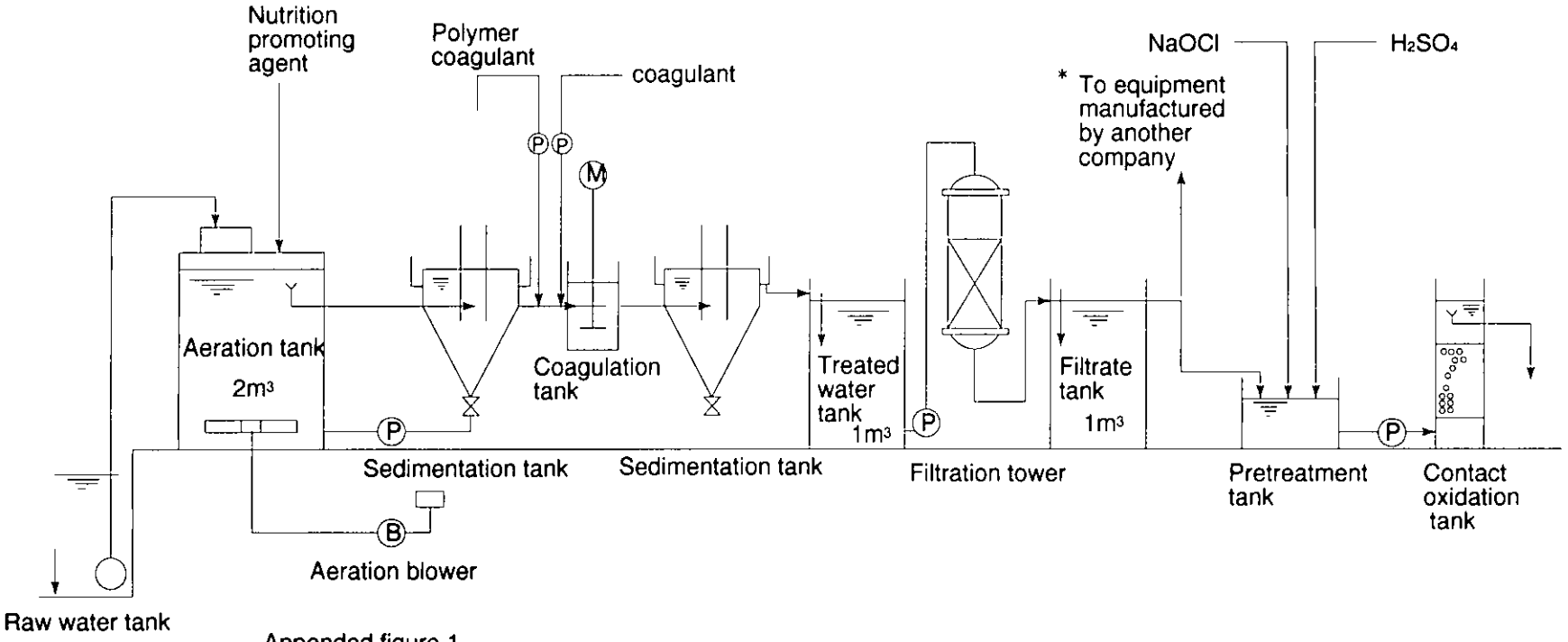
(1) The activated sludge, coagulating sedimentation, filtration and contact oxidation methods : Kurita Water Industries, Ltd.

(2) The oxidation method by ozone and the granular activated carbon adsorption method : Orugano, Ltd.

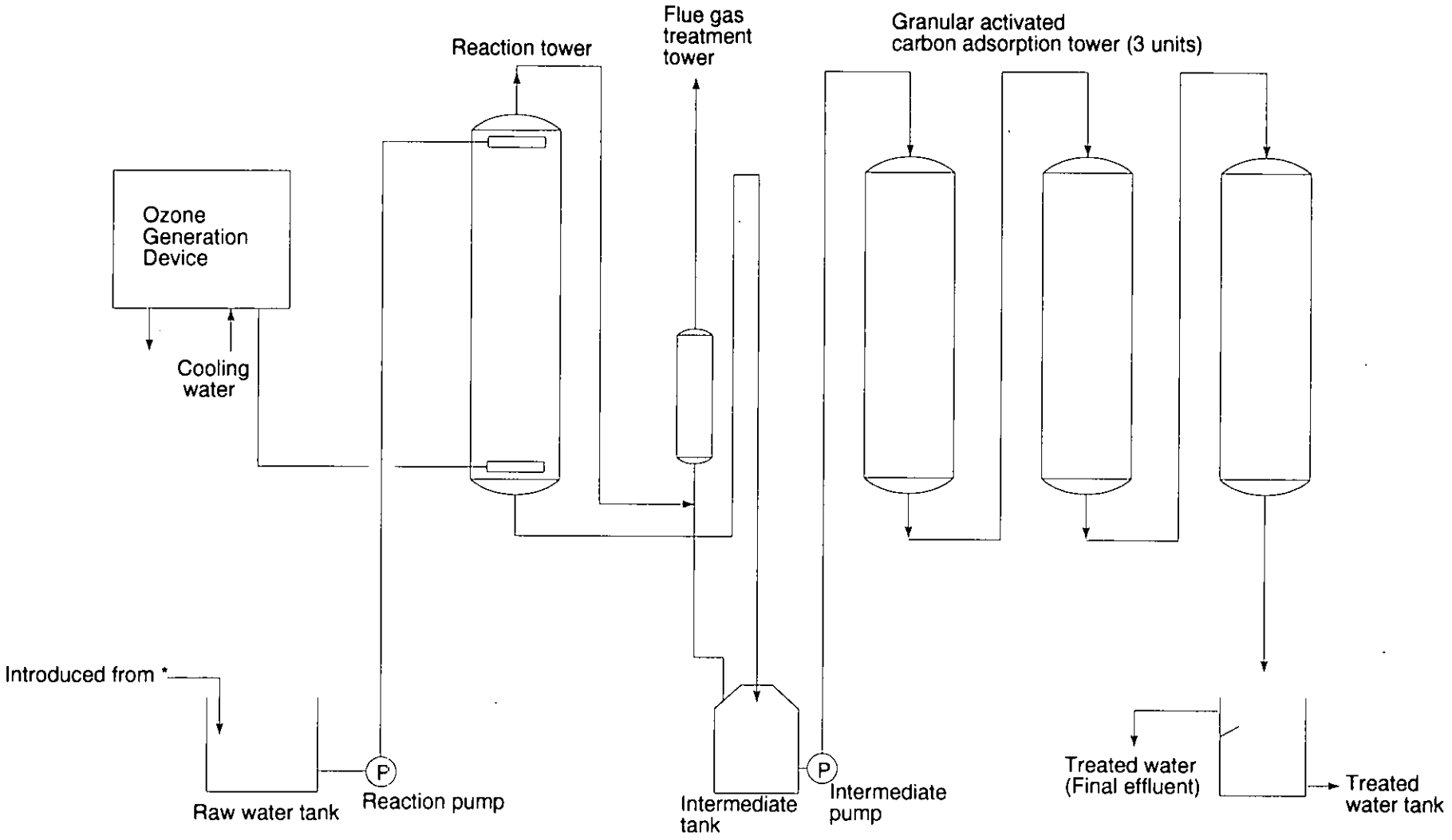
(3) The oxidation method by light and chlorine : Toray Engineering, Inc.

5. Method of commissioning

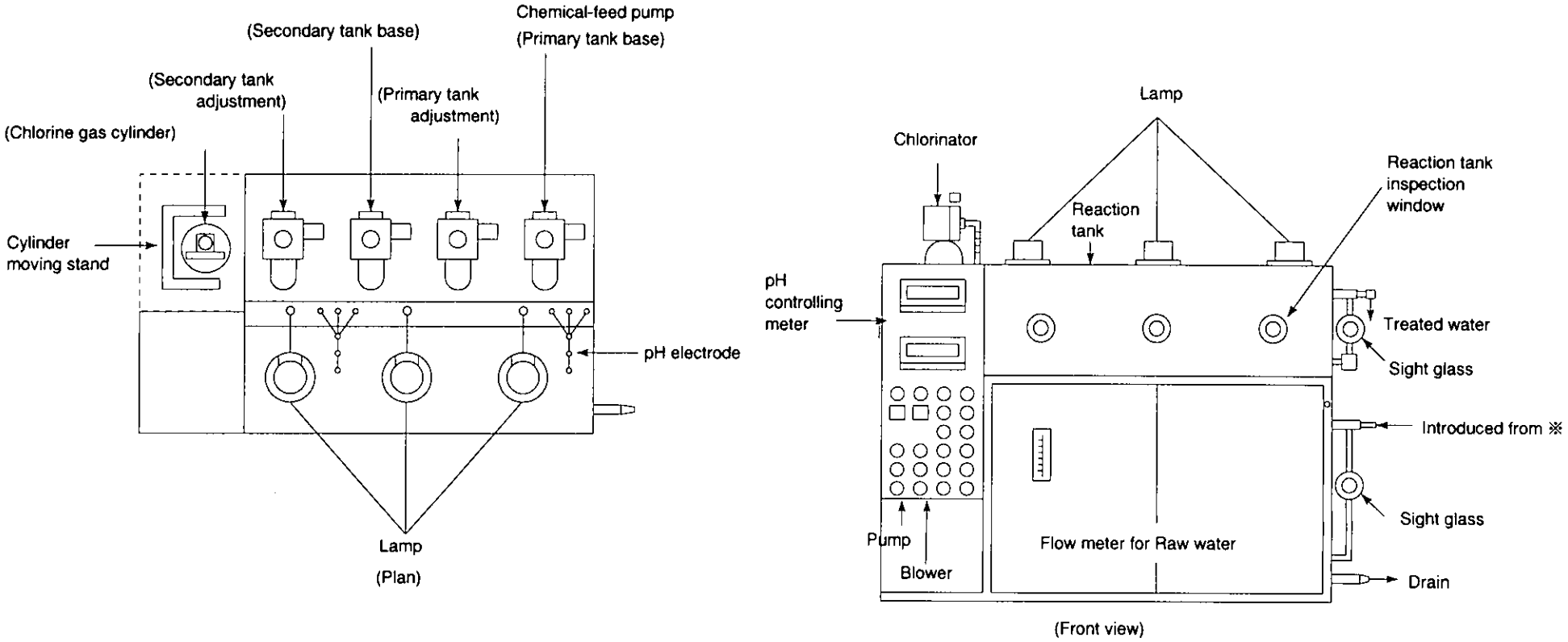
\In reference to every treatment method, a contract on commission is to be made with the Environmental Pollution Control Service Corporation individually, and the research is to be conducted according to the contract.



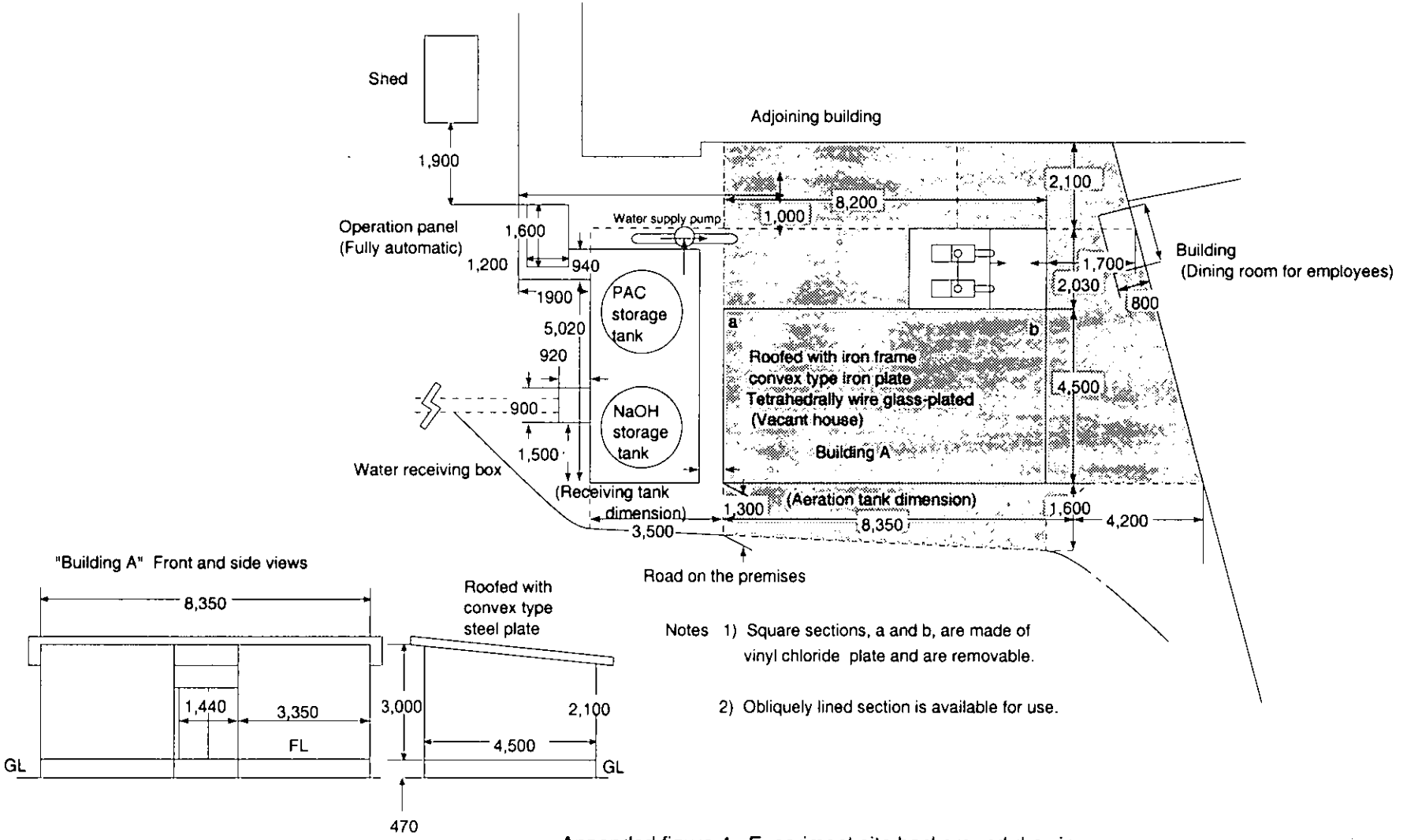
Appended figure 1
Activated sludge, coagulating sedimentation, filtration, contact oxidation method



Appended figure 2 Oxidation by ozone, granular activated carbon adsorption method



Appended figure 3 Oxidation method by light and chlorine



Notes 1) Square sections, a and b, are made of vinyl chloride plate and are removable.

2) Obliquely lined section is available for use.

Appended figure 4 Experiment site background drawing

INVESTIGATIVE REPORT ON THE DYE WASTEWATER ADVANCED TREATMENT TECHNOLOGY

THE ACTIVATED SLUDGE, COAGULATING SEDIMENTATION, FILTRATION AND CONTACT OXIDATION METHODS

1974 REPORT ON THE RESEARCH COMMISSIONED
FOR POLLUTION CONTROL PUBLIC WORK

DECEMBER 1974

KURITA WATER INDUSTRIES, LTD.

CONTENTS

1. Subject of the Research

Investigation and research on the dye wastewater advanced treatment technology

(The activated sludge, coagulating sedimentation, filtration and contact oxidation methods)

2. Contents of the Research

2.1 Target

In the dyeing processing arranging industry, since the types of chemicals used vary with the kind, color, and light and shade of the material to be dyed, the quality and amount of wastewater change greatly. Furthermore, some of the chemicals used do not allow such treatment processes as activated sludge, coagulating sedimentation, filtration, etc. to remove their COD components. Consequently, there are some cases where the water quality standard can not be enhanced.

This investigation is aimed at establishing the advanced treatment technology which aims to satisfy the Osaka Bay water area strict standard (Type 2 water area).

COD	15mg/ ℓ or less
BOD	20mg/ ℓ or less
SS	20mg/ ℓ or less

2.2 Contents of the research implemented

2.2.1 Test Liquid

Synthetic model wastewater, which was produced by mixing dyeing processing wastewater discharged from factory A affiliated with factory J's housing complex cooperative and sulphur dye wastewater discharged from factory B was used. Top dyeing was applied to most stages of the dyeing processing .

2.2.2 Items for the research

(1) Operation of processes from the activated sludge method to filtration

As pretreatment for advanced treatment, the activated sludge and coagulating sedimentation methods and filtration were to be carried out, and the the effects of the the treatment by those methods were to be verified.

(2) The contact oxidation treatment

Conditions were to be determined by a batch type experiment conducted with wastewater treated by the methods mentioned in (1). Relations between flow velocity and COD removal were to be examined by a continuous type experiment.

2.3 Location of the research implemented

Factory A located in Sakai City

2.4 Outline of the research implemented

Figure-1 shows a research facility flow sheet. Raw water was sampled from a wastewater storage tank owned by factory A by using a submersible pump. It appears that the retention time of the storage tank was about 30 minutes.

The appointed amount of raw water flowed into an aeration tank ($2m^3$) via a weighing tank, and excess water overflowed into the storage tank.

The mixed solution flowing out of the aeration tank was divided into supernatant and activated sludge in an activated sludge sedimentation tank (1 m^3), and the activated sludge was returned to the aeration tank by a

return sludge pump. The return sludge rate ranged from 80 to 100%. As a nutrient for activated sludge, nitrogen of urea and phosphorus of dipotassium phosphate were used, and the proper quantity of each of them was thrown into the aeration tank once a day.

Coagulants were added to the wastewater treated by activated sludge in a reaction tank. The treated wastewater flowed into a coagulating sedimentation tank (1 m^3) after flocs were formed. Then, the treated wastewater was separated from the flocs and flowed into a coagulation treatment tank. Sludge which sedimented in the coagulating sedimentation tank was pulled out once a day.

A filter was filled with 40 ℓ of filter sand and was operated at a filtration rate of 2.6m/H. Filtrate was stored in a filtrate tank and used in advanced treatment experiments. Backwash with tap water was applied to the filter once a day.

3. Analysis and Measuring Methods

Analyses of sample water and of sludge were conducted in accordance with the following.

Item	Analysis Method
Temperature	JIS K0102 · 4
External appearance	JIS K0102 · 5
Turbidity	
Absorbance	
Transparency	JIS K0102 · 6
pH	JIS K0102 · 8
COD_{Mn}	JIS K0102 · 13
COD_{Cr}	JIS K0102 · 15
BOD	JIS K0102 · 16
Total chrome	JIS K0102 · 51
Chromic acid	JIS K0102 · 51
Total Iron	JIS K0102 · 47
Nickel	JIS K0102 · 41
Total nitrogen	JIS K0102 · 27
Total phosphorus	JIS K0102 · 27
SS	JIS K0102 · 10
Residual chlorine	JIS K0102 · 26
ABS principle	JIS K0102 · 22
DO (dissolved oxygen)	JIS K0102 · 24
SV	Japan Sewage Works Association's sewage test method
SVI	Japan Sewage Works Association's sewage test method
Settling velocity	Japan Sewage Works Association's sewage test method
MLSS	Japan Sewage Works Association's sewage test method
MLVSS	Japan Sewage Works Association's sewage test method
I_2 consumption	Japan Sewage Works Association's sewage test method
Microscopic examination	Microscopic examination of activated sludge by a microscope

4. Outline of the Research

4.1 Progress of the research

600 ℓ of return sludge was sampled at Ishizu sewage treatment plant on September 17, and the sampled return sludge was regarded as seeding sludge. Water passage started after the seeding sludge was aerated in an empty space for two days, and data collection started from September 24. Activated sludge treatment was operated under four conditions.

Coagulating sedimentation and the filter were operated under almost fixed conditions. As coagulants, 100 - 150ppm of aluminum sulfate and 1ppm of polymer coagulants KURIFLOC PN 133 were used from September 26 to October 24. From October 25 to November 18, instead of aluminum sulfate, PAC was used in the same quantity as aluminum sulfate. Since the amount of activated sludge carried over was 100ppm and over from November 18, the amount of PAC to be added was increased to 180 to 200ppm.

The contact oxidation treatment greatly differed from the activated sludge and the coagulating sedimentation and filtration treatment in terms of experiment methods, so that the filtrate was sent to the General Research Institute of Kurita Water Industries, Ltd., where an experiment on the contact oxidation treatment was conducted.

4.2 Experiment conditions

Operation conditions for the activated sludge treatment can be classified into four categories according to the period of the experiment. Table-1 shows operation conditions for the activated sludge experimental equipment.

Table-1 Operation conditions for the activated sludge testing equipment

RUN	Period	Operation conditions		
		Flow rate	Space loading	Raw water
1	Sep.24 - Oct.31	6.5m³/day	0.5Kg/m³ · day	Factory A only
2	Nov.01 - Nov.13	7.0	0.5	Factory A only
3	Nov.14 - Nov.22	7.0	0.5	Addition of Sulphur dye wastewate
4	Nov.23 - Nov.29	14.0	1.1	Factory A only

Table-2 Chemical- feed to rate coagulating sedimentation equipment unit

Period	The amount of chemical fed (ppm)	
	Inorganic coagulant	Polymer coagulant
Sep.24 - Oct.24	Aluminum sulfate 100 - 150	PN133 1.0
Oct.25 - Nov.18	PAC 100 - 150	PN133 1.0
Nov.18 - Nov.18	PAC 180 - 200	PN133 1.0

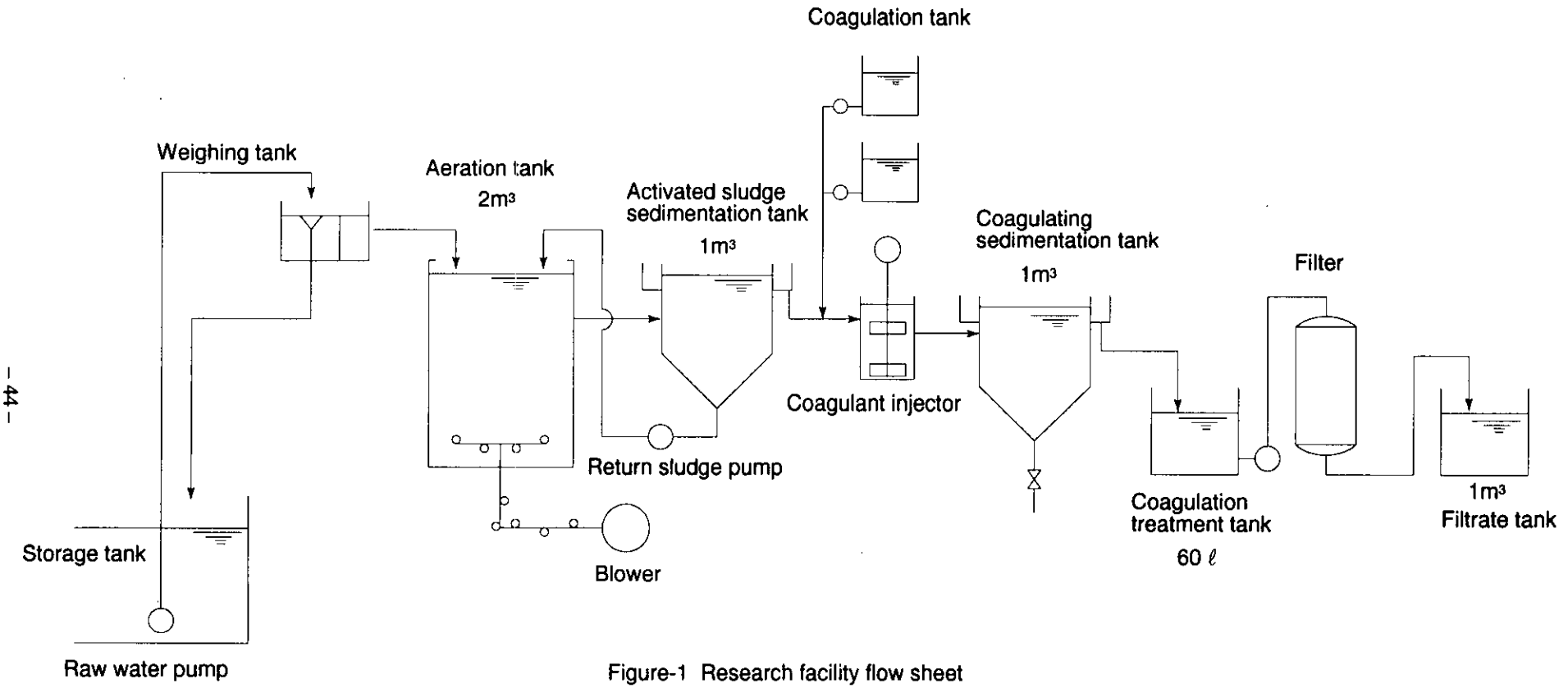


Figure-1 Research facility flow sheet

The filtration rate of the filter was 2.6m/H, and backwash was carried out once a day.

The amount of COD_{Mn} of treated wastewater could not be 15ppm or less by activated sludge, coagulating sedimentation, and filtration. Consequently, spherical catalysts (CN balls) were employed, and COD removal was examined by contact oxidation with chlorine..

Prior to use of the CN balls, according to directions mentioned in a catalog of CN balls, they had been dipped in a 3% NaClO solution until foaming was observed, and then they were washed before being used in experiments.

In an experiment by the batch method, 10g of CN balls was put into 500m ℓ of test liquid. The designated amount of NaClO was added to the liquid, and pH was controlled by sulfuric acid. Then, the liquid was shaken for 40 minutes so that the CN balls could come in contact with it. After that, the liquid was filtrated by a filter paper 5 Type C, and COD of the liquid was analyzed.

As for a water passage experiment, after NaClO was added to 2 ℓ of test liquid, the liquid passed through a glass tower having an internal diameter of 27mm which was filled with CN balls, on the condition that SV was 5.1 ℓ / hr. Treated wastewater (510m ℓ) collected between the times, 20 minutes and 80 minutes after water passage started, was measured in terms of pH, residual chlorine, and COD.

In each experiment, COD was measured after residual chlorine was removed by sodium hypochlorite.

4.3 Results of the research

4.3.1 The activated sludge treatment

Results of the activated sludge treatment are shown in Table-3. Although the quality of raw water varied greatly, a change in the quality of treated wastewater was relatively small since the retention time of the aeration tank was long. Numerical values for the aeration tank related operation are shown in Table-4. The temperature of the water inside the aeration tank was on the order of 30℃, which was a good condition for the activated sludge treatment. SVI of sludge was generally 100 or less, and so the sludge settling efficiency was satisfactory.

The amount of COD_{Mn} of the wastewater treated by activated sludge slightly varied with the treatment condition. Particularly, it is 100ppm and over in the case of RUN 4, which originated in activated sludge carried over.

Regarding removal of color, there are only qualitative observation results. However, it was recognized that red and yellow colors tended to be difficult to remove in general.

The influence of addition the of sulphur dye wastewater was mainly represented by the fact that the quantity of activated sludge carried over increased in the sedimentation tank. However, the influence of the addition of sulphur dye wastewater on the quality of the final filtrate was hardly recognized, so it can be concluded that the addition of sulphur dye wastewater does not seriously hinder treatment effects. As a result of a microscopic examination, even when the value of SV was high, filamentous fungi were hardly observed. The number of protozoa was generally small, and the number of pelmatozoic Ciliata (Vorticella, Carehesium sp) was extremely small.

4.3.2 Coagulating sedimentation / filtration

When wastewater treated by activated sludge was treated by coagulating sedimentation, the treated wastewater was in a favorable condition. The amount of COD_{Mn} was about 45ppm after the coagulating sedimentation treatment. As for the amount of coagulant used, treatment was possible only with 200 ppm of PAC and 1ppm of polymer coagulant, even in the cases of RUN 3 and 4 where the amount of activated sludge carried over was remarkably large. The quality of wastewater treated by coagulating sedimentation and the quality of filtrate are shown in Table-5. The amount of COD_{Mn} of filtrate is 40ppm on average, and consequently advanced treatment needs to be added in order to attain the target value of 15ppm.

Concerning color, as in the case of the activated sludge treatment, it was difficult to remove red and yellow colors.

4.3.3 Sludge production

As a result of the calculation based on an increase in the amount of MLSS and the amount of sludge pulled out, in the case where the amount of sludge carried over was small, the amount of excess sludge produced by the activated sludge treatment varied from 0.23 to 0.28Kg · dry sludge /Kg-BOD.

Table-6 shows surveyed values of the amount of coagulant added and the amount of sludge produced in the case of coagulating sedimentation. If the amount of sludge carried over is not large on the condition that 150ppm of PAC is added, it appears that the amount of sludge produced by coagulation will be 0.1Kg · dry sludge /m^3 of wastewater. Meanwhile, judging from Table-5, if the average amount of BOD of raw water is 180ppm, the amount of excess sludge produced will be 0.05Kg · dry sludge /m^3 of wastewater, so that the total amount of sludge produced will be 0.15Kg dry sludge /m^3 of wastewater.

4.3.4 Contact oxidation

Table-7 shows the results of the analysis of sample water used in an experiment.

Table-8 shows the results of an experiment by the batch method conducted with the sample water on October 23. Table-8 indicates the results of the examination of optimum conditions by changing the pH value at the time of the reaction. When the pH value was 2.6, the lowest COD value was obtained. However, the concentration of nickel contained in treated wastewater became high when the pH value was low. Consequently, the pH value must be 8 or more in actuality. Table-9 shows the results obtained when the amount of chlorine was changed on the condition that the pH value was fixed. The influence of the amount of chlorine added was little.

Table-10 shows the results of water passage experiments in terms of COD removal. The table indicates that while a decrease in the amount of COD by oxidation with chlorine only was remarkable, the effect of CN balls was little. In all experiments, color could be removed for the most part by adding chlorine.

4.3.5 Summary of results of the experiment

The experiments were aimed at treating dye wastewater to the level at which the COD_{Mn} value of 15ppm or less could be attained. The activated sludge, coagulating sedimentation, filtration, and contact oxidation methods were examined.

Results of the treatment by the activate sludge, coagulating sedimentation, and filtration methods are summarized in Table-11.

Table-3 Quality of water treated with activated sludge

Sampling date and time	Raw water									Water treated with activated sludge							
	Water temperature	pH	COD Mn	COD Cr	BOD	SS	Turbidity	Transparency	External apperance, others	pH	COD Mn	COD Cr	BOD	SS	Turbidity	Transparency	External apperance, others
9/20 15.00	℃ 37.5	6.8	ppm 162	ppm	ppm	ppm		9.5	Light orange	6.4	ppm 35	ppm	ppm	ppm		8	Light blue
21 10.00	33.0	7.6	63			13		15	Light red	5.9	32			45		10	Light blue
22																	
23																	
24 10.00	31.0	7.2	92	403	135	40		10	Light orange	7.6	32	94	21	30		24	Light green
25 10.30	34.5	6.9	138					8	Light red	7.4	43					18	Almost nil
26 11.00	38.5	6.3	140			37		9	Dark red	7.5	49			14		18	Slightly brown
15.00		6.8	150				61	10	Dark red	7.5	58					12	Light red
27 9.30	34.0	7.0	105	454	147			10	Light red	7.3	43	206	56		80	10	Light red
28 11.00	36.5	8.4	98			11		15	Light yellow	7.6	51			38		6	Slightly brown, turbid
29																	
30 10.30	37.5	6.1	126					16	Almost nil	7.2	50					7	Yellow, slightly turbid
10/1																	
2 16.30	34.0	7.4	122			288		57	Grayish white, turgid	7.8	32			30		10	Nil
3 13.30	34.0	7.1	112					57	Grayish white, turgid	7.7	34					14	Nil
4 10.30	37.0	6.4	135	586	175		91	12	Light green	7.2	35	106	22		40	20	Nil

Sampling date and time		Raw water									Water treated with activated sludge							
		Water temperature	pH	COD Mn	COD Cr	BOD	SS	Turbidity	Transparency	External apperance, others	pH	COD Mn	COD Cr	BOD	SS	Turbidity	Transparency	External apperance, others
		℃		ppm	ppm	ppm	ppm					ppm	ppm	ppm	ppm			
10 / 5	10.20	37.0	5.8	150			57		15.5	Red	7.0	30			5>		30	Nil
6																		
7	13.45	35.5	7.1	104					8	Light red	7.6	46					19	Light green
8	13.00	33.5	6.6	118	661	201		198	8	Green	7.5	33	113	85		53	13	Nil
9	10.00	35.5	6.1	120			5		12	Light green	7.2	40			24		12	Light yellow, turbid
10																		
11		Factory is out																
12		Raw water is stopped																
13																		
14	14.00	32.5	5.1	122		101			22	Light yellow	6.4	48					7	Slightly yellow
15	11.00	34.0	7.2	106	396	101	13	55	18	Light red	7.6	48	178	81	25	53	16	Light green
16	15.00	37.0	8.9	142					8	Dark red	7.7	81					6	Light orange
17	13.30	35.5	6.6	198					12	Yellowish brown	7.6	82					6	Dark red
18	10.30	37.5	7.2	142	518	97	18	58	17	Dark red	7.3	70	210	50	40	59	8	Light red
19		Factory is out															10	
21	13.30	35.5	7.5	112					17	Turbid, beige	7.0	46					9	Turbid, beige
22	10.30	34.0	7.2	122	594	176	14	104	10	Pink — ABS 1.2, T-Cr 0.5>, Cr(VI)Nil, T-N1991, T-P5.4	7.4	27	145	10>	21	33	24	Almostnil — ABS 1.0, T-Cr 0.5, Cr(M)Nil

Sampling date and time	Raw water									Water treated with activated sludge							
	Water temperature	pH	COD_{Mn}	COD_{Cr}	BOD	SS	Turbidity	Transparency	External apperance, others	pH	COD_{Mn}	COD_{Cr}	BOD	SS	Turbidity	Transparency	External apperance, others
10 / 23 9.30	℃	7.1	ppm 95	ppm	ppm	ppm		11	yellow	7.3	ppm 39	ppm	ppm	ppm		14	Slightly blue
10.00		6.0	114					14	Light yellow	7.6	41					18	Slightly blue
11.30		6.9	100					12.5	Light yellow	7.5	41					17	Slightly yellow
13.30		7.0	139					9	Light red	7.6	47					13	Light yellow
14.30		6.7	170					9.5	Light dark brown	7.3	45					15	Light yellow
15.30		6.9	176					7	Reddish brown	7.4	43					16	Light yellow
16.30		6.9	132					11	Reddish brown	7.4	39					19	Light yellow
24 10.30		4.7	174					17.5	Nil	7.3	40					15	Light red
25 13.30		7.2	142	613	273	14	75	15	Light brown	7.6	140	404		24	96	9	Turbid, bright yellow
26 13.30		6.8	116					7	Pale beige	7.6	68					10	Bright yellow
27		6.6	186					5>	Dark brown								
28 13.30		7.2	111					9	Light brown	7.5	43					11.5	Dark brown
29 12.00		6.9	126	526		9	108	9	Light green	7.4	47	150		24	36	13	Light brown
30 12.30		7.1	106					18	Nil	7.4	37					18	Almost nil
31 14.30		6.8	148					17	Light brown	7.5	46					15	Light brown

Sampling date and time	Raw water									Water treated with activated sludge							
	Water temperature	pH	COD Mn	COD Cr	BOD	SS	Turbidity	Transparency	External apperance, others	pH	COD Mn	COD Cr	BOD	SS	Turbidity	Transparency	External apperance, others
11 /1 11.20	℃	7.2	ppm 113	ppm 568	ppm 252	ppm 13.6	95	14	Light reddish purple T-N15.7 T-P3.1	7.7	ppm 46	ppm 145	ppm 32	ppm 10.5	35	16	Yellow slightly tubid T-N263 T-P55
2 10.00		6.9	168					12	Green								
14.00		7.5	145					4.5	Tubid green	7.5	49					11	Light brown
3	Factory is out.																
4																	
5 15.30		7.7	141					14	Light green	7.4	80					6	Brown
6 14.30		7.2	184				70	7	Green	7.8	49.5				47	14	Light brown
7 9.30		7.8	136				75	6	Light blue	6.4	53				45	9	Light brown
10.30		7.6	156				95	6	Light blue	6.4	64.5				48	7	Light brown
11.30		6.3	164				72.5	8.5	Light blue	6.6	72				69	7	Light brown
12.30		6.8	172			9.0	80	8	Light blue	6.8	78.7			61	75	7	Pale brwon
13.30		6.9	166				82.5	7.5	Light blue	6.9	85				62	7	Pale brwon
14.30		7.1	128	516	170		66	11	Light blue T-Cr 0.5 >	6.9	76	277	26		70	6	Pale brwon
15.30		7.2	124				125	9	Green	7.1	60				62.5	7	Pale brwon
16.30		7.0	140				73	14	Green	7.1	78				65	7	Pale brwon

Sampling date and time	Raw water									Water treated with activated sludge							
	Water temperature	pH	COD_{Mn}	COD_{Cr}	BOD	SS	Turbidity	Transparency	External apperance, others	pH	COD_{Mn}	COD_{Cr}	BOD	SS	Turbidity	Transparency	External apperance, others
	℃		ppm	ppm	ppm	ppm					ppm	ppm	ppm	ppm			
11/7 18.30		5.8	128				45	13	Green	7.3	74				70	7	Pale brown
8 14.00		6.9	148	556	120	100	150	7	Green	7.4	52	124	9.0	15	33	18	Slightly yellow
9 15.00		6.5	132				41	12	Rddish purble	7.8	58				35.5	13	Pale yellow
10 10.00		7.2	168					11	Rddish purble	7.8	56					13	Pale reddish purple
11 14.00		7.1	186				75	9	Rddish purble	7.6	48.5				37	10	Pale reddish purple
12 12.00		7.4	122	588	164	70	54	11	Rddish purble T-N 44.1 T-P 2.4	7.8	43.5	182	14.0	25	36	12	Pale brown T-N 28.2 T-P 3.1
13 9.30		4.7	202						Pale yellow	7.7	84					6	Brown
10.30		5.1	224						Dark green								
11.30		6.8	182						Lihgt green	8.0	83					7	Brown
14.00		7.1	158						Reddish brown								
15.00		6.2	176						Reddish purple	8.1	81					7	Light brown
17.00		7.1	164						Pale yellow	8.1	84					8	Pale yellow
14 ┐																	
Sulphur dye wastewater passes.																	
15 ┘																	
16 10.30		9.4	172					9	Dark reddish purple	7.7	88					8	Reddish purple

Sampling date and time		Raw water									Water treated with activated sludge							
		Water temperature	pH	COD Mn	COD Cr	BOD	SS	Turbidity	Transparency	External apperance, others	pH	COD Mn	COD Cr	BOD	SS	Turbidity	Transparency	External apperance, others
11 / 16	14.30	℃	9.6	ppm 148	ppm	ppm	ppm		8	Dark reddish purple	8.1	ppm 84	ppm	ppm	ppm		5	Reddish purple
	14.30		7.3	144					10	Reddish purple								
17	13.30		10.3	168					6.5	Dark reddish purple	8.5	99					6	Dark reddish purple
18	11.00		10.4	156			25		9	Dark reddish orange	7.6	99			110		6	Reddish orange
19	13.00		9.3	196				83	4	pale dark brown	7.6	84				62.5	7	Pale yellow
	16.00		10.0	164			33.3	73	6	Pale yellowish-green; T-Cr 0.5 > T-Fe2.2 T-N4.5 T-P1.0 I_2 Comsumption 92.6	7.4	76			60	60	8	pale brown; T-Cr 0.5 > T-Fe2.6 T-N12.4 T-P3.4 I_2 Comsumption 12.7
20	12.00		10.0	116	417	126	26.7	55	11	Pale dark green	7.4	62	247	44.5	77	70	8	pale brown
21	10.00		10.0	160				64.5	9	Pale dark red	7.3	52				75	6	Reddish purple
	11.30		9.9	118				66.3	10	Pale green	7.4	52.5				102	4	Pale reddish purple
	13.00		9.2	156				100	10	Pale dark green	7.3	51				90.5	5	Pale reddish purple
	14.30		9.9	136				95	6	Pale dark green	7.4	62				130	4.5	Pale reddish purple
	16.00		9.9	130				72.5	8.5	pale reddish brown; T-Cr 0.5 > Cr(VI)0.12 T-N 31.5 T-P 2.5 I_2 Comsumption 190	7.4	71				150 <	4.5	Reddish brown; T-Cr 0.5 > Cr(VI)0.04 T-N 20.9 T-P 2.8 I_2 Comsumption 11.4
22	13.00		9.4	178	697	298	67	65	7	Pale black	7.6	71	315	60.8	130	80	4.5	Pale brown
23		Factory is out.																
24																		

Sampling date and time	Raw water									Water treated with activated sludge							
	Water temperature	pH	COD_{Mn}	COD_{Cr}	BOD	SS	Turbidity	Transparency	External apperance, others	pH	COD_{Mn}	COD_{Cr}	BOD	SS	Turbidity	Transparency	External apperance, others
11 / 25 13.00	℃	9.0	ppm 168	ppm	ppm	ppm	43.8	9	Reddish purple	7.3	ppm 133	ppm	ppm	ppm	142	4.5	Pale dark brown
26 10.00		9.1	184				62.5	16	Pale blue, H_2S Chemical	7.5	119				170	4	Brown
11.00		9.9	138				43	17	Brown								
12.00		8.7	162				32	15	yellow	7.7	110				124	5	Pale brown
13.00		9.1	128				56	7	Pale brown								
14.00		10.0	166				55.5	8	Pale red	7.6	103				110	5	Pale yellowish brown
15.00		9.6	168				51.5	12	Red T-Cr 0.5 > I_2 Comsumption60.3 T-N 12.8 T-P 2.5 ABS 1.5								
16.00		9.8	162	588	198	30	42.5	12	Purple	8.2	114	507	169	160	145	5	Pale brown I_2 Comsumption 20.9 T-N48.7 T-P5.0
17.00		10.1	172				63.8	6	Reddish purple								
27 11.30		10.0	132	574	157	25	74	8	Pale red T-Cr 0.5 > I_2 Comsumption60.3 T-N1 12.8 T-P 2.5 ABS 1.5	8.0	98	517	83	200	125	5.5	Brwon I_2 Comsumption 5.7 T-N 36.2 T-P 4.9
28 11.30		9.7	192				148	5	Blackish brown	7.5	104				173	5	Brwon
16.00		9.2	152				170	3	Blackish brown	7.9	92				140	4	Brwon
29 11.00		9.7	116				95	8	Pale brown	7.5	88				157	4	Dark brown
15.00		7.6	128	506	174	45	85	7.5	Pale red T-N 8.8 T-P 3.0 T-Cr 0.5 > I_2 Comsumption 22.8	7.5	74	299	66.8	120	125	5	Brwon T-N 27.1 T-P 4.6
30 10.00		7.3	132				40	13	Pale yellowish green	7.5	85				80	6	Pale brown

Table-4 Aeration tank operation numerical value (1)

Date	Flow m^3/day (Sulphur dye wastewater Ratio %)	D·T (hrs)	Space loading (kg-BOD/m^3 day)	SV (%)	MLSS (ppm)	MLVSS (ppm)	SVI (cm^3/g)	Water temperature (℃)	DO (ppm)	Sludge setting velocity (m/hr)	Volume of sludge removed (ℓ)	Remarks
9/17												Sludge is thrown in.
18				18								Return 2m^3/hr×⁻12hr
19				18								
20				18				24.0				Raw water is put in.
21				17	2,700		63					
22												
23												Return rate 300%
24	6.5	7.4	0.44	23	3,300		70	26.5				Continuous operation starts.
25	6.5	7.4		24	3,020		80	30.5		2.4		
26	6.5			25	2,920		86	30.0				
27	6.5		0.48	28				30.5				
28	6.5			27	3,100		87	30.0	0.2~0.3			Return sludge 7,300ppm
29	6.5											
30	6.5			27				27.0				
10/1	6.5			31								

Date	Flow m^3/day (Sulphur dye wastewater Ratio %)	D·T (hrs)	Space loading (kg-BOD/m^3 day)	SV (%)	MLSS (ppm)	MLVSS (ppm)	SVI (cm^3/g)	Water temperature (℃)	DO (ppm)	Sludge setting velocity (m/hr)	Volume of sludge removed (ℓ)	Remarks
10/2	6.5			31				30.0				Removed sludge concentration 1.71%
3	6.5			26	3,200		81	30.5			90	Return sludge after removal 8,200ppm
4	6.5			31				30.5			25	Return rate 87%
5	6.5			43	2,900	2,400	148	29.0			15	
6	6.5											
7	6.5			34				31.5		1.4	30	
8	6.5		0.65	52	3,400	2,700	15.3	31.5			30	
9	6.5			56				30.0				
10												
11												
12												
13												
14	6.5	7.4		28	3,800	2,200	74	22.5				Return sludge concentration 7,800ppm
15	6.5	7.4	0.33	33				28.5		2.0		
16	6.5	7.4		30	3,400		88	32.0	0.2~0.3			

Date	Flow m^3/day (Sulphur dye wastewater Ratio %)	D·T (hrs)	Space loading (kg-BPD/m^3 day)	SV (%)	MLSS (ppm)	MLVSS (ppm)	SVI (cm^3/g)	Water temperature (℃)	DO (ppm)	Sludge setting velocity (m/hr)	Volume of sludge removed (ℓ)	Remarks
10/17	6.5	7.4		34				31.5				
18			0.32	33				26.0	5.0			
19				33						1.0		
20												
21	6.5	7.4		26	2,500		104	24.5	4.1			
22			0.65	29				27.0	5.0			
23				32					2~2.5			
24				33	4,100		81		2~2.5			
25			0.89	59					1.0		30	
26				35					1.8		15	
27												
28				36	4,300		84		2.6		15	
29				40					2.0		30	
30				36	3,650		104		2.5		60	
31				38					4.0	1.3	15	

Table-4 Aeration tank operation numerical value

Date (Month/day)	Flow m^3/day (Sulphur dye wastewater Ratio %)	D·T (hrs)	Space loading (kg-BOD/m^3 day)	SV (%)	MLSS (ppm)	MLVSS (ppm)	SVI (cm^3/g)	Water temperature (℃)	DO (ppm)	Sludge setting velocity (m/hr)	Volume of sludge removed (ℓ)	Remarks
11/1	6.5	7.4	0.82	43								
2	5.9	8.1		38	3,900		97		4.0	1.2	0	Return sludge 10,900ppm
3												
4												
5	8.6	5.6		38	5,200	1,560	73	27	5.0		0	Fe content in sludge 1.5%
6	7.6	6.3		56	5,100		110	27	2.7	0.5	0	
7	7.5	6.4	0.64	44	4,640 4,980		95 76	32	2.5~5	1.8	15	RS 11,600ppm
8	6.6	7.3	0.40	38 74	5,800		128	31	2.5~3		15	
9	7.0	6.9		40				30	5.0	1.2	15	
10	7.0	6.9		40	5,300		75				5	
11	8.6	5.6		41	5,300		77	28	3.3	1.0	0	
12	7.0	6.9	0.57	76	5,800		131	29	2.0		0	
13	7.0	6.9		75					1.5~3	0.2	60	
14	6.8 (3.3)	7.1									0	Sulphur dye wastewater starts passing.
15	7.0 (4.9)	6.9		75	5,700	4,390	132			0.2	0	
16	7.5 (4.3)	6.4		76				25	1.0~2.3	0.2	60	

Table-4 Aeration tank operation numerical value

Date (Month/day)	Flow m^3/day (Sulphur dye wastewater Ratio %)	D·T (hrs)	Space loading (kg-BOD/m^3 day)	SV (%)	MLSS (ppm)	MLVSS (ppm)	SVI (cm^3/g)	Water temperature (℃)	DO (ppm)	Sludge setting velocity (m/hr)	Volume of sludge removed ()	Remarks
11/17	7.1 (10)	6.8						24	1.5~2.0		0	
18	7.1 (3.3)	6.8		85	5,200		163	27	0.6~2.5	0.2	45	Sulphur dye wastewater is changed. Return sludge 14,500ppm
19	6.8 (4.5)	7.1		70	5,400		130	28	0.2~2.5		60	
20	6.8 (4.2)	7.1	0.43	47		4,100		26	0.5~1.2	0.4	45	
21	6.8 (4.2)	7.1		60	6,300		95	27.5	0.5~1.2	0.2	60	
22	7.0 (4.2)	6.9	1.00					25	0.2		0	
23	13.8	3.5									0	
24	14.4 (4.0)	3.3		36.5	4,400	3,080	83			1.2	60	Sulphur dye wastewater is changed.
25	14.4 (4.0)	3.3		22	3,500		63	32	0.7~1.3	2.4	30	Return sludge 17,000ppm
26	14.0 (4.0)	3.4	1.4	15	2,100		71	33	0.3~1.2	2.6	0	
27	14.4 (4.0)	3.3	1.1	15	1,200		125	28.5	0.6~1.5	2.6	0	Return sludge 11,600ppm
28	14.4 (4.0)	3.3		13.5	1,300		104	28	0.2~0.8	2.6	0	
29	14.4 (4.0)→8.6	3.3→5.6	1.3→0.75	13	1,800	1,420	72	28	0.3~0.4	2.3	0	
30	8.6	5.6		19				28	0.8~1.2	1.5	0	

NOTE) Parenthesized figures in the colomn of flow show the inflow rate (%) of factory B's wastewater containing sulphur dye wastewater.
It may be considered that the inflow rate for the period of Nov. 18 to 22 is equal to 10% because the COD and BOD values of the above-mentioned wastewater were about twice as thick as the average.

Date	Water treated by coagulating sedimentation								Water treated by filtration							
	pH	Turbidity	Trans parency	SS	COD_{Mn}	CODcr	BOD	External appearance, others	pH	Turbidity	Trans parency	SS	COD_{Mn}	CODcr	BOD	External appearance, others
9/20																
21																
22																
23																
24								11:30 Band polymer injection starts								
25																
26	6.3		30<	5>	33			Light yellow Band 110ppm polymer 1ppm								
	6.3		〃		40			Light red Band 170ppm polymer 1ppm								
27	6.8	17	〃		31	76	10>	Dark red								
28	6.2		〃	5>	35			Nil								
29																
30	4.4		30<		33			Nil Band 110ppm polymer 0.6ppm								
10/1																
2	7.1		30<	5>	38			Nil								
3	6.8		〃		20			〃 Removed sludge concentrarion 5100ppm	6.5		30<		10.0			Almost nil
4	5.6	8	〃		20	58	10>	Slightly green Band 138ppm polymer 0.6ppm	5.6	2.4	30<		16.6	56	10>	Nil, slightly green
5	4.9		〃	5>	21			Slightly red	6.1		30<	5>	18.2			Nil, slightly green
6																
7	6.9		30<		28			Light green	6.6		30<		25.6			Light green
8	4.9	16	〃		19.5	61		Light green Slight addition of soda ash	4.5	4.5	30<		17.3	61	10>	Slightly green
9	6.5		〃	5>	26			Light green	6.5		30<	5>	24.5			Slightly green
10																
11		Factory is out.														
12				Raw water is cut.												
13																

Date	Water treated by coagulating sedimentation								Water treated by filtration							
	pH	Turbidity	Trans parency	SS	COD_{Mn}	CODcr	BOD	External appearance, others	pH	Turbidity	Trans parency	SS	COD_{Mn}	CODcr	BOD	External appearance, others
10/14	5.4		30<		27			Slightly yellow Slight addition of soda ash	6.4		30<		12.8			Nil, slightly yellow
15	7.1			5>	29	94	12	Light green	6.9	15	30<	5>	28.3	78	10>	Light green
16	6.9		18		66			No coagulation Light yellow								
17	6.8		8		53			Dark red	6.8		30<		53			Dark red
18	4.4	57	15	46	47	133	10>	Dark red	6.5	19	30<	5>	58	157	12	Dark red
19		Factory is out.			Raw water is cut.											
21	4.7		30<		23.6			Almost Nil	4.5		30<		26.0			Slightly dark pink
22	5.5		30<	10	27.8	74	10>	Almost Nil ABS 0.7 T-Cr 0.5>	5.0	11	30<	5>	15.5	64	10>	Almost nil ABS 0.7 T-Cr 0.5>
23	6.4		30<		22.8			Almost Nil Cr6+ Nil T-N 1 T-P 4	5.5		30<		24.0			Almost nil Cr6+ Nil T-N 197.6
	6.7		30<		25.8				6.6		30<		26.0			Almost nil T-P 0.32
	6.8		30<		23.3			Nil, slightly yellow	6.4		30<		22.3			Slightly yellow
	6.8		30<		27.5			Nil, slightly yellow	6.7		30<		27.0			Slightly yellow
	6.9		30<		27.5			Nil, slightly yellow	6.8		30<		25.0			Slightly yellow
	7.0		30<		27.8			Nil, slightly yellow	6.9		30<		25.0			Slightly yellow
	7.1		30<		25.0			Nil, slightly yellow	6.9		30<		22.5			Slightly yellow
24	6.9		30<		35.8			Nil, slightly yellow	6.8		30<		33.3			Slightly yellow
25	6.7	68	17	112	128	336	65	Blight yellow, no coagulation	6.7	55	22	20	138	341	72	Blight yellow
26	7.3		30<		46			Yellow Change to PAC, 100ppm	7.1		30<		41.6			Light yellow
27																
28	7.3		30<		29.6			Slightly dark yellow	7.2		30<		40.4			Yellow
29	7.0	6	30<	5>	32.6	74		Yellow	6.9	3.0	30<		29.4	83		Yellow
30	7.2		30<		27.0			Almost nil	7.0		30<		26.3			Nil
31	7.4		30<		27.8			Nil, slightly yellow	7.4		30<		23.8			Nil, slightly yellow

Sampling date and time		Water treated by coagulating sedimentation								Filtrate							
		pH	COD_{Mn}	CODcr	BOD	SS	Turbidity	Trans parency	External appearance, others	pH	COD_{Mn}	CODcr	BOD	SS	Turbidity	Trans parency	External appearance, others
11/1	11:20	7.3	28.5	89.7	32	5>	6	30<	Light green T-N 10.2 T-P 0.9	7.1	27.0	81.6	10>	5>	4.5	30<	Light green T-N 7.3 T-P 0.5
2	10:00																
	14:00	7.4	30					30<	Slightly yellowish green	7.3	30					30<	Slightly yellowish green
	3																
	4																
5	15:30	7.3	41.2					30<	Slightly yellowish brown	7.2	38.5					30<	Slightly yellowish brown
6	14:30	7.4	33.8				7.5	30<	Slightly yellowish green	7.3	31.2				6.0	30<	Slightly yellowish green
	9:30	4.7	32				10	27	Pale yellow	7.2	32				5.0	30<	Slightly yellow
	10:30	5.0	29				7.5	30<	Slightly yellowish green	6.2	20				1>	30<	Slightly yellow
	11:30	5.2	40.7				10	30<	Slightly yellow	5.4	32				4.0	30<	Slightly yellow
	12:30	5.4	42.7			5>	7	30<	Slightly yellow	5.4	40.7			5>	2.5	30<	Slightly yellow
	13:30	6.1	46.7				8	30<	Slightly yellow	6.0	42				5.0	30<	Slightly yellow
	14:30	6.4	47	116	22	10	11	30<	Slightly yellow	6.4	38.7	91.6	23	5>	6.5	30<	Slightly yellow
	15:30	6.7	40				11	30<	Slightly yellow	6.5	38				6.5	30<	Slightly yellow
	16:30	6.8					11	30<	Slightly yellow	6.7					6.5	30<	Slightly yellow
	18:30	6.9	43.5				11	30<	Slightly yellow	7.0	41.3				9.5	30<	Slightly yellow
8	14:00	7.3	36.5	103	5>	5>	11	30<	Slightly yellow	7.3	34	98.8	5>	5>	7.5	30<	Slightly yellow
9	15:00	7.3	45				10	30<	Pale yellow	7.3	33.7				7.0	30<	Pale yellow
10	10:00	7.5	35					30<	Pale reddish purple	7.5	35					30<	Slightly yellow
11	14:00	7.6	38				9	30<	Pale reddish purple	7.4	37.3				5.0	30<	Pale reddish purple
12	12:00	7.6	31.3	108	11.0	6	9.6	30<	Slightly yellow T-N 8.0 T-P 1.0	7.6	28.3	102	10>	5>	7.5	30<	Slightly yellow T-N 5.0 T-P 0.9
13	9:30	7.5	50.5					30<	Pale yellow	7.4	50.5					30<	Pale yellow
	10:30																
	11:30	7.6	51					30	Yellow	7.5	51						Yellow
	14:00																
	15:00	7.9	54.5					25	Yellow	7.9	55.5						Yellow
	17:00	7.8	45					30<	Yellow	7.9	44						Yellow
16	10:30	7.4	52					30<	Reddish purple	6.9	58.5					30<	Pale reddish purple

Sampling date and time	Water treated by coagulating sedimentation								Filtrate							
	pH	COD_{Mn}	CODcr	BOD	SS	Turbidity	Trans parency	External appearance, others	pH	COD_{Mn}	CODcr	BOD	SS	Turbidity	Trans parency	External appearance, others
11/16 14:30	7.4	58					30<	Pale reddish purple	7.4	48					30<	Pale reddish purple
17 13:00	7.9	58.5					30<	Reddish orange	7.8	56					30<	Reddish orange
18 11:00	7.5	64.5					21	Pale reddish orange	7.5	61.5			8		30<	Pale orange
19 13:00	7.2	58.5				14.8	30<	Pale yellow T-Cr 0.57	7.2	60.5				9	30<	Pale yellow
16:00	7.2	51			10	10	30<	Pale yellow T-Fe 1.8 T-N 9.2 T-P 0.5	7.2	53			5>	9	30<	
20 12:00	7.2	39	98.8	10>	6.7	7	30<	Slightly yellow	7.2	35	105	10>	5>	5	30<	Slightly yellow T-Cr 0.5>
21 10:00	7.1	25.5				6	30<	Reddish purple	6.9	24				4.5	30<	Reddish purple T-Fe 13 T-N 8.8
11:30	7.1	20.5				7.5	30<	Reddish purple	6.9	18.3				6	30<	Reddish purple T-P 0.4
13:00	7.1	20.8				7.5	30<	Reddish purple	7.1	20.3				6	30<	Reddish purple
14:30	7.1	21.5				8	30<	Reddish orange	7.0	20.5				7	30<	Reddish orange
16:00	7.3	21.0				13	30<	Pale reddish orange	7.2	21.0				9	30<	Pale reddish orange
22 13:00	7.4	29	87.0	16.8	8	7.5	30<	Slightly brown T-N 17.1 T-P 0.3 T-Cr 0.5> Cr(VI) 0.04	7.4	27.7	81.5	10>	5>	5.5	30<	Slightly brown T-N 17.1 T-P 0.3 T-Cr 0.5> Cr(VI) 0.04
23																
24																
25 13:00	7.2	60				32.5	14	Slightly yellow	7.2	45.7				15	30<	Slightly yellow
26 10:00	7.3	52				19.3	25	Light	7.0	21.5				7	30<	Slightly yellow
11:00																
12:00	7.1	52.5				12	30<	Slightly yellow	7.2	47				10	30<	Slightly yellow
13:00																
14:00	7.2	57				13.8	30<	Slightly yellow	7.1	48				7.5	30<	Slightly yellow
15:00																Consumption I_2 18.4 T-N 14.8 T-P 0.3 ABS 0.6
16:00	7.4	52	195	40.2	16	12.5	30<	Slightly yellow Consumption I_2 cosumption 3.2 T-N 19.3	7.4	52	175	39.2	4	6.5	30<	Slightly yellow
17:30								Slightly yellow T-P 0.4								
27 11:30	7.2	46	136	18.9	12	7.5	30<	Consumption I_2 cosumption 3>	7.2	42	125	14.4	5	4	30<	Slightly yellow Consumption I_2 3> T-N 4.1 T-P 0.4 ABS 0.5
28 11:30	7.0	40				9	30<	Slightly yellow T-N 5.8	7.0	37				3.5	30<	Slightly yellow
16:00	7.1	39				12.5	30<	Slightly yellow T-P 0.3	7.0	38				5	30<	Slightly yellow
29 11:00	6.9	36				13	30<	Slightly yellow	6.8	34				10	30<	Slightly yellow
15:00	7.2	35	109	16.7	12	18.8	30<	Slightly yellow T-N 21.3 Consumption T-P 0.6	7.1	32	96	11.9	5>	15	30<	Slightly yellow T-N 20.7 T-P 0.3
30 10:00	7.3	35					30<	Slightly yellow Consumption	7.2	33					30<	Slightly yellow T-Cr 0.5>

Table-6 Sludge production in coagulating sedimentation

Item / Date	Amount of PAC added ppm	Amount of PN-133 added ppm	Amount of sludge Removed sludge concentration × Volume ppm ℓ	Sludge production kg·ds/day	Flow (Raw water) m³/d	Sludge production kg·ds/m²	Remark	
							Water treated by activated sludge	Water treated by coagulation
11/18~11/19	146	1	5,200×45	0.23	7	0.03	8/8 SS 15ppm	8/8 SS 5>
11/13	150	1	9,100×30	0.27	7	0.10		
11/17~11/18	121	1	13,300×60	0.8	7	0.11	11/18 SS 110ppm	11/19 SS 20ppm
11/20~11/21	191	1	8,500×120	1.0	6.8	0.15	11/20 SS 77ppm	11/20 S 6.7ppm
11/26~11/27	200	1	12,100×195	2.4	14.4	0.16	SS 11/26 SS 160ppm 11/27 SS 200ppm	 11/26 SS 16ppm 11/27 SS 12ppm

Table-7 Contact oxidation experiment sample water quality

No.	Item / Sample	Sample of Oct. 23 10/23	Sample of Nov. 21 11/21	Sample of Nov. 27 11/27
1	External appearance Odor	Colorless, transparent, foaming	Red, transparent, foaming	Light yellow, foaming
2	pH (-)	6.5	7.9	8.1
3	Transparency (degree)	30 or more	30 or more	30 or more
4	Suspended solid (SS) (ppm)	-	-	-
5	COD Mn (ppm)	41.3	26.0	0.6~0.8
6	BOD (ppm)	-	-	-
7	COD Cr (ppm)	68.2	72.6	122
8	Absorbance (-10gT)	-	0.655	0.143
Remark		Sample name shows sampling date.	Absorbance value was obtained on condition that the wavelength was 510 nm 50 mm cell.	Absorbance value was obtained on condition that the wavelength was 455 nm 50 mm cell.

Analysis conforms to the industrial effluent testing method, JISK-0102.

Table-8 COD_{Mn} removal by CN ball (Influence of pH)

Amount of NaClO added as Cl_2 (ppm)	NaClO theoretical equivalent against COD_{Cr} (-)	Regulated pH (-)	pH of treated water pH (-)	Residual chlorine of treated water Cl_2 (ppm)	COD Mn of treated water (ppm)	Ni (ppm)
400	1.26	-1.5	2.5	90.5	33.2	665
400	1.26	2.6	4.1	81.0	32.5	37.9
400	1.26	4.8	6.4	114	36.5	2.6
400	1.26	6.2	6.6	116	34.6	2.0
400	1.26	8.1	8.1	132	34.8	Trace
400	1.26	9.7	9.4	148	35.6	Trace

Table-9 COD_{Mn} removal by CN ball (Influence of amount of NaClO added)

NaClO added as Cl_2 (ppm)	NaClO theoretical equivalent against COD_{Cr} (-)	Regulated pH (-)	pH of treated water PH (-)	Residual chlorine of treated water Cl_2 (ppm)	COD Mn of treated water (ppm)	Ni (ppm)
600	1.89	2.6	3.6	203	30.4	39.3
800	2.52	2.6	3.5	274	28.5	41.5
1000	3.15	2.6	3.5	376	28.3	36.9
1500	4.73	2.6	3.4	586	25.1	47.0

Table-10 Result of treatment by water passage experiment

Sample	Amount of NaClO added	Chlorinating water				Water treated by CN ball			
	Cl_2 ppm	Residual chlorine Cl_2 ppm	pH	COD_{Mn} ppm	Absorbance -log T	Residual chlorine Cl_2 ppm	pH	COD_{Mn} ppm	Absorbance -log T
Nov. 21	(Raw water)		7.9	26.0	0.655				
	950	500	7.8	19.5	0.010	216	8.3	17.5	0.010
	1,180	1,080	7.8	13.4	0.010	237	8.3	13.9	0.010
	2,360	2,015	7.8	15.6	0.010	550	8.2	11.4	0.010
Nov. 27	(Raw water)		8.1	58.3	0.143				
	550	430	7.0	46.8	0.025	176	7.5	41.8	0.025
	1,100	912	7.1	46.8	0.025	257	7.3	43.7	0.025
	2,200	1,855	7.1	46.6	0.025	850	7.0	41.5	0.025

As a result of the experiment, the following can be said.

1) The quality of raw wastewater is as follows:

BOD 200ppm (on average)

COD_{Mn} 170ppm (on average)

SS 50ppm (on average)

2) Treated wastewater with the quality mentioned below can be attained by the treatment up to filtration.

BOD 20ppm or less (on average)

COD_{Mn} 40ppm or less (on average)

SS 5ppm or less (on average)

3) If the aeration tank space loading is 1.0Kg-BOD/m^3 · day or less in the case of the activated sludge treatment, it does not have a great influence on the final treated wastewater.

4) Mixing of sulphur dye wastewater increases the amount of SS of the wastewater treated by activated sludge. However, if coagulating sedimentation and filtration are conducted, mixing of sulphur dye wastewater does not have a great influence on the wastewater quality.

5) As for the amount of chemical to be fed in the case of coagulating sedimentation, 150 - 200ppm of aluminum sulfate or PAC and 1ppm of polymer coagulant can produce satisfactory flocs.

6) It was found that the amount of sludge produced was estimated to be about 0.15Kg(dried sludge) per 1m^3 of wastewater.

Regarding removal of COD_{Mn} by contact oxidation, the following can be said.

7) For the most part, decrease in the amount of COD was caused by the action of oxidation only with chlorine. Effects of the CN balls were hardly recognized.

8) It was made clear that even if the amount of COD_{Mn} of filtrate was 40ppm on average, it was difficult to reduce it to 20ppm or less by oxidation with chlorine.

Table-11 Result of wastewater treatment by activated sludge, coagulating sedimentation and filtration

Period of operation			9/24~10/31		11/1~11/13		11/14~11/22		11/23~11/29	
Tank load			0.5kg-BOD/㎥·day		0.5		0.5		1.0	
MLSS			3,000~4,000 ppm		5,000~5,800		5,000~6,000		1,200~3,500	
Raw water			Dye factory A only		Dye factory A only		Addition of sulphur dye wastewater		Addition of sulphur dye wastewater	
Raw water	pH		6.9	(4.7~8.9)	6.8	(4.7~7.7)	9.8	(9.2~10.4)	9.5	(8.7~10.1)
	Transparency	(Degree)	12	(5>~22)	11	(4.5~23)	8	(4~11)	9.7	(3~17)
	Turbidity	(Degree)	94	(55~198)	80	(41~150)	75	(55~100)	72	(32~170)
	SS	(ppm)	39	(5~288)	48	(13.6~100)	36	(25~57)	33	(25~45)
	COD Mn	(ppm)	129	(63~198)	157	(113~224)	154	(116~196)	155	(116~192)
	COD Cr	(ppm)	528	(396~661)	557	(516~588)	557	(417~697)	556	(506~588)
	BOD	(ppm)	169	(97~273)	177	(120~252)	212	(126~298)	176	(157~198)
Water treated by activated sludge	pH		7.2	(5.9~7.8)	7.4	(6.4~8.1)	7.6	(7.3~8.5)	7.7	(7.3~8.2)
	Transparency	(Degree)	14	(6~30)	9.3	(6~18)	5.9	(4.5~8)	4.7	(4~5.5)
	Turbidity	(Degree)	56	(33~96)	53	(33~75)	91	(60~150<)	141	(110~173)
	SS	(ppm)	27	(5>~45)	28	(10.5~61)	94	(60~130)	160	(120~200)
	COD Mn	(ppm)	46	(27~140)	66	(43.5~85)	73	(51~99)	104	(74~133)
	COD Cr	(ppm)	178	(94~404)	182	(124~277)	281	(247~315)	441	(299~517)
	BOD	(ppm)	44	(10>~85)	20	(9~32)	53	(44.5~60.8)	106	(66.8~169)
Water treated by coagulating sedimentation	pH		6.4	(4.4~7.4)	6.9	(4.7~7.9)	7.3	(7.1~7.9)	7.2	(6.9~7.4)
	Transparency	(Degree)	30<	(8~30<)	30<	(25~30<)	30<	(21~30<)	30<	(14~30<)
	Turbidity	(Degree)	29	(6~68)	9.3	(6~11)	9.0	(6~14.8)	15	(9~32.5)
	SS	(ppm)	20	(5>~112)	5>	(5>~10)	11	(6.7~20)	13	(12~16)
	COD Mn	(ppm)	34	(19.5~128)	38	(28.5~54.5)	40	(20.5~64.5)	47	(35~60)
	COD Cr	(ppm)	113	(61~336)	104	(89.7~116)	93	(87.0~98.8)	147	(109~79.5)
	BOD	(ppm)	10>	(10>~65)	18	(5>~32)	10	(10>~16.8)	25	(16.7~40.2)
Water treated by filtration	pH		6.5	(4.5~7.4)	7.0	(5.4~7.9)	7.2	(6.9~7.8)	7.1	(6.8~7.4)
	Transparency	(Degree)	30<	(22~30<)	30<	(~)	30<	(~)	30<	(~)
	Turbidity	(Degree)	16	(2.4~55)	5.6	(1>~9.5)	6.8	(4.5~9)	8.4	(3.5~15)
	SS	(ppm)	5>	(5>~20)	5>	(~)	5>	(5>~8)	5>	(~5)
	COD Mn	(ppm)	31	(10~138)	37	(20~55.5)	39	(20.3~61.5)	40	(21.5~52)
	COD Cr	(ppm)	120	(56~341)	94	(81.6~102)	93	(81.5, 105)	132	(96~175)
	BOD	(ppm)	10>	(10>~72)	10>	(5>~23)	10>	(10>, 10>)	22	(11.9~39.2)

Note) Numerical value indicates the average (min.-max.) and the average was found by using the arithmetic mean.

5. Consideration

Regarding the dye wastewater advanced treatment, field experiments on the treatment were conducted. The experiments on dye wastewater treatment were conducted with material to be dyed. The Chemicals used which are contained in dye wastewater vary with the type, light, and shade, etc. of the material to be dyed, which causes a variation in the quality and amount of wastewater. In the experiments made this time, although there was no variation observed in the amount of water since the designated amount of water flowed into an aeration tank, a considerable change in the quality of water was observed. However, since the load on the aeration tank was relatively low and the retention time of the tank was long, the quality of treated wastewater was stable.

It appears that the load on the aeration tank can be dealt with sufficiently by the activated sludge method if the load is situated in the range of the experiments, namely 1.0Kg BOD/m^3 day or less. However, mixing of sulphur dye wastewater exceedingly deteriorated for settling efficiency of activated sludge and decreased the amount of MLSS. Consequently, it is desirable for the water surface loading of the activated sludge sedimentation tank is to be low. In the case of RUN 4, the water surface loading is 17.8 m^3/m^2 day, and a value which is equal to or lower than that figure should be applied to the design of the actual equipment. Furthermore, in dealing with the case where the outflow of SS is remarkable, it will be more effective if an addition of polymer coagulants at the inlet of the sedimentation tank is made possible.

A decrease in the amount of DO is another problem in the case where sulphur dye wastewater is mixed. Even if the load on the aeration tank is the same, there are some cases where the DO value reaches 0.5ppm or less if sulphur dye wastewater is mixed. Accordingly, sufficient scope should be allowed in aeration equipment.

There were no particular problems with coagulating sedimentation. The settling efficiency of flocs produced was good. As for the inorganic coagulant, PAC, which requires only a small amount of alkali to be added, it is, is considered to be more favorable even if the coagulant is to be added in large quantities. As for a polymer coagulant, nonionic matter is effective, and an addition of the coagulant in the quantity of 1ppm is enough.

Concerning a filter, since the filtration rate was low, no problems were observed during the experiments. However, the filtration rate must vary from 10 to 15m/H on the actual equipment. Since the amount of SS contained in wastewater treated by coagulating sedimentation is expected to range between 15 and 20ppm, a filter which captures large quantities of SS, such as a double layer filter, should be adopted.

Many effects of contact oxidation on COD removal can not be expected. Particularly, the effects of catalysts are little, so it can be concluded that they are inappropriate for the removal of COD of dye wastewater.

6. Treatment equipments design

According to the results of the experiments that have been mentioned in the preceding chapters, a treatment facility is to be designed in three cases, depending on the amount of wastewater: 1,000m³/day, 3,000m³/day, and 6,000m³/day. As for contact oxidation, since it did not achieve its initial goal, a design is not to be worked out.

6.1 Design conditions

1) The amount of treated wastewater

Three cases: 1,000m³/day, 3,000m³/day and 6,000m³/day

2) Water quality

	Raw water	Treated wastewater
pH	6.5 - 10	6.8 - 8.6
BOD	200ppm	20ppm
CODMn	170ppm	40ppm
SS	50ppm	5ppm

3) Treatment conditions

Activated sludge	Aeration tank space loading	0.8Kg BOD/m³ · day
	MLSS	3,000 to 4,000ppm
	Sedimentation tank water surface loading	15m³/m² · day
	Amount of return sludge	100%
Coagulating sedimentation	Amount of chemical to be fed	200ppm of PAC 1ppm of Polymer coagulant
	Coagulation tank retention time	20 minutes
	Sedimentation tank water surface loading	25m³/m² · day
Filter	Form	Pressure type · double layer filter
	Filtration rate	10m/H
Sludge treatment	Amount of polymer dehydrating agent to be used	1.5% (against dry sludge)
	Sludge is to be carried out as dehydrated cake	

6.2 Flow sheet

A treatment equipment flow sheet is shown in Figure-2.

Table-12 shows an outline of the specifications of the equipment to be used in a treatment facility. Figure-3 shows a plane layout drawing.

6.3 Construction cost

Table-13 shows the construction cost according to the amount of treated wastewater.

Table-13 Dye wastewater treatment facility construction cost
(Integration standard, December 1974)

(Units: 1,000 yen)

Volume of treated water	1,000m³/Day	3,000	6,000
Activated sludge	32,000	65,300	104,700
Coagulating sedimentation	11,600	25,200	40,900
Filtration	10,300	19,800	32,700
Sludge dehydration	14,300	31,100	52,500
Building	22,500	30,000	42,000
Electric instrumentation	31,700	64,300	106,100
Total	122,400	230,700	378,900

6.4 Operation expenses

When the operation expenses were calculated, the electricity costs, chemical costs, labor costs, and sludge transport expenses were determined as major items. The following is the calculation standard for each item.

1) Electricity cost

Unit price 10yen/KWH

It was determined that a raw water pump, aeration equipment, a filtrate pump, and chemical-feed pumps for activated sludge and coagulating sedimentation were to be operated at all times. As for other equipment, operation time was fixed according to circumstances.

2) Chemical cost

A unit price and the amount of chemical to be used were determined as follows:

Chemical for promoting nutrition · Urea 50yen/Kg

Phosphorus (75%) 200yen/Kg

Quantity of addition BOD : N : P=100 : 5 : 1

Inorganic coagulant PAC 30yen/Kg 200ppm

Polymer coagulant 1,800yen/Kg 1.0ppm

Polymer dehydrating agent 3,500yen/Kg 1.5Kg against dry sludge

3) Sludge transport expenses

Truck rental fee 10,000yen / once for a 4-t truck

Table-14 shows the operation expenses according to the amount of treated wastewater.

Table-14 Dye wastewater treatment facility operation expenses

		1,000m³/Day	3,000	6,000
1. Electricity cost		7,300 yen	16,200 yen	26,800 yen
2. Chemical cost	Nutrition promoting agent	(1,750)	(5,250)	(10,500)
	Coagulant	(6,000)	(18,000)	(36,000)
	Macromolecule	(1,800)	(5,400)	(10,800)
	Dehydrating agent	(4,800)	(14,400)	(28,800)
		14,350	43,050	86,100
3. Sludge transport expense		10,000	20,000	30,000
Total		31,650	79,250	142,900
Unit price for treatment		31.2 yen/m³	26.4	23.8

6.5 Operation personnel

It was determined that the number of operation personnel directly engaged in operation was to be 2 in the cases of 1,000 and 3,000m³/day, and 3 in the case of 6,000m³/day.

Since analysts and persons on night duty were involved with other departments, they were not taken into consideration when the operation expenses were calculated.

	Outline of specifications	Volume of water		
		1,000m³/day	3,000m³/day	6,000m³/day
1. Activated sludge				
Raw water tank	Reinforced concrete, serving as a receiving tank for filter backwash water	Effective capacity 60m³	180	270
		3.0m×9.2m×3.0m deep×1 tank	6.6×11×3.0×1	9.0×12×3.0×1
Raw water pump	For submersible pump wastewater	0.8m³/min×6m×2.2KW×2 units (1)	2.2×6m×5.5×2 (1)	4.4×6m×18.5×2 (1)
Weighing tank	Made of steel plate, for raw water and return sludge	1 set	2 sets	2 sets
Aeration tank	Reinforced concrete 0.8kg-BOD/m³D	9.2m×9.2m×4m deep(250m³)×1 tank	11×11×4.5(375)×2	12×12×4.7(500)×3
Aeration equipment	Made of FRP, turbine type	1,250mm ϕ ×15KW×1 unit	1,600×22×2	1,600×27×2
Sedimentation tank	Reinforced concrete, round shape Water surface loading 15m³/m²·D·rake·trough	10m ϕ ×3m deep×1 tank	16.5×3×1	24×3.5×1
Nutrition promoting agent solution and strorage tank	Made of steel plate, lining, with a mixer	1.8m ϕ ×1.5m high(3m³)×2 tanks	2.0×2.3(6)×2	2.5×3.0×(12)×2
Chemical-feed pump	For nutrition promoting agent, variable flow	0.4ℓ/min×2kg/cm²×0.1KW×2 units (1)	0.8×2×0.2×2(1)	1.6×2×0.4×2(1)
2. Coagulating sedeimentation				
Coagulation tank	20min retention, reinforced concrete with a flocculator	Effective capacity 15m³	45	90
		2.5m×2.5m×3.0m deep×1 tank	3.6×3.6×4.1×1	3.6×7.2×4.1×2
Sedimentation tank	Reinforced concrete, round shape, with rake	8.5m ϕ ×3m deep×1 tank	15×3×1	21×3.5×1
	Water surface loading 2.5m³/m²·D			
Inorganic coagulant storage tank	Made of steel plate, rubber lining Receiving from a rotary car	2m ϕ ×2.7m long(8m³)×1 tank For about 30 days	2×2.7(8)×1 For about 10 days	2×2.7(8)×2 For about 10 days
Polymer coagulant solution and storage tank	Made of steel plate, with a mixer	1.8m ϕ ×1.5 high(3m³)×2 tanks	2.0×2.3(6)×2	2.5×3.0(12)×2
Chemical-feed pump	For inorganic coagulant, variable flow	0.4ℓ/min×2kg/cm²×0.1KW×2 units (1)	0.8×2×0.2×2(1)	1.6×2×0.4×2(1)
Chemical-feed pump	For polymer coagulant, variable flow	2.4ℓ/min×2kg/cm²×0.2KW×2 units (1)	5.0×2×0.4×2(1)	10×2×0.75×2(1)
Transfer tank	Adjusting flow at the time of filter backwash Reinforced concrete	Effective capacity 50m³	150	250
		5.0m×5.0m×3.0m deep×1 tank	7.8×7.8×3.0×1	10×10×3.0×1
3. Filtration				
Filtration tower	Made of steel plate, pressure type double layed filtration	2.4m ϕ ×2.5m high×1 unit	3.8×30×1	3.8×30×2
	Filtration rate 10m/H			

	Outline of specifications	Volume of water		
		1,000m³/day	3,000m³/day	6,000m³/day
Filter pump	Horizontal type, centrifugal	0.8m³/min×10m×3.7KW×2 units (1)	2.2×10×7.5×2(1)	2.2×10×7.5×3(1)
Backwash pump	Horizontal type centrifugal, backwash speed m/H	3.2m³/min×6m×11KW×1 unit	9.0×6×18.5×2 (1)	9.0×6×18.5×2 (1)
Filtrate tank	Reinforced concrete	Effective capacity 50m³	150	250
	Storing water in the amount necessary for backwash	5.0m×5.0m×3.0m deep×1 tank	7.8×7.8×3.0×1	10×10×3×1
4. Sludge dehydration				
Sludge thickener	Reinforced concrete or made of steel plate	3m φ ×3m deep×1 tank (Steel plate)	5×3.2×1 (Concrete)	8.5×3.5×1 (Concrete)
	Thickener type, with rake			
Dehydrator	Using polymer dehydrating agent special form	MSP 50 type×1 unit	MSP 50 type×2 units	MSP 100 type×2 units
Sludge coagulation tank	Made of plate sheet, with a mixer	0.9m φ ×1.5m high(0.5m³)×1 tank	1.3×1.8(1.5)×1	1.6×2.1(3.0)×1
Dehydrating agent solution and storage tank	〃	1.1m φ ×1.5m high(1m³)×2 tanks	1.6×2.1(3.0)×2	2.0×2.4(6.0)×1
Chemical feed pump	For dehydrating agent, variable flow	15 ℓ/min×2kg/cm²×0.75KW×2 units (1)	15×2×0.75×3(1)	30×2×1.5×3(1)
Cake hopper	Made of steel plate, with accessories such as a belt conveyor	1m×2m×2.0m high(2m³)×1 unit	2×2.5×2.5(6)×1	2.5×3.0×3.0(12)×1
Separating liquid tank	Reinforced concrete	1.2m×2m×2.5m deep(5m³)×1 tank	2×3×2.5(10)×1	2×5×2.5(20)×1
Separating liquid pump	For transferring separating liquid, submersible pump	0.1m³/min×10m×0.75KW×2 units (1)	0.2×10×1.5×2(1)	0.4×10×2.2×2(1)
5. Building	Light weight steel frame, slated	Total 150m²	200	300
	Block wall for major sections, 2 storied			
6. Electricity, instrumentation	Receiving power facility, panel board, operation panel, instrumentation, wiring work, lighting, etc.	1 set	1 set	1 set

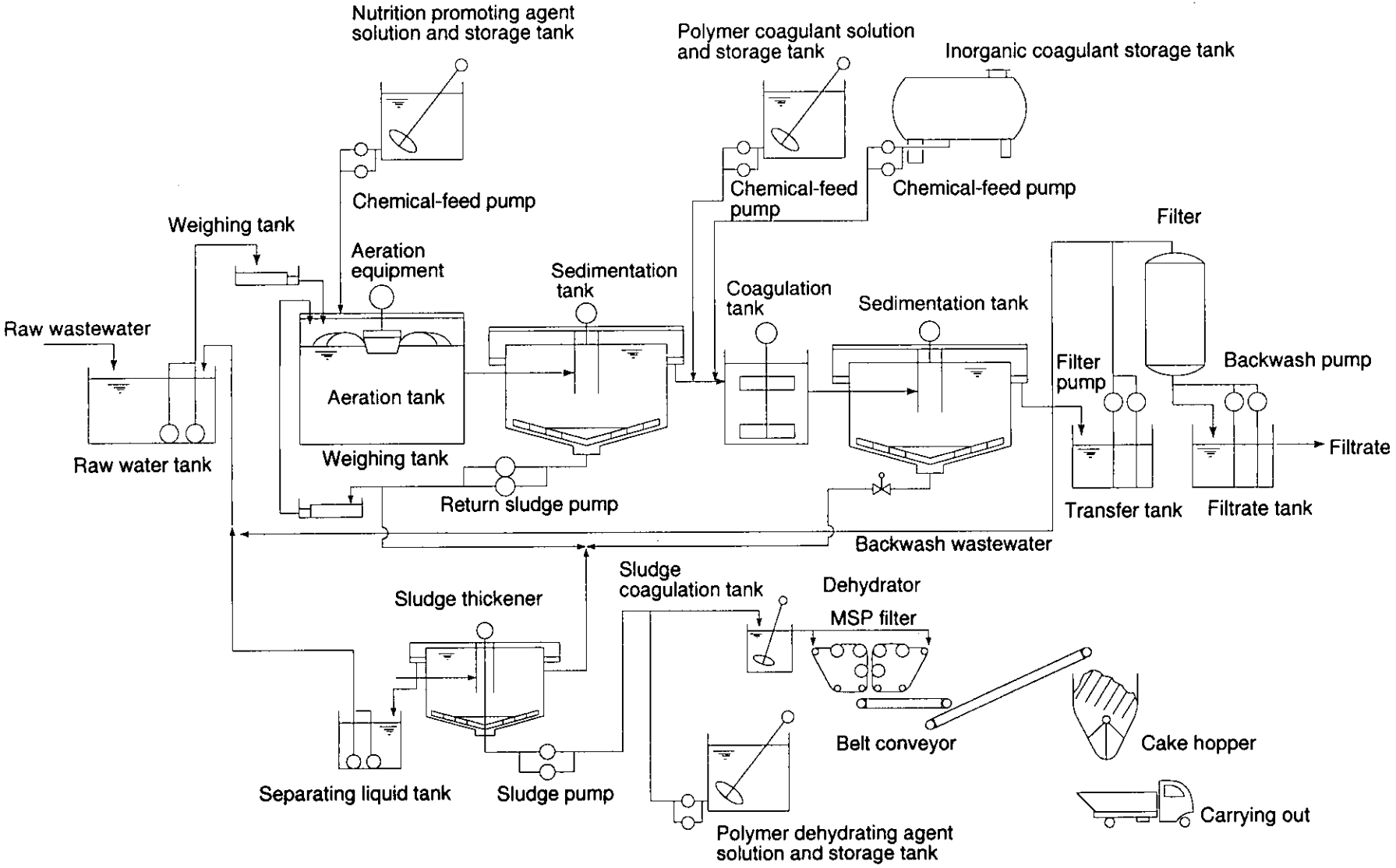


Figure-2 Flow sheet

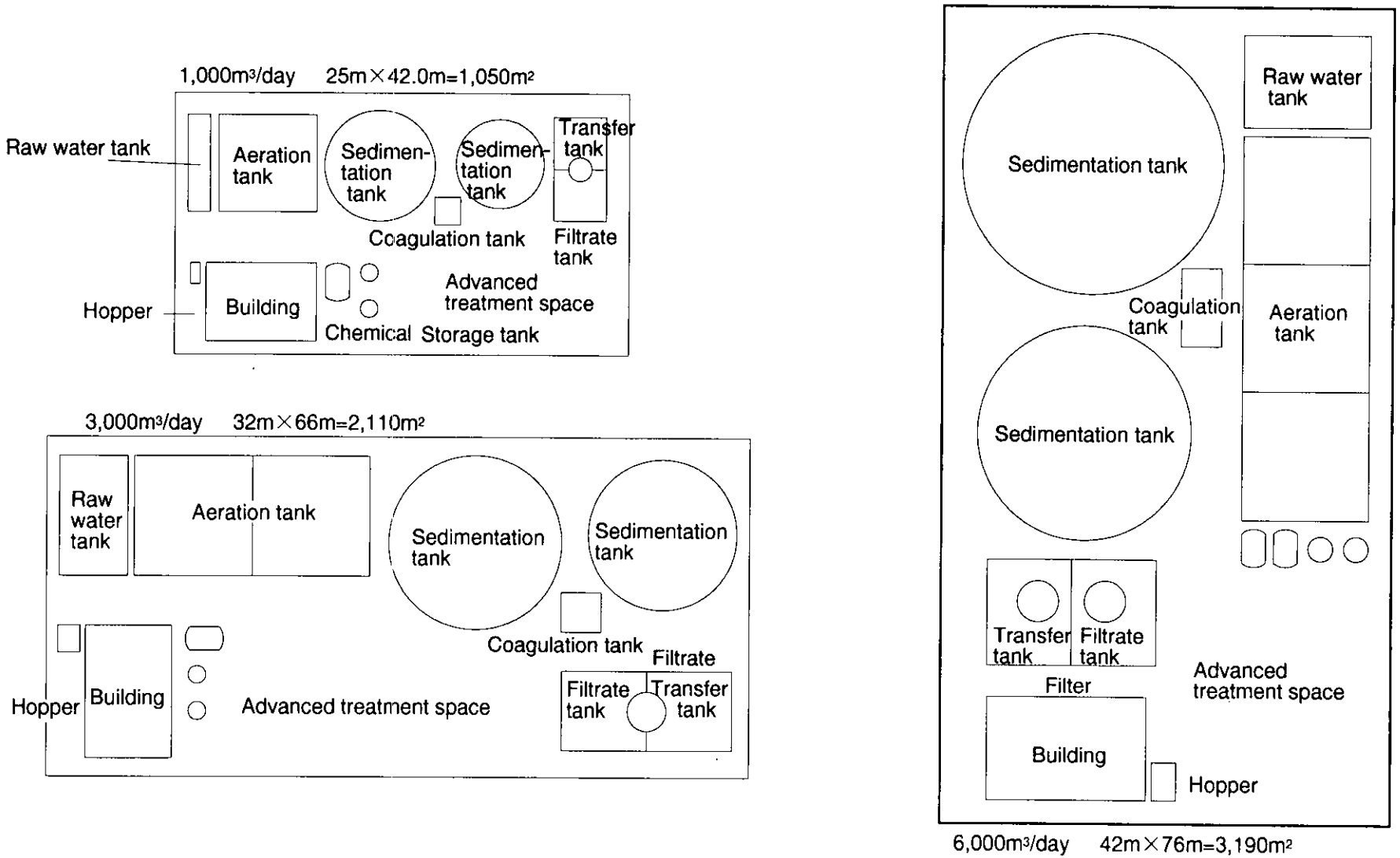
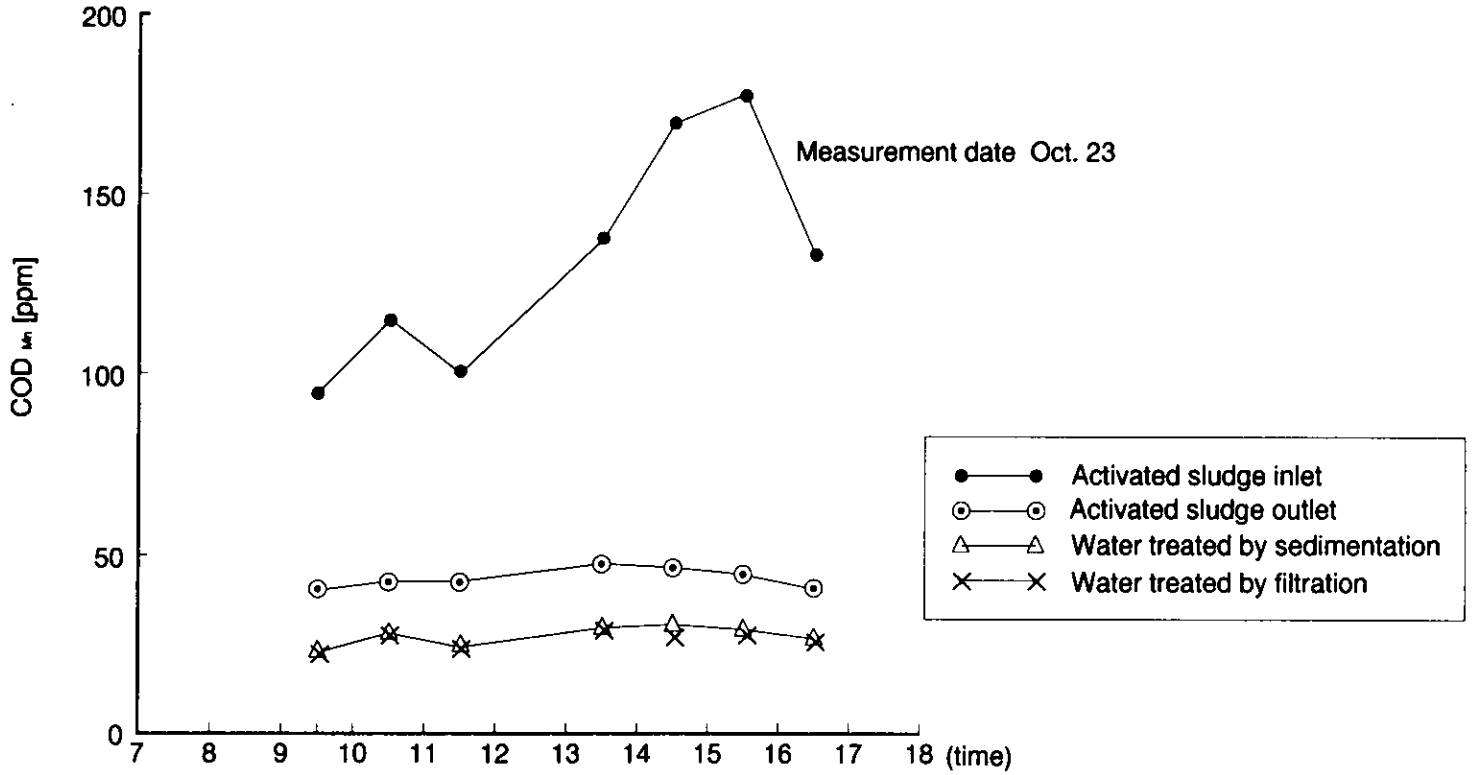


Figure-3 Treatment facility plane layout drawing

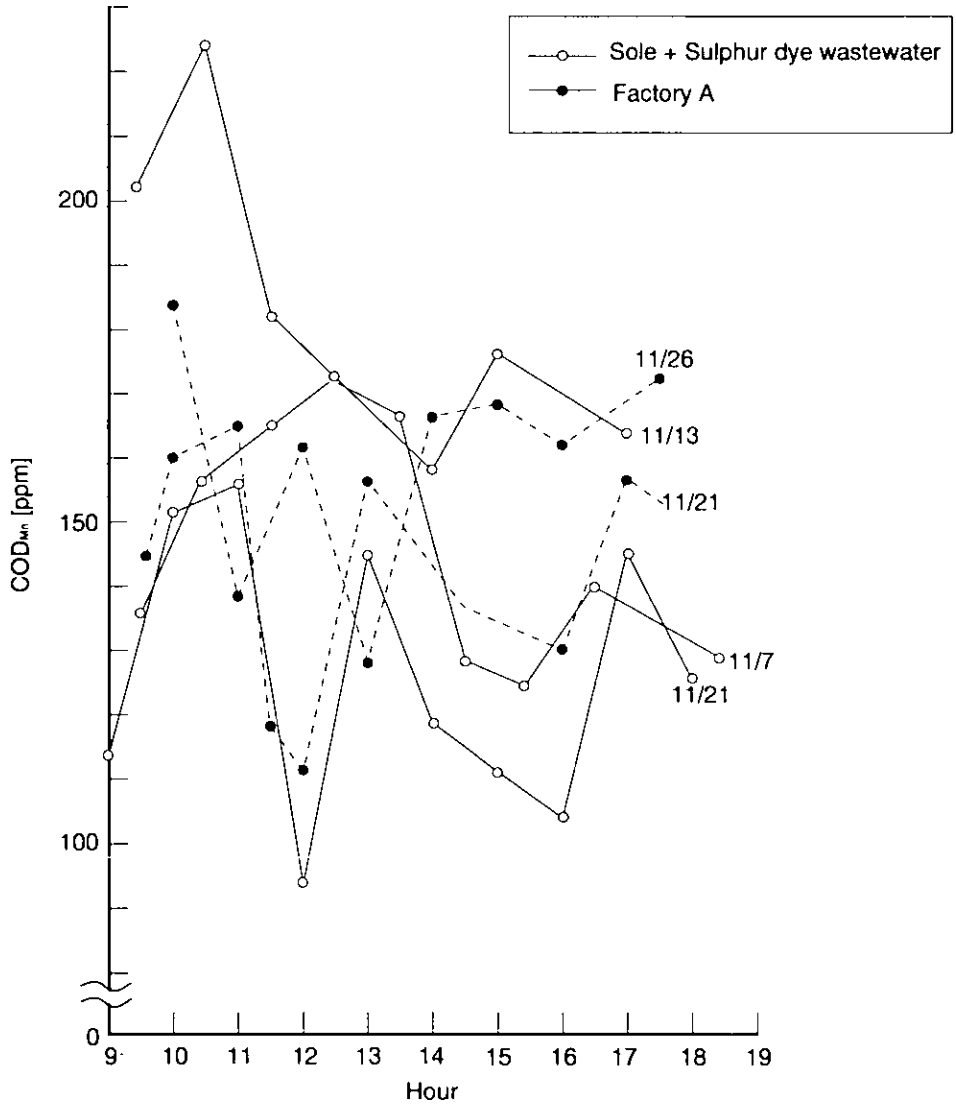


Appended figure-1 Water quality change in raw water and each treatment process (On Oct. 23)

While the raw water changes in the quality, the quality of treated water in each process is stable.

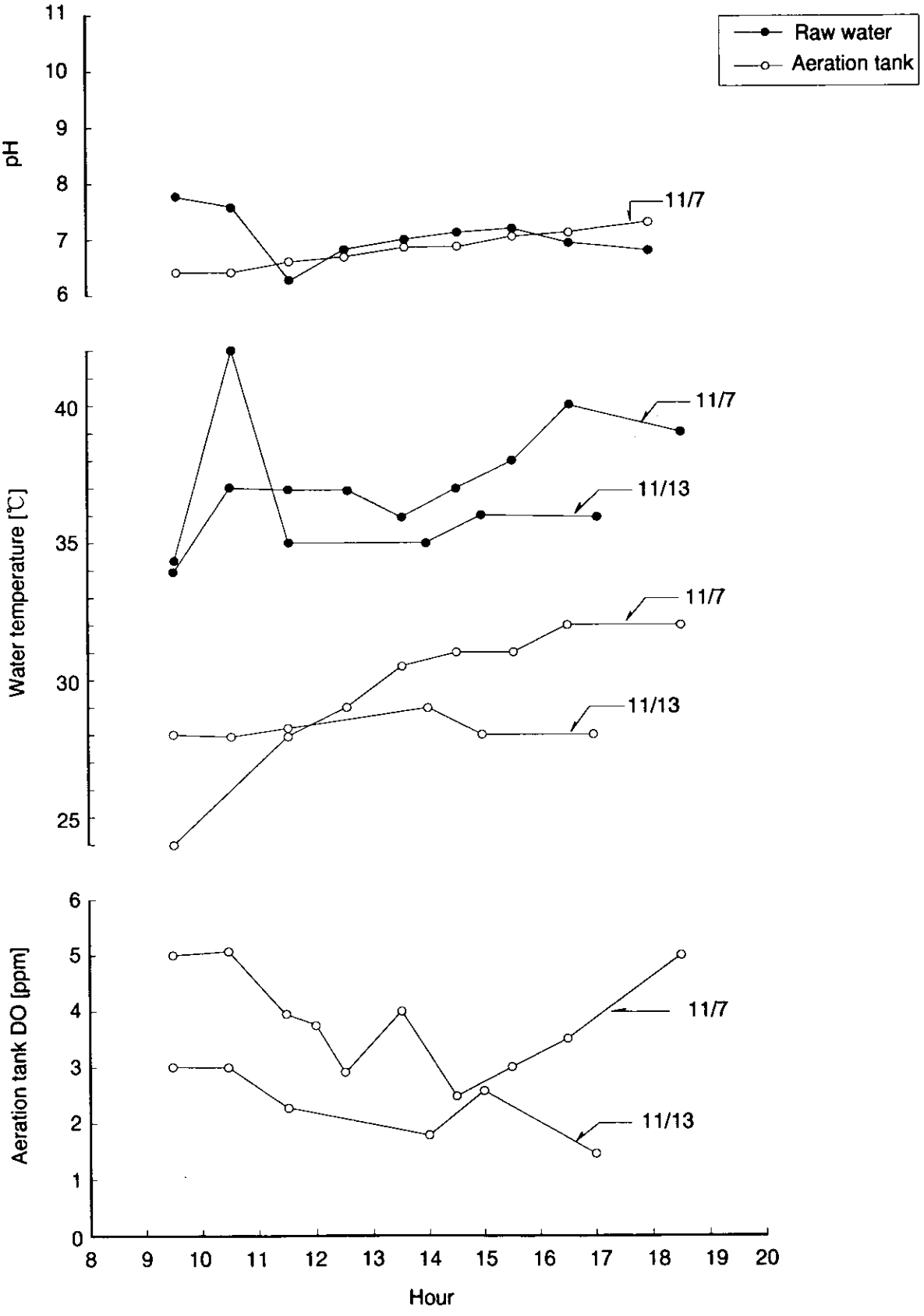
Appended figure-2 Hourly variation in raw water quality (COD_{Mn})
Considerable variation with time is is recognized.

Figure-2 Hourly variation in raw water COD_{Mn}

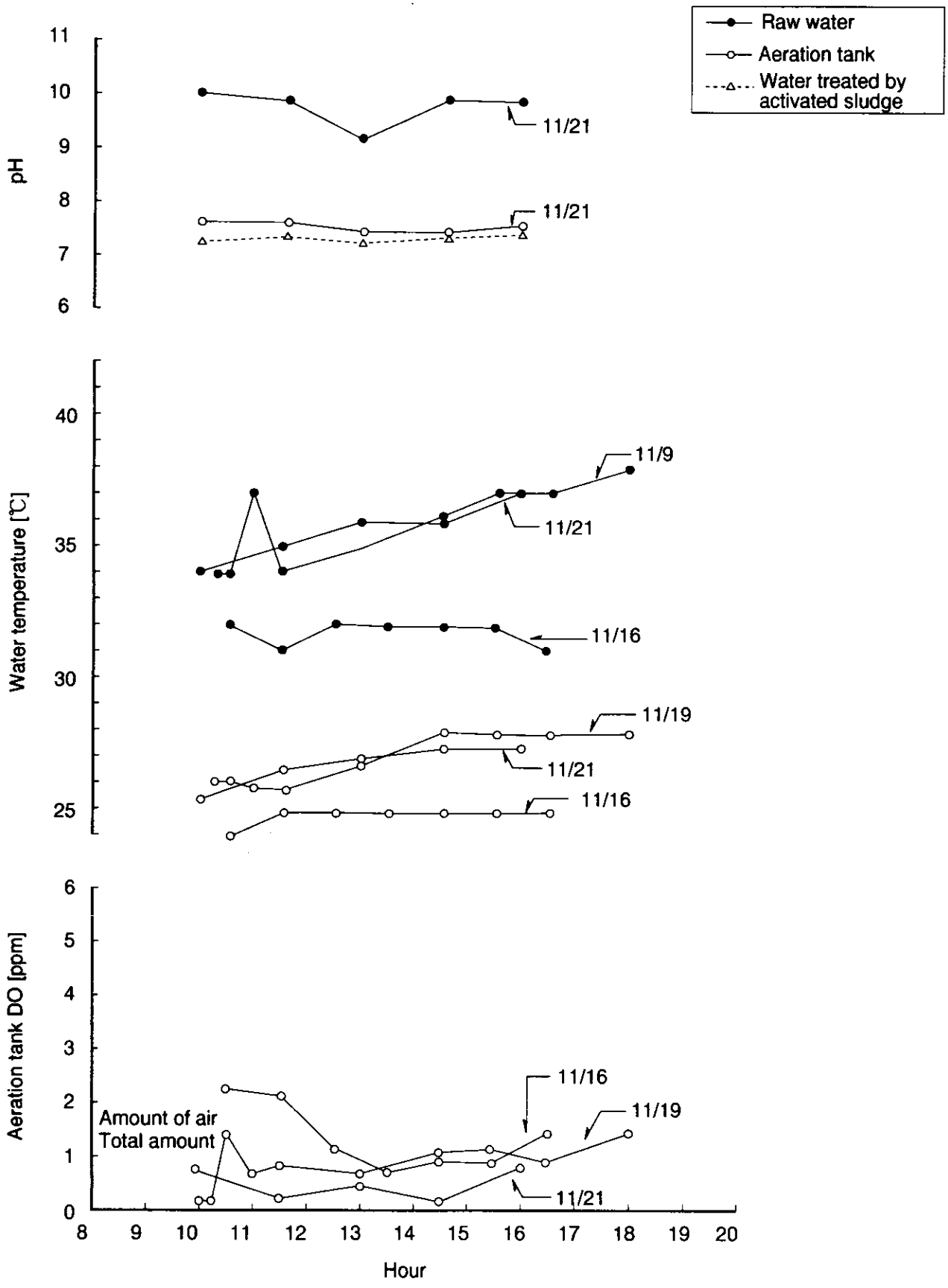


Appended figure-3 Change in aeration tank DO, water temperature and pH (RUN 2)
Appended figure-4 Change in aeration tank DO, water temperature and pH (RUN 3)
Appended figure-5 Change in aeration tank DO, water temperature and pH (RUN 4)

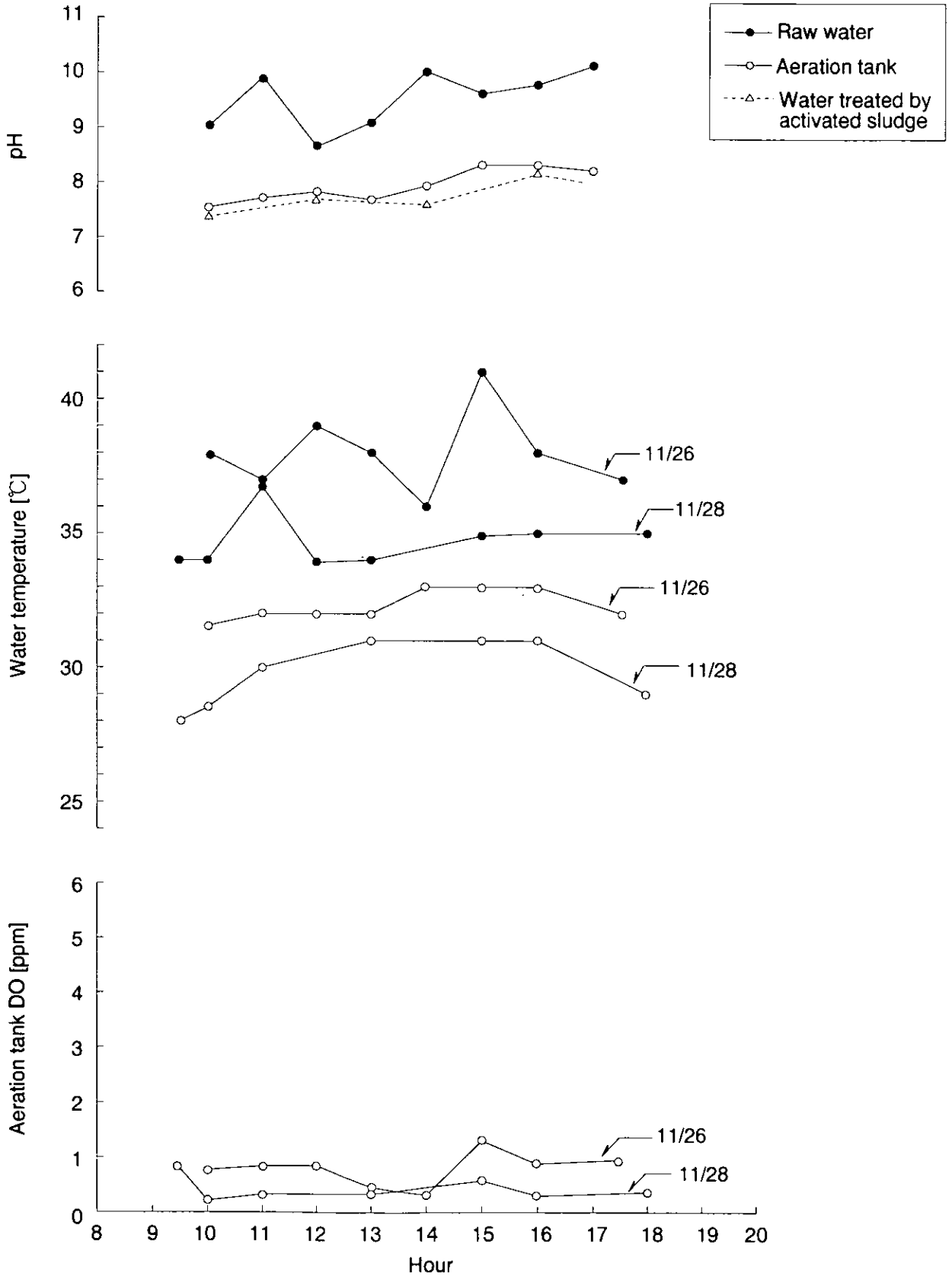
It is understood that the DO level is lower in the case of RUN 3 and 4 where sulphur dye wastewater is added than in the case of RUN 2 where it is not added.



Appended figure-3 Hourly variation in aeration tank DO, water temperature and pH (RUN 2)



Appended figure-4 Hourly variation in aeration tank DO, water temperature and pH (RUN 3)



Appended figure-5 Hourly variation in aeration tank DO, water temperature and pH (RUN 4)

INVESTIGATION AND RESEARCH ON THE DYE WASTEWATER ADVANCED TREATMENT TECHNOLOGY

THE OXIDATION METHOD BY OZONE AND THE GRANULAR ACTIVATED CARBON ADSORPTION METHOD

1974 REPORT ON THE RESEARCH COMMISSIONED
FOR POLLUTION CONTROL PUBLIC WORK

DECEMBER 1974

ORUGANO, LTD.

CONTENTS

1. Subject of the Research

Investigation and research on the dye wastewater advanced treatment

(The oxidation method by ozone - the granular activated carbon adsorption method)

2. Contents of the Research

2.1 Target

In the dyeing processing arranging industry, since the types of chemicals used vary with the kind, color, and light and shade of material to be dyed, the quality and amount of wastewater which is discharged from a company involved in the industry change greatly. Consequently, the results of the treatment by existing treatment facilities are not necessarily satisfactory.

Accordingly, this research is to be aimed at establishing the advanced treatment technology which aims to satisfy the Osaka Bay water area strict standard (Type 2 water area).

2.2 Contents of the research implemented

2.2.1 Test Liquid

As for the test liquid offered to the research, there were three types :

(1) Dye wastewater discharged from factory A affiliated with factory J's housing complex cooperative (hereinafter referred to as dye raw wastewater)

(2) Wastewater obtained by treating the above dye raw wastewater with activated sludge, coagulating sedimentation and filtration (hereinafter referred to as secondary effluent)

(3) Wastewater obtained by mixing sulphur dye wastewater with the aforementioned dye raw wastewater by about 5% and treating the synthetic wastewater with activated sludge, coagulating sedimentation, and filtration (hereinafter referred to as synthetic wastewater which has undergone secondary treatment)

2.2.2 Items for the research

(1) Investigation of changes in the quality and amount of water with the passage of time

(2) Research on the amount of ozone to be added and the properties of treated wastewater

(3) Research on the properties of wastewater treated by granular activated carbon adsorption

(4) Research on the recovery of the capability of spent activated carbon which has been regenerated

(5) Research on optimum treatment facilities for the oxidation method by ozone and the granular activated carbon adsorption method

2.2.3 Items for the analysis

Items for water quality analysis ..... pH, COD, BOD, SS, anionic surfactants, n-Hexane extracts, total chrome, color (average absorbance), external appearance

Items for analysis on granular activated carbon capability ..... Packing density, iodine value

Items for granular activated carbon equilibrium adsorption measurement ... COD

2.3 Location of the research implemented

2.3.1 The oxidation method by ozone, the granular activated carbon adsorption method

Factory A located in Sakai City

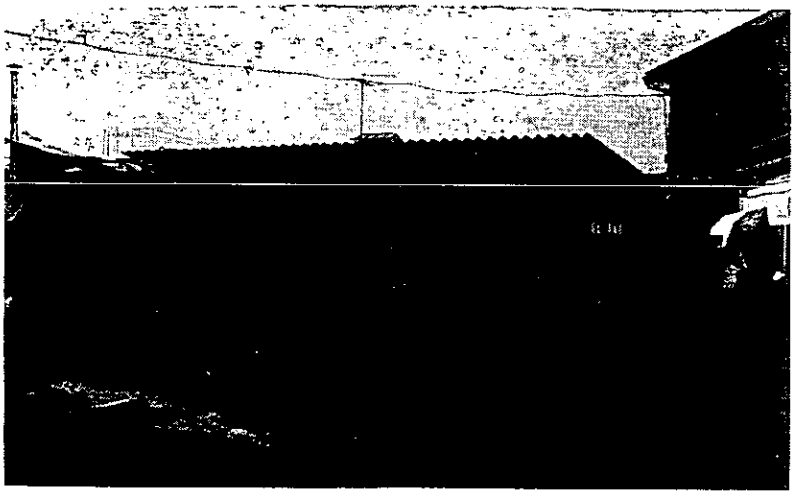
2.3.2 Experiments on ozone batch and granular activated carbon equilibrium adsorption, and granular activated carbon regeneration and capability measurement

at a laboratory in the Environmental Technology Department, Orugano, Ltd.

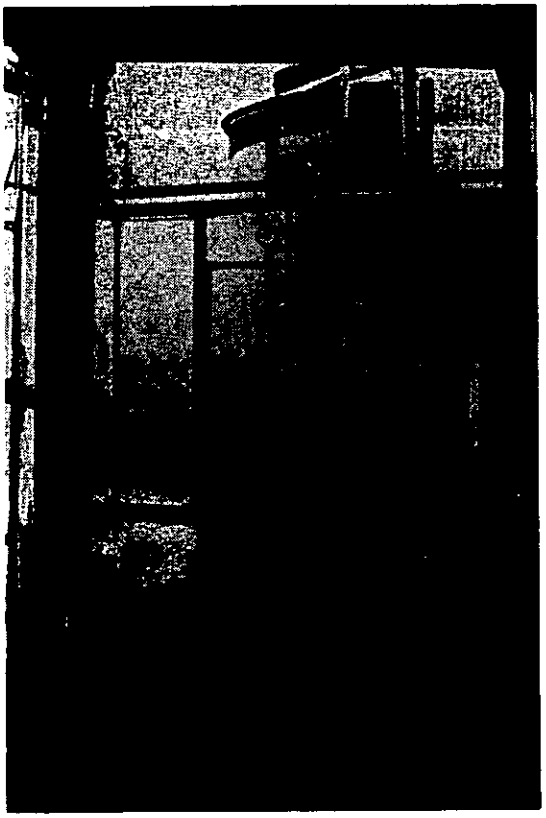
5-5-16 Hongo, Bunkyo-ku, Tokyo

2.4 Outline of research facility

An outline of the equipment for oxidation by ozone and granular activated carbon adsorption which was established in factory A is shown in Figure-1. Test liquid pumped up from a secondary effluent tank or a dye raw wastewater tank was split into two portions after passing through a sand filter. One portion of the dye raw wastewater was stored in a filtrate tank and used in the granular activated carbon adsorption experiment. The other portion entered an ozone oxidation tower at the top and came into contact with the ozonizing air which was diffused by a diffuser in the counter-current direction. After that, the portion was stored in an ozonized water tank and used in the granular activated carbon adsorption experiment. The granular activated sludge adsorption equipment consisted of two systems: one for secondary effluent, and the other for secondary effluent which had undergone ozonization. The three-tower serial water passage was applied to both of the systems. As for the external appearance of the location where the research facility was established along with the equipment for oxidation by ozone and granular activated carbon adsorption, pictures are attached.



External appearance of the location of the facility



Ozone oxidation tower (left) and granular activated carbon adsorption equipment (right)

3. Analysis and Measuring Methods

3.1 Water quality analysis method

Item	
pH	JIS · K · 0102- 8
COD	JIS · K · 0102-13
BOD	JIS · K · 0102-16
SS	JIS · K · 0102-10.2
Anionic surfactant	JIS · K · 0102-22.1.1
n-Hexane extract	JIS · K · 0102-18
Total chrome	JIS · K · 0102-51.1
Color (average absorbance)	the average absorption method by using representative wave length

Note 1. The average absorption method by using representative wave length is a method in which the absorption (-log T) is measured when the wave length is 370, 420, 470, 500, 530, 550, 570, 610, 660, and 750nm respectively, the average of the measured values is taken, and it is used as an index for the thickness of color.

Absorption spectrophotometer used .... HITACHI model 102, absorption spectrophotometer

Length of cell applied ..... 10mm cell

Note 2. As for terms which indicate external appearance, the following words were applied as a prefix. If, for instance, the color of brown is taken , it can be described as blackish brown, dark brown, grayish brown, light brown, and slight brown in descending order from the thickest.

3.2 Granular activated carbon equilibrium adsorption measuring method

Granular activated carbon equal to the one used in the adsorption experiment was crushed so that not less than 95% of the crushed activated carbon could pass through a 325-mesh sieve. The known amount of the sieved activated carbon was mixed with 300m ℓ of test liquid, and the mixture was shaken for 2 hours at a fixed temperature of 25℃. After that, the activated carbon was removed by filtration, and COD of the filtrate was measured. Calculations were was made by using the measured value, and an equilibrium adsorption diagram was made.

3.3 Granular activated carbon regeneration and capability measuring methods

3.3.1 Regeneration method

As for regeneration, roasting regeneration was conducted by using a muffle furnace. First, the furnace was heated at 950℃, and mixed gas, which was obtained by letting nitrogen and carbon dioxide flow at flow rates of 6 ℓ /min and 4 ℓ /min, respectively, under the standard condition, was allowed to flow. Next, sample activated carbon from which the water was completely swished was put on a stainless wire net and roasted for 30 minutes at 950℃. Right after being roasted, the activated carbon was poured into water, cooled rapidly, and dried.

3.3.2 Capability measuring method

Brand new activated carbon, activated carbon which had already undergone the regeneration process, and the one which had not were analyzed.

Item	Method	
Packing density	JIS proposal for revision	the granular activated carbon test method
Iodine value	JIS proposal for revision	the granular activated carbon test method

3.4 Method of measuring ozone contained in the ozonizing air

The fixed volume of ozonizing air which was sampled in a gas sampling tube was allowed to blow into a potassium iodide solution. Isolating iodine was titrated with a sodium thiosulphate solution. The follwing reaction was observed :

$$O_3 + 2KI + H_2O = I_2 + 2KOH + O_2$$

$$I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6$$

Accordingly, the following can be said.

0.1N $Na_2S_2O_3$ solution 1m ℓ = 2.4mgO_3

4. Outline of the Research

4.1 Items for the experiments

In accordance with the items for the research mentioned in 2.2.2, experiments were conducted on the following items.

(1) Oxidation of dye raw wastewater and secondary effluent by ozone

(2) Granular activated carbon adsorption and granular activated carbon equilibrium adsorption with four types of wastewater: dye raw wastewater, dye raw wastewater treated by ozone, secondary effluent, and secondary effluent treated by ozone

(3) Ozone batch and granular activated carbon equilibrium adsorption experiment with synthetic wastewater which has undergone secondary treatment

(4) Regeneration of granular activated carbon used in the above-mentioned experiment item (2) and measurement of the capability of the granular activated carbon

4.2 Progress during the period of the experiments

4.2.1 Establishment of experimental equipment

Equipment and appliances were carried in ..... on October 8

Establishment of the equipment and appliances and preparation for the experiments ..... October 8 - October 13

4.2.2 Progress of the experiments

The following shows the progress of the experiment by item.

(1) Experiment on oxidation by ozone

October 15 - November 14	experiment with the test liquid mentioned in 2.2.1 (2)
November 19 - November 30	experiment with the test liquid mentioned in 2.2.1 (1)

(2) Activated carbon adsorption experiment

October 29 - November 14	experiments with the test liquid mentioned in 2.2.1 (2) and with wastewater obtained by treating the test liquid by ozone
November 19 - December 1	experiments with the test liquid mentioned in 2.2.1 (1) and with wastewater obtained by treating the test liquid by ozone

(3) Ozone batch experiment and activated carbon equilibrium adsorption experiment with the test liquid mentioned in 2.2.1 (3) ..... conducted with a sample collected on November 29

(4) Granular activated carbon regeneration and capability measurement .... conducted with granular activated carbon which had undergone the adsorption experiment

4.3 Experiment methods and conditions

The following shows experiment methods and conditions by item.

4.3.1 Experiment on oxidation by ozone

Figure-1 shows an outline of the experimental equipment.

Test liquid pumped up from the secondary effluent tank or the dye raw wastewater tank was introduced to the ozone reaction tower after passing through the sand filter. The test liquid which entered the tower at the top

came in contact with the ozonizing air diffused by the diffuser in the counter-current direction. Thus, the test liquid was oxidized by ozone. The test liquid oxidized by ozone went out of the tower at the bottom and was stored in the ozonized wastewater tank. The ozonizing air was produced by (silent discharge) that was caused by letting the air, which had been dehumidified with a silica gel, pass through an ozonizer. As for flue gas which came out of the reaction tower, it was diffused in the atmosphere as clean air after the ozone was decomposed and removed by activated carbon.

The following are the experiment conditions.

Ozone reaction tower (counter-current contact tower with racks and steps)	200 ϕ x 2,000H
Effective depth of water	1,500mm
Ozone gas concentration	5.0 - 18.1mg O_3/ ℓ - air
Ozone gas flow rate	150 - 490 ℓ /H
Test liquid flow rate	70 - 250 ℓ /H
Flue gas treatment tower	50 ϕ x 1,000H filled with granular activated carbon for the gaseous phase
Sand filter	200 ϕ x 1,200H
Sand grain size	0.55mm
Sand layer height	700mm

4.3.2 Experiment on granular activated carbon adsorption

Figure-1 shows an outline of the experimental equipment.

The test liquid oxidized in the ozone reaction tower (secondary effluent which had undergone ozonization) was allowed to pass through the activated carbon tower at a fixed flow rate after being stored in the ozonized wastewater tank temporarily.

The three-tower serial water passage was applied. For the purpose of observing the influence of oxidation by ozone, filtrate (secondary effluent) which had not yet undergone oxidation by ozone was also allowed to pass through the activated carbon simultaneously. Thus, treatment conditions were observed.

As for dye raw wastewater, experiments on activated carbon adsorption were also conducted with raw wastewater which had undergone ozonization and with very raw wastewater.

The following are the experiment conditions.

Activated carbon used	Pittsburgh granular activated carbon CAL
Activated carbon tower	
For letting wastewater treated by ozone through	80 ϕ x 1,200H x 3 towers
Quantity of activated carbon filled	5.0 ℓ /1 tower
Activated carbon layer height	1.0m/1 tower
For letting filtrate through	26 ϕ x 1,300H x 3 towers
Quantity of activated carbon filled	0.6 ℓ /1 tower
Activated carbon layer height	1.0m/1 tower

Volume of water let through

Secondary effluent which has undergone ozonization	75 ℓ /H
Secondary effluent	9.0 ℓ /H
Dye raw wastewater which has undergone ozonization	50 ℓ /H
Dye raw wastewater	6.0 ℓ /H

4.3.3 Experiments on ozone batch and activated carbon equilibrium adsorption with synthetic wastewater which has undergone secondary treatment

(1) Ozone batch experiment

Figure-2 shows an outline of the experimental equipment.

Test liquid was put into a diffuser bottle with a capacity of 500m ℓ , and the ozonizing air was allowed to blow into the bottle so that the liquid could be oxidized by ozone. The amount of ozone required by oxidation was calculated in accordance with the amount of ozone added and the amount of ozone which had not reacted.

Volume of test liquid	400m ℓ
Ozone gas concentration	5.0mg O_3/ ℓ -G
Ozone gas flow rate	20 ℓ /H

(2) Activated carbon equilibrium adsorption experiment

Experiments on activated carbon equilibrium adsorption were conducted with the test liquid which had not yet undergone the above-mentioned process of oxidation by ozone and with the one which had, according to the granular activated carbon equilibrium adsorption measuring method mentioned in 3.2.

4.3.4 Granular activated carbon regeneration and capability measurement

The granular activated carbon used in the adsorption experiment was pulled out out of the tower after water passage ended. Then, the activated carbon was regenerated in accordance with the regeneration method mentioned in 3.3.1. As for measurement of the capability of the activated carbon, brand new granular activated carbon, and granular activated carbon which had not yet undergone the process of regeneration, and the one which had were measured according to the capability measuring method mentioned in 3.3.2.

4.4 Results of the experiments

The following shows the results of the experiments by item.

4.4.1 Results of the experiment on oxidation by ozone

(1) In the case of secondary effluent

Table-1 shows the results obtained from October 15 to November 14.

Analyzed values (for total chrome, anionic surfactant, n-Hexane extract, and SS) other than those recorded in this table are shown in Table-2.

Figure-3 is formed by plotting the values obtained from 11:00 to 13:00 which are shown in Table-1. Figure-4 shows the hourly variations of October 30, 31, and November 1.

(2) In the case of dye raw wastewater

Table-3 shows the results obtained from November 19 to November 30.

Analyzed values other than those recorded in this table are shown in Table-4. Figure-5 is formed by plotting the values obtained from 11:00 to 15:00 which are shown in Table-3. The figure shows daily variations. Figure-6 shows hourly variations of November 21.

4.4.2 Results of the experiment on granular activated carbon adsorption

(1) In the cases of secondary effluent and secondary effluent which has undergone ozonization
Tables-5 and -6 show the results obtained from October 29 to November 14. Figure-7 shows the relation between the water passage time and the amount of COD at the outlet of the activated carbon tower. Figure-8 shows the results of the equilibrium adsorption experiment conducted with sample wastewater collected at 14:00 on October 31, and at 12:00 on November 13.

(2) In the cases of dye raw wastewater and dye raw wastewater which has undergone ozonization
Tables-7 and -8 show the results obtained from November 19 to December 1. Figure-9 shows the relation between the water passage time and the amount of COD at the outlet of the activated carbon tower. Figure-10 shows the results of the equilibrium adsorption experiment conducted with sample wastewater collected at 17:00 on November 26.

4.4.3 Results of the experiments on ozone batch and granular activated carbon equilibrium adsorption with synthetic wastewater which has undergone secondary treatment

(1) Results of the ozone batch experiment
The following shows results the of the ozone batch experiment conducted with synthetic wastewater which had undergone secondary treatment. The synthetic wastewater was sampled at 13:00 on November 29.

Results of the ozone batch experiment

Ozone absorbed dose (ppm as O_3)	External appearance	Color (average absorbance)	COD (ppm as O)
- (raw water)	light pink color	0.027	36.0
2.0	light pink color	0.016	36.0
4.1	sligltlly pink color	0.011	35.3
6.5	sligltlly pink color	0.006	34.4

(2) Results of the granular activated carbon equilibrium adsorption experiment
Experiments on equilibrium adsorption were conducted with the synthetic wastewater that had undergone secondary treatment, which was used in (1), and with the synthetic wastewater which had undergone ozonization besides secondary treatment (ozone absorbed dose: 4.1ppm). Results of the experiments are shown in Figure-11.

4.4.4 Results of granular activated carbon regeneration and capability measurement

The granular activated carbon used in the adsorption experiment was pulled out of the activated carbon tower after water passage had ended. After that, the activated carbon was regenerated. Then, new activated carbon, activated carbon which had not yet undergone the process of regeneration, and the one which had were measured in terms of capability. The following shows the results of the measurement.

Brand new granular activated carbon

Packing density	Iodine value
0.445	1,040

● Activated carbon through which the secondary treated water and its water treated by ozone passed

	Activated carbon through which the water treated by ozone passed				Activated carbon through which the secondary treated by ozone passed			
	Before regeneration		After regeneration		Before regeneration		After regeneration	
	Filling density	Iodine value	Filling density	Iodine value	Filling density	Iodine value	Filling density	Iodine value
No. 1 Tower	0.502	847	0.438	979	0.498	865	0.424	1023
2	0.484	907	0.427	1013	0.494	876	0.429	991
3	0.469	969	0.420	1056	0.477	931	0.432	1071
1'	0.450	1036	0.410	1107	0.448	1076	0.393	1133

● Activated carbon through which the dye wastewater and its water treated by ozone passed

	Activated carbon through which the water treated by ozone passed				Activated carbon through which the secondary treated by ozone passed			
	Before regeneration		After regeneration		Before regeneration		After regeneration	
	Filling density	Iodine value	Filling density	Iodine value	Filling density	Iodine value	Filling density	Iodine value
No. 1 Tower	0.501	852	0.433	997	0.493	872	0.425	1016
2	0.499	881	0.447	981	0.500	856	0.429	1034
3	0.487	854	0.441	1017	0.497	844	0.422	1023
1'	0.460	953	0.418	1111	0.465	916	0.383	1034
2'	0.446	961	0.408	1031	0.442	994	0.411	1016

5. Consideration

Of all the types of wastewater discharged from various industries, wastewater discharged from dyeing factories is one of the most difficult to treat.

It may safely be said that the difficulty with the treatment of wastewater discharged from dyeing factories originates in the diversity of the quality and amount of the wastewater. Moreover, in terms of a form of company, small-to-medium-sized factories are the nucleus of the dyeing industry under the present conditions.

There are some treatment methods that have been put into practice for the past several years. However, judging from the recent tendency in the effluent standard, it is no exaggeration to say that a simple treatment method can not deal with the numeric or ecnomic standard .

Consequently, it is necessary to set up equipment which is comprehensively favorable by combining some unit operations. In this investigation and research, the focus was placed on finding what sort of advanced treatment could attain what level of water in the case where advanced treatment was to be conducted with secondary effluent (wastewater treated by activated sludge, coagulating sedimentation, filtration, etc.) .

As unit operations, oxidative decomposition treatment (oxidation by ozone) and adsorption treatment (activated carbon adsorption) were selected. The quality of treated wastewater was aimed at being the one which could satisfy the regulatory value for the Osaka Bay special conservation water area (Type 2 water area). As a result of the investigation and research, it was found that by carrying out oxidation by ozone and activated carbon adsorption, the aforementioned regulatory value could be fully satisfied. If desalination (the reverse osmosis method, the ion exchange method, the electrodialysis method, etc.) is conducted after the treatment, reuse of water and the closed system will be possible.

Treatment methods that have been carried out in the past are attended with much difficulty in terms not only of the quality of water but of the treatment of the sludge that is produced by a treatment facility. Taking this fact into consideration, it is considered a necessary condition that the amount of sludge produced by a treatment facility is nil or extremely small.

Dye wastewater used in this investigation and research was not colored much, and the COD value of the wastewater was lower than expected.

Based on the evidence of the experiment data, the ozone absorption rate is considerably low. The rate, however, is the value obtained by this experimental equipment. Accordingly, with actual equipment, it is fully possible to attain the absorption rate of 95% and more, according to the past results.

As a matter of course, the point of ozonization is to remove COD. In addition, but not only that, it is to get rid of color by making good use of the strong oxidizing power of ozone. By combining ozone treatment and activated carbon treatment, the activated carbon's capability of adsorbing is expected to grow. According to the data of the experiments conducted this time, as indicated in Figures-7 and -9, when the case where secondary effluent is ozonized and then treated by activated carbon and the case where secondary effluent is treated by activated carbon without being ozonized are compared on the condition that the water passage rate is the same (double the amount of treated wastewater per unit activated carbon), the water passage time is longer in the former by about 11% in the case of one cycle, and by about 12% in the case of two cycles. Likewise, as for dye raw wastewater, the water passage time is longer when the wastewater is ozonized by about 9.5% in the case of two cycles, and by about 17% in the case of three cycles than in the case where it is not. Generally, if activated carbon treatment is aimed at decoloring colored water and removing COD, sometimes color leakage is observed in advance of COD leakage. Hence, in the case where the degree of coloring is low, as in the case of the sample water used in the experiments, by directly treating secondary effluent with activated carbon, the goal can be achieved. Nevertheless, taking into account the changes in the degree of coloring, the combination of ozonization and activated carbon treatment appears to be effective even if the cost of equipment may rise slightly. As a result, in the case where secondary effluent is ozonized, the amount of ozone to be added is expected to vary from 15 to 20gO_3/m^3 of wastewater.

As a result of the experiments, it is considered favorable that the calculation of the quantity of granular activated carbon to be used for treatment is to be based on 2.0-2.5m^3 of wastewater/kg · C .

As for the operation expenses, they are mostly dominated by activated carbon treatment, so that it is desirable that a factory regenerates activated carbon for itself. There are various regeneration facilities. In the case of regeneration by heating which is conducted most commonly, the cost of equipment is comparatively high when the amount of activated carbon regenerated is small.

Besides, taking into consideration the fact that the dyeing processing industry is based on the aforementioned form of company, it is to be desired that the regeneration of activated carbon be carried out jointly by grouping factories.

Judging from the results of the experiments on the regeneration of activated carbon which was used under various conditions, it is clear that the spent activated carbon can be regenerated to the same level as a brand-new one.

Generally speaking, it may safely be said that the combination of the oxidation method by ozone and the granular activated carbon adsorption method give full play to the performance in terms of dye wastewater advanced treatment.

However, in the case where such matter as chrome is mixed, this treatment system can not be expected to deal with it sufficiently, and, consequently, it is necessary to isolate wastewater which contains matter such as chrome in the dyeing process and to treat it separately.

6. Dye Wastewater Treatment Facilities (which respectively deal with the amount of wastewater as follows: 1,000m^3/day, 3,000m^3/day, and 6,000m^3/day)

As mentioned in this report, with advanced treatment for secondary effluent in view, experiments were conducted mainly by combining the oxidation method by ozone and the granular activated carbon adsorption method.

In the case of the quality of dye raw wastewater used in the experiments this time, it does not appear that the merits of the above-mentioned combination are remarkable.

It rather appears that the treatment of secondary effluent can be done only with granular activated carbon. An experiment on the direct treatment of dye raw wastewater by oxidation by ozone and granular activated carbon adsorption was also conducted. However, as a result of the experiment, an economical facility will not be anticipated if the effluent standard must be satisfied.

Accordingly, as the title of this report says, a trial calculation was done on the condition that secondary effluent was to be treated by a combination of oxidation by ozone and granular activated carbon adsorption.

A flow sheet is shown in Figure-12. An outline of a facility and the quality of treated wastewater is shown in Table-9. The cost of equipment, operation expenses, the construction area, and operation personnel are shown in Table-10.

Table-1 Result table for treatment of secondary treated water by ozone
Activated sludge→Coagulating sedimentation→Filtration→O_3 treatment

Sampling date and time	Wastewater flow (ℓ/H)	O_3 gas flow (Nℓ/H)	Gasliquid ratio (G/L)	Exhaust CO_3 gas concentration (mgO_3/N ℓ)	Raw CO_3 gas concentration (mgO_3/N ℓ)	Amount of O_3 added (ppm)	O_3 absorbed dose (ppm)	O_3 absorption rate (%)	Filter outlet effluent water quality					Quality of water treated by ozone					Remark
									pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absorbance (-log T)	pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absorbance (-log T)	
10/15 10:00	100	250	2.50	7.20	4.00	18.0	8.5	47.1	6.8	Light green	27.0	-	0.020	6.9	Colorless	20.4	-	0.007	
13:00	150	250	1.67	7.90	4.47	13.2	5.7	43.2	6.8	〃	27.2	-	0.020	6.9	Colorless	23.9	-	0.007	
15:30	150	204	1.36	8.93	4.93	12.1	5.4	44.6	6.9	Light green	28.0	-	0.020	6.9	Colorless	25.0	-	0.006	
10/18 10:00	100	300	3.00	5.15	2.40	15.8	8.3	53.4	6.9	Reddish pink	60.5	-	0.123	6.9	Light pink	52.2	-	0.040	
13:00	100	150	1.50	8.70	3.78	13.1	7.4	56.6	6.9	Reddish pink	60.5	-	0.123	6.9	Light pink	-	-	0.040	
15:00	150	300	2.00	9.39	4.92	18.8	8.9	48.4	6.9	Reddish pink	60.5	-	0.123	6.9	Slightly pink	-	-	0.025	
17:00	150	200	1.33	12.4	5.84	16.5	8.8	52.9	6.9	Reddish pink	60.5	-	0.123	6.9	Slightly pink	49.4	-	0.022	
10/25 10:10	150	240	1.60	16.2	7.17	25.9	14.5	55.9	6.7	Bright yellow	111	-	0.098	7.0	Light yellow	104	-	0.063	
12:00	104	260	2.50	14.3	7.55	35.8	16.9	47.2	6.8	Bright yellow	112	-	0.105	7.0	Light yellow	103	-	0.060	
10/26 10:00	150	204	1.36	8.93	4.93	12.2	5.4	44.2	6.7	Bright yellow	78.5	-	0.042	7.0	Slightly yellow	70.8	-	0.013	
13:00	150	204	1.36	8.50	4.78	11.6	5.2	44.7	6.7	Bright yellow	70.3	-	0.040	6.9	Slightly yellow	63.0	-	0.013	
10/29 13:00	150	250	1.67	11.4	5.60	18.9	9.5	50.3	6.9	Light yellow	38.4	-	0.025	7.0	Slightly yellow	37.0	-	0.008	
18:00	150	250	1.67	11.1	5.42	18.5	9.5	51.3	7.0	Light yellow	29.1	-	0.026	7.2	Slightly yellow	25.7	-	0.009	
10/30 10:00	200	200	1.00	14.3	6.87	14.3	7.4	51.8	6.9	Light yellow	30.5	-	0.015	7.0	Slightly yellow	29.8	-	0.009	
11:30	250	200	0.80	14.6	5.50	11.7	7.3	62.2	6.7	Light yellow	29.8	-	0.014	6.8	Slightly yellow	26.9	-	0.008	
14:00	150	260	1.73	14.2	6.64	24.5	13.1	53.4	6.9	Light yellow	28.3	18.4	0.014	7.0	Colorless	24.5	9.8	0.004	
16:00	140	250	1.79	14.8	7.46	26.5	13.1	49.6	6.8	Light yellow	28.8	-	0.018	6.9	Colorless	26.3	-	0.004	
20:00	100	250	2.50	14.1	7.90	35.3	15.5	44.0	6.8	Light yellow	30.0	-	0.017	7.0	Colorless	28.8	-	0.004	
10/31 11:00	200	200	1.00	10.6	5.53	10.6	5.1	47.7	6.8	Light yellow	28.5	-	0.017	7.1	Slightly yellow	26.7	-	0.007	
12:00	250	220	0.88	11.0	5.38	9.7	5.0	51.5	6.7	Light yellow	28.1	-	0.017	6.9	Slightly yellow	24.9	-	0.007	
14:00	150	200	1.33	11.2	6.64	14.9	6.1	41.0	6.9	Light yellow	30.0	-	0.016	7.1	Slightly yellow	26.9	-	0.006	
16:00	200	200	1.00	11.4	5.80	11.4	5.6	49.1	6.8	Light yellow	29.8	-	0.019	7.0	Slightly yellow	27.3	-	0.007	
20:00	200	200	1.00	11.4	5.80	11.4	5.6	49.1	7.0	Light yellow	31.8	-	0.020	7.0	Slightly yellow	28.0	-	0.007	
11/1 10:00	150	150	1.00	17.7	9.40	17.7	8.3	46.9	7.0	Light yellow	37.6	-	0.019	7.1	Slightly yellow	34.5	-	0.007	
12:00	200	150	0.68	17.9	8.75	12.0	6.2	51.4	7.0	Light yellowish green	34.5	-	0.018	7.0	Slightly yellow	32.4	-	0.007	
16:00	150	150	1.00	16.8	8.60	16.8	8.2	48.9	7.0	Light yellowish green	34.9	10.7	0.020	7.0	Slightly yellow	32.8	10.0	0.007	
20:00	110	150	1.36	17.2	9.93	23.4	9.9	41.6	6.8	Light yellowish green	35.5	-	0.019	7.0	Slightly yellow	31.8	-	0.007	
11/2 10:00	200	200	1.00	10.5	5.31	10.5	5.2	49.5	6.8	Light yellowish green	37.3	-	0.019	6.9	Slightly yellow	33.0	-	0.006	
11:00	200	200	1.00	10.7	5.40	10.7	5.3	49.5	6.9	Light yellowish green	38.5	-	0.020	6.9	Slightly yellow	33.8	-	0.008	
13:00	200	200	1.00	10.7	5.40	10.7	5.3	49.5	6.9	Light yellowish green	35.1	-	0.019	6.9	Slightly yellow	31.5	-	0.008	
11/7 13:30	150	200	1.33	5.02	1.36	6.7	4.9	73.1	6.8	Light yellowish green	37.1	-	0.027	6.9	Slightly yellow	29.4	-	0.011	
16:00	150	200	1.33	11.5	2.92	14.5	10.6	73.1	7.0	Light yellowish green	41.4	-	0.026	6.9	Slightly yellow	32.6	-	0.012	
11/8 13:00	200	200	1.00	9.58	4.90	9.6	4.7	49.0	6.8	Light yellowish green	42.4	-	0.027	7.0	Slightly yellow	40.2	-	0.009	
16:00	150	200	1.33	9.58	5.24	12.7	5.8	45.7	6.9	Light yellowish green	47.0	-	0.028	7.0	Slightly yellow	39.9	-	0.010	
11/9 14:30	150	200	1.33	10.3	4.22	13.7	8.1	59.1	6.9	Light yellowish green	34.6	9.4	0.024	7.0	Slightly yellow	30.9	7.0	0.009	
11/10 13:30	150	200	1.33	10.4	5.24	13.9	7.0	50.4	7.0	Light reddish brown	41.5	-	0.035	6.9	Slightly pink	38.3	-	0.015	
11/11 13:00	200	200	1.00	9.94	2.51	9.9	7.4	74.7	7.0	Light reddish brown	42.4	-	0.038	7.0	Slightly pink	38.5	-	0.022	
17:00	200	200	1.00	14.0	4.79	14.0	9.2	65.7	7.0	Light reddish brown	37.7	-	0.044	7.0	Slightly pink	33.3	-	0.025	
11/12 14:00	200	200	1.00	10.3	5.47	10.3	4.9	47.6	6.7	Light reddish brown	33.2	-	0.036	6.7	Slightly yellow	30.6	-	0.014	
11/13 13:00	200	200	1.00	11.2	6.06	11.2	5.1	45.5	6.8	Light reddish brown	47.6	-	0.064	6.9	Slightly yellow	42.6	-	0.019	
11/14 13:00	200	200	1.00	10.4	5.30	10.4	5.1	49.0	6.8	Light yellowish brown	50.2	-	0.038	6.9	Slightly yellow	47.1	-	0.012	

Table-2 Water quality analysis result for secondary treated water and its water treated by ozone oxidation and activated carbon adsorption

Sampling date and time	Sample name	Total chrome (ppm as Cr)	Anionic surfactant (ppm)	h-Hexane extracted substance (ppm)	Suspended solid (SS) (ppm)
10/18 15:00	Secondary treated water	0.05 or less	0.39	5.8	3.3
	Water treated by ozone	0.05 or less	0.24	5.1	2.9
	Water treated by activated carbon	-	-	-	-
10/29 18:00	Secondary treated water	0.08	0.49	7.2	4.8
	Water treated by ozone	0.08	0.22	7.0	4.6
	Water treated by activated carbon	0.07	0.2 or less	5.0 or less	2.5 or less
10/31 14:00	Secondary treated water	0.05 or less	0.68	5.0 or less	4.2
	Water treated by ozone	0.05 or less	0.2 or less	5.0 or less	2.8
	Water treated by activated carbon	0.05 or less	0.2 or less	5.0 or less	2.5 or less
11/8 10:00	Secondary treated water	0.07	0.77	5.0 or less	6.2
	Water treated by ozone	0.08	0.33	5.0 or less	6.4
	Water treated by activated carbon	0.08	0.2 or less	5.0 or less	2.5 or less
11/13 12:00	Secondary treated water	-	0.98	6.2	3.6
	Water treated by ozone	-	0.60	5.0 or less	2.5 or less
	Water treated by activated carbon	-	0.2 or less	5.0 or less	2.5 or less

Note: Water treated by activated carbon is effluent at outlet of the 3rd tower in the experiment of passage of water treated by ozone.

Table-3 Result table for experiment on oxidation of dye raw wastewater by ozone

Nov. 19 13:00-Nov. 30 17:00, 1974

Sampling date and time	Wastewater flow (/H)	O_3 gas flow (N ℓ/H)	Gasliquid ratio (G/L)	Exhaust CO_3 gas concentration (mgO_3/N ℓ)	Raw CO_3 gas concentration (mgO_3/N ℓ)	Amount of O_3 added (ppm)	O_3 absorbed dose (ppm)	O_3 absorption rate (%)	Raw wastewater water quality				Filter effluent water quality				O_3 treeated wastewater quality				Remark
									pH	External appearance	COD (ppm O)	Average absor-bance (-log T)	pH	External appearance	COD (ppm O)	Average absor-bance (-log T)	pH	External appearance	COD (ppm O)	Average absor-bance (-log T)	
11/19 14:00	200	468	2.34	15.7	5.94	36.7	22.8	62.1	6.7	Reddish purple	180	0.072	6.7	Reddish purple	161	0.073	6.9	Light yellow	147	0.050	O_3 treatment started at 13:00 on Nov. 19.
18:00	140	468	3.34	15.7	8.14	52.4	25.3	48.3	-	Reddish purple	131	-	-	Reddish purple	122	0.073	-	Light yellow	110	0.047	
11/20 11:00	150	390	2.60	18.1	9.60	47.1	22.1	46.9	-	Light red	97.2	0.048	-	Light red	83.7	0.048	-	Light yellow	72.8	0.030	
14:00	240	400	1.67	18.1	8.47	30.2	16.1	53.3	-	Red	91.6	0.067	-	Red	76.3	0.067	-	Light red	68.1	0.048	
17:00	100	490	4.90	14.9	9.12	73.0	28.3	38.8	6.9	Red	118	0.080	6.9	Red	98.6	0.081	7.0	Light red	85.9	0.042	
11/21 11:00	105	340	3.24	17.4	11.2	56.4	20.1	35.6	-	Red	156	0.080	-	Red	146	0.078	-	Light red	130	0.058	
14:00	100	340	3.40	17.4	9.48	59.2	26.9	45.4	7.5	Bluish green	118	0.091	7.5	Bluish green	107	0.091	7.3	Light yellow	92.9	0.037	
11/23 12:00	100	340	3.40	17.4	9.48	59.2	26.9	45.4	7.0	Bluish green	100	0.081	7.2	Bluish green	89.9	0.077	7.2	Light yellow	84.5	0.040	O_3 treatment was suspended all day on Nov. 22.
11/24 15:00	100	340	3.40	17.3	9.20	58.8	27.5	46.8	6.8	Dark green	85.0	0.092	6.8	Dark green	80.5	0.090	6.9	Slightly yellow	74.1	0.033	
11/25 12:00	150	440	2.93	16.2	6.72	47.5	27.8	58.5	-	Dark green	90.2	0.059	-	Dark green	83.8	0.059	-	Slightly yellow	77.3	0.029	
15:00	140	440	3.14	16.3	6.82	51.2	29.8	58.2	6.3	Dark red	83.8	0.050	6.3	Dark red	80.1	0.050	6.5	Light yellow	76.5	0.033	
11/26 12:00	160	400	2.50	18.0	5.96	45.0	30.1	66.9	-	Bright yellow	106	0.047	-	Bright yellow	97.6	0.049	-	Light yellow	94.3	0.039	
17:00	70	470	6.71	15.6	8.92	10.5	44.8	42.7	7.0	Bright yellow	126	0.050	7.0	Bright yellow	118	0.050	7.0	Light yellow	95.6	0.038	
11/28 12:00	150	420	2.80	15.2	6.14	42.6	25.4	59.6	-	Dark brown	133	0.129	-	Dark brown	123	0.120	-	Dark brown	105	0.070	O_3 treatment was suspended all day on Oct. 27.
17:00	150	420	2.80	15.2	6.10	42.6	25.5	59.9	6.9	Dark brown	103	0.090	6.8	Dark brown	97.0	0.090	6.9	Light brown	92.2	0.050	
11/29 12:00	50	420	8.40	15.2	8.33	12.8	57.7	45.1	-	Blackish brown	115	0.163	-	Blackish brown	103	0.160	-	Light brown	94.0	0.060	
17:00	150	420	2.80	15.2	6.13	42.6	25.4	59.6	7.0	Dark brown	106	0.098	7.0	Dark brown	100	0.098	7.0	Light brown	94.0	0.061	
11/30 12:00	150	420	2.80	15.3	6.60	42.8	24.4	57.0	-	Grayish brown	100	0.084	-	Grayish brown	91.8	0.080	-	Gray	86.4	0.050	
17:00	100	420	4.20	15.3	9.10	64.3	26.0	40.4	-	Grayish brown	120	0.072	-	Grayish brown	113	0.072	-	Gray	106	0.046	

Table-4 Analysis result for dye raw wastewater water quality

Sampling date and time	Sample name	BOD (ppm as O)	Total chrome (ppm as Cr)	Anionic surfactant (ppm)	h-hexane extracted substance (ppm)	Suspended solid (SS) (ppm)
11/20 17:00	Dye raw wastewater	105	0.21	1.01	5.0 or less	8.9
	Filtrate	100	0.09	1.01	5.0 or less	4.2
	Water treated by ozone	96.6	0.09	0.86	5.0 or less	4.3
	Water treated by activated carbon	-	0.09	0.2 or less	5.0 or less	2.5 or less
11/24 15:00	Dye raw wastewater	90.6	0.27	0.74	12.3	19.7
	Filtrate	79.8	0.09	0.70	7.4	4.6
	Water treated by ozone	76.3	0.10	0.72	7.0	4.6
	Water treated by activated carbon	-	0.09	0.2 or less	5.0 or less	2.5 or less
11/26 17:00	Dye raw wastewater	118	-	0.91	16.1	27.0
	Filtrate	110	-	0.94	9.0	5.3
	Water treated by ozone	110	-	0.44	8.7	4.0
	Water treated by activated carbon	-	-	0.2 or less	5.0 or less	2.5 or less
11/28 12:00	Dye raw wastewater	136	0.41	1.44	11.8	12.6
	Filtrate	124	0.16	1.36	6.8	4.0
	Water treated by ozone	120	0.14	0.92	6.2	4.0
	Water treated by activated carbon	-	0.13	0.2 or less	5.0 or less	2.5 or less

Note: Water treated by activated carbon is effluent of the 3rd tower in the experiment of passage of water treated by ozone.

Table-5 Result table for treatment of secondary treated water by ozone by activated carbon adsorption
Activated sludge→Coagulating sedimentation→Filtration→Activated carbon

Oct. 29 18:00-Nov. 13 17:00, 1974

Sampling date and time	Activated carbon water passage time (Hr)	Activated carbon tower influent water quality					No. 1 tower effluent water quality					No. 2 tower effluent water quality					No. 3 tower effluent water quality					Remark
		pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absorbance (-log T)	pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absorbance (-log T)	pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absorbance (-log T)	pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absorbance (-log T)	
10/29 18:00	6.0	7.0	Light yellow	29.1	-	0.026	7.2	Colorless	4.0	-	0.000	7.1	Colorless	2.5	-	0.000	7.1	Colorless	2.0	-	0.000	Water passage started at 12:00 and stopped at 18:00 on Oct. 29.
10/30 14:00	11.5	6.9	Light yellow	29.0	12.0	0.014	6.9	Colorless	6.3	2.0 or less	0.000	6.9	Colorless	3.0	2.0 or less	0.000	6.9	Colorless	2.5	2.0 or less	0.000	Water passage started at 8:30 on Oct. 30.
20:00	17.5	6.8	Light yellow	30.0		0.017	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
10/31 9:30	31.0	6.8	Light yellow	30.0	-	0.017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
14:00	35.5	6.8	Light yellow	29.5	-	0.016	7.2	Colorless	8.0	-	0.000	-	Colorless	5.4	-	0.000	-	Colorless	3.3	-	0.000	
20:00	41.5	6.9	Light yellow	31.0	-	0.019	-	-	-	-	-	-	-	-	-	-	-		-	-	-	
11/1 10:00	55.0	7.0	Light yellow	37.6	-	0.019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
16:00	61.0	7.0	Light yellowish green	34.5	10.2	0.020	7.0	Colorless	14.1	3.3	0.000	7.0	Colorless	5.2	2.0 or less	0.000	7.0	Colorless	3.5	2.0 or less	0.000	
11/2 10:00	79.0	6.9	Light yellowish green	36.9	-	0.019	7.0	Colorless	16.6	-	0.000	7.0	Colorless	6.5	-	0.000	7.0	Colorless	4.5	-	0.000	
16:00	85.0	6.9	Light yellow	36.9	-	0.019	-	-	17.0	-	-	-	-	7.0	-	-	-	-	4.8	-	-	Water passage stopped at 16:00 on Nov. 2. Water passage stopped all day from No. 3 to 6.
11/7 18:00	89.0	6.8	Light yellow	40.1	-	0.027	7.0	Colorless	16.8	-	0.008	7.1	Colorless	9.2	-	0.000	7.1	Colorless	5.1	-	0.000	Water passage stopped at 14:00 on Nov. 7.
11/8 10:00	105	7.0	Light yellow	46.2	-	0.027	7.0	Slightly yellow	26.5	-	0.007	-	Colorless	12.6	-	0.000		Colorless	8.4	-	0.000	
18:00	113	6.8	Light yellow	47.0	-	0.028	7.0	Slightly yellow	31.7	-	0.008	-	Colorless	11.2	-	0.000		Colorless	7.2	-	0.000	
11/9 11:00	130	6.9	Light yellow	34.4	-	0.024	-	Slightly yellow	25.0	-	0.014	-	Colorless	13.5	-	0.000		Colorless	6.4	-	0.000	
16:00	135	6.9	Light yellow	34.6	9.4	0.025	6.9	Slightly yellow	25.5	4.9	0.016	6.9	Colorless	14.6	3.2	0.000	6.9	Colorless	7.7	2.0 or less	0.000	Water passage stopped at 16:00 on Nov. 9. (The first cycle ended.)
11/11 15:00	5.0		Light yellow	37.7	-	0.040	-	Slightly yellow	18.1	-	0.013	-	Colorless	8.9	-	0.007	-	Colorless	2.9	-	0.007	Water passage started at 10:00 on Nov. 11. (The second cycle started.)
11/12 11:00	25.0	7.0	Light yellow	31.2		0.028	7.1	Light yellow	19.3	-	0.020	7.1	Slightly yellow	9.1	-	0.012	7.1	Colorless	5.5	-	0.007	
16:00	30.0	-	Light yellow	30.8		0.026		Light yellow	17.4	-	0.021	-	Slightly yellow	6.9	-	0.011	-	Slightly yellow	5.7	-	0.007	
11/13 12:00	50.0	7.1	Light yellow	41.7		0.063	7.0	Light yellow	29.4	-	0.027	7.0	Slightly yellow	13.5	-	0.019	7.0	Colorless	6.2	-	0.016	
17:00	55.0	7.0	Light yellow	59.8	12.3	0.066	7.0	Light yellow	42.5	7.6	0.036	6.8	Light yellow	16.2	3.8	0.022	6.8	Colorless	7.0	2.0 or less	0.016	Water passage stopped at 17:00 on Nov. 13.(The second cycle ended.)

Table-6 Result table for treatment of secondary treated water by ozone by activated carbon adsorption
Activated sludge→Coagulating sedimentation→Filtration→Activated carbon

Oct. 29 18:00-Nov. 14 9:00, 1974

Sampling date and time	Activated carbon water passage time (Hr)	Activated carbon tower influent water quality					No. 1 tower effluent water quality					No. 2 tower effluent water quality					No. 3 tower effluent water quality					Remark
		pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absor-bance (-log T)	pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absor-bance (-log T)	pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absor-bance (-log T)	pH	External appearance	COD (ppm O)	BOD (ppm O)	Average absor-bance (-log T)	
10/29 18:00	6.0	7.2	SLightly yellow	25.7	-	0.009	7.2	Colorless	2.7	-	0.000	7.1	Colorless	2.0	-	0.000	7.1	Colorless	1.8	-	0.000	Water passage started at 12:00 and stopped at 18:00 on Oct. 29.
10/30 14:00	11.5	7.0	SLightly yellow	28.3	10.0	0.008	7.0	Colorless	4.3	2.0 or less	0.000	6.9	Colorless	3.0	2.0 or less	0.000	6.9	Colorless	2.0	2.0 or less	0.000	Water passage started at 8:30 on Oct. 30.
20:00	17.5	6.9	SLightly yellow	25.9	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
10/31 9:30	31.0	7.0	SLightly yellow	24.3	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
14:00	35.5	7.4	SLightly yellow	25.0	-	0.010	7.3	Colorless	7.8	-	0.000	7.3	Colorless	3.6	-	0.000	7.3	Colorless	3.2	-	0.000	
20:00	41.5	7.0	SLightly yellow	30.0	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
11/1 10:00	55.5	7.1	SLightly yellow	34.5	-	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
16:00	61.5	7.0	SLightly yellow	31.0	9.6	0.007	7.0	Colorless	9.3	3.7	0.000	7.0	Colorless	3.6	2.0 or less	0.000	7.0	Colorless	3.2	2.0 or less	0.000	
11/2 10:00	79.5	6.9	SLightly yellow	32.2	-	0.006	6.9	Colorless	12.0	-	0.000	7.0	Colorless	3.8	-	0.000	7.0	Colorless	2.5	-	0.000	
16:00	85.5	6.9	SLightly yellow	32.2	-	0.006	-	-	12.5	-	-	-	-	4.0	-	-	-	-	2.5	-	-	Water passage stopped at 16:00 on Nov. 2. Water passage stopped all day from No. 3 to 6.
11/7 18:00	89.5	6.9	SLightly yellow	38.0	-	0.014	6.8	Colorless	12.9	-	0.004	7.0	Colorless	6.8	-	0.000	7.0	Colorless	4.2	-	0.000	Water passage started at 14:00 on Nov. 7.
11/8 10:00	105.5	6.9	SLightly yellow	40.6	-	0.015	7.1	Colorless	21.0	-	0.004	7.1	Colorless	9.5	-	0.000	-	Colorless	8.6	-	0.000	
18:00	113.5	7.0	SLightly yellow	42.0	-	0.008	7.0	Colorless	19.3	-	0.002	7.1	Colorless	8.5	-	-	-	Colorless	6.4	-	-	
11/9 11:00	130.5	6.9	SLightly yellow	30.5	-	0.007	-	Colorless	16.4	-	0.002	-	Colorless	6.7	-	-	-	Colorless	5.1	-	-	
16:00	135.5	7.0	SLightly yellow	34.3	7.0	0.007	7.0	Colorless	15.6	5.8	0.002	7.0	Colorless	6.4	2.2	0.000	7.1	Colorless	4.8	2.0 or less	0.000	
11/10 9:00	150.5	7.0	SLightly yellow	31.8	-	0.006	-	Colorless	23.5	-	0.002	-	Colorless	10.7	-	-	-	Colorless	6.6	-	-	
14:00	155.5	6.9	SLightly yellow	33.1	-	0.008	7.1	Colorless	25.5	-	0.002	7.1	Colorless	10.9	-	-	7.1	Colorless	6.4	-	-	Water passage stopped at 14:00 on Nov. 10. (The first cycle ended.)
11/11 15:00	5.0	-	SLightly yellow	33.1	-	0.022	-	Colorless	12.7	-	0.005	-	Colorless	5.0	-	0.004	-	Colorless	2.1	-	0.000	Water passage started at 10:00 on Nov. 11. (The second cycle started.)
11/12 11:00	25.0	6.8	SLightly yellow	30.8	-	0.016	6.9	Slightly yellow	16.2	-	0.008	6.9	Slightly yellow	7.1	-	0.008	7.0	Colorless	4.1	-	-	
16:00	30.0	-	SLightly yellow	28.2		0.017	-	Slightly yellow	13.3	-	0.008	-	Slightly yellow	6.6	-	0.008	-	Colorless	4.1	-	0.000	
11/13 12:00	50.0	7.2	SLightly yellow	43.7	-	0.019	7.2	Slightly yellow	21.4	-	0.011	7.0	Slightly yellow	9.0	-	0.008	7.0	Colorless	5.2	-	0.002	
17:00	55.0		SLightly yellow	52.5	-	0.014	-	Slightly yellow	25.6	-	0.008	-	Slightly yellow	12.6	-	0.006	-	Colorless	5.2	-	0.002	
11/14 9:00	71.0	7.0	SLightly yellow	54.1	17.2	0.016	7.0	Slightly yellow	27.8	6.8	0.009	7.0	Slightly yellow	11.3	2.7	0.006	7.0	Colorless	5.6	2.0 or less	0.003	Water passage stopped at 9:00 on Nov. 14. (The second cycle ended.)

Table-7 Result table for experiment on dye raw wastewater activated carbon absorption
Dye wastewater storage tank→Filter→Activated carbon

Nov. 19 15:00-Nov. 26 17:00, 1974

Sampling date and time	Activated carbon water passage time (Hr)	Activated carbon tower influent water quality				No. 1 tower effluent water quality				No. 2 tower effluent water quality				No. 3 tower effluent water quality				Remark
		PH	External appearance	COD (ppm O)	Average absor-bance (-log T)	PH	External appearance	COD (ppm O)	Average absor-bance (-log T)	PH	External appearance	COD (ppm O)	Average absor-bance (-log T)	PH	External appearance	COD (ppm O)	Average absor-bance (-log T)	
11/19 15:15		6.7	Reddish purple	142	0.073	-	-	-	-	-	-	-	-	-	-	-	-	Water passage started at 15:00 on Nov. 19. (The first cycle started.)
18:00	3.0	-	Reddish purple	117	0.080		Cloudy	43.8	0.015		Cloudy	20.6	0.015	-	Cloudy	15.9	0.015	
11/20 9:00	18.0	-	Yellowish brown	146	-	-	Cloudy	78.3	-	-	Cloudy	46.2	-	-	Cloudy	35.3	-	
11:00	20.0	-	Light red	111	-	-	-	-	-	-	-	-	-	-	-	-	-	
14:00	23.0	-	Red	97.1	-	-	-	-	-	-	-	-	-	-	-	-	-	
17:00	26.0	7.0	Red	101.0	0.070	7.1	Cloudy	34.0	0.017	7.1	Cloudy	22.7	0.015	7.1	Cloudy	19.6	0.014	
11/21 9:00	42.0	-	Red	110	-	-	Light red	49.2	-	-	Cloudy	33.8	-	-	Cloudy	27.0	-	
17:00	50.0	7.3	Bluish green	87.0	0.080	7.2	Light red	55.0	0.022	7.2	Cloudy	39.2	0.020	7.2	Cloudy	31.0	0.020	
11/22 9:00	66.0	-	Bluish green	146	-	-	Cloudy	89.5	-	-	Cloudy	63.0	-	-	Cloudy	52.7	-	Water passage stopped at 9:00 due to backwash on Nov. 22.
11/23 10:00	67.0	-	Bluish green	140	-	-	-	-	-	-	-	-	-	-	-	-	-	Water passage started at 9:00 on Nov. 23.
12:00	69.0	7.1	Bluish green	109	0.091	7.1	Cloudy	55.3	0.022	7.0	Cloudy	38.7	0.020	7.0	Cloudy	35.4	0.020	
17:00	74.0	-	Light green	109	-	-	Cloudy	60.0	-	-	Cloudy	37.6	-	-	Cloudy	28.6	-	
11/24 9:00	90.0	-	Dark green	118	-	-	Cloudy	70.9	-	-	Cloudy	50.5	-	-	Cloudy	35.4	-	Water passage stopped at 9:00 on Nov. 24. (The first cycle ended.)
																		Water passage started at 12:00 on Nov. 24. (The second cycle started.)
11/24 15:00	3.0	7.0	Dark green	89.4	0.094	6.9	Cloudy	35.6		7.0	Cloudy	31.1		6.8	Cloudy	18.5	-	
11/25 9:00	21.0		Dark green	101	-	-	Cloudy	63.5	-	-	Cloudy	36.8	-	-	Cloudy	24.4	-	
12:00	24.0		Dark green	83.7	-	-	-	-	-	-	-	-	-	-	-	-	-	
15:00	27.0	-	Dark red	70.6	-	-	-	-	-	-	-	-	-	-	-	-	-	
17:00	29.0	7.0	Dark green	84.6	0.055	7.0	Cloudy	60.4	-	7.0	Cloudy	35.1		7.0	Cloudy	23.2		
11/26 9:00	45.0		Dark green	108	-	-	Cloudy	81.8		-	Cloudy	47.6	-	-	Cloudy	42.1	-	
12:00	48.0	-	Dark red	114	-	-	-	-	-	-	-	-	-	-	-	-	-	
17:00	53.0	6.7	Bright yellow	99.0	0.060	6.9	Light yellow	80.7	-	6.9	Slightly yellow	45.0	-	6.9	Cloudy	40.8		Water passage stopped at 17:00 on Nov. 26. (The second cycle ended.)
11/28 12:00	3.0	6.5	Dark brown	117	-	6.8	Light yellow	53.8	-	6.8	Slightly yellow	39.0		6.8	Slightly yellow	23.4	-	Water passage started at 9:00 on Nov. 28. (The third cycle started.)
17:00	8.0		Dark brown	89.8	-	-	-	-		-	-	-	-	-	-	-	-	
11/29 10:00	25.0		Dark brown	101	-	-	Light brown	73.2		-	Light yellow	46.9	-	-	Light yellow	43.8	-	
14:00	29.0		Dark brown	108	-	-	-	-	-	-	-	-	-	-	-	-	-	
17:00	32.0	7.0	Dark brown	86.2	0.172	7.0	Light brown	62.4	0.072	7.0	Light brown	40.2	0.051	7.0	Light yellow	35.2	0.039	
11/30 10:00	49.0	7.1	Dark brown	106	0.110	6.8	Light brown	70.2	0.061	6.8	Light brown	45.5	0.043	6.9	Light yellow	37.3	0.033	
16:00	55.0		Grayish green	110			Light green	75.5	-	-	Light green	51.0	-	-	Light green	41.8	-	Water passage stopped at 16:00 on Nov. 30. (The third cycle ended.)

Table-8 Result table for experiment on activated carbon absorption for dye raw wastewater treated by ozone

Dye wastewater storage tank→Filter→O3 treatment tower→Activated carbon

Nov. 19 15:00-Nov. 27 10:00, 1974

Sampling date and time	Activated carbon water passage time (Hr)	Activated carbon tower influent water quality				No. 1 tower effluent water quality				No. 2 tower effluent water quality				No. 3 tower effluent water quality				Remark Remark
		pH	External appearance	COD (ppm O)	Average absor-bance (-log T)	pH	External appearance	COD (ppm O)	Average absor-bance (-log T)	pH	External appearance	COD (ppm O)	Average absor-bance (-log T)	pH	External appearance	COD (ppm O)	Average absor-bance (-log T)	
11/19 15:15		7.1	Light yellow	132	0.042	-	-	-	-	-	-	-	-	-	-	-	-	Water passage started at 15:00 on Nov. 19. (The first cycle started.)
18:00	3.0	6.8	Light yellow	108	0.040	6.9	Cloudy	36.2	0.015	7.0	Cloudy	18.1	0.014	6.8	Cloudy	14.5	0.014	
11/20 9:00	18.0	-	Light yellow	140	-	-	Cloudy	73.0	-	-	Cloudy	41.4	-	-	Cloudy	32.5	-	
11:00	20.0	-	Light yellow	106	-	-	-	-	-	-	-	-	-	-	-	-	-	
14:00	23.0	-	Light yellow	95.9	-	-	-	-	-	-	-	-	-	-	-	-	-	
17:00	26.0	7.0	Light yellow	100	0.045	7.0	Cloudy	42.0	0.016	7.0	Cloudy	20.1	0.013	7.0	Cloudy	17.0	0.013	
11/21 9:00	42.0	-	Light red	109	-	-	Cloudy	54.5	-	-	-	-	-	-	-	-	-	
17:00	50.0	7.0	Light yellow	78.8	0.050	7.0	Cloudy	36.0	0.020	7.0	Cloudy	28.0	0.017	7.0	Cloudy	19.0	0.017	
11/22 9:00	66.0	-	Light yellow	133	-	-	Cloudy	77.5	-	-	Cloudy	55.0	-	-	Cloudy	45.0	-	Water passage stopped at 9:00 due to backwash on Nov. 22.
11/23 10:00	67.0	-	Light yellow	131	-	-	-	-	-	-	-	-	-	-	-	-	-	Water passage started at 9:00 on Nov. 23.
12:00	69.0	7.2	Light yellow	87.3	0.043	7.1	Cloudy	51.2	0.020	7.1	Cloudy	31.6	0.017	7.1	Cloudy	28.4	0.017	
17:00	74.0	-	Light yellow	109	-	-	Cloudy	56.7	-	-	Cloudy	35.4	-	-	Cloudy	27.8	-	
11/24 9:00	90.0	-	Light yellow	116	-	-	Cloudy	65.8	-	-	Cloudy	38.7	-	-	Cloudy	32.9	-	Water passage stopped at 9:00 (The first cycle ended.) and started at 12:00 (The second cycle started.) on Nov. 24.
15:00	3.0	7.0	Light yellow	88.0	0.043	7.0	Cloudy	37.6	-	7.0	Cloudy	29.1	-	7.0	Cloudy	15.8	-	
11/25 9:00	21.0	-	Light yellow	95.5	-	-		44.6	-	-		34.0	-	-		28.9	-	
12:00	24.0	-	Light yellow	81.9	-	-	-	-	-	-	-	-	-	-	-	-	-	
15:00	27.0	-	Light yellow	75.0	-	-	-	-	-	-	-	-	-	-	-	-	-	
17:00	29.0	7.0	Light yellow	88.1	0.030	7.0	Cloudy	37.5	-	7.0	Cloudy	30.2	-	7.0	Cloudy	24.2	-	
11/26 9:00	45.0	-	Light yellow	96.0	-	-	Cloudy	56.0	-	-	Cloudy	35.7	-	-	Cloudy	28.0	-	
12:00	48.0	-	Light yellow	95.5	-	-	-	-	-	-	-	-	-	-	-	-	-	
17:00	53.0	6.8	Light yellow	104	0.041	6.8	Slightly yellow	61.3	-	6.8	Cloudy	39.6	-	6.8	Cloudy	29.9	-	
11/27 10:00	70.0	-	Light yellow	95.0	-	-	Slightly yellow	63.0	-	-	Cloudy	40.2	-	-	Cloudy	36.0	-	Water passage stopped at 10:00 on Nov. 27. (The second cycle ended.)
11/28 12:00	3.0	-	Light red	104	-	-	Slightly yellow	42.8	-	-	Slightly yellow	32.8	-	-	Cloudy	17.9	-	Water passage started at 9:00 on Nov. 28. (The third cycle started.)
17:00	8.0	7.0	Dark brown	89.8	-	-	-	-	-	-	-	-	-	-	-	-	-	
11/29 10:00	25.0	-	Light dark brown	91.8	-	-	Light brown	51.5	-	-	Light yellow	33.9	-	-	Slightly yellow	29.9	-	
14:00	29.0	-	Light brown	109	-	-	-	-	-	-	-	-	-	-	-	-	-	
17:00	32.0	7.0	Light brown	103	0.068	7.0	Light yellow	54.0	0.044	7.0	Light brown	37.2	0.036	7.0	Light yellow	33.6	0.030	
11/30 10:00	49.0	6.8	Light brown	98.0	0.060	6.9	Light yellow	51.6	0.040	6.9	Light brown	33.4	0.030	6.9	Light yellow	29.7	0.025	
16:00	55.0	-	Gray	101	-	-	-	-	-	-	-	-	-	-	-	-	-	
12/1 11:00	74.0	-	Gray	125	-	-	Gray	70.5	-	-	Light gray	46.2	-	-	Cloudy	38.5	-	Water passage stopped at 11:00 on Dec. 1. (The third cycle ended.)

Table-9 Outline of ozone and activation treatment and treated water quality

Classification \ Item \ Volume of treated water per hour			1,000m³/day	3,000m³/day	6,000m³/day	NOTES
Operation conditions	Operation time	Hrs	24	24	24	
	Volume of treatment water per hour	m³/H	42	125	250	
	Power source		220V 60Hz	←do	←do	
Ozone treatment facilities	Amount of ozone added	max ppm	20	←do	←do	Outline of facilities ◎Ozone generation facility 1 set · Compressor 1 unit · Dehumidification device 1 set · Ozonizer 1 unit · Electric instrumentation 1 set ◎Reaction tower 1 unit ◎Flue gas treatment facility 1 set (Activated carbon type) ◎Reaction pump 1 set ◎Piping valves and others 1 set
	Amount of ozone generated	kg O_3/H	0.84	2.5	5.0	
	Reaction tower	1 unit	1,600 ϕ ×5,000H	2,800 ϕ ×5,000H	4,000 ϕ ×5,000H or2,800 ϕ ×5,000H 2 units	
Activated carbon adsortion and regeneration facilities	Adsorption tower	2 units	1,400 ϕ ×4,500H	2,400 ϕ ×4,500H	3,400 ϕ ×4,500H	Outline of facilities ◎Quenching tank 1 unit ◎Compression transfer tank 2 units ◎Supplementary tank 1 unit ◎Carbon catcher 1 unit ◎Kerosene storage tank 1 unit ◎Pumps 1 set ◎Piping valves 1 set
	Used activated carbon receiving and discharge tank	1 unit	1,400 ϕ ×4,500H	2,400 ϕ ×4,500H		
	Regenerated activated carbon supply tank	1 unit	1,400 ϕ ×4,500H	2,400 ϕ ×4,500H		
	Amount of activated carbon initially required	T	5	15	30.5	
	Activated carbon regeneration furnace	1 unit	1,215 ϕ ×4 with burner	1,835 ϕ ×4 with burner	1,835 ϕ ×4 with burner	
	Electric and instrumentation facilities		1 set	1 set	1 set	

Classification \ Item \ Type		Raw wastewater	Secondary treated water	Target treated water quality (Osaka bay type 2 water area)	Ozone and activated carbon treatment reference value
Water quality	PH	6.3~7.5	6.7~7.2	5.8~8.6	6.8~7.3
	COD_{Mn} (ppm)	80~180	30~60	20(Daily average 15)	5~7
	BOD 5 (ppm)	90~140	9~15	~	2 or less
	SS (ppm)	8~30	2~6	30(Daily average 25)	2.5 or less
	Chromaticity (-log T)	0.048~0.173	0.018~0.123	~	0.000~0.003

Table-10 Trial calculation result

Classification \ Item \ Value of treated water		1000m³/day	3000m³/day	6000m³/day
Rough facility cost (Unit: 1,000 yen)	Ozone treatment facility	37,000	74,500	137,000
	Activated carbon adsorption facility	48,000	85,500	140,000
	Activated carbon regeneration facility	60,000	110,000	145,000
	Total	¥145,000	¥270,000	¥422,000
Operation expenses (¥/m³)	Ozone treatment facility	6.6	5.8	5.7
	Activated carbon adsorption facility	1.3	1.2	1.2
	Activated carbon regeneration facility	19.6	18.2	17.4
	Total	27.5	25.2	24.3
Construction area (m²)	Indoor section	30	40	80
	Outdoor section	60	120	220
	Total	90	160	300
Number of operation personnel		0.5~1	0.5~1	0.5~1

Note) 1. Rough facility costs

The expenses of civil engineering and construction work covering the foundation and building for a concrete storage equipment are not included. The standard for the sum of money is the one for December 1974.

2. Operation expenses

Simple operation expenses excluding redemption interest and labor costs

Unit price	Electricity	¥10/kwh
	Kerosene	¥33/ℓ-oil
	Activated carbon	¥460,000/T.C
	Vapor	¥1,000/T.S (It is not necessary in some cases.)

3. Construction area

The area of a storage tank is not included. The tank can be set up in three dimensions according to the location.

4. Operation personnel

The number of 0.5 means that one person can operate other equipment as well.

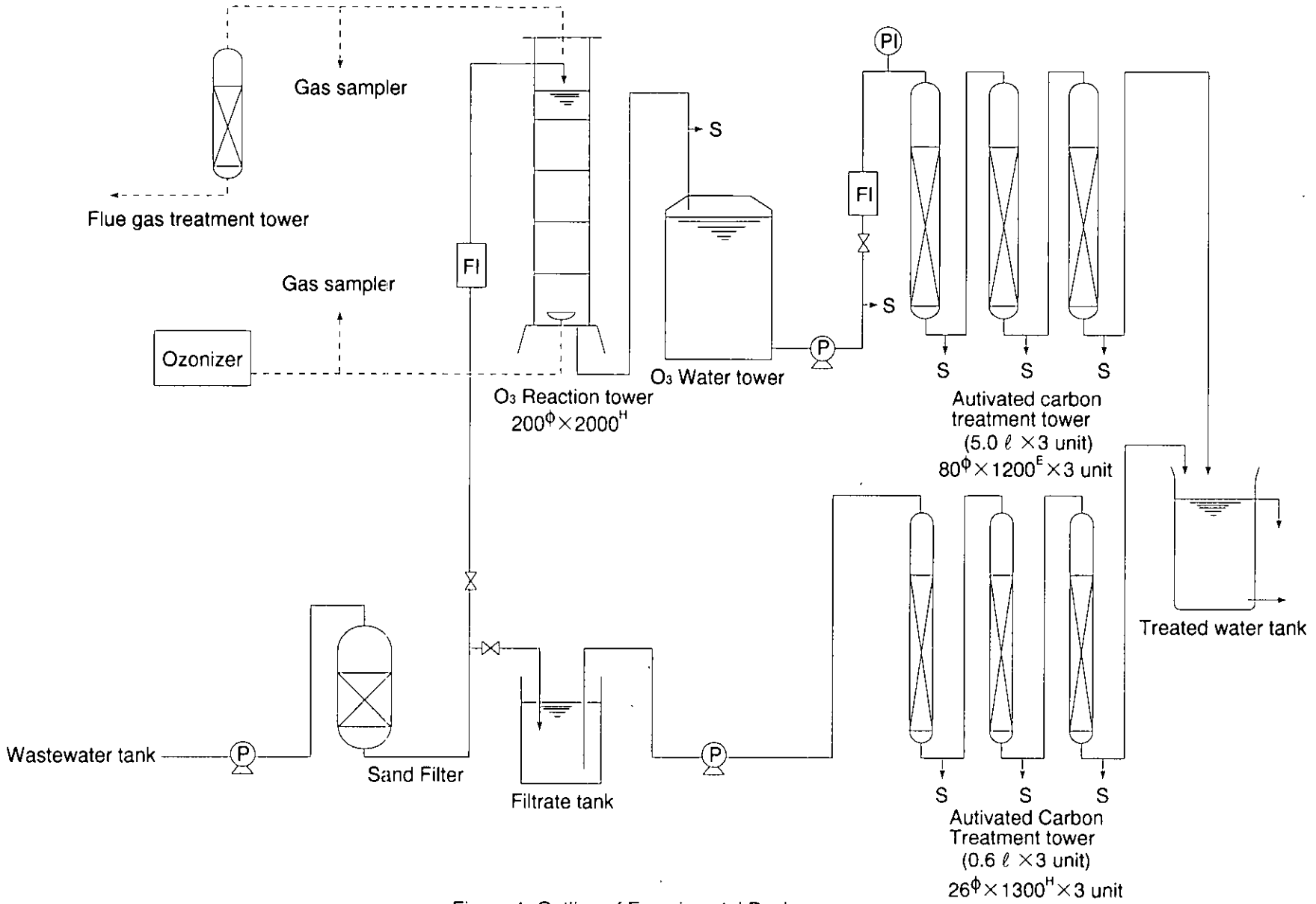


Figure-1 Outline of Experimental Device

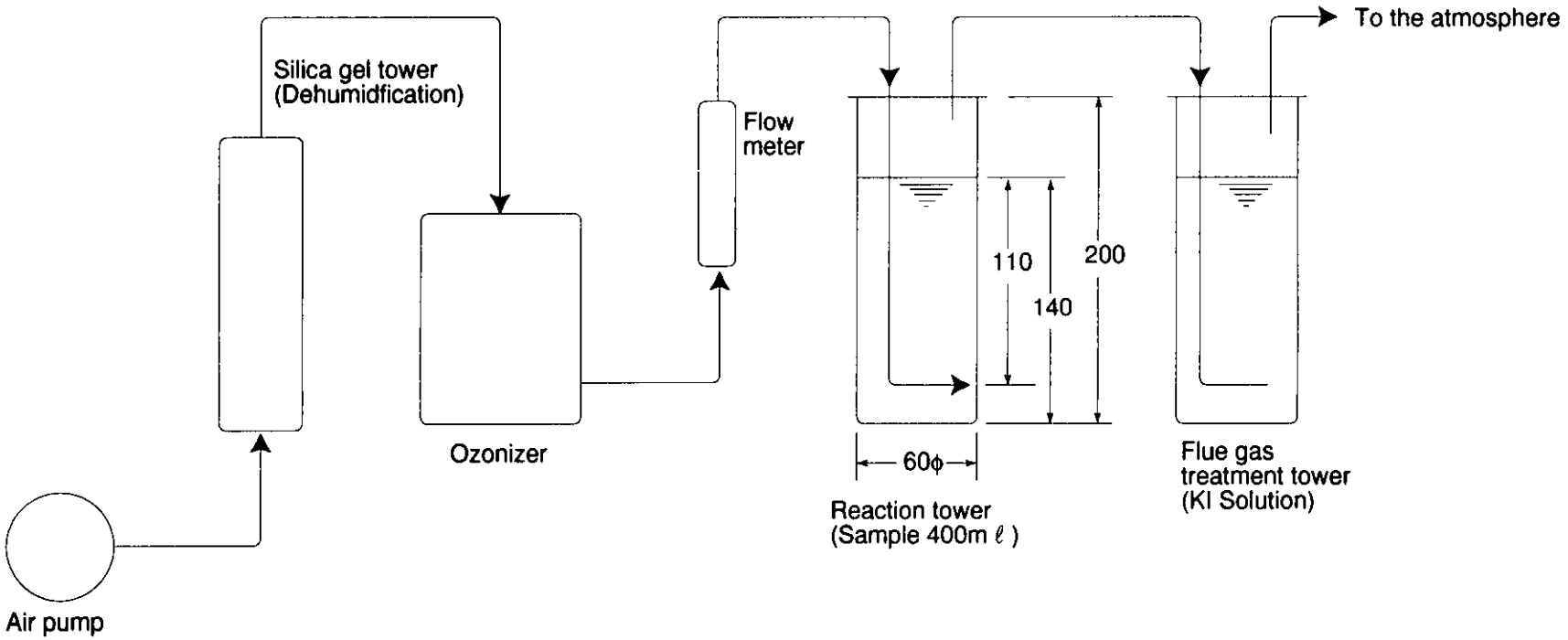


Figure-2 Ozone Batch Experimental Device

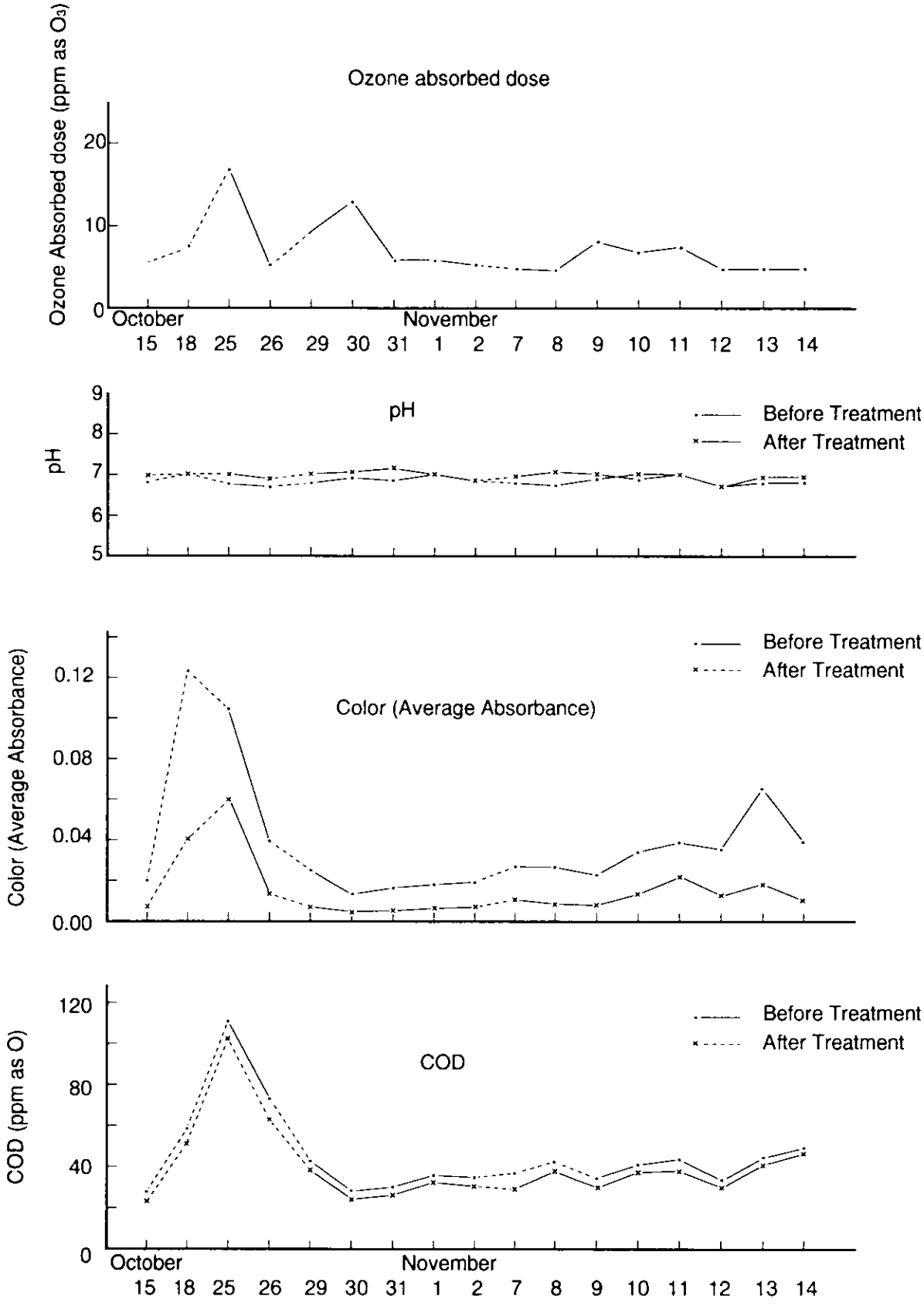


Figure-3 Result of Experiment on Oxidation by Ozone with Secondary Effluent

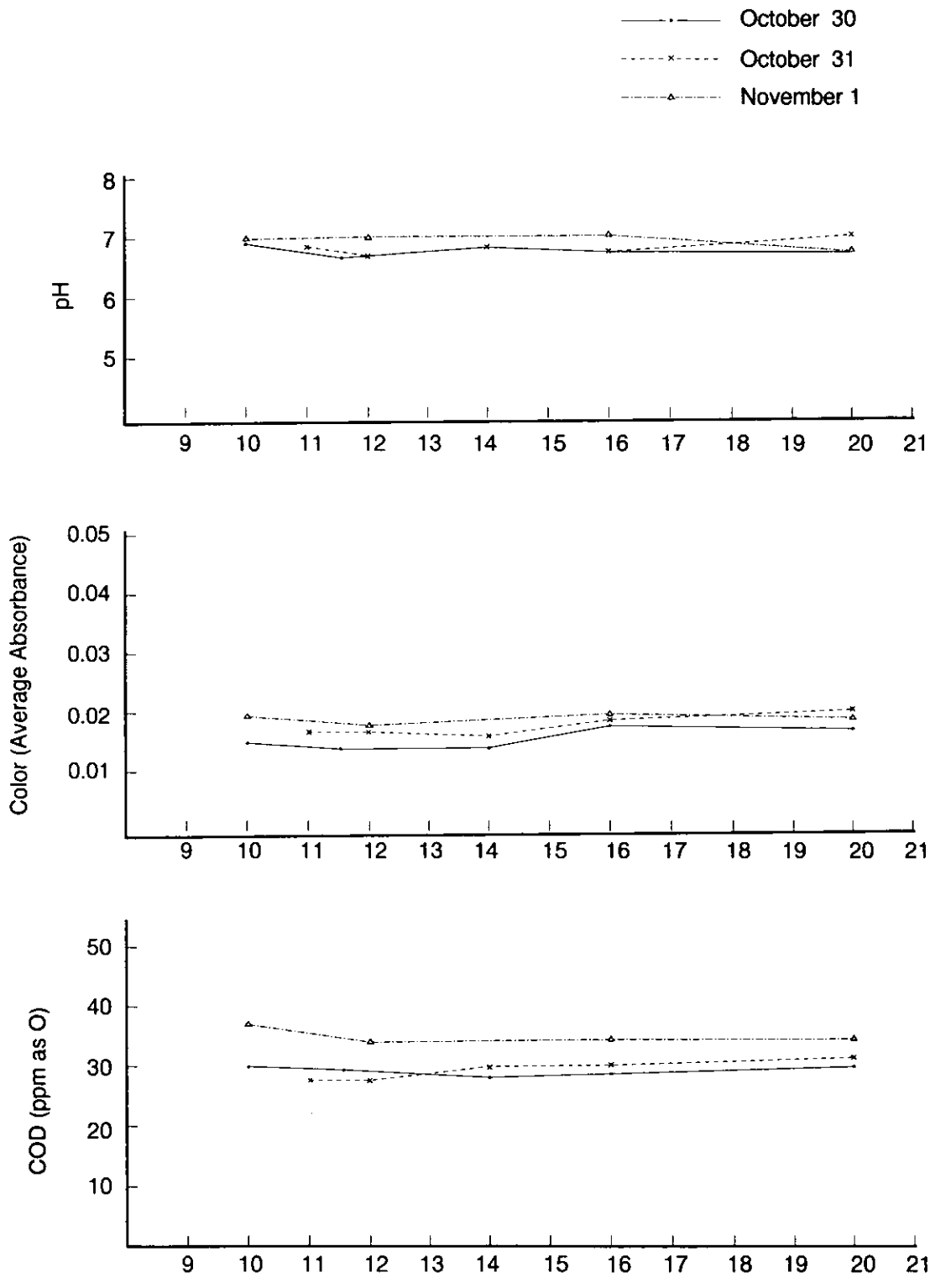


Figure-4 Secondary Effluent Quality Hourly Variation

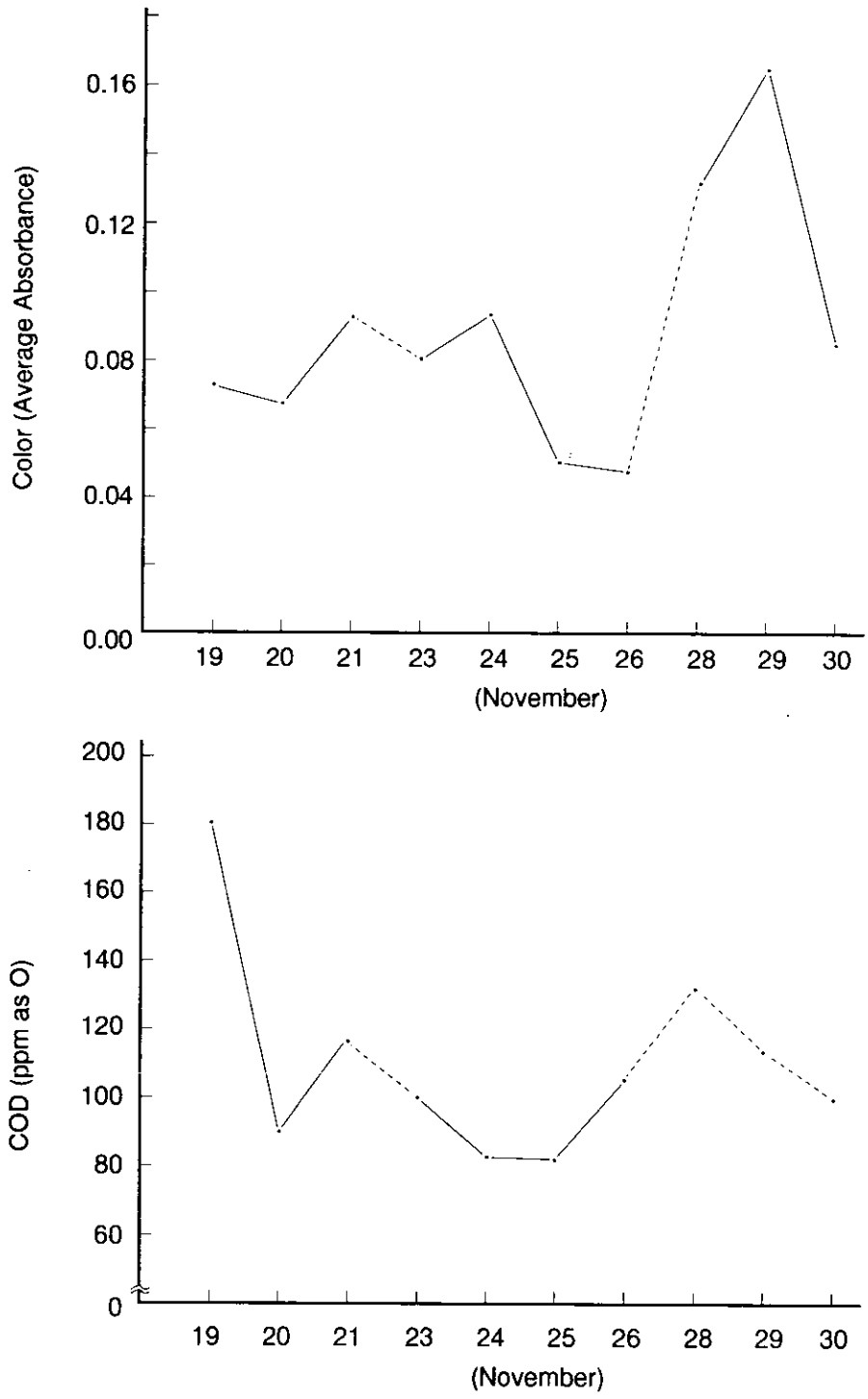


Figure-5 Dye Raw Wastewater Quality Daily Variation

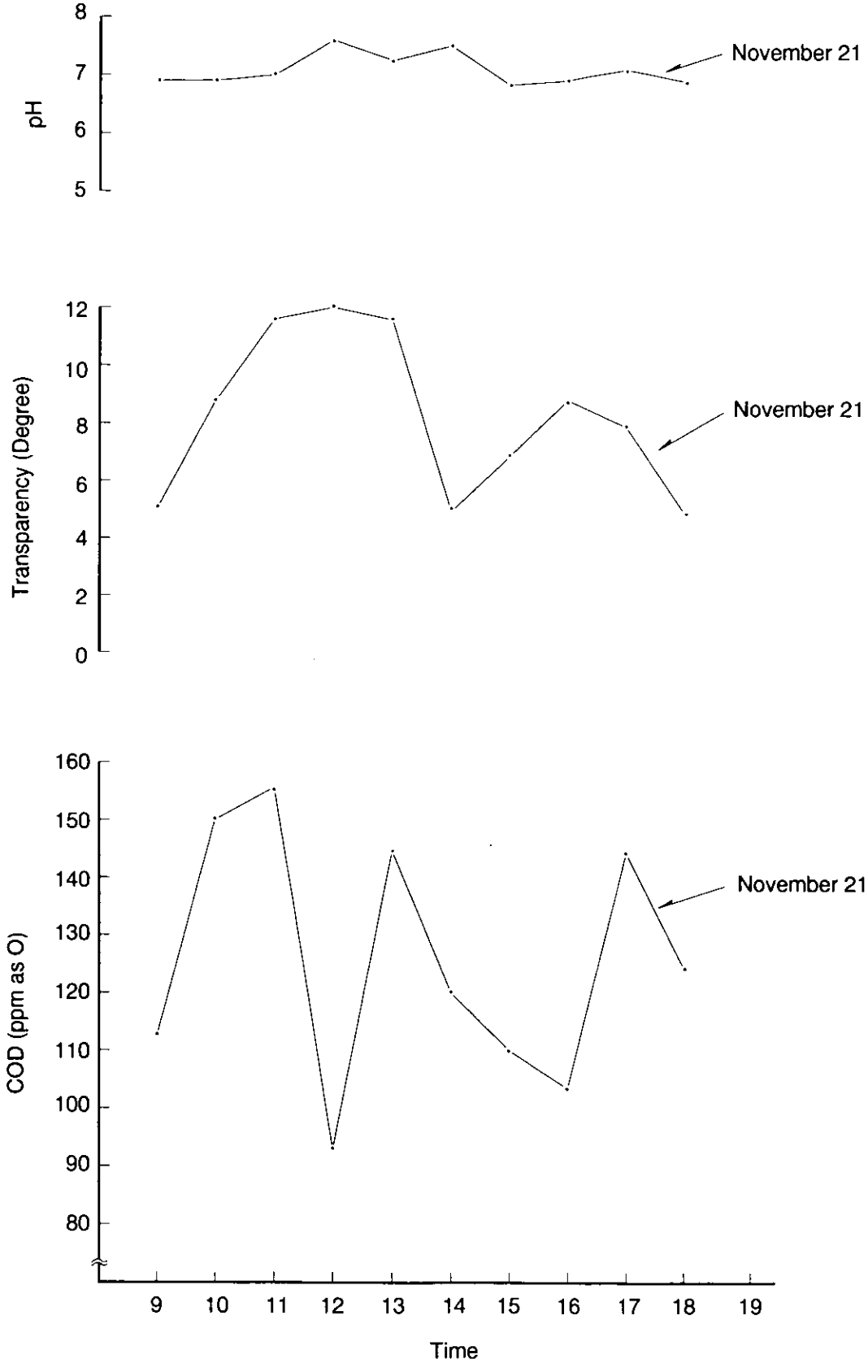
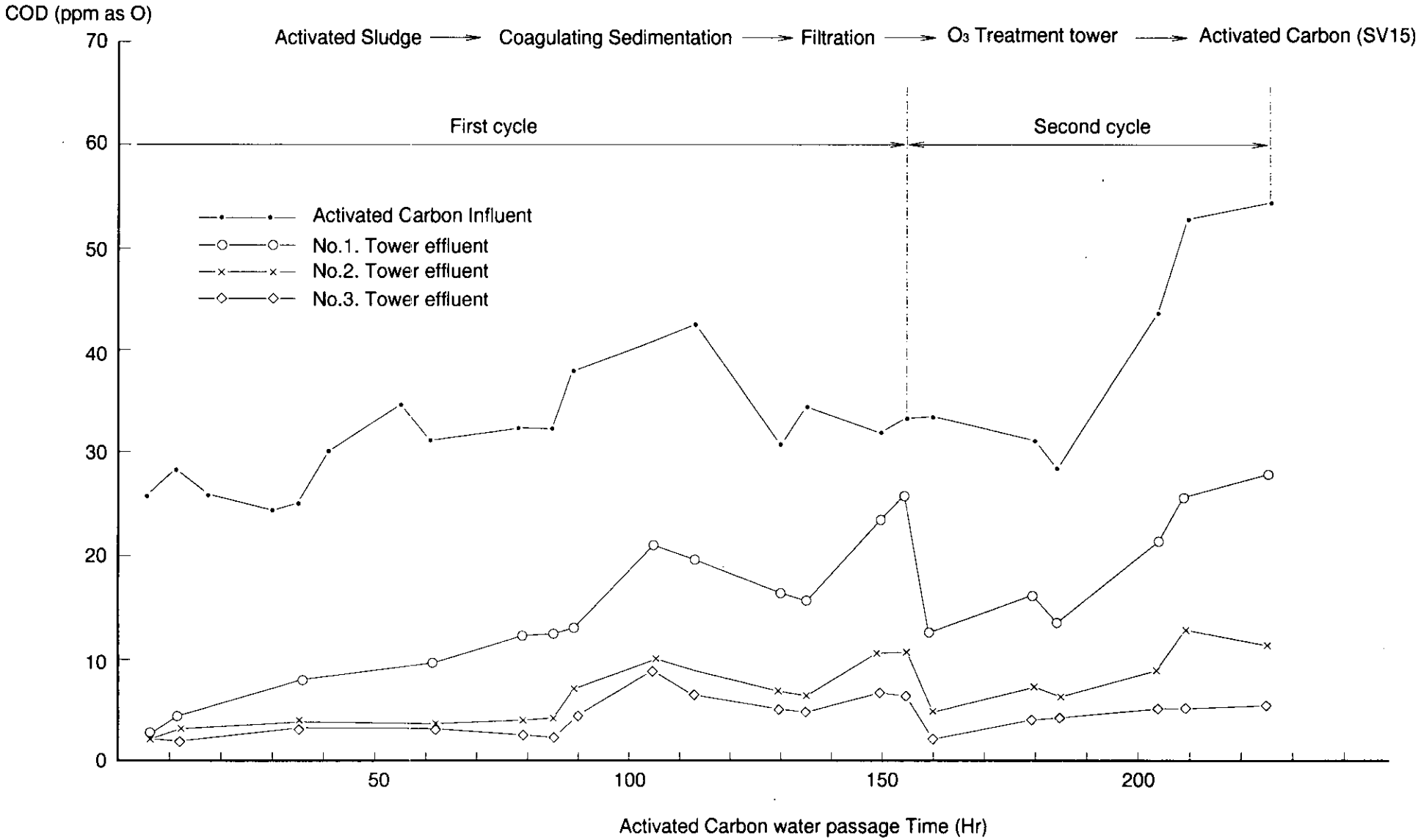


Figure-6 Dye Raw Wastewater Quality Hourly Variation


COD (ppm as O)
Activated Sludge → Coagulating Sedimentation → Filtration → O3 Treatment tower → Activated Carbon (SV15)
First cycle
Second cycle
Activated Carbon Influent
No.1. Tower effluent
No.2. Tower effluent
No.3. Tower effluent
70
60
50
40
30
20
10
0
50
100
150
200
Activated Carbon water passage Time (Hr)

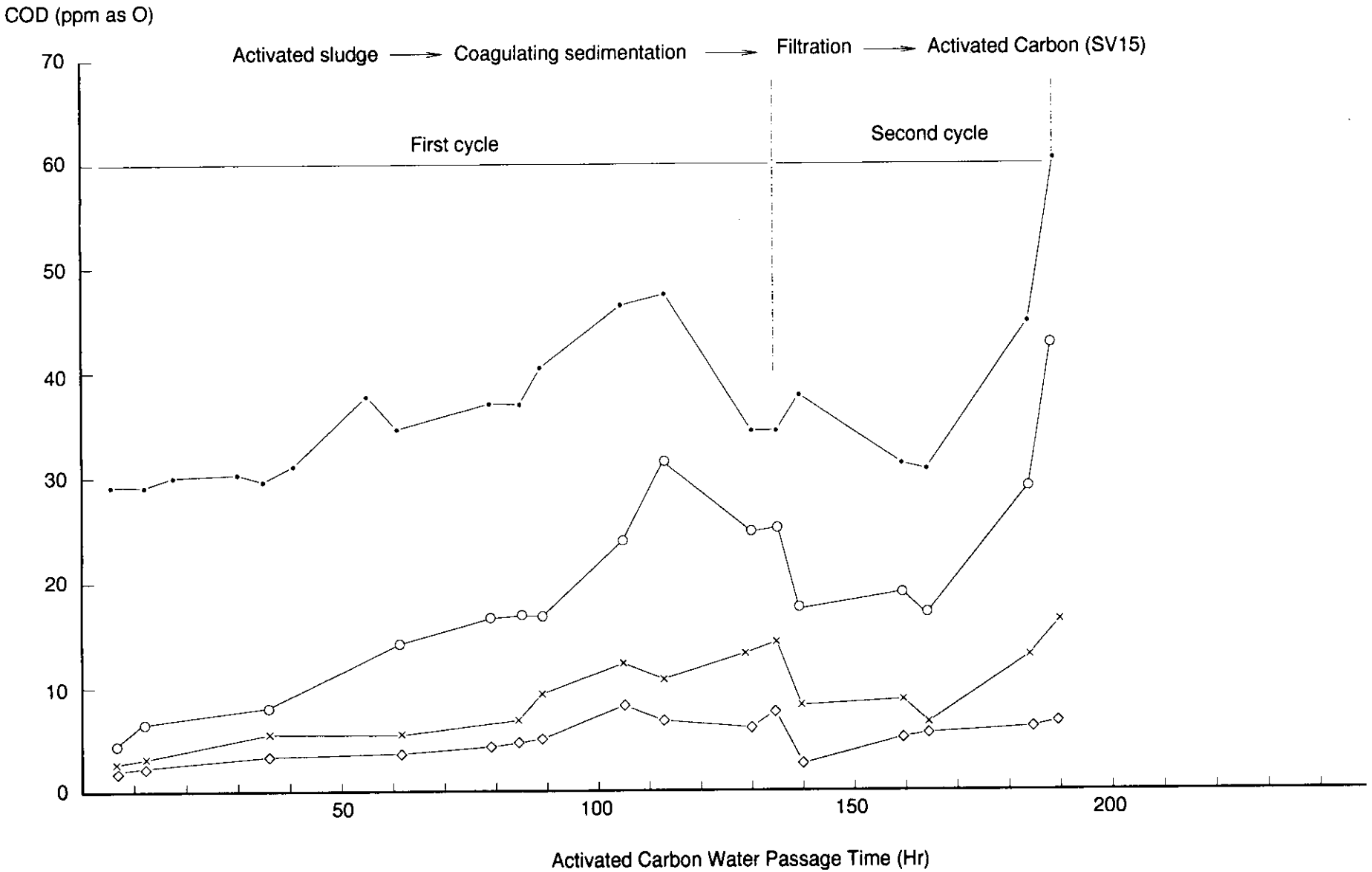


Figure-7 Result of Activated Carbon AdsorptionExperiment on secondary Treated Water

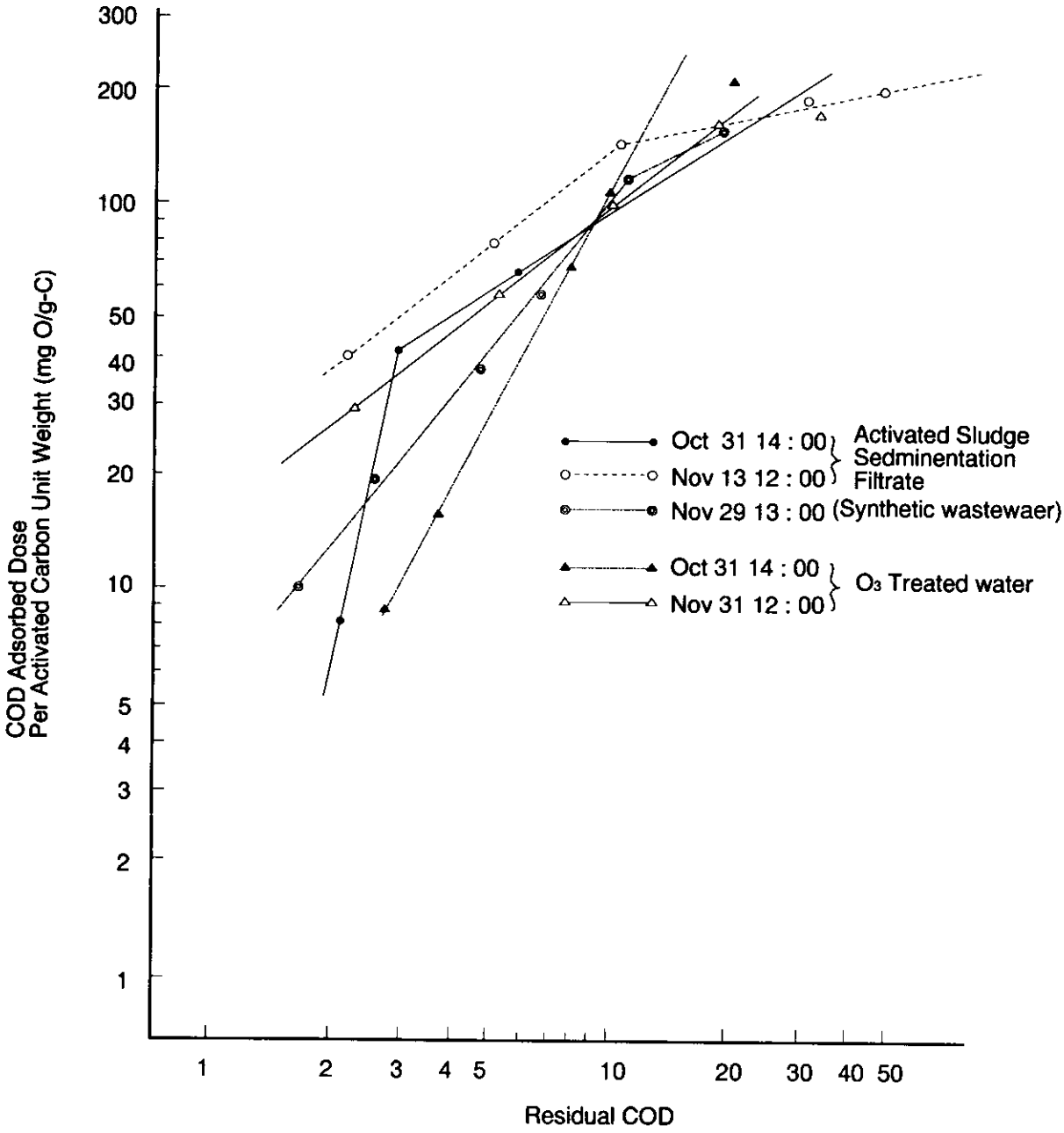


Figure 8 Activated carbon Equilibrium absorption diagram for
Secondary Effluent and Secondary Effluent Treated by Ozone

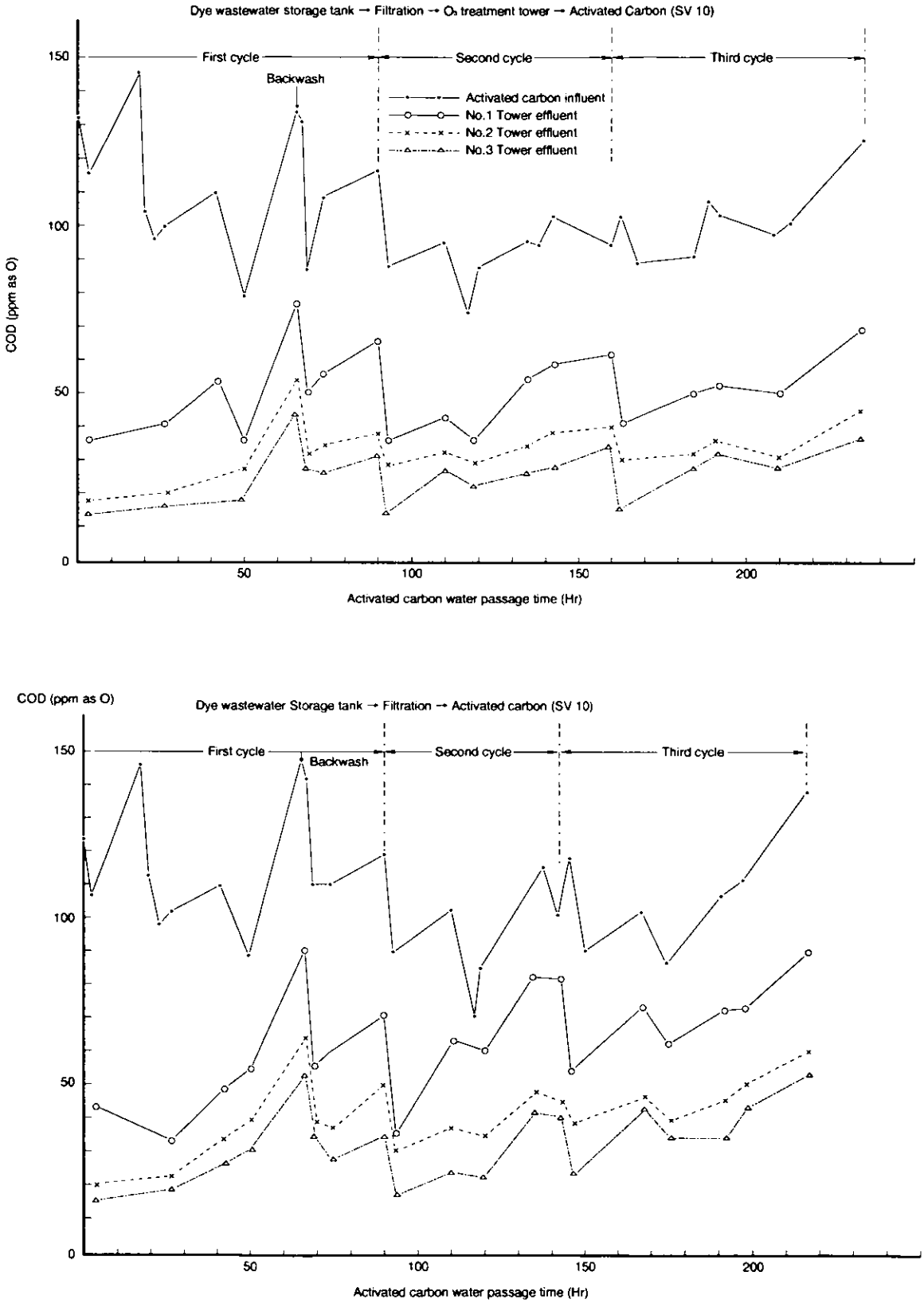


Figure-9 Result of experiment on dye raw wastewater activated carbon adsorption

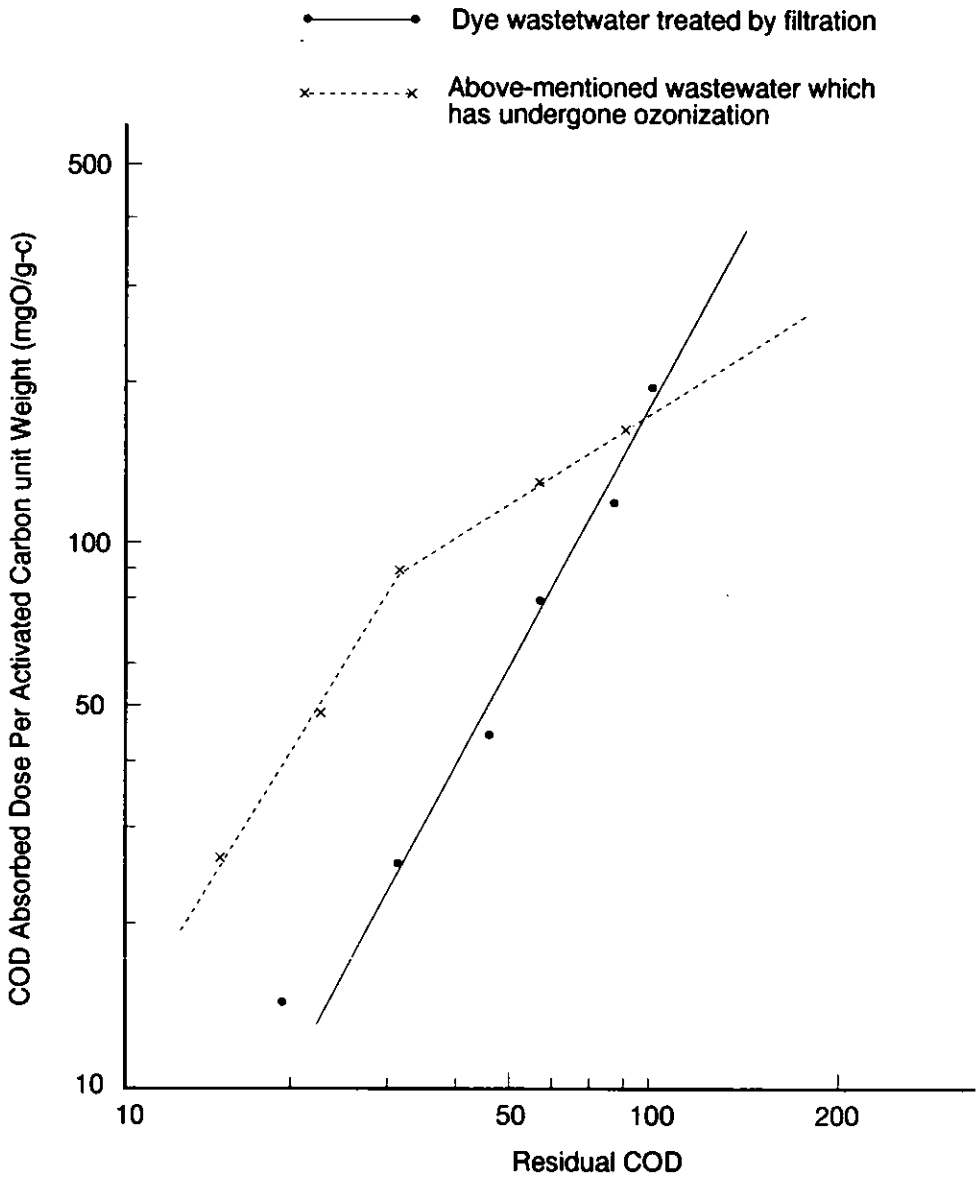


Figure-10 Activated Cabon Equilibrium Adsorption Diagram for Dye Wastewater

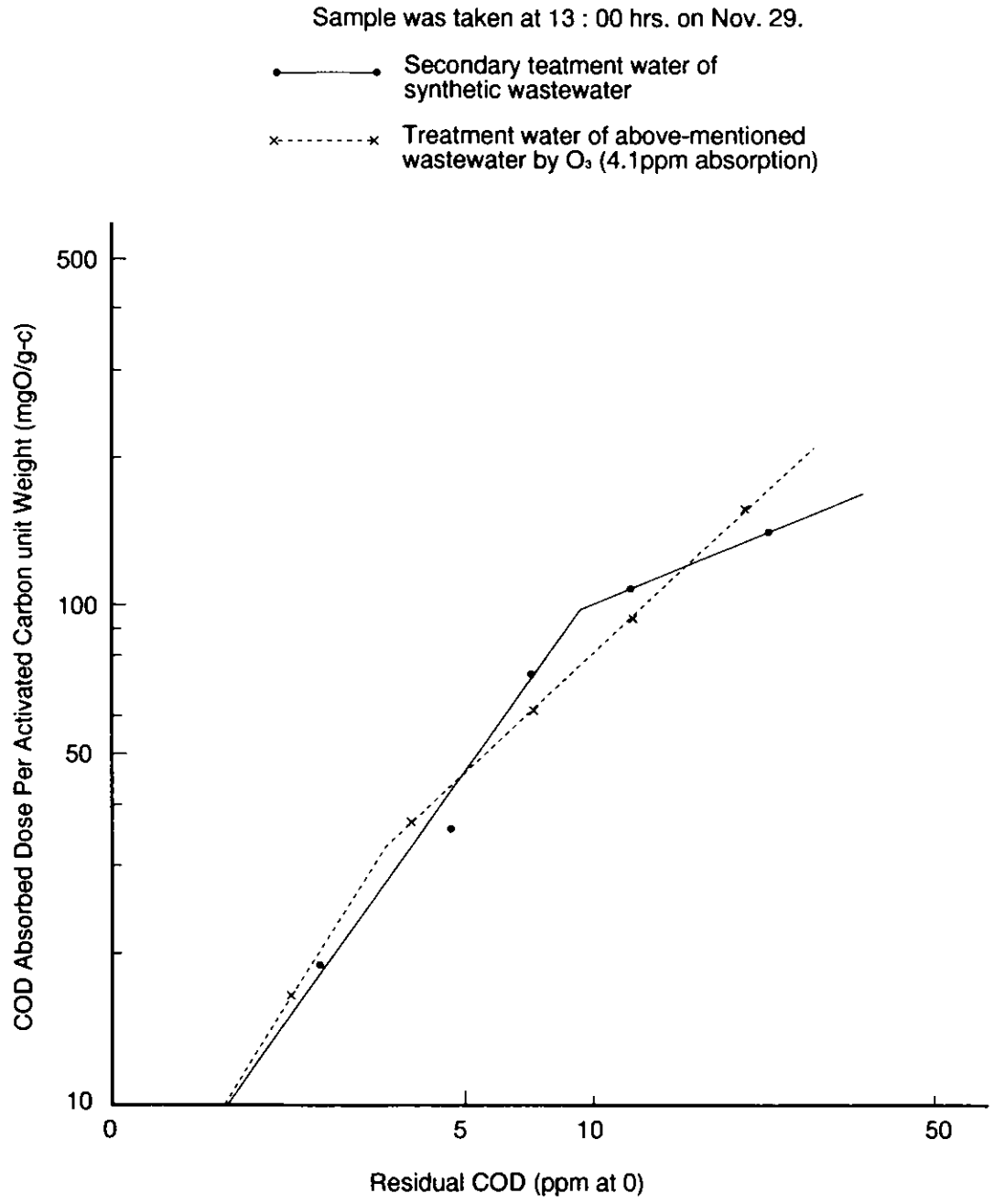


Figure-11 Secondary treatemt water of synthetic wastewater and activated carbon equilibrium adsorption Diagram for its water treated by ozone

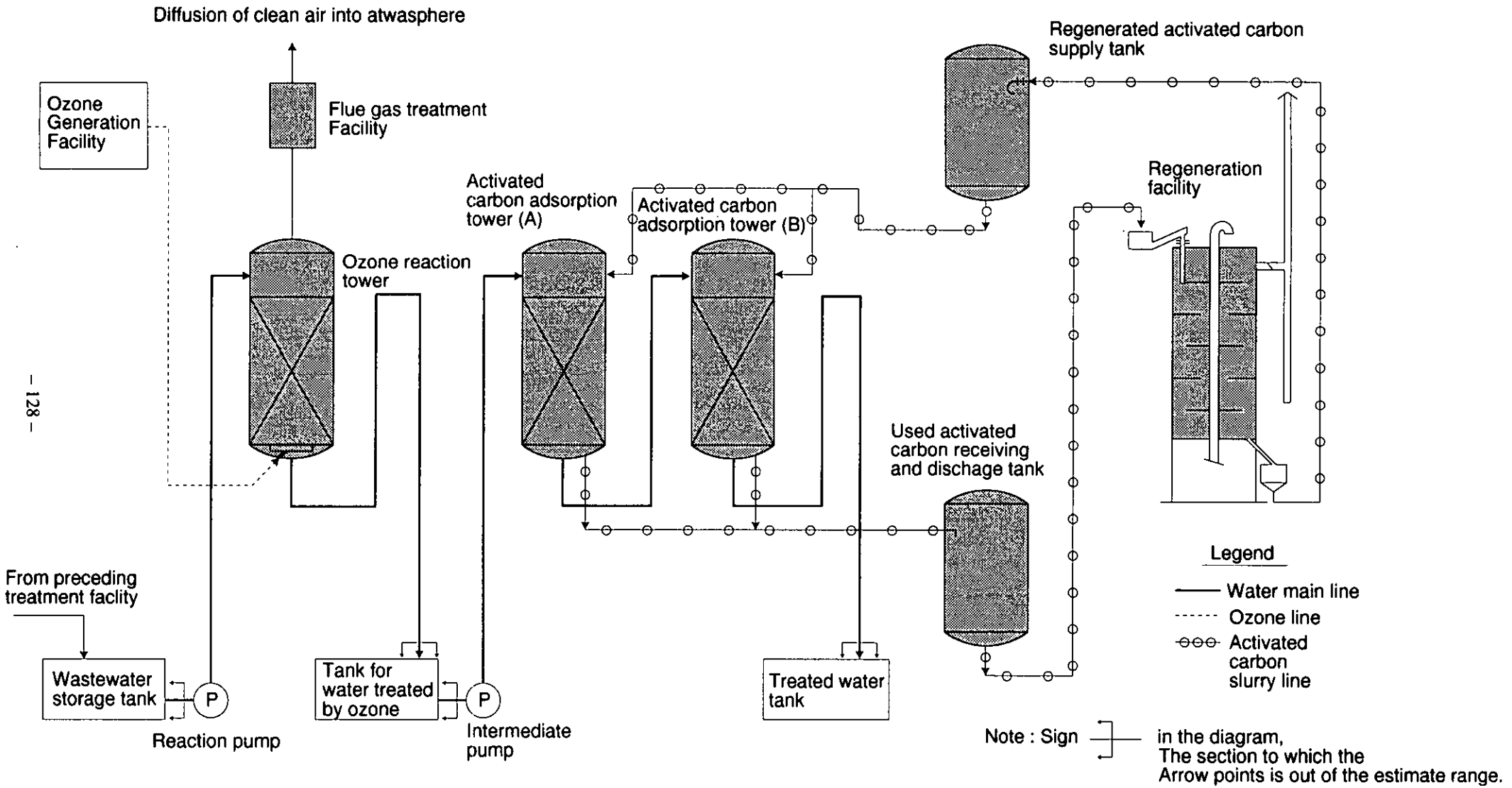


Figure-12 Dye Wastewater Advanced Treatment Flow Sheet

INVESTIGATION AND RESEARCH ON THE DYE WASTEWATER ADVANCED TECHNOLOGY

THE OXIDATION METHOD BY LIGHT AND CHLORINE

1974 REPORT ON THE RESEARCH COMMISSIONED
FOR POLLUTION CONTROL PUBLIC WORK

DECEMBER 1974

TORAY ENGINEERING, INC.

CONTENTS

1. Subject of the Research

Investigation and research on the dye wastewater advanced treatment technology

(The oxidation method by light and chlorine : "LIGHTOX" method)

2. Contents of the Research

2.1 Target

In the dyeing processing arranging industry, since the types of chemicals used vary with the kind, color, and light and shade of material to be dyed, the quality and amount of wastewater which is discharged from a company involved in the industry change greatly. Consequently, the results of treatment by existing treatment facilities are not necessarily satisfactory.

Accordingly, this research was aimed at establishing advanced treatment technology which aimed to satisfy the Osaka Bay water area strict standard (Type 2 water area).

2.2 Contents of the research implemented

2.2.1 Test liquid

Wastewater obtained by treating dye wastewater discharged from factory A affiliated with factory J's industrial housing complex cooperative by activated sludge, coagulating sedimentation and filtration was regarded as test liquid. (hereinafter referred to as pretreated wastewater)

2.2.2 Items for the research

(1) To grasp the properties of raw water

(2) To confirm the treatment effects of the oxidation method by light and chlorine

(a) Quality of treated wastewater

(b) Relations between COD removal and the amount of chlorine required

(c) Relations between COD removal and the irradiation time

(d) Effects on decolorization

(e) Others

2.2.3 Items for analysis (wastewater which is a subject of investigation)

Industrial raw wastewater, pretreated wastewater, and wastewater treated by the oxidation method by light and chlorine

2.3 Location of the research implemented

Factory A located in Sakai City

2.4 Outline of research facility

(a) Twenty-liter batch type reactor

Lamp capacity	100W (special mercury lamp)
Tank effective capacity	20 ℓ

(b) Sixty-liter continuous reactor

Lamp capacity	300W
Tank effective capacity	67 ℓ
Capacity of treatment	40 - 120 ℓ /Hr

Details are as per attached figure.

3. Analysis and Measuring Methods

Item	Method
pH	JIS. K-0102. 8
BOD_5	JIS. K-0102. 16
CODMn	JIS. K-0102. 13
CODCr	JIS. K-0102. 15
Total Chrome T-Cr	JIS. K-0102. 51
SS	JIS. K-0102. 10.2
n-Hexane extract	JIS. K-0102. 18
NH_3	JIS. K-0102
Absorbance	by using a spectrophotometer

4. Outline of the Research

4.1 Progress during the period of the research

9/20 - 10/15	Installation and adjusting operation
10/16 - 10/20	Grasp of quality of raw water and determination of conditions
10/21 - 11/30	Batch type test by using a 20 ℓ reaction tank Continuous test by using a 60 ℓ continuous tank
12/1 - 12/20	Summarization of experiment results, design of an actual plant, removal of equipments, etc.

4.2 Experiment conditions and methods

4.2.1 Batch type treatment

Twenty liters of pretreated wastewater was poured into a circular container made of polyvinyl chloride which was provided with a pH meter. After that, sodium hypochlorite in the quantity equal to or more than its equivalent against COD of raw wastewater was added. After the pH value of the reaction liquid was controlled by sulfuric acid to about 5, the liquid was stirred by using a pump for about 10 minutes. Then, a portion of the reaction liquid was sampled, and the value of COD and the amount of residual chlorine were measured. (This process corresponds to the dark reaction.)

Next, with a 100W special mercury lamp turned on, while the reaction liquid continued to be stirred by a pump, the liquid was sampled at regular intervals, and the value of COD and the residual chlorine were measured. (This process corresponds to the light reaction.) The reaction was stopped when the value of COD fell to the target value. During the reaction, in order to maintain the pH value of the reaction liquid at 5 ± 1, caustic soda was added to the liquid depending on the circumstances, and the hydrochloric acid, which was produced by the undermentioned reaction, was neutralized.

$$HOC\ell \xrightarrow{\text{light irradiation}} HC\ell + O^*$$

In the case where the residual chlorine was used up before the value of COD reached the target value, sodium hypochlorite was added so that the reaction could go on.

4.2.2 Continuous treatment

With a 300W special mercury lamp turned on, pretreated wastewater, to which chlorine in a quantity that was slightly larger than its equivalent was added, was continuously supplied by a pump to a reaction tank of 67 ℓ in effective capacity (divided into 3 chambers) with an automatic pH controlling meter. Thus, the oxidation reaction occurred. After the reaction, caustic soda was automatically added to the reaction liquid so that the value of pH of the liquid could be controlled to 5 ± 1. Chlorine was continuously supplied to the reaction liquid from a gas cylinder before light was irradiated. The flow rates of the reaction liquid and chlorine gas were controlled by a flow meter so that they could be uniform. After water was allwed to go through for a specified time, the wastewater of each tank and effluent, the COD value, and the amount of residual chlorine were measured.

4.3 Results of the experiments

4.3.1 Analysis of the properties of raw water

Results of the investigation of diurnal fluctuation and daily fluctuation as to industrial raw wastewater and raw water flowing into "LIGHTOX" are as shown in Attached Tables-1, 2, 3, and 4. Table-1 is a summary of the properties of industrial raw wastewater and of raw water flowing into "LIGHTOX". The concentration of CODMn of raw water flowing into "LIGHTOX" varied from 23 to 73ppm, and the concentration was 1.5 - 5 times that stipulated by the Osaka Bay strict standard.

$CODCr/COD_{Mn} \fallingdotseq 2$ (see Figure 1) The relation of $CODCr/BOD_5 > 10$ existed, and the value of BOD5 was lower than that of COD_{Mn}. Thus, the effects of activated sludge treatment in the stage of pretreatment were recognized.

Surface tension was also small, which proves that surfactants were present.

Concerning T-Cr which is toxic substance, 0.34ppm of the substance was detected from industrial raw wastewater. However, as to "LIGHTOX" raw water which had undergone pretreatment, the amount of the substance detected was 0.03ppm, and consequently there was no particular problem with the concentration.

Figures-2 and -3 show examples of changes in the amount of COD_{Mn}. Compared with the daily fluctuation, the diurnal fluctuation is not very remarkable.

Table-1 Water Quality of Raw Water

Measured Item	Raw Wastewater from Factory			"Lightox" inflow Raw Water		
	$\tilde{x}$	n	min～max	$\tilde{x}$	n	min～max
External Appearance	Colored, Turbid	57	Yellow, Red and Green colors	Slightly Colored	61	Mostly Yellow, Red and Green colors
Transparency (cm)	15.3	56	5.5～23	30or more	61	30 or more
PH	6.8	54	5.3～7.7	7.2	63	6.7～7.4
SS (ppm)	19.8	1	19.8	4.1	18	3.3～5.2
BOD_5 (ppm)	172	4	27～250	7.1	15	6.0～14.8
COD_{Mn} (ppm)	148	54	83～197	43.8	61	23～72
CODcr (ppm)	487	29	323～816	76.1	32	51～144
T-cr (ppm)	0.13	4	0.02～0.34	0.02	5	0.01～0.03
Surface Tension (dyne/cm)	45.9	8	44～50	60	8	58～64
n-Hexane. Extracted substance (ppm)	4	2	2.7～5.3	1.6	14	1.1～2.4

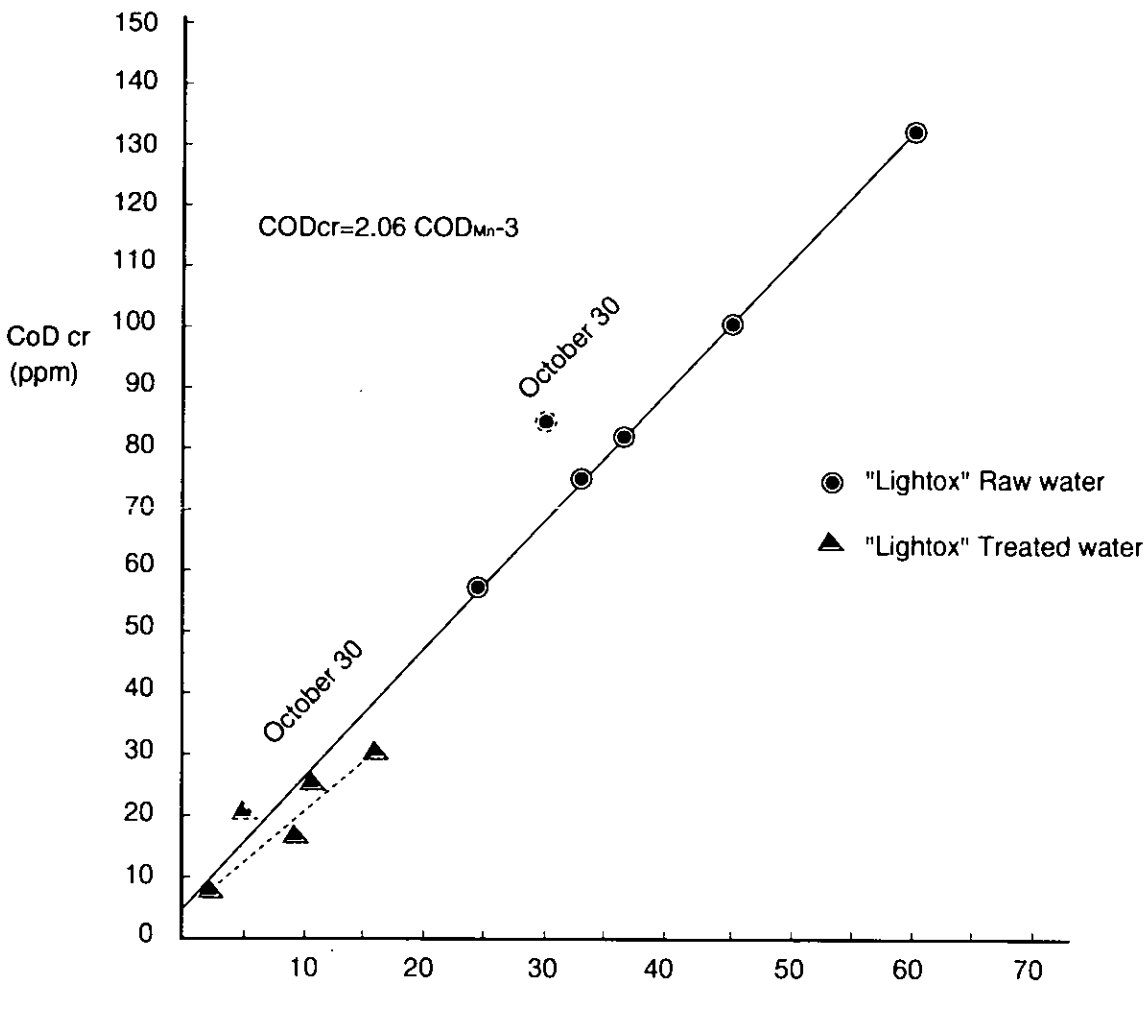


Figure-1 Correlation between CODcr and COD_{Mn}.

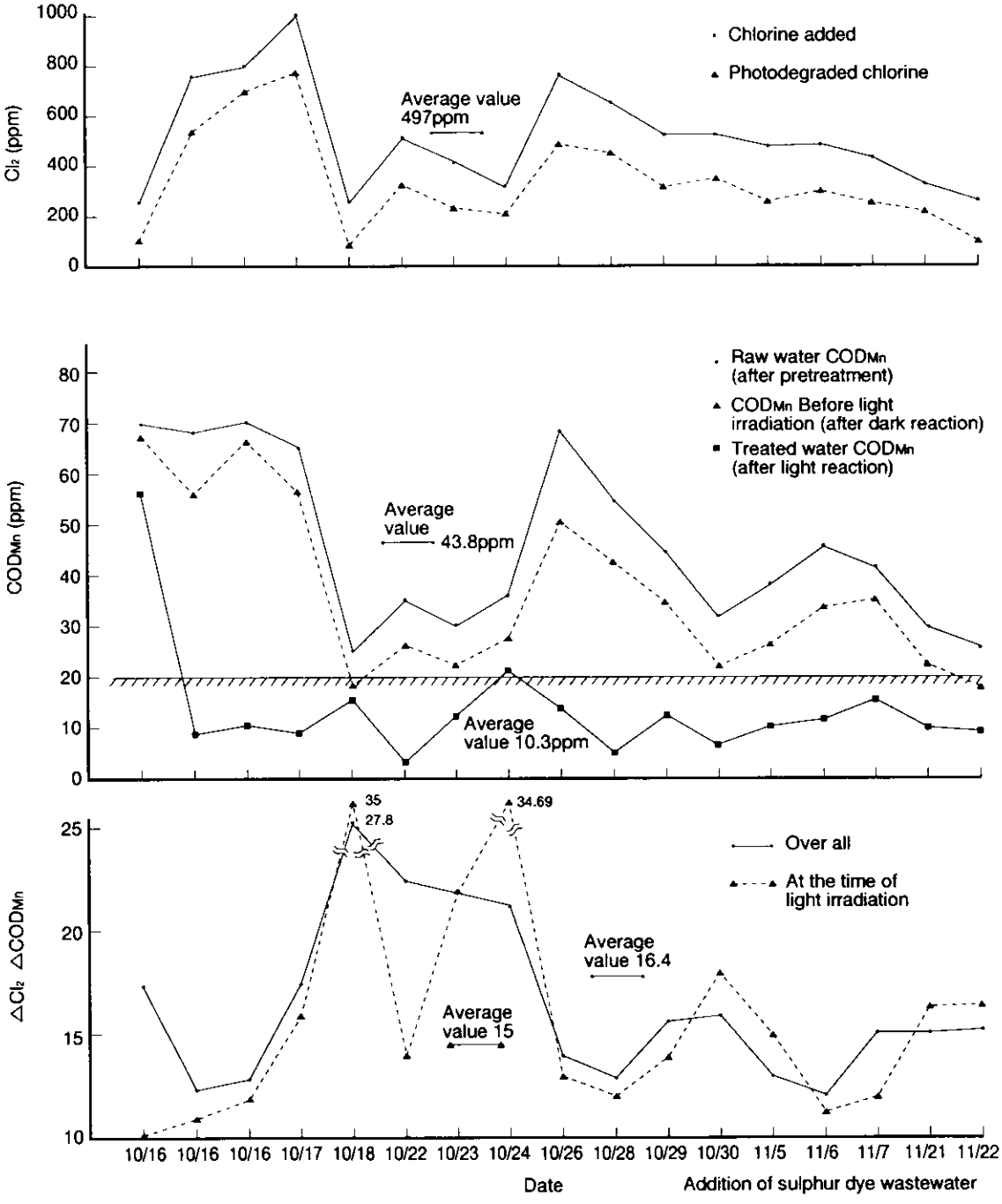


Figure-2 Relation among Quantity of Chlorine, Change in COD $_{Mn}$ and $\triangle Cl_2/\triangle COD_{Mn}$

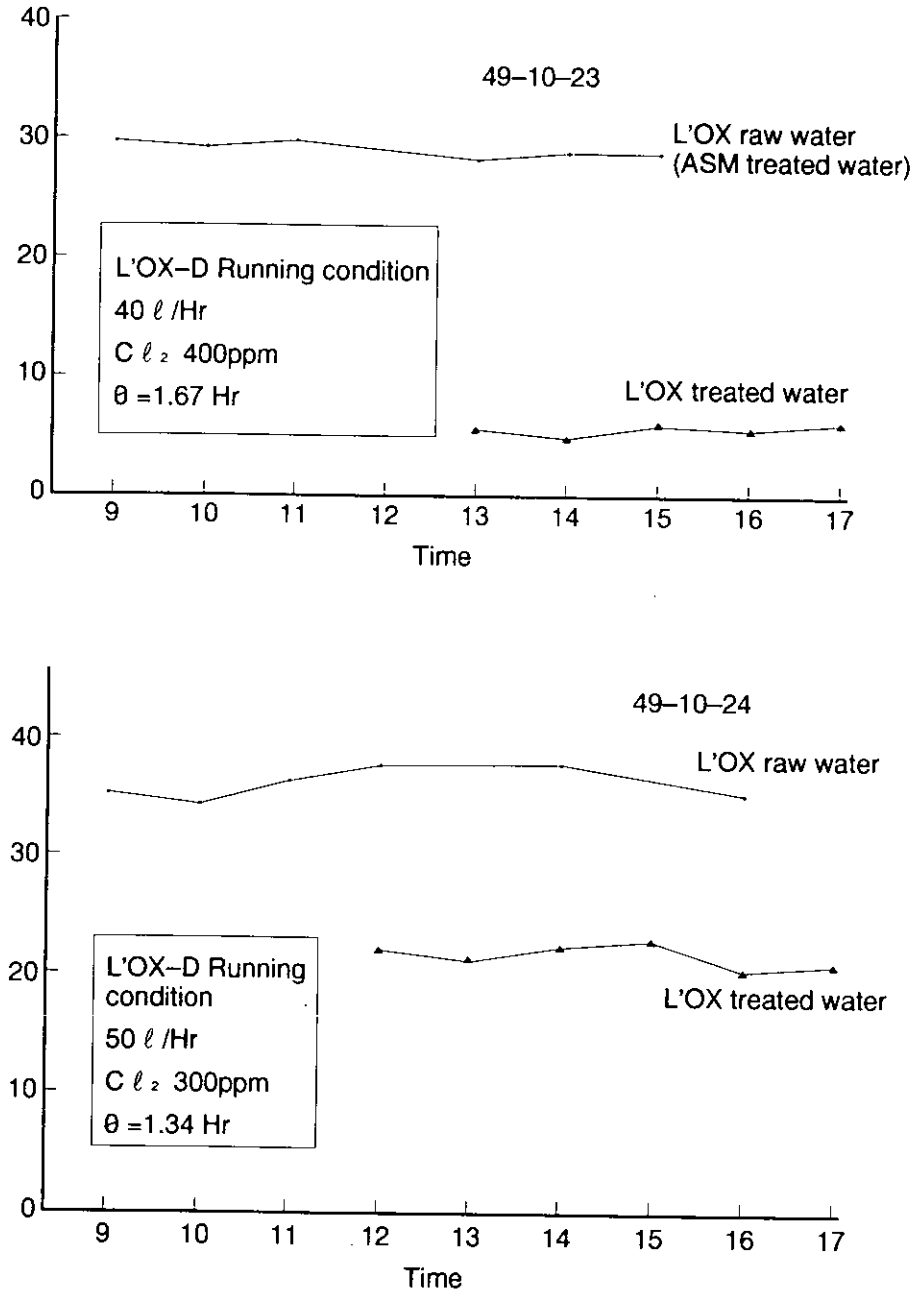


FIGURE-3 Relation between change in COD_{Mn} within a Day and Treatment Effect

4.3.2 Quality of treated wastewater

Results of the examination of the batch type reaction and the continuous reaction are shown in Tables-2 and -3.

Results obtained by arranging those data in order are shown in Table-4 and Figure-2.

As for COD, color tone, n-Hexane extract and SS, a satisfactory result which could satisfy the Osaka Bay strict standard were obtained in every item.

Treated wastewater of the same quality was also obtained in the case of wastewater mixed with sulphur dye waste liquid.

Treated wastewater was completely colorless and transparent.

4.3.3 Relations among COD removal, chlorine consumption, and reaction time

(a) The amount of chlorine

Relations between the amount of chlorine added and the amount of chlorine consumed and changes in the amount of COD are as shown in Tables-2 and -3, and Figure-2.

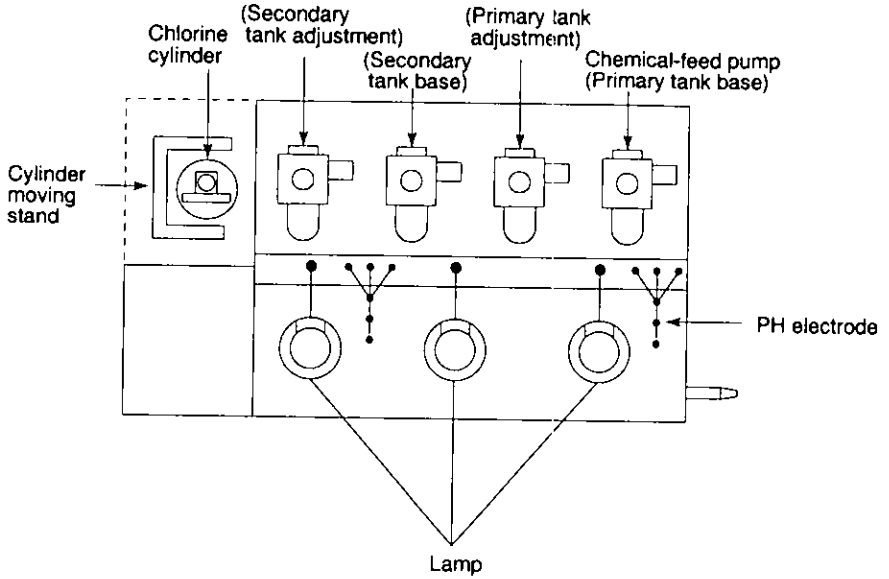
In the tests carried out this time, examination was conducted by adding 100 - 1,000ppm of chlorine (500ppm on average). In the dark reaction (without light irradiation), 100 - 280ppm of chlorine reacted.

The value of $\triangle Cl_2/COD_{Mn}$ varied from 10 to 30 in the dark reaction, and the value of $\triangle Cl_2/COD_{Mn}$ was 15 on an average in the light reaction. The relation between the amount of COD removed and the amount of chlorine consumed in the whole reaction was as follows: $\triangle Cl_2/\triangle COD_{Mn} \fallingdotseq 16.5$. The relation did not change even in the case where sulphur dye wastewater was mixed.

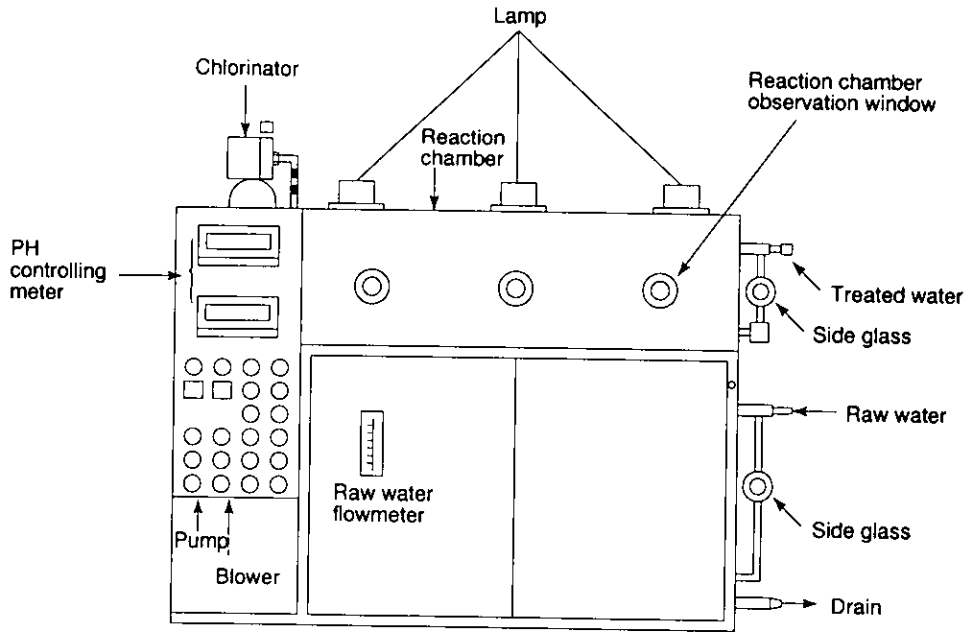
(b) Reaction time

Relations among the reaction time, changes in the amount of COD and chlorine consumed in the batch type reaction and the continuous reaction are as shown in Tables-2 and -3 and Figures-4 - 8. Relations between the amount of chlorine added (almost the same as the amount of chlorine consumed) and the reaction time in the batch type reaction can be summarized as in Figure-9. (A solid line shows the average value and a dotted line shows the maximum value.)

Photooxidation method (Continuous reactor)

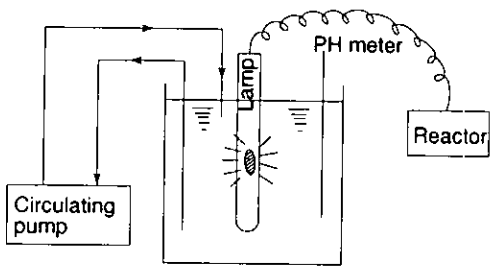


(Plan view)



(Front view)

Photooxidation method (20 batch type reactor)



Appended figure-1

Table-2 "LIGHTBOX" 20ℓ Batch type operation result

Experiment No.	Date	Cl_2 Added	Lightox batch type treatment											Remark
			Dark reaction			Lamp irradiation							ΔCl_2 / ΔCOD Mn in total	
			Cl_2 used	COD Mn: Raw Water / After reaction	COD Mn: ΔCOD Mn	Treatment time	Cl_2: Before irradiation / After irradiation	Cl_2: ΔCl_2	COD Mn: Before irradiation / After irradiation	COD Mn: ΔCOD Mn	ΔCl_2 / ΔCOD Mn	H*		
		PPM	PPM	PPM	PPM	min.	PPM	PPM	PPM	PPM				
1	10/16	250	150	70/66	4	40	100→2	98	66/56	10	9.8	1.95	17.7	
2	〃	750	224	68/56	12	75	526→3	523	56/9	47	11.1	2.30	12.7	
3	〃	776	100	70/66	4	110	676→0	676	66/11	55	12.3	1.90	13.2	Cl_2 (350+426ppm) 2 time split addition
4	10/17	1000	246	65/56	9	120	756→11	745	56/9	47	15.9	1.90	17.7	COD Cr 132ppm (Raw water)→15ppm (Treated water) PH=6.8
5	10/18	250	180	25/18	7	30	70→0	70	18/16	2	35.0	2.16	27.8	COD Cr 53ppm (〃)→30 〃 PH=6.9
6	10/22	500	185	35/26	9	57	315→0	315	26/3	23	13.7	2.10	15.6	COD Cr 73ppm (〃)→7 〃 PH=7.2
7	10/23	400	175	30/22	8	40	225→0	225	22/12	10	22.5	2.48	22.2	
8	10/24	300	92	36/27	9	40	208→0	208	27/24	3	69.3	2.40	25.0	
9	10/26	750	280	68/50	18	60	470→0	470	50/14	36	13.1	2.65	13.9	** BOD=7.4ppm COD Cr=25ppm T-Cr=0.01ppm PH=6.9
10	10/28	625	194	54/42	12	75	431→0	431	42/5	37	11.6	2.04	12.8	** BOD=3.5ppm COD Cr=13.4ppm T-Cr=0.03ppm n-Hex=1.1ppm
11	10/29	500	100	44/34	10	60	300→0	300	34/12	22	13.6	2.05	15.6	** BOD=7.3ppm COD Cr=31ppm n-Hex=1.3ppm T-Cr=0.02ppm
12	10/30	500	180	31/22	9	60	320→2	318	22/6	16	19.9	2.10	19.9	COD Cr 86ppm (Raw water)→21ppm (Treated water) PH=7.3
13	11/5	450	249	38/26	12	50	201→0	201	26/10	16	12.6	2.07	16.1	
14	11/6	450	151	45/35	10	65	299→0	299	35/12	23	13.0	1.80	13.6	
15	11/7	400	160	41/34	7	60	240→4	236	34/14	20	11.8	1.67	14.8	COD Cr 95.4ppm→23ppm (Treated water) PH=7.6 n-Hex=1.2ppm
16	11/21	300	103	29/21	8	63	197→0	197	21/9	12	16.4	1.58	15.0	Mixing of sulphur dye wastewater by 5% PH=7.1 n-Hex=1.1ppm SS=3.4ppm
17	11/22	250	110	25/17	8	43	140→0	140	17/8.5	8.5	16.5	1.85	15.2	
	~ ×	497	169		9	62		320		22.8	19	2.0	17	

* Reaction speed relative index ** Treated water analysis result

Table-3 "LIGHTBOX" Continuous operation result

Experiment No.	Date	Amount of luquid supplied (ℓ /Hr)	Amount of Cℓ2 added (PPM)	Holding			Dark reaction				Lump irradiation					Whole treatment		
				Primary tank (min)	Secondary tank (min)	Tertiary tank (min)	$\triangle Cl_2$ (PPM)	COD_{Mn} (PPM)	$\triangle COD_{Mn}$ (PPM)	$\triangle Cl_2 / \triangle COD_{Mn}$	$\triangle Cl_2$ (PPM) Before irradiation / After irradiation	$\triangle Cl_2$	COD_{Mn} (PPM) Before irradiation / After irradiation	$\triangle COD_{Mn}$	$\triangle Cl_2 / \triangle COD_{Mn}$ in total	$\triangle COD_{Mn}$ (PPM)	$\triangle Cl_2 / \triangle COD_{Mn}$ in total	Remark
	10/							Row water / After irradiation										
6	22	30	500	54	40	40	184	35→26	9	20	316→16	300	26→6	20	15	29	17.2	
7	23	40	400	40	30	30	194	30→22	8	24	206→17	189	22→6	16	12	24	16.7	
8	24	50	300	33	24	24	88	36→27	9	10	211→8	203	27→21	6	34	15	20.0	
9	26	40	750	40	30	30	279	68→50	18	16	471→56	415	50→22	28	15	46	16.3	
10	28	40	625	40	30	30	191	54→42	12	16	434→90	344	42→10	32	11	44	14.2	
11	29	40	500	40	30	30	200	47→34	13	15	300→13	287	34→15	19	15	32	15.6	
12	30	50	500	33	24	24	180	31→22	9	20	320→7	313	22→6	16	20	25	20.0	
16	11/21	50	300	33	24	24	105	30→18	12	9	195→15	180	18→5.5	12.5	14.4	24.5	11.4	Mixing of sulphur dye wastewater by 5%
$\tilde{x}$			484	-	-	-	178	-	11.3	16	-	279	-	18.7	15	29.9	16.4	

* Experiment No. correponds to that of the batch type test.

TABLE-4 Water quality of "LightOX" treated water

Measured item	$\tilde{x}$	n	min~max
External appearance	Colorless, transparent	–	–
Transparency (cm)	30 or more	–	–
PH	7.1	7	6.5~7.6
SS (ppm)	< 5	1	3.4
BOD_5 (ppm)	6.1	3	3.5~7.4
CODMn (ppm)	10.6	50	3~24
CODCr (ppm)	19.2	8	7~31
n–Hexane Extracted substance (ppm)	1.2	4	1.1~1.3
Surface tension (dyne/cm)	70	8	68~72
T–Cr (ppm)	0.02	3	0.01~0.03

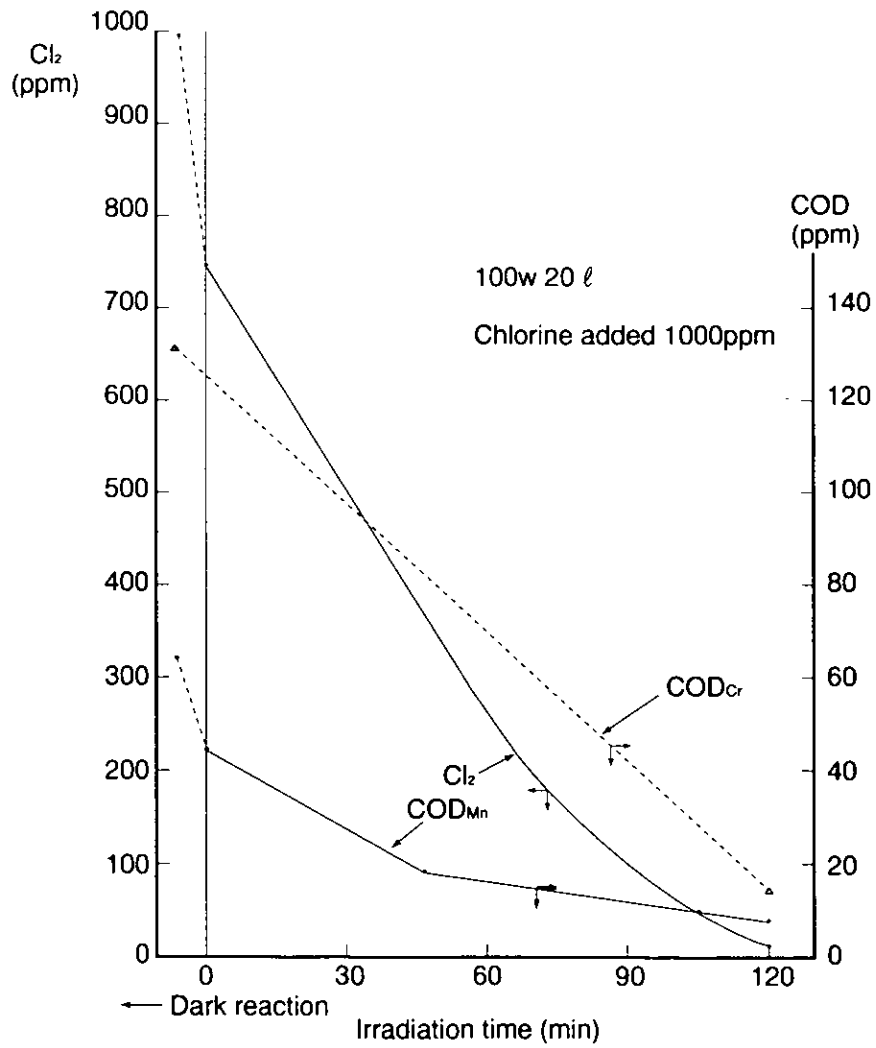


Figure-4 Batch type test result (wastewater of Oct.17)

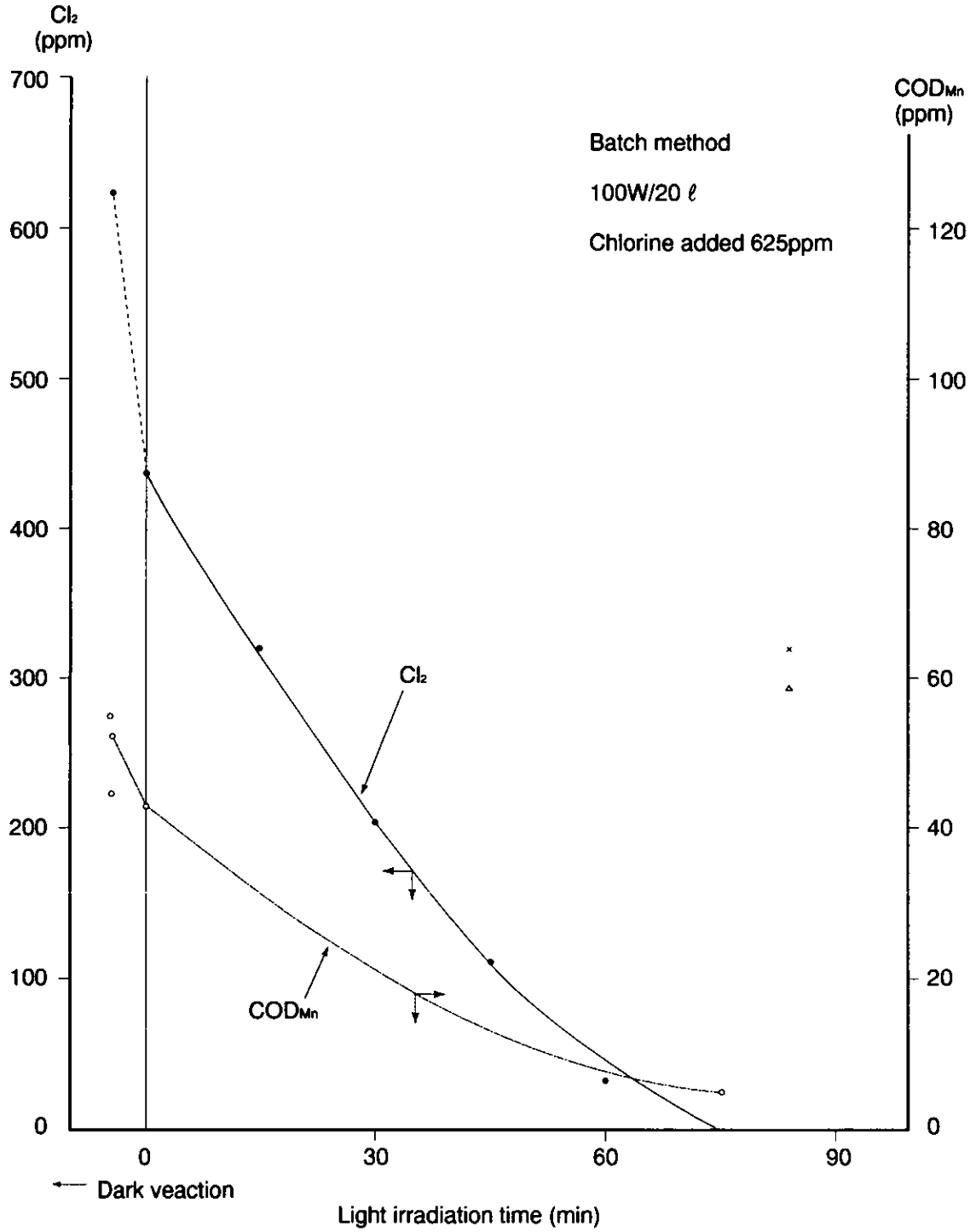


Figure-5 Batch type test result (wastewater of Oct. 28)

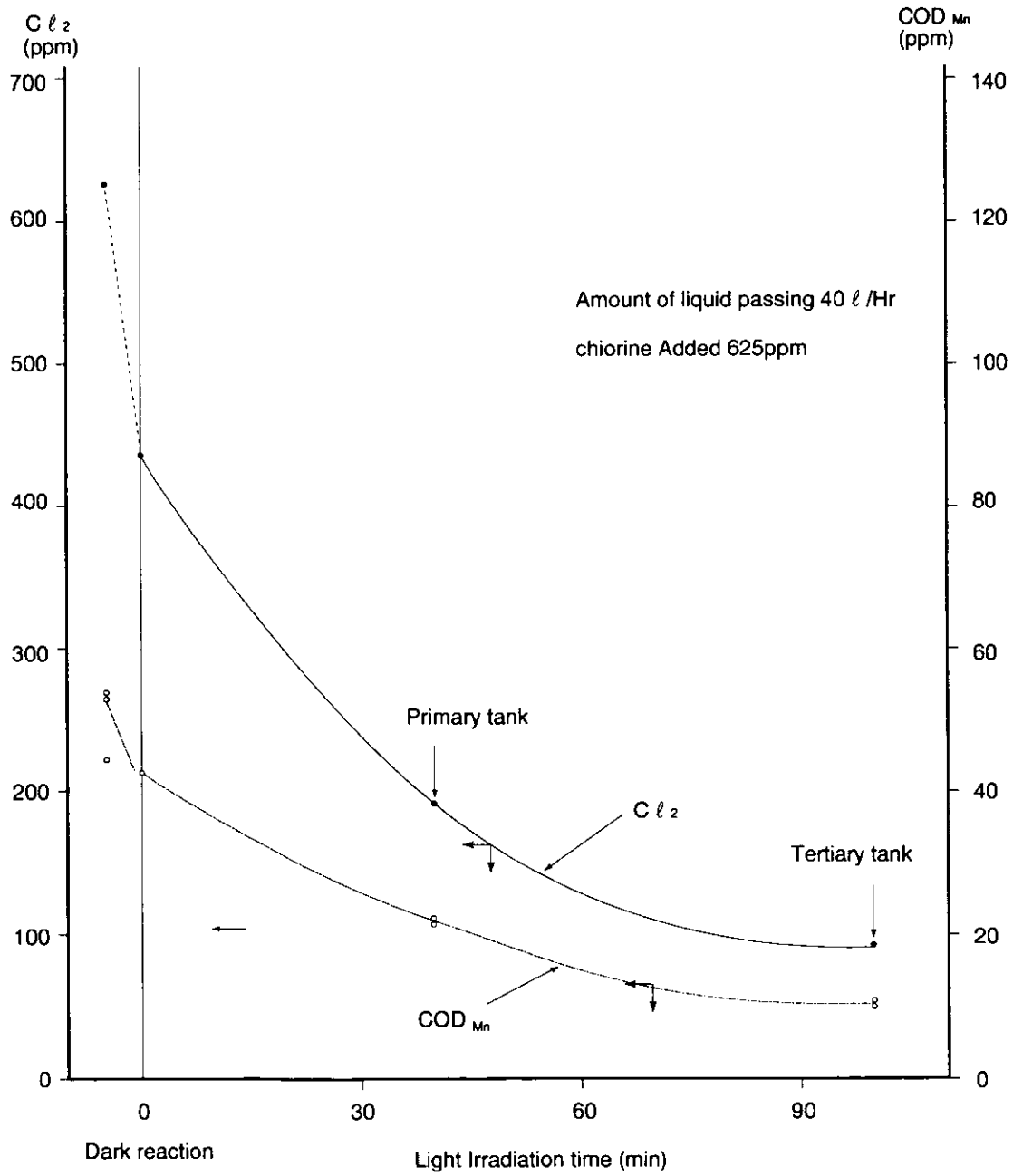


Figure-6 Continuous Test Result (Wastewater of Oct. 28)

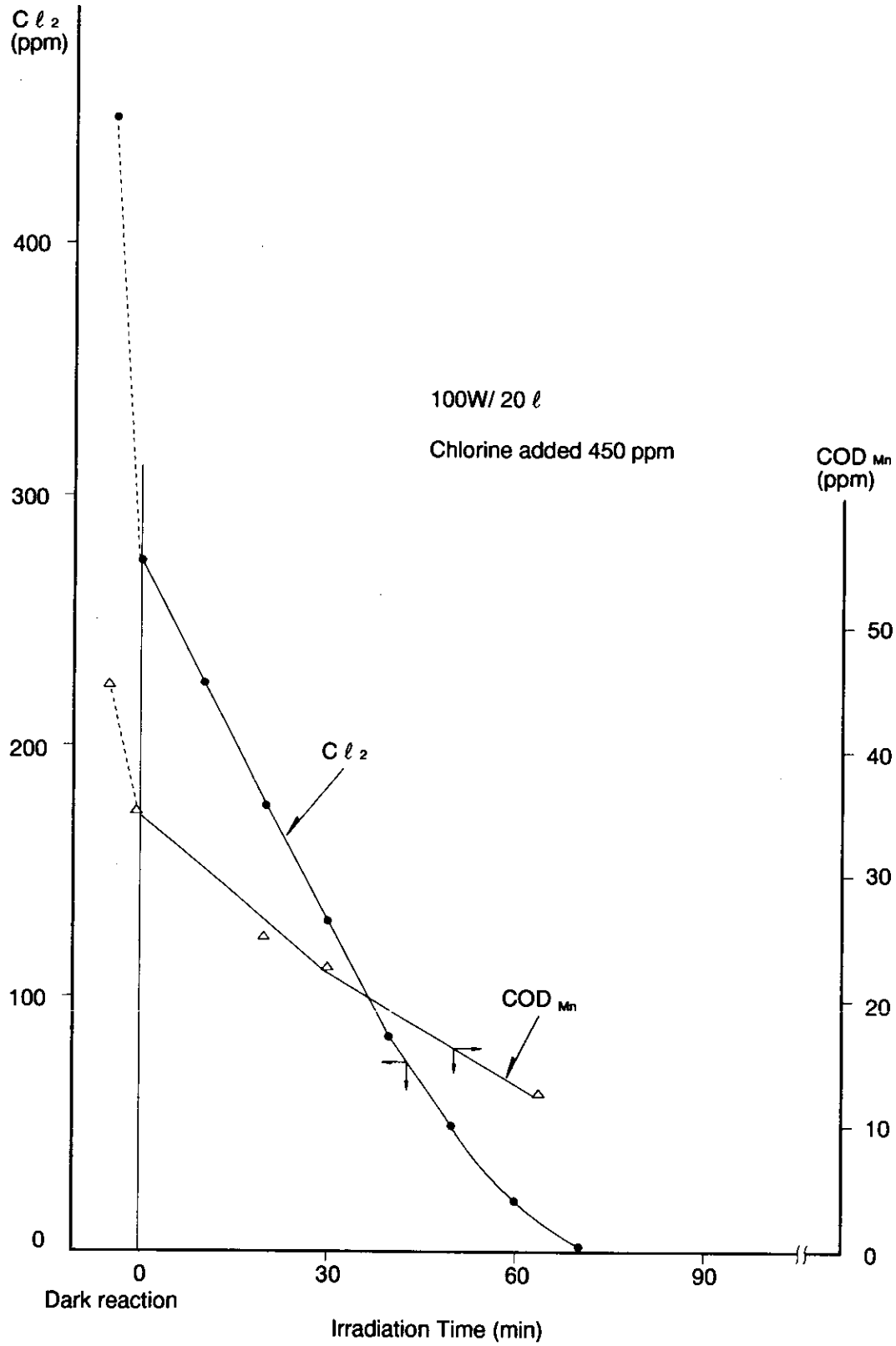


Figure-7 Batch type test result (wastewater of Nov 6)

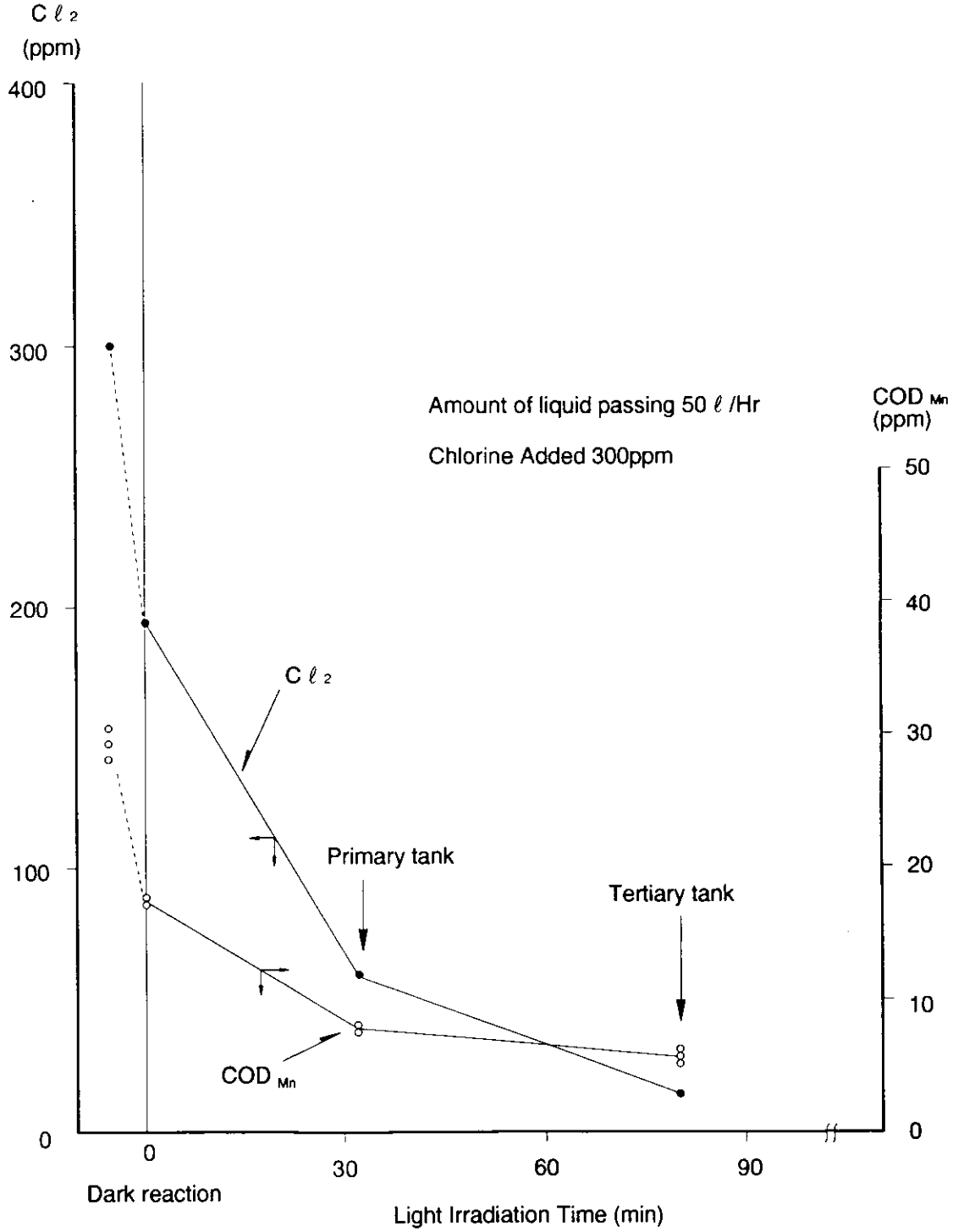


Figure-8 Continuous Test Result (Nov 29. mixing of sulphur dye wastewater)

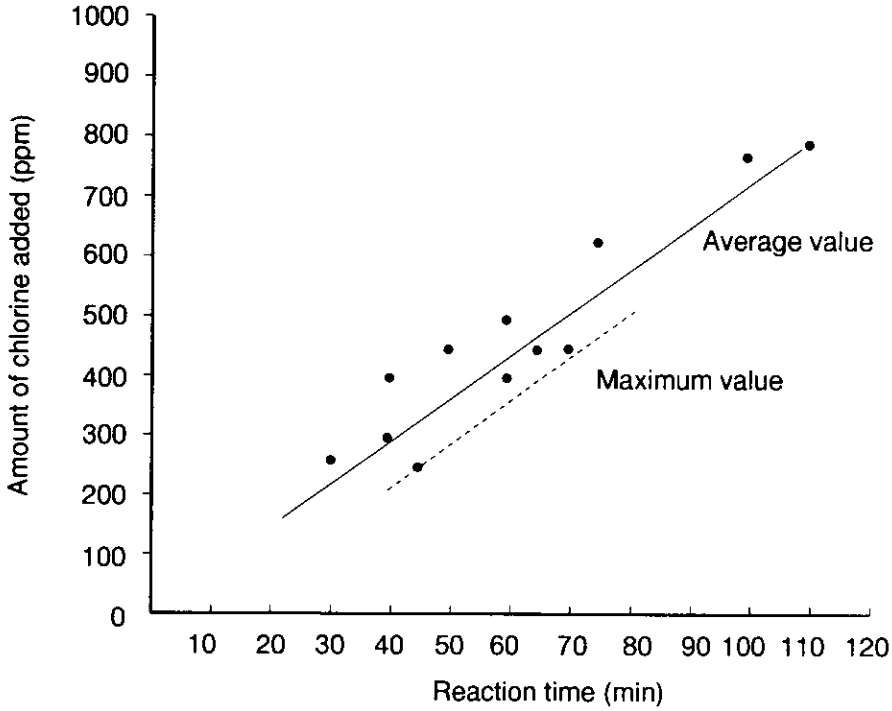


Figure-9 Relation between Amount of Added chlorine and Reaction Time in Batch Type

4.3.3 Effect by concurrent use with activated carbon

Test result is shown in Table-5,6 and adsorption Isotherm is shown in Fig-10.

Table-5 11/12 Result of Activated Carbon Adsorption (sole) Treatment for Wastewater Sampled on Nov.12

Amount of Addition	COD_{Cr} ppm	$\triangle COD_{Cr}$ ppm	COD_{Mn} ppm	$\triangle COD_{Mn}$ ppm	mg COD_{Cr} /g-AC	mg COD_{Mn} /g-AC
0	80	-	42.5	-	-	-
75	58.7	21.3	32.1	10.4	284	139
150	51.1	28.9	25.1	17.4	193	116
300	25	54.9	15.1	27.4	183	91
600	10.9	69.1	6.3	36.2	115	60
900	6.4	73.6	4.4	38.1	82	42

(Powdered carbon contact time 50Hr)

Table-6 Result of Treatment of Wastewater Sampled on Nov.12 by using "Lightox" and Activated Carbon Adsorption Together

"Lightox"	Chlorine consumption	COD_{Cr} ppm	$\triangle COD_{Cr}$ ppm	COD_{Mn} ppm	$\triangle COD_{Mn}$ ppm	Remark	
	0	81.2	-	41.1	-	$\triangle C_2/\triangle CODcr = 5.4$	
	200ppm	47.2	34	24	17.1	$\triangle C_2/\triangle CODcr = 11.7$	
Activated Carbon	Amount of Activated Carbon Added	COD cr ppm	$\triangle$COD cr ppm	COD_{Mn} ppm	$\triangle COD_{Mn}$ ppm	mg COD cr /g-AC	mg COD_{Mn} /g-AC
	0	47.2	-	24	-	-	-
	50	38.8	8.4	19.2	4.8	168	96
	100	36.4	10.8	17.0	7.0	108	70
	200	25.0	22.2	12.3	11.7	111	59
	300	20.2	27.0	10.2	13.8	90	46
	400	10.2	37.0	6.1	17.9	93	45

(Powdered carbon contact time 50Hr)

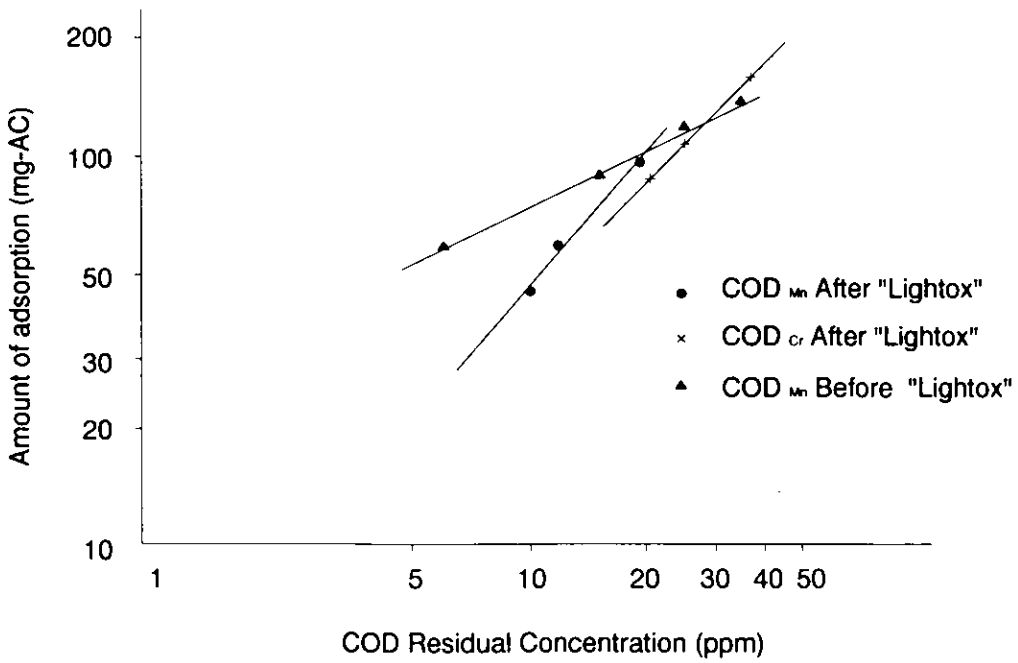


Figure-10 Activated Carbon Adsorption Isotherm

5. Consideration

5.1 Quality of raw water

As mentioned in 4.3.1, although the daily fluctuation in the quality of raw water is considerably great, the diurnal fluctuation is not as great as the daily fluctuation.

In the case of the wastewater used this time, the amount of COD_{Mn} remaining even after the activated sludge, coagulating sedimentation and filtration treatment is about 1.5 - 5 times the amount of COD_{Mn} stipulated by the Osaka Bay strict standard. Judging from the measured value of surface tension and the reactivity observed in the treatment of oxidation by light and chlorine, the greater part of the COD_{Mn} components are estimated to be surfactants.

As for Cr^{+6} which is a toxic substance, the concentration of the substance was relatively low in the tests conducted this time, so it prsented was no problem. However, it is desired that chrome dye waste liquid is treated in advance at its source.

5.2 Quality of treated wastewater and the effects of treatment

The quality of treated wastewater is as shown in the aforementioned Table-4. In the case where experiment conditions were incorrectly determined, the value of COD sometimes exceeded the standard value. However, it appears that if the amount of chlorine to be added is 500ppm or more, the Osaka Bay strict standard value can be fully attained, regarding all the items including COD, color, n-Hexane extract, SS, etc. The deterioration of the quality of treated wastewater observed on October 18 and 24 is considered to have been caused by addition of an extremely small quantity of chlorine and the mixing of persistent substances with the wastewater.

In the case of the wastewater used in the tests this time, the value of $\triangle C\ell_2/COD_{Mn}$ is approximately twice the theoretical value (about 9). Compared with the amount of COD removed, the amount of chlorine consumed is large. Accordingly, the effects of oxidation are not very good. About 17ppm of chlorine is required to remove 1ppm of COD_{Mn}.

It generally appears that the cause of the high value of $\triangle C\ell_2/\triangle COD_{Mn}$ observed at the time of the dark reaction is an N compound such as NH4+. In the case of the tests conducted this time, since ammonium sulfate was used by the factory, approximately 3ppm of NH_3-N was detected from raw wastewater. About 30ppm of $C\ell_2$ is consumed by 3ppm of NH_3-N in the following reaction.

$$2NH_3 + 3C\ell_2 \longrightarrow N_2 + 6HC\ell$$

(Partially, NO_3, is produced.)

The mixing of sulphur dye wastewater did not have an influence on the treatment effects in the tests conducted this time.

As for the reaction rate and reaction time of the wastewater used this time, as Table-2 shows, the relative index (H) of the reaction rate ranges between 1.58 and 2.0. Considering that the wastewater was treated by activated sludge, the reaction rate is slightly higher than usual.

The relative index of the reaction rate of wastewater containing surfactants varied from 2 to 3, as Table-7 shows. Since the index value is very close to the relative index value of the reaction rate of the wastewater used this time, it is appropriate to consider that the majority of COD components are surfactants.

Table-7 Oxidation Efficiency and Reaction Speed Ratio of Various Types of Wastewater

Type of Wastewater (Substance to be Oxidized)	△C ℓ 2/△CODcr	H
Sugar	4.4	7
Starch	4.4	7
Multivalent Alcohol	4.4	6
Amino acid	5.3	4
Protein	5.5	4
surfactant	4.4	2.5～3.0
Ketone Ether (solvent)	5.4	2.5
Fatty Acid	3～5	2.3
Wastewater from water purification tank	10*	1.6
Domestic wastewater	5～6	1.8～2.2
Activated sludge wastewater	6.2*	1.7

(Notes) * Amount of C ℓ 2 required Due to NH_3 has increased.
*Chemical Equipment 1974 No.5

5.3 Use of activated carbon at the same time

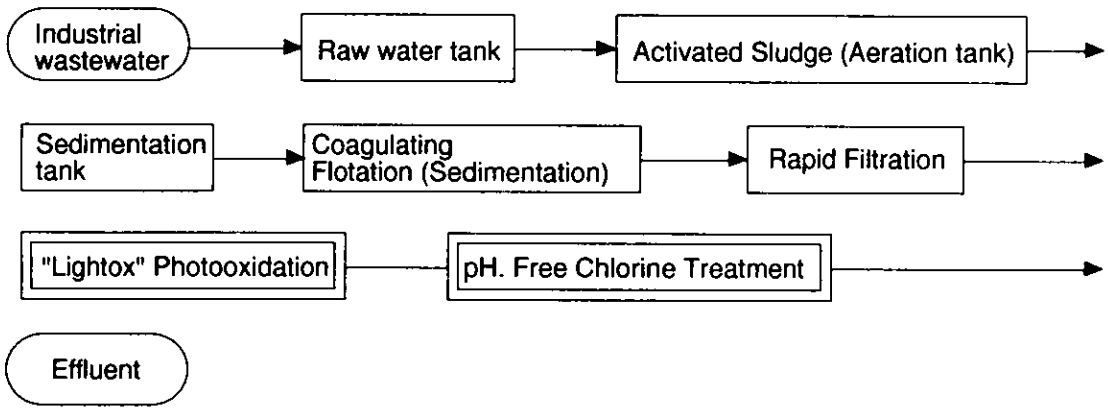
In general, the movements of COD components in regard to activated carbon adsorption vary with whether oxidation is conducted. In the case of the wastewater used in the tests, an incline of the adsorption isotherm is steeper after oxidation by light and chlorine is conducted than before it is conducted. Consequently, the concentration dependence becomes heavy.

As mentioned earlier, it is fully possible to reduce the amount of COD only by oxidation by light and chlorine. Accordingly, it appears that it is not necessary to use activated carbon adsorption as well.

6. Dye Wastewater Treatment Facilities (which respectively deal with the amount of wastewater as follows: 1,000m³/day, 3,000m³/day and 6,000m³/day)

6.1 Facility flow sheet

A wastewater treatment facility outline flow estimated from the results of the investigation and research conducted this time is as described below. An outline of a "LIGHTOX" photooxidation treatment facility is as shown on the separate flow sheet.



A process in a dual square corresponds to one for which the cost of equipment was calculated in Item (6).

6.2 Trial calculation of the cost of equipment and the running cost

On the assumption that the wastewater which has the same quality as the wastewater used this time has was to be treated, trial calculations of the cost of equipment and of the running cost were done involving the six cases mentioned below. Results of the trial calculations are as follows:

(a) Premises for design and trial calculation

	"LIGHTOX" influent		"LIGHTOX" treated wastewater	
	CASE A	CASE B	CASE A	CASE B
pH	7 ± 1	CASE B	CASE A	CASE B
SS	≦ 5ppm	CASE B	CASE A	CASE B
CODMn	≦ 45ppm	≦ 30ppm	≦ 15ppm	CASE B

(b)Design calculation

CASE A	CASE B		
$\triangle COD_{Mn}$	= 30ppm	$\triangle COD_{Mn}$	= 15ppm
$\triangle C\ell_2$	= 500ppm	$\triangle C\ell_2$	= 250ppm
Dark reaction	180ppm	Dark reaction	100ppm
Light reaction	308ppm	Light reaction	150ppm
	θ = 2Hr		θ = 1.33Hr

Lamp electricity 3.45KWH/m³
1,000m³/day 3,450KWH/day
↓
150KWH
3,000m³/day 450KWH
6,000m³/day 900KWH

Lamp electricity 2.32KWH/m³
2,320KWH/day
↓
100KWH
300KWH
600KWH

Table-8 Result of Trial Calculation for Equipment cost and Others

Item \ Treatment capacity	Volume of Wastewater					
	1000m³ / Day		3000m³ / Day		6000m³ / Day	
	Case A	Case B	Case A	Case B	Case A	Case B
Equipment cost (million yen)	163	138	300	235	538	375
Equipment Area (m^2)	200	130	580	380	1,100	750
Electricity for Equipment (KW)	165	110	500	330	1,000	660
Running Cost (Yen / Day)	96,900	58,900	290,700	176,700	581,400	353,400
Operation Personnel	0.3/shift		0.3/shift		0.3/shift	

* Calculation for the capacity of equipment was done provided that treatment equipments operated for 24 hours.

** Equipment deprecitation and labor costs are excluded.

Running cost trial calculation base

$C\ell_2$	¥50/Kg
NaOH	¥30/Kg
Na_2SO_3	¥170/Kg
Electricity	¥10/KWH
Lamp consumption	¥5/KWH

7. Summary

As part of the investigation and research on the dye wastewater advanced treatment technology, the oxidation method by light and chlorine, "LIGHTOX", was examined by using industrial wastewater which had been pretreated (by activated sludge, coagulation and filtration), and the following results were obtained.

1. It is possible to attain the COD_{Mn} value of 15ppm or less (the Osaka Bay regulatory value) by treating the pretreated wastewater using the oxidation method by light and chlorine.

If wastewater has the same quality that the wastewater used this time has, in order to remove 10ppm of COD_{Mn}, roughly 165ppm of chlorine, 186ppm of caustic soda, and 1.15KWH/m3 of lamp electricity are required.

2. The oxidation method by light and chlorine makes complete decolorization almost possible.

3. As a result of the trial calculation, the running cost necessary for the oxidation treatment by light and chlorine is estimated at 3.3 yen per 1ppm of COD_{Mn} removed.

4. As a result of the trial calculation, the cost of equipment is estimated at about 163 million yen on the condition that the amount of COD_{Mn} removed is 30ppm and that the amount of wastewater to be treated is 1,000m³/day.

Appended table-1 Result of water quality analysis for factory A's raw water and pretreated wastewater (1)

Date / Water sampling time	Item to be analysed	Factory raw water										ASM treated water (LIGHTOX inflow raw water)									
		External appe-arance	Trans-parency cm	Water temp. ℃	pH	COD Mn PPM	COD Cr PPM	BOD PPM	n-Hex extracted substance PPM	SS PPM	T-Cr PPM	External appe-arance	Trans-parency cm	Water temp. ℃	pH	COD Mn PPM	COD Cr PPM	BOD PPM	n-Hex extracted substance PPM	SS PPM	T-Cr PPM
10/16	9:00											Pale green	30 or more		7.2	70					
	11:00											Pale green	30 or more		6.9	72					
	14:00											Pale green	30 or more		7.0	67	144				
	16:00											Pale green	30 or more		6.9	66					
10/17	9:00	Reddish brown	14		6.9	182						Light red	30 or more		6.7	58					
	11:00	Reddish brown	13		6.9	168	486					Light red	30 or more		6.7	68					
	14:00	Yellow	14		6.8	174						Light red	30 or more		6.8	62	132	10.1	2.4	5.2	
	16:00	Red	19		7.1	172						Light red	30 or more		7.0	71					
10/18	9:00	Red	18		6.8	121						Light yellow	30 or more		7.0	25					
	11:00	Red	16		6.7	134						Light yellow	30 or more		6.8	23					
	14:00	Red	17		6.9	110	323	27	2.7	-	0.04	Light yellow	30 or more		6.9	24	53	4.8	1.1	3.9	0.03
	16:00	Red	18		6.9	121						Light yellow	30 or more		7.3	27					
10/22	9:00	Light red	14		7.0	121						Light red	30 or more		6.9	40					
	11:00	-	-	21	-	-						Light red	30 or more	18	7.1	33	79	5.1	1.0	3.1	0.02
	14:00	Light red	17		6.8	130	372					Light red	30 or more		6.8	34					
	16:00	-	-		-	-						Light red	30 or more		6.9	-					
10/23	9:00	Light red	20		-	100						Colorless	30 or more		7.0	30	68	4.5	-	2.5	
	11:00	Light red	18		6.9	111	341					Colorless	30 or more		7.0	30					
	14:00	Light red	16		-	-						-	30 or more		-	-					
	16:00	Light red	17		-	-						Colorless	30 or more		7.1	29					

Appended table-2 Result of water quality analysis for factory A's raw water and pretreated wastewater (2)

Item to be analysed / Date Water sampling time		Factory raw water										ASM treated water (LIGHTOX inflow raw water)									
		External appe-arance	Trans-parency cm	Water temp. ℃	PH	COD Mn PPM	COD Cr PPM	BOD PPM	n-Hex extracted substance PPM	SS PPM	T-Cr PPM	External appe-arance	Trans-parency cm	Water temp. ℃	PH	COD Mn PPM	COD Cr PPM	BOD PPM	n-Hex extracted substance PPM	SS PPM	T-Cr PPM
10/24	9:00	Light red	18.5		5.3	128						Colorless	30 or more		7.3	36					
	11:00	Light red	17		6.6	165	491					Colorless	30 or more		7.4	36	94	-	2.4	4.8	
	14:00	Light yellow	16		6.9	141						Colorless	30 or more		7.3	38					
	16:00	Light yellow	17		6.9	128						Colorless	30 or more		7.3	35					
10/26	9:00	Other	15		6.8	108						Yellowish green	30 or more		7.0	68					
	11:00	Milky	22		6.5	112						Yellowish green	30 or more		7.1	71					
	14:00	Milky	20		6.6	122	503	248	-		0.34	Yellowish green	30 or more		7.0	68	131	1.4	2.1	4.1	0.02
	16:00	Red	21		5.6	127						Yellowish green	30 or more		7.0	66					
10/28	9:00	Yellowish brown	17		7.1	106						Yellowish green	30 or more		7.2	54					
	11:00	-	-		-	-						Yellowish green	-		-	-					
	14:00	Yellowish brown	10		7.3	139						-	30 or more		7.3	44	79	5.1	2.4	3.1	0.03
	16:00	Yellowish brown	12		6.9	124	527	229	5.3		0.05	Yellowish green	30 or more		7.1	52					
10/29	9:00	-	-		-	-						-	- more		-	-					
	11:00	Pale yellow	16		7.1	98	371					Yellow	30 or more		7.4	44	76	5.8	1.6	3.3	0.02
	14:00	-	-		-	-						-	-		-	-					
	16:00	Yellowish green	13		7.0	110						Yellow	30 or more		7.2	49	79			3.2	
10/30	9:00	Yellowish green	-		7.3	-						Yellow	30 or more		7.0	-					
	11:00	Yellowish green	19		7.3	83	532					Yellow	30 or more		7.0	31	86	4.9	1.8	3.4	
	14:00	Yellowish green	19		6.7	143	695					Yellow	30 or more		6.7	31	76				
	16:00	Yellowish green	12		6.9	144	746					Yellow	30 or more		6.8	34	75				

Attached table-3 Result of water quality analysis for factory A's raw water and pretreated wastewater (3)

Date / Water sampling time	Item to be analysed	Factory raw water										ASM treated water (LIGHTOX inflow raw water)									
		External appearance	Transparency cm	Water temp. ℃	PH	COD_{Mn} PPM	COD Cr PPM	BOD PPM	n-Hex extracted substance PPM	SS PPM	T-Cr PPM	External appearance	Transparency cm	Water temp. ℃	PH	COD_{Mn} PPM	COD Cr PPM	BOD PPM	n-Hex extracted substance PPM	SS PPM	T-Cr PPM
11/1	9:00	Reddish brown	10	33	7.5	184						Yellowish green	30 or more	17	7.4	38					
	11:00	Light reddish brown	14	38	7.2	154						Yellowish green	30 or more	17	7.4	38					
	14:00	Milky	16	37	7.2	137	398					Yellow	30 or more	17	7.4	36	76.1	-	2.2	4.1	
	16:00	Red	9	35	6.9	162						Yellow	30 or more	16	6.8	38					
11/5	11:00	Turbid lightly green	9	38	7.7	178	488					Pale Yellowish green	30 or more	15	7.4	38	69.0				
	14:00	Yellowish green	24	39	7.4	197	503					Pale Yellowish green	30 or more	15	7.3	42	70.4	8.4	2.1	3.8	
	16:00	Yellowish green	18	38	6.1	188						Pale Yellowish green	30 or more	15	7.2	40					
	17:00	Yellowish green	19	36	6.4	179						Pale Yellowish green	30 or more	15	7.0	39					
11/6	9:00	Light yellow	23	33	5.8	165	436			Absorbance	0.233	Yellow	30 or more	14	7.3	45	95.4			4.7	0.025
	11:00	Turbid green	7.0	33	7.3	165	498				0.31	Yellow	30 or more	14	7.2	37	83.6			3.5	0.020
	13:00	Turbid green	5.5	35	6.3	190	603				0.36	Yellow	30 or more	15	6.9	39	79.0			3.7	0.021
	15:00	Green	17	33	7.4	143	321				0.27	Yellow	30 or more	15	7.4	40	76.1	7.9		3.6	0.020
	17:00	Green	15	34	7.2	151	409					Yellow	30 or more	15	6.9	40	78.3				-
11/7	9:00	Bluish green	6	37	7.6	163	491					Yellow	30 or more	14	7.3	45	90.3			4.6	
	11:00	Turbid light green	7	34	6.8	176						Yellow	30 or more	14	7.2	37					
	13:00	Turbid light green	7	36	6.3	173						Yellow	30 or more	15	6.9	39					
	15:00	Green	10	37	7.1	131	388	250	NH_3-N 326	198	0.02	Yellow	30 or more	15	7.4	40	82.5	14.8	NH_3-N 3.0	2.0	0.02
	17:00	Green	12	37	7.2	163						Yellow	30 or more	15	6.9	40					
11/12	9:00																				
	11:00											Yellow	30 or more	15	7.2	43.5	75.8	4.2	2.0	-	0.01

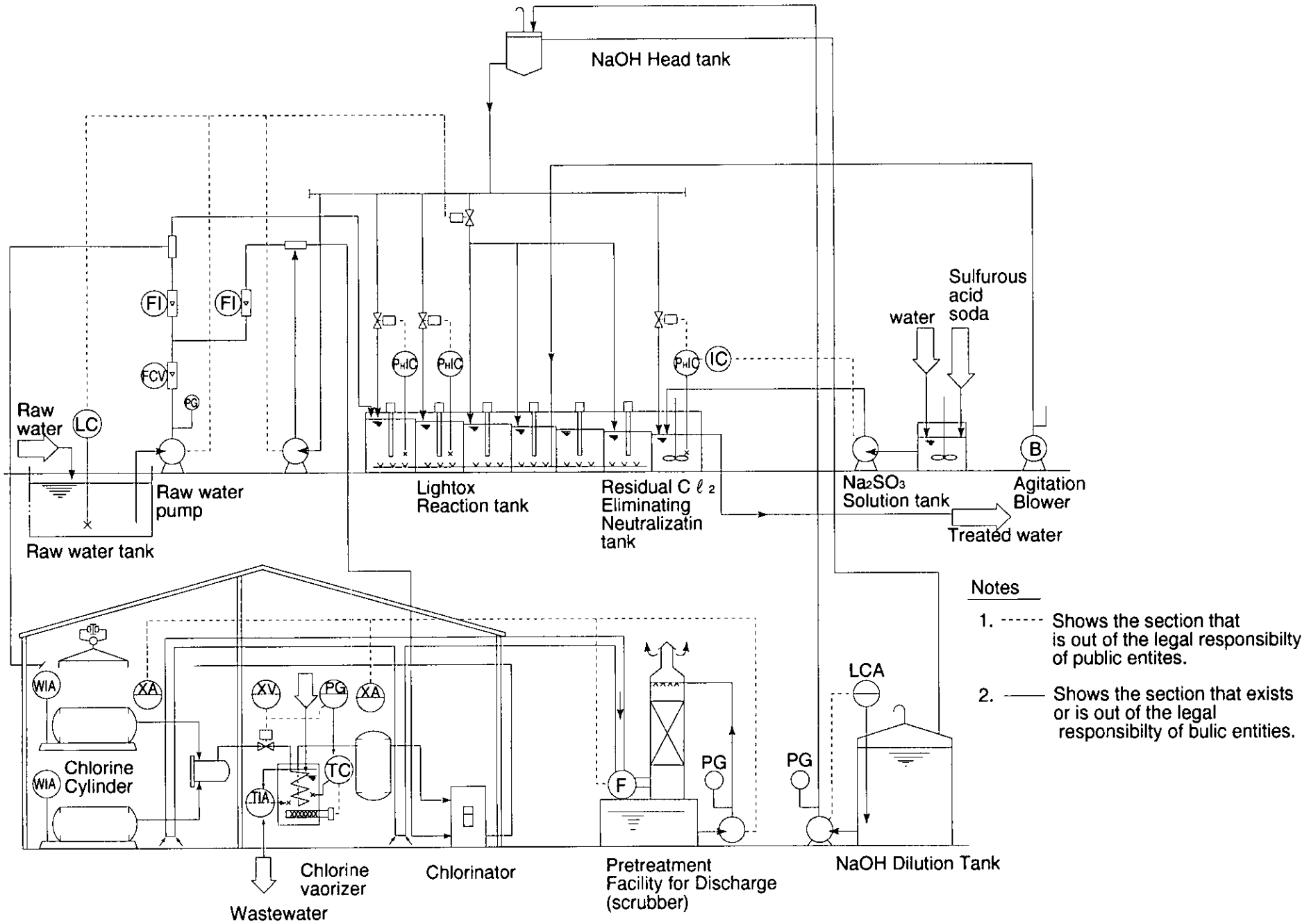
Absorbance

(Note: Absorbance 650m● 2cm cell value)

Appended table-4 Result of water quality analysis for factory A's raw water and pretreated wastewater (4)

Date / Water sampling time / Item to be analysed		Factory raw water								ASM treated water (LIGHTOX inflow raw water)									
		External appe-arance	Trans-parency cm	Water temp. ℃	PH	COD Mn PPM	COD Cr PPM	BOD PPM	n-Hex extracted substance PPM	External appe-arance	Trans-parency cm	Water temp. ℃	PH	COD Mn PPM	COD Cr PPM	BOD PPM	n-Hex extracted substance PPM	* Surface tension dyne/cm	** Surface tension dyne/cm
11/21	9:00	Turbid red	11	35	6.7	184	582		50	Pink	30 or more	17	6.6	30	53	4.8	1.0	62	72
	11:00	Turbid yellow	15	36	7.3	193	460		45	Pink	30 or more	17	6.6	27	56			64	72
	13:00	Turbid green	14	37	7.4	146	555		45	Red	30 or more	18	6.9	23	51			60	71
	15:00	Cloudy	15	38	6.9	156	452		45	Red	30 or more	18	7.1	22	56			58	69
	17:00	Pink	15	38	7.2	143	552		45	Red	30 or more	17	7.0	25	78			58	68
11/22	10:00	Light green	19	33	7.0	188	796		44	Pink	30 or more	14	7.4	33	67			58	69
	13:00	〃	17	38	6.9	192	816		44	Pink	30 or more	16	7.0	32	65	6.0	1.1	58	70
11/23	11:00	Light green	18	38	7.0	183	564		47	Light green	30 or more	17	6.8	39	65	6.1	1.2	60	72

* Raw water ** Treated water


NaOH Head tank
Sulfurous acid soda
water
Raw water
LC
FI
FI
FCV
PG
PHIC
PHIC
PHIC
IC
B
Raw water pump
Raw water tank
Lightox Reaction tank
Residual C ℓ 2 Eliminating Neutralizatin tank
Na2SO3 Solution tank
Agitation Blower
Treated water
WIA
XA
XV
PG
XA
Chlorine Cylinder
WIA
TC
TIA
F
PG
PG
LCA
Chlorine vaorizer
Wastewater
Chlorinator
Pretreatment Facility for Discharge (scrubber)
NaOH Dilution Tank
Notes
1. ------ Shows the section that is out of the legal responsibilty of public entites.
2. —— Shows the section that exists or is out of the legal responsibilty of bulic entities.