REPORT BY THE COMMITTEE ON OIL-CONTAMINATED WASTEWATER TREATMENT TECHNOLOGY

MARCH 1997

JAPAN ENVIRONMENT CORPORATION

This Rescarch studied and surveyed the technology of treating oil-contaminated wastewater and has been discussing the method five times since the 1st discussion held on July 17. 1972.

Since then, the attached interim report was submitted based on which the study and research on the oil-contaminated wastewater treatment technology was conducted.
This is to report results created based on the survey and research.

CONTENTS

I. Necessity of Establishing (the) Oil-contaminated Wastewater Treatment Technology

In recent years, environmental pollution due to oil-contaiminated wastewater, more particularly wastewater containing mineral oil, has given rise to such tremendous pollution problems as river and marine pollution. The problem of oily-smelling fish owing to ballast water and the wastewater from petroleum refining, petrochemical plants and others, and the drifting of tar balls due to tankers and such are striking examples.

The following are the major sources of oil-contaminated wastewater and the actual state of their control.

1. Major Sources of Oil-contaminated Wastewater

(1) Machine shops

(a) Wastewater mixed with oil leaking from machine tool, hydraulic apparatus and press
(b) Floor cleaning water

(2) Casting and forging factories

(a) Floor cleaning water
(b) Wastewater from wet type dust collector
(c) Wastewater containing oil leaking from press

(3) Painting shops

(a) Wastewater produced by electrodeposition painting
(b) Wastewater produced by degreasing and cleaning conducted in the painting pretreatment process
(c) Floor cleaning water

(4) Marine products processing factories

(a) Wastewater containing oil leaking from processing machine
(b) Fish cleaning water
(c) Floor cleaning water

(5) Vessels

(a) Dirty ballast
(b) Engine bilge
(c) Tank cleaning water

(6) Petrochemical and gas manufacturing plants

(7) Iron mills and steel mills

Wastewater produced by cold and hot rolling

(8) Petroleum refining plants and waste oil recycling plants

(a) Leakage from tank, pump piping and others

(b) Sludge at the bottom of tank

(c) Wastewater produced by neutralization washing (white water) after treatment of lubricant and wax by oxidation

(9) Fat and oil processing factories

(10) Food manufacturing factories

(11) Wire rod manufacturing factories

(12) Vehicle maintenance shops

(13) Oil supply stations (SS)

(14) Other places handling lubricants

2. Control and Actual State of the Oil-contained Wastewater

To prevent environmental pollution caused by oil-contaminated wastewater, the Water Pollution Control Law and the Law relating to the Prevention of Marine Pollution and Maritime Disaster have been enacted, so that stringent control is applted.

The effluent standards based on the Water Pollution Control Law is 5 ppm or less for mineral oil of any sort and is 30 ppm or less for animals and vegetable fats and oils. Furthermore, each prefecture intensifies its control by setting more stringent standard if required, and in some cases a standard of 1 ppm or less for mineral oil of any kind, which is strict, is in effect.

Regarding the Law relating to the Prevention of Marine Pollution and Maritime Disaster, the ocean dumping of any kind of waste oil has been completely banned, and strict restrictions are imposed on the oil discharged from marine facilities.

Though the strict restrictions are imposed for the prevention of environmental pollution due to oil, because of a rapid increase in oil consumption, among other things, environmental pollution caused by oil has not been entirely remedied.

For this reason, there is a movement toward more stringent control regardless of the presence of treatment technology in some cases, as well as a movement to control the absolute quantity.

From a technical point of view, as relatively new methods, the activated sludge method in such areas as petroleum refining, petrochemistry, painting plants and marine products processing, and the electrolytic method for the wastewater produced by rolling have begun to be adopted. As for the bilge wastewater of vessels and such, major ports and harbors have established an oil separator in order, and the activated sludge method is employed simultaneously in some cases.

As for the difficulty of treating various kinds of oil-contaminated wastewater in general, adecision is based on the form taken by the oil contained in the wastewater. In the case where the oil content is emulsitied by adding surfactant and the like, but not yet free oil, or in the case where the grain size of the oil content is 10m or less, the treatment is said to be exceedingly difficult. Accordingly, it is observed that treating the oil-contaminated wastewater discharged from petroleum refining, petrochemistry, vessels and others, which is said to be comparatively rich in free oil content and large in grain size, is relatively easy. Furthermore, dilution of the wastewater with other types of process wastewater at the same plant can be anticipated to some extent in those types of industries. As compared with the wastewater discharged by those industries, the wastewater from machine shops contains a large amount of cutting oil, lubricant and such, and therefore treatment of this type of wastewater markally difficult. Cutting oil can be classified into many kinds including water-soluble and water-insoluble. Water-soluble cutting oil, to which a large amount of surfactant is added as an emulsification stabilizer, is in a state of emulsion when in wastewater, and is mostly 10m or less in oil diameter. Consequently, this type of oil is said to be the most difficult to treat. Since machine shops belong to the non-water consuming type industry producing little wastewater, dilution can not be anticipated. Intensification of controls, accordingly, will necessitate the treatment by which the standard value can be satisfied only at the source of the wastewater containing cutting oil.

In the light of a form of enterprise engaged in this type of cutting and machining, a large number of small to medium-sized enterprises are recognized. The result of the 4th Investigation into Machine Tools and Equipment conducted by the Ministry of International Trade and Industry also indicates that the small to medium-sized enterprises account for approximately 90 % of about 18,000 establishments with 30 employees or more. Though the statistics are not available on establishments with 30 employees or less, thier number is suspected to be quite large. Under the present conditions, the treatment of aging cutting oil and wastewater treatment are considered in sufficient.

Besides the aforementioned conditions, a high-speed grinding and cutting method has recently been advocated, aiming to achieve higher machining accuracy but sacrificing efficiency in terms of cutting and machining, this trend is expected to spread further in future. Consequently, a water-soluble oil agent for high-speed grinding, either of high efficiency emulsion type or soluble type is being sold on the market.

Meanwhile, with the advent of recent change in the industrial structure of our country, it is to be expected that the inclination toward high knowledge-intensive industries such as the machine industry will expand in future.

Furthermore, reallocation of factories will accelerate industrialization in the inland areas, and as a natural consequence, some advanced preventive measures against the environmental pollution including the oil-contaminated wastewater will be required.

This committee concluded that of the entire oil-contaminated wastewater, the wastewater containing cutting oil which was discharged by machine shops was the most difficult to treat. Judging from the actual conditions of the use of cutting oil, it was also observed that the machine shops discharging the wastewater were mainly small and medium-sized businesses. Accordingly, the committee regarded it as an issue of urgent necessity to establish an economical treatment method which would be suited to the small and medium-sized enterprises, and decided to examine intensively the issue of wastewater containing cutting oil.

II. Progress of Examination by the Committee on Oil-contaminated Wastewater Treatment Technology (Outline)

This committee has conducted examinations successively five times around the time when the researches commissioned were conducted in order to develop treatment technology for the oil-contaminated wastewater which is one of the causes of the recent pollution of water including that of rivers. The following is a summary of the progress of each examination.
The committee decided to set limits to the subject of the investigation and research since the investigation into and researches on the entire oil-contaminated wastewater were difficult due to restrictions of time and budget.
As a result of the examination, an aqueous solution of water-soluble cutting oil agent (JIS K-2241 Type W_I) , which is considered the most difficult wastewater to treat, was selected as a subject of the research. As to a treatment method, the electrolytic, adsorption, and physico-chemical treatment methods were chosen. Thus, a report on implementation of the researches commissioned covering the grain size distribution measurement which was aimed at clarifying various characteristics of the oil-contaminated wastewater was submitted. (interim report appendix-2) This committee investigated the report in all respects, and also examined other items. Accordingly, this report was made by the committee.

1. The First Meeting of the Committee

(1) Examination of the sources of oil-contaminated wastewater

The following are the standards to be set for subjects of treatment

(a) Oil-contaminated wastewater discharged from small to medium-sized enterprises and small businesses
(b) Oil-contaminated wastewater which has become a pollution problem at the present time
(c) Oil-contaminated wastewater whose subject areas (discharge points) cov a wide field

In accordance with the above, the following 5 types were selected as the subjects, and are to be examined further.

(a) Machine shops
(b) Casting forging factories
(c) Wire rod manufacturing factories
(d) Vehicle maintenance shops
(e) Oil supply stations (SS)

(2) Examination of the properties of oil-contaminated wastewater

Judging from the source (1) mentioned above, subjects of the investigation would appear to be metal working oil (cutting oil, quenching oil), rolling oil, motor oil, etc. However, in the interest of efficiency of treatment, the undermentioned 3 types of oil based on the classification of the oil into water-soluble and water-insoluble categories were selected.

(a) Water-insoluble cutting oil agent (JIS-K 2241 types 1-3)
(b) Water-soluble cutting oil agent (JIS-K 2241 type W_I)

(c) Water-soluble cutting oil agent (JIS-K 2241 type W_2)

(3) Examination of various treatment methods (see appendix 1)

As to treatment methods, the following observations were made.

(a) The treatment of free oil is nearly established at the present time, so that only the data for each treatment
method are to be prepared.

(b) Regarding methods mainly depending on chemicals, since their efficiency varies with the kind of chemical to
be used, examination of the chemical is required.

(c) As for the electrolytic method, a comparative study of diverse methods of the same type is needed.

(4) Examination of the grain size distribution measurement

Since the capacity of treating (removing) oil content in the oil-contaminated wastewater treatment is mostly affected by the grain size of oil content, the research commissioned by the committee is to include the grain size distribution measurement as an item for study.

2.The Second Meeting of the Committee

(1) The National Working Oil Industrial Society gave its view and the results are as follows.

There are few water-soluble cutting oil manufacturers that can display their clear leadership concerning a treatment method at the time of discharging their own products, and the fact is that the treatment of water-soluble cutting oil is rarely conducted.

(2) Examination of the subject wastewater for researches commissioned

The subsequent investigation found out that there were cases where a distributor received an aging solution of water-insoluble cutting oil, and recycled or incinerated it, and so the treatment had not necessarily become a problem. It also became clear that research on the oil-contaminated wastewater due to leaking oil was not considered necessary.

In addition, the water-soluble cutting oil agent type W_2 hardly contains oil, so that it is hard to regard it as the subject of research on the oil-contaminated wastewater.

For the above reasons, this committee decided to adopt the water-soluble cutting oil agent type W_1 as the oil-contaminated wastewater that would be the subject of the research.

(3) Examination of the treatment methods

The preceding indication and the contents of the research commissioned were examined.

(a) As for each method, the range of its treatment capacity was examined.

- Whether treating oil-contaminated wastewater in a state of emulsification is possible, or whether only floating oil and dispersed oil can be treated.
- Whether removing the oil content in highly concentrated wastewater is possible, etc.

(b) Comparative study of chemicals is to be carried out.

- According to the materials, since there are many types of coagulants and the suitability of coagulants varies, a coagulant to be examined is to be limited to one adopted in the research commissioned.
- Concerning an adsorbent, a comparative experiment is to be carried out in the research commissioned.
- Since materials for an enzyme agent are almost nil, investigation of the agent is to be postpned.

(c) Related methods and related matters to be studied are :

- Destruction of emulsion by salting out
- Sludge dewatering method, etc.

3. The Third Meeting of the Committee

The interim report (see appendix 2) with a separate sheet describing an outline of the research commissioned which had been examined in the previous two meetings of the committee was submitted.
(research commissioned)

4. The Fourth Meeting of the Committee

The contents of each report on the research commissioned which had been conducted based on the interim report were examined, and the following were pointed out.

(a) Disposal of the scum produced in primary treatment and separated oil disposal need to be examined.

(b) Development of secondary treatment including new technology needs to be hastened. (e.g. the activated sludge method and other recycling technology)

(c) As for the electrolytic method, an examination by long-term continuous operation is needed.

(d) This research proves that it is hard to remove both oil content and COD by the oil-contaminated wastewater treatment, and consequently careful consideration needs to be given to a surfactant which is added to cutting oil.

5. The Fifth Meeting of the Committee

After the result of the previous meetings and the report of the research commissioned had been examined, this report was made and submitted.

III. Contents of the Research Commissioned

1. Electrolytic Method

(1) Research on optimum pH

In every type of electrolytic method, the optimum pH in terms of its treatment efficiency is to be examined.

(2) Research on electrolytic conditions

In every type of electrolytic method, materials of the anode and cathode and their durability are to be examined.

Various electrolytic conditions in every type of electrolytic method, namely bath voltage, bath current and a distance between the electrodes are to be examined.

(3) Research on such matters as the amount of sedimentation promoter and the number of revolutions of an agitator

The kinds of addition agents which include a flotation agent, etc. and the amount of addition agent to be added are to be examined.

(4) Research on sludge produced

As to sludge produced, such matters as its solid-liquid separation and combustibility are to be examined.

(5) Elucidation of the reaction mechanism

Taking account of the result of the research and past experiences, the reaction mechanism involved in the electrolytic method is to be examined.

2. Physical and Chemical Treatment Method (salting-out method, coagulation method)

(1) Research on the kind, addition amount and treatment conditions of emulsion breaker

From among various kinds of emulsion breakers, one which is particularly effective against the water-soluble cutting oil agent is to be selected out, and such matters as the addition amount, pH adjustment, separation time and treatment conditions are to be examined.

(2) Research on the kind, addition amount and treatment conditions of coagulant and salting- out agent

From among diverse types of inorganic-salt and polymer coagulants, one which is particularly effective against the water-soluble cutting oil agent is to be selected, and such matters as the addition amount, coagulation effect, pH adjustment and treatment conditions are to be examined.

(3) Research on the pressure flotation method

Under varied conditions of pressure (such as pressure, circulation ratio, retention time, etc.), relevance of the amount of scum and treated water to the condition of pressure is to be clarified.

(4) Research on filtration

As for filter media, the kind (such as activated carbon), filling amount, durability, recycling method and treatment conditions are to be examined, and optimum filtration conditions are to be made clear.

(5) Research on scum treatment

The heat value of and treatment method for scum produced are to be examined.

(6) Research on dehydration

Optimum dehydration conditions by using a dehydrator (including a precoat filter) are to be examined.

3. Bubble Association Method

(1) Research on association flotation of oil content by employing the counter-current bubble association method

(a) Examination of making wastewater properties more suitable by adding metallic salts or by controlling
pH

(b) Examination of air action (association flotation effect and agitation effect)

(c) Examination of bubble association equipment (RASHIHI RING)

(2) Research on the collection of floating oil

(a) Selection of collection material

(b) Examination of running operation

(3) Research on establishment of equipment

(a) Integration of counter-current bubble association equipment and floating oil collecting equipment

(b) Establishment of automatization and instrumentation

4. Adsorption Method

(1) Various conditions of treatment by a purification agent and clay mineral are to be selected, and such matters as the treatment efficiency for oil content and economical efficiency are to be clarified and comparatively studied.

(2) The filtration efficiency and combustibility of a purification agent and clay mineral after the oil content treatment are to be clarified.

5. Grain Size Distribution Measurement

The grain size distribution is to be found, and differences among the samples are to be clarified.

6. Other Common Research Subjects

To make a comparison in terms of the economic efficiency among various methods, the construction cost, required plottage, runnning cost, operation personnel, etc. are to be examined, and the results are to be reported.

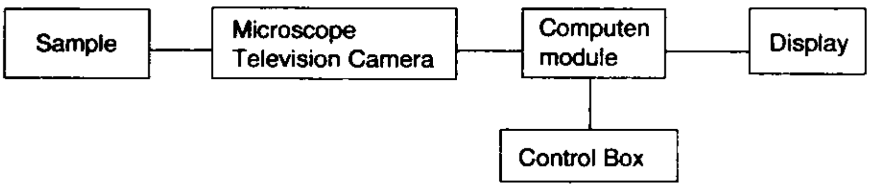
IV. Result of the Research Commissioned

A. Grain Size Distribution Measurement
(entrusted to Ishikawajima-Harima Heavy Industries Co., Ltd.)

1. Outline of the research

For the study of oil-contaminated emulsified wastewater treatment technology, the grain size distribution of the oil-contaminated wastewater containing water-soluble cutting oil agent is to be measured, and various characteristics of the samples used in the researches commissioned are to be clarified.

2. Equipment



3. Samples

(1) SHIMIRON FC-1
diluted with water by a factor of 25 (sample mark FC)
(manufactured by Daido Kagaku Kogyo)

(2) YUSHIROKEN GC
diluted with water by a factor of 35 (sample mark GC)
(manufactured by Yushiro Kagaku Kogyo)

(3) YUSHIROKEN EE56
diluted with water by a factor of 20 (sample mark EE)
(manufactured by Yushiro Kagaku Kogyo)

(4) Mixture of the above (1), (2) and (3) in the ratio of 1:1:2
(volume percent) (sample mark 1-1-2)

(5)Actual wastewater offered by the corporation (sample mark S)

4.Results of the measurement

(1) Grain size distribution of emulsion particles
In the adjusted sample, the number of particles was counted in a size range of from 1 to 10m at 1m intervals to find percentages. (see Table-1 and Figure -1)

Regarding a particle of 1m and less in size, an assumption was made by using the variable magnification scale of microscope. The following are the results.

(a) In every sample, the size of an emulsion particle is mostly distributed in the range of 1 to 10m, and the type of distribution regarded as the normal distribution type is one in which the distribution centers mainly around 2 to 3m .

(b) It can be presumed that the number of particles of 1m and less and of 10m or more in size is quite small in every sample.

Table-1 An Example of Results of the Measurement

Grain size	The 1st measurement				The 2nd measurement				The 3rd measurement				E	F	G
(μ)	A	B	C	D	A	B	C	D	A	B	C	D			
1	2,618			100	2,779			100	2,617			100			100
	(A_1)	378	14		(A1)	386	14		(A_1)	370	14		14	14	
2	2,240			86	2,393			86	2,247			86			86
		886	34			1,051	38			994	38		37	51	
3	1,354			52	1,342			48	1,253			48			49
		304	22			565	20			536	22		21	72	
4	767			29	777			28	690			26			28
		304	12			344	12			291	11		12	84	
5	463			18	433			16	399			15			16
		886	34			1,051	38			994	38		37	51	
6	276			11	248			9	261			10			10
		105	4			95	3			112	4		4	94	
7	171			7	153			6	149			6			6
		76	3			45	2			65	3		3	97	
8	95			4	108			4	84			3			4
		35	1			57	2			34	1		1	98	
9	60			2	51			2	50			2			2
		25	1			20	1			17	1		1	98	
10	35			1	31			1	33			1			1

Sample FC-1
Date of measurement November 8
A: numerical value (piece)
B: An - An + 1,n = 1,2,3... (An is the number of pieces of n É or more in size)
C: (B / A1) x 100 (%)
D: (An + 1 / A1) x 100 (%), n = 1,2,3....
E: average value of C
F: cumulative value of E
G: average value of D

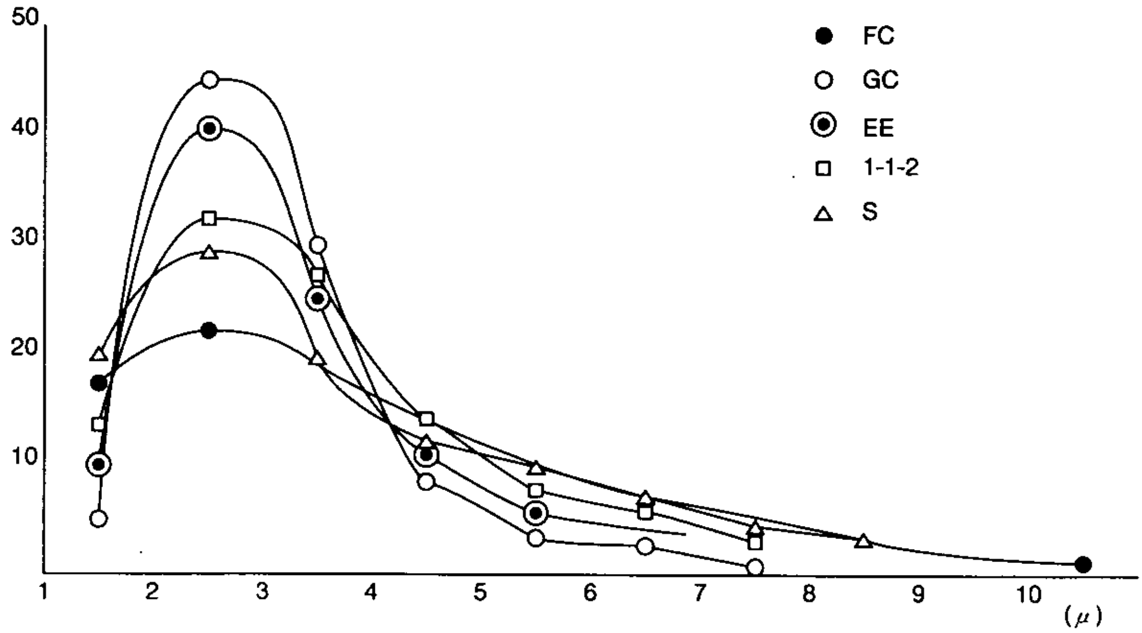


Figure-1 Grain Size Distribution (Average distribution)

(2) Tendency of change in the grain size with the passage of time

With the same sample that had been adjusted, measurement was carried out 5 to 8 times at intervals of about 7 days, and the subject of oloservation was whether or not there were any changes in the grain size distribution with the lapse of time. According to the observation, every sample had slight dispersion in the distribution (a slippage at the peak position and a difference in the distribution percentage=oscillation), but a tendency fowards regular charge with the lapse of time was not observed. Consequently, it can be stated that the measured 5 samples showed no changes with the passage of time.

(3) Stability of samples

Stability of a sample can be judged from the degree of the aforementioned oscillation. A sample with less oscillation is more stable, and so the samples GC and 1-1-2 are more stable than the others.

According to the deviation calculation for the grain size distribution, regarding the order of samples in terms of stability, GC, which is the most stable, comes first, and 1-1-2, S, EE and FC follow in the order named. (GC>1-1-2>S>EE>FC) (see Table-2)

Table-2 Difference in the Deviation Found from the Logarithmic Probability Normal Distribution Figure

Sample	16% point	50% point	Deviation	Difference in deviation
FC-1	a) 5.3	3.0	2.3	2.1
	b) 8.6	4.2	4.4	
GC	a) 3.4	2.2	1.2	0.2
	b) 4.7	3.3	1.4	
EE56	a) 3.2	2.2	1.0	1.3
	b) 5.8	3.5	2.3	
1-1-2	a) 4.4	2.5	1.9	0.4
	b) 5.8	3.5	2.3	
S	a) 4.5	2.7	1.8	1.1
	b) 6.8	3.9	2.9	

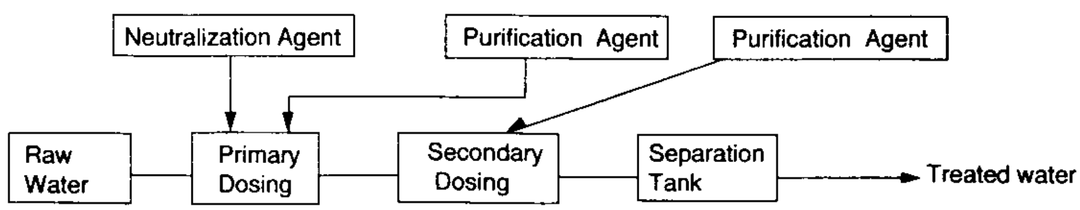
a) minimum value b) maximum value

B. Adsorption Method (entrusted to the Government Industrial Research Institute, Osaka and the National Research Institute for Pollution and Resources)

1. Outline of the research

By employing diverse types of purification agents that have such actions as destruction and separation, adsorption and coagulation of an emulsifying agent, their treatment efficiency and economical efficiency are to be clarified. In addition, such matters as the filtration efficiency and combustibility of saturation purification agents after treatment are to be made clear.

2. Flow sheet
(by the Government Industrial Research Institute, Osaka)



3. Treatment method

After the purification agent is added to the oil-contaminated emulsified wastewater in a primary chemical-feed tank (In the case where two kinds of purification agents are used, a secondary chemical-feed tank is to be employed as well, flotation or precipitation follows.)

4. Samples and properties

Table-1 Samples and properties

Item	Government Industrial Research Institute, Osaka		National Research Institute for Pollution and Resources
	Mixed wastewater	Actual wastewater (industry D)	Actual wastewater (offered by the corporation)
External appearance	milky and cloudy wearing	cludy wearing brown and gray colors	milky
pH	9.75	7.90	9.8
BOD (ppm)	19,680	2,000	-
COD (ppm)	8,520	2,970	-
TOC (ppm)	30,500	6,000	-
TOD (ppm)	110,000	7,600	-
Oil content	31,130	3,626	10,200

5. Purification agent to be used

(a) NYU KATORE No.1 and No.2

(b) B-20

(c) TAI CLEAN KP-101, KP-N, OP

(d) GUREZIN CF, CF-H at the Government Industrial Research Institute, Osaka

(e) MOMORIRONAITO at the National Research Institute for Pollution and Resources

6. Result of the research

(1) Optimum pH range for oil content removal

In the case of NYU KATORE No.1, the optimum pH range of raw water is not less than 9, and the oil removal rate drops when the pH value is 8 and less.

In the case of NYU KATORE No.2, the highest oil removal rate is attained when the pH of raw water is around 6, and the removal rate is lowered when it is either acid or alkaline.

In the case where the NYU KATORE No.1 and No.2 are mixed together for use, a good removal effect is observed in the pH range of 4.5 to 10.

The optimum pH of B-20 ranges from 4 to 10.

In the case where TAICLEAN KP-101and OP are mixed for use, the optimum pH ranges between 4.3 and 6 approximately. Meanwhile, in the case where the TAICLEAN KP-N and

OP are mixed for use, the optimum pH value is around 9.
Since the optimum pH range of TAICLEAN is relatively narrow, care needs to be given to pH before treatment. As compared with the pH of raw water, that of treated water is more likely to be on to the alkali side.
The optimum pH ranges from 4.0 to 9.0 in terms of oil removal in the case of GUREZIN CF, but the optimum pH range is actually 4.0 to 7.0 since the external appearance of treated water deteriorates when the pH is 7 or more.
Regarding MONMORIRONAITO (?), there is no need especially to control the pH in the case of actual wastewater.

(2) Amount of purification agent to be added

The required amount of purification agent to be added at the optimum pH value was examined.

Table-2 Optimum pH and amount of purification agent to add

Purification Agent	Synthetic Wastewater		Actual Wastewater		Reference
	Required Addition volume	Time of Addition	Required Addition volume	Time of Addition	
Nyu Katoke No.1	33 kg/m³	-	- kg/m³	-	
Nyu Katoke No.2	70	-	-	-	
Mixture of Nyu Katoke No.1 and No.2 for use	26	Add No.2 not less than 5min after adding No.1	NO.1 5 NO.2 3	Add No.2 not less than 5min after adding NO.1	Addition Ratio between No.1 and No.2 = 5 : 3
B-20	50		17	-	Addition in optimum quantity or more increases COD and TOC
Mixture of Tai clean K101 and OP for use	40	10min after adding KP101	5	Add OP 5 to 10 min after adding KP101	Possibility of redispersion in the case of synthetic Wastewater
Mixture of Tai clean KP-N and OP for use	14	3 to 10 min after adding KP-N	5	Add OP 3 to 10min after adding OP	Optimum mixing ratio is 1 : 1
Gureein CF	8.5	-	3	-	
Monmorironaito	-	-	1	-	Add 0.5kg of $CaCl_2$ and 2.5kg of $K_2Al_2(SO_4)_3$ 10 min after adding

(3) Filtration efficiency of sludge

The filtration efficiency is poor in all cases but B-20 and MONMORIRONAITO.
The exfoliation efficiency of cake is poor in all cases but B-20, and clogging of filter cloth occurs soon in many cases.
The heat value of cake ranges from 3,400 to 7,400 Kcal/kg, and the cake appears to be autogenously combustible.

(4) Results of the treatment

①As to the oil content, the treatment that could attain the value equal to or below the effluent standard was possible in all cases but MONMORIRONAITO which was aimed at treating synthetic wastewater. Implementation of emulsion break by salting out, however, will make the treatment possible even in the case of MONMORIRONAITO .

② Removing COD and BOD is difficult, and so other types of treatment are needed.

4.Chemical cost

Table-3 Necessary chemical cost per m^3 of wastewater

Purification agent	Unit price (yen / Kg)	Synthetic wastewater (yen / m^3)	Actual wastewater (yen / m^3)
NYUKATORE No.1	175	5,775	
NYUKATORE No.2	225	15,750	
Mixture of NYUKATORE No.1 and No.2 for use		5,200	1,550
B-20	550	27,500	9,350
TAICLEAN KP-101	300		
TAICLEAN OP	300		
TAICLEAN KPN	300		
Mixture of TAICLEAN KPN and OP for use		4,200	1,500
GUREZIN CF	550	4,675	1,650
MONMORIRONAITO	13		740 (Of this, MONMORIRONAITO costs ¥13)

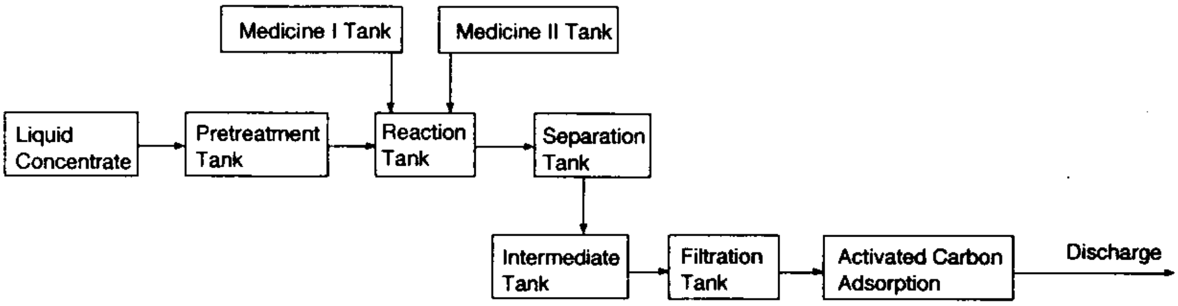
C. Physical and Chemical Treatment Method

C-1. Salting-Out Method (entrusted to Nippon Yuka Kogyo)

1. Outline of the researches

Regarding the oil-contaminated emulsified wastewater containing water-soluble cutting oil agent, effective agglutination working is to be elucidated in order to achieve treatment that can finally attain a value equal to or below the effluent standard stipulated by the Water Pollution Control Law: treatment in which the froths and treated water which have undergone the flotation treatment are separated and filtered under optimum conditions, and undergo an activated carbon adsorption process.

2. Flow sheet



3. Treatment method

To begin with, free oil content of the wastewater is removed to a certain degree by pretreatment. In the following reaction tank, after the special agents I and II are added in the order named, flocs are grown and buoyancy results in the multi-stage reaction tank. In the following decomposition tank, the scum and treated water are separated. Floces and the like which can not be removed at this stage are adsorbed in the intermediate tank, filtration tank, and activated carbon adsorption tank, and then the treated water is discharged.

4. Samples and properties

Table-1 Samples and properties

Sample	External appearance	pH	SS (ppm)	COD (ppm)	BOD (ppm)	Oil content (ppm)
1.Actual wastewater	milk gray color	8.36		9,130	18,600	20,500
2.Diluted YUSHIROKEN GC solution by a factor of 35	milk white color	9.0	708	12,830	12,150	28,000
3.Diluted YUSHIROKEN	milk white color	9.4	1,858	23,830	14,600	47,500
4.Diluted FC	milk white color	9.4	3,363	25,650	15,860	45,500
5.Mixed waste liquid, mixture of above 2, 3 and 4 in the ratio of 1 : 2 : 1	milk white color	9.3	939	24,450		42,500

5. Amount of special medicines to be added

Table-2 shows the results of treatment according to the amount of special agents I and II to be added.

(1) Mere treatment with the special agents leaves an appreciable amount of oil content in the treated water, and accordingly careful subsequent treatment is required.

(2) In the case where subsequent treatment is taken into consideration, the required amount of agent to be added is 0.2 to 1.0% in the case of agent I, and 0.5 to 2.5% in the case of agent II.

Table-2 Addition amount and effect of the agents I and II

Amount of agent to be added		Separation tank oil content (ppm)				
Agent I (%)	Agent II (%)	Actual Wastewater	GC	EE56	FC	Mixture
0.2	0.5	2,086		2,894		1,208
0.6	1.5	942	391	1,120	662	493
1.0	2.5	633	248	743	453	375

Note) Agent I : surfactant
Agent II : inorganic salt

6. Intermediate tank and filtration tank

The function of the intermediate tank and filtration tank is aimed at removing SS, and the effluent standard is fully met in the filtration process by removing 90 to 99% of the residual SS content. Table-3 shows the result of treatment conducted by adding 1.0% of agent I and 2.5% of agent II. As to the oil content, activated carbon adsorption follows.

Table-3 Effect of separation tank and filtration tank

	SS (ppm)		Oil content (ppm)	
	Separation tank	Filtration tank	Intermediate tank	Filtration tank
Actual wastewater	526	14.2	160	67
GC	138	13.7	88	49
EE・56	853	54	147	48
FC	553	4.0	89	21
Mixed wastewater	403	24.6	84	35

7. Activated carbon adsorption

The result of activated carbon adsorption is as shown in Table-4.

Table-4 Result of Activated Carbon Adsorption

	External appearance	pH	COD(ppm)	BOD(ppm)	Oil content (ppm)
Actual wastewater	colorless,transparent	7.52	96	94.3	13.1
GC	colorless,transparent	7.65	64	38.8	3.2
EE-56	colorless,transparent	8.27	193	68.9	11.9
FC	slight yellow, transparent	8.53	298	135	8.3
Mixed wastewater	slight yellow, transparent	8.39	115	196	7.7

(Examination)

(1) Though the oil content is in excess of the standard oil content (that is 5 ppm even by activated carbon adsorption), in all cases but GC, it appears that a slight change in setting conditions such as correction of the time of contact with the activated carbon will enable the oil content to be 5 ppm and less.

(2) Though there are some cases where the standard is exceeded as to COD and BOD, it appears that, as in the case of oil content removal, the standard can be met under the adequate conditions of activated carbon adsorption.

8. Research on scum

The properties of scum are as shown in Table-5 .

Table-5 Properties of Scum

	External appearance	Scum generation ($C\ell/m^3$ raw water)	Water content (%)	Total heat value (Kcal / Kg)
Actual wastewater	liver-brown, strong offensive smell, sticky, hard	50	61	9,760
GC	light yellow, strong offensive smell, not sticky	60	54	10,050
EE-56	light yellow, weak offensive smell, sticky, hard	77	56	9,490
FC	light yellowish-white, strong offensive smell, sticky, hard	55	51	9,950
Mixed wastewater	-	63	-	-

(Note)

The total heat value was obtained when the scum was dried at a temperature of 105 to 110℃ to have a constant weight.

The water content of the scum was obtained right after the scum had been separated in the separation tank . The scum was dehydrated considerably. Dehydration with diatomite and the like enables the water content to vary from 35 to 45%. It is considered that there is no particular need to conduct dehydration.

The problems include the large amount of additional agent required and the vast volume of scum produced .

9. Construction cost

Table-6 Construction Cost

100/hr	0.5 m^3/ hr	5 m^3/ hr
2,000,000 (yen)	2,600,000 (yen)	4,700,000 (yen)

(Note)

The Internal packing of pretreatment tank, intermediate tank, filtration tank and activated carbon tank is not included.

10. Running cost

Table-7 Running cost

Item	100/hr	0.5 m^3/ hr	5 m^3/ hr
Electricity	90 yen / m^3	35	9.9 (yen)
Chemical (I + II)	900 - 3,600 yen / m^3	900 - 3,600	900 - 3,600
Activated carbon	75 yen / m^3	75	75
Packing (pretreatment tank, intermediate tank)	20 - 40 yen / m^3	20 - 40	20 - 40
Packing (filtration tank)	30 - 70 yen / m^3	30 - 70	30 - 70
Total	1,115 - 3,875 yen / m^3	1,060 - 3,820 yen / m^3	1,035 - 3,795 yen / m^3

(Note)

The calculation was made under the condition that 0.2-0.8% of agent I and 0.5-2.0% of agent II were to be added.

11. Construction area and operation personnel

Table-8 Construction area and operation personnel

Item	100ℓ /hr	0.5 mℓ/ hr	5 mℓ/ hr
Construction area	1.0 m	* 2.8m	18.9m
Operation personnel	1 person	1 person	1 person

C-2. Coagulating Flotation Method
(entrusted to Mitsubishi Kakoki Kaisha, Ltd.)

1. Outline of the research

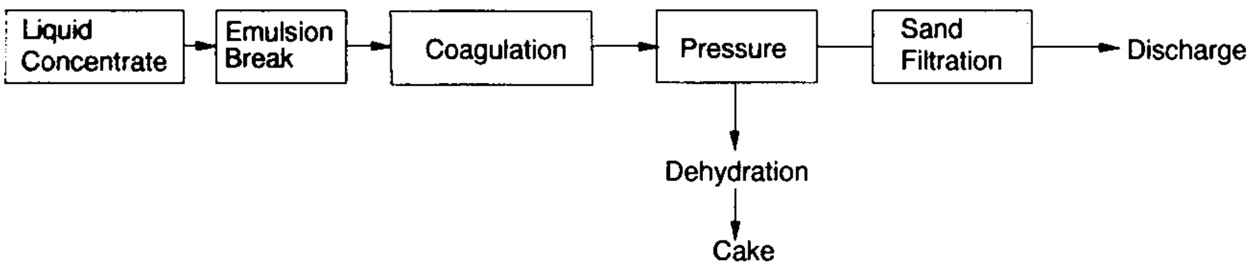
Treatment conditions involving emulsion breakers, such as kind and addition amount are to be clarified, and treatment conditions invdving a coagulant such as the amount of it to be added, etc. are to be examined. As to produced scum, the filtration efficiency, etc. are to be studied, and a method of treating the scum is to be made clear. Furthermore, comprehensive research in to the construction cost, running cost, etc. is to be conducted.

2. Samples and properties

Table-1 Samples and properties

No.	Sample name	External appearance	pH (ppm)	COD (ppm)	BOD (ppm)	Oil content (ppm)
A	Sample offered by the corporation	milky and cloudy	8.4	6,900	894	25,000
B	Diluted FC-1 solution by a factor of 25	milky and cloudy	9.8	12,300	4,604	27,500
C	Diluted YUSHIROKEN GC solution by a factor of 35	milky and cloudy	9.0	10,500	3,123	23,500
D	Diluted YUSHIROKEN EE 56 solution by a factor of 20	milky and cloudy	9.6	14,500	2,863	40,500
E	Mixture of B,C and D in the ratio of 1:1:2	milky and cloudy	9.4	11,800	3,821	32,500

3. Flow sheet



4. Emulsion break

A preparatory experiment by employing a beaker test and an experiment by means of a test plant were conducted. The following are the results.

(1) Acid dissolution (conc H_2SO_4 is used) is performed promptly when the PH value becomes 1 and less. There are no changes in the COD value, but the higher the temperature, the higher the oil content removal rate is.

(2) Similarly, as to salting out ($MgSO_4 \cdot 7H_2O$ is used), the higher the temperature, the higher the oil content removal rate is.

(3) The following shows the comparison between acid dissolution and salting out.

Table-2 Comparison of emulsion break

Item	Acid dissolution	Salting out
Level of Danger	great (pH1 and less)	small
Chemical cost	300 yen /m^3	350 yen / m^3
Treatment temperature	80 ℃	80 ℃
Retention time	30 min	60 min

(4) As a conclusion, no big difference is observed between the two, and consequently a choice should be made in consideration of such matters as equipment materials and operational problems.

(5) An example of the result of the experiments of acid dissolution and salting out is as shown in the following table.

Table-3 Effect of emulsion break

	Acid dissolution					Salting out			
Item	Separating Oil vo 1%		Water quality of Lower Liquid after it is laid quietly for 60min.			Separating Oil volume 1%	Water quality of Lower Liquid after it is laid quietly for 60min.		
Sample	30 min	60 min	PH	COD	Oil content	60min	PH	COD	Oil content
A	3.3	3.3	0.9	1,040	900	3.2	8.0	1,200	1,400
B	5.8	5.8	0.9	650	344	5.3	9.5	709	350
C	4.1	4.1	0.9	410	340	3.0	8.2	630	875
D	8.1	8.1	0.9	-	-	6.0	9.1	9.6	850
E	6.8	6.8	0.9	600	474	4.4	9.0	768	90

5. Coagulation and pressure flotation

The following show the results of the experiments of coagulation and pressure flotation conducted under the conditions mentioned below after the emulsion break by acid dissolution and salting out.

(1) Experimental conditions

Coagulant : Aluminium sulphate 300ppm (Acid dissolution) 200ppm (Salting out)
Sanpoly-A-530 2ppm

Pressure flotation : Circulating ratio 3 : 1
Pressure 3kg / cm^2
Flotation velocity 9.5m / hr
} The beaker test after the pretreatment by acid dissdution

Circulating ratio 3: 1
Pressure 3kg / cm^2
Current velocity 0.5m^3 / hr
Agitation : rapid agitation
slow agitation
} The plant test after the pretreatment by salting out

(2) Results

(i) Results of the beaker test conducted under the aforementioned conditions after the pretreatment of emulsion break by acid dissolution

Table-4 Results of the beaker test

Sample	Scum volume (vol %)	Water quality of treated water					
		External appearance	pH (ppm)	SS (ppm)	COD (ppm)	BOD (ppm)	Oil content
A	3.2	yellow, transparent	6.6	126	591	121	125
B	2.2	Light yellow, transparent	6.8	42	493	389	55
C	2.2	colorless, transparent	7.0	12	374	93	100
D	3.2	yellow, transparent	7.3	18	473	354	75
E	3.5	slight yellow, transparent	7.5	28	453	312	100

(ii) Results of the plant test conducted after the pretreatment of emulsion break by salting out

Table-5 Results of the plant test

Sample	Scum volume (vol %)	Water quality of treated water						
		External appearance	pH (ppm)	SS (ppm)	COD (ppm)	BOD (ppm)	Oil content
A	1.0	yellow, transparent	7.5	90.5	596	202	70
B	1.0	slight yellow, transparent	8.4	35.5	374	512	25
C	1.1	colorless, transparent	6.9	30.0	460	180	40
D	1.3	slight yellow, transparent	8.4	32.0	424	422	375
E	1.0	slight yellow, transparent	8.3	37.0	499	217	55

(3) Examination

The standard can not be met merely by emulsion break and coagulating flotation. Since it is concluded that too much can not be expected since the amount and kind of coagulating flotation agent need to be studied further, advanced treatment is required.

6. Sand filtration

The experiment of sand filtration by using a Mitsubishi BAMAKU deep filter conducted as subsequent treatment for the aforementioned coagulating flotation treatment showed little effect.

7. Dehydration efficiency

The following shows the results of the experiment on dehydration efficiency of the sludge produced by the wastewater treatment.

Table-6 Dehydration efficiency of sludge

Item / Sample name	Sludge External Appearance	Sludge concentration (%)	Sludge Treatment Amount (kg/m³ • H)	Cake Water content (%)	Solid content in Filtrate (ppm)	Reference
A	Brown, sticky	21.0	-	-	-	The Sludge concentration of sample A was so high that the sludge could not be dehydrated by vacuum filtration
B	Milky, smelling	9.5	450	84	54	
C	Milky, smelling	3.7	280	55	120	
D	Milky, smelling	1.7	700	82	56	
E	Milky, smelling	3.0	800	77	55	

Note) The above is based on a precoat filter.

8. Construction cost

0.5 m^3/Hr	15,100,000 yen
5 m^3/Hr	15,800,000 yen

The construction cost covers treatment of sand filtration, but does not cover secondary teatment.

9. Running cost

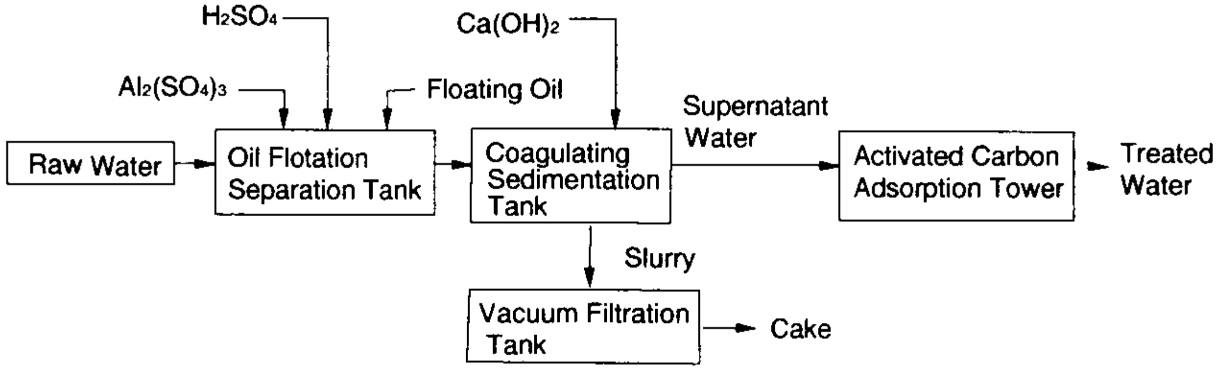
0.5 m^3/Hr	1,649 yen/Hr	3,398 yen/m^3
5 m^3/Hr	2,422 yen/Hr	484 yen/m^3

C-3. Coagulating Sedimentation Method
(entrusted to Mitsui Engineering & Shipbuilding Co., Ltd.)

1. Outline of the research

The aims of this research are as follows: to determine conditions for emulsion breaker, to find optimum agglutination conditions, and to examine an economical treatment method that can finally attain the value equal to or below the effluent standard by activated carbon adsorption.

2. Flow sheet



3. Treatment method

As to the oil-contminated emulsified wastewater, it is separated into free oil and separated liquid by using an emulsion breaker in the oil flotation separation tank, which is followed by agglutination in the coagulating sedimentation tank. Then, after the oil content of supernatant is adsorbed by the activated carbon adsorption tower, the treated water is discharged. Slurry is discharged as cake by a vacuum dehydrator.

4. Samples and properties

Table-1 shows the properties of raw water.

Table-1 Samples and properties

Waste water	External appearance	pH	SS (ppm)	COD (ppm)	BOD (ppm)	*Oil content (ppm)	
						n-H method	extraction I.R method
Actual wastewater	considerable quantity of floating oil, uniformly emulsified	7.9	569	3,230	3,800	2,686	3,120
FC-1	uniformly emulsified, milk white	9.2	0	11,300	5,130	32,081	31,200
EE-56	uniformly emulsified, milk white	9.6	0	10,970	3,490	43,899	35,600
GC	uniformly emulsified, milk white	9.2	0	5,950	3,000	33,486	34,400
Mixed wastewater	uniformly emulsified, milk white	9.4	0	9,800	4,300	38,400	31,700

* The oil content was analyzed by the n-H extraction method and the I.R method, and no great difference was observed between the two.

5. Results of the research

(1) Examination of emulsion breaker

From among various kinds of emulsion breakers, aluminum sulfate was selected and used in past experience.

As a result of the investigation made into the amount to be added by conducting a beaker test, the optimum addition amount was 1,000 ppm for the actual wastewater, 7,000 ppm for FC-1, 7,000 ppm for EE-56, 2,000 ppm for GC, and 7,000 ppm for the mixed wastewater.

The oil content removal rate against the raw water was not less than 99% in all cases but the actual water.

A plant experiment (100 r/hr) was conducted according to the aforementioned addition amounts. The pH value of treated water mostly ranged roughly from 4 to 5. While the retention time of the oil flotation separation tank was set to 1 hour in the beaker test in past experience, it was 2 hours in the plant test. The problem is that the amount of aluminum sulfate to be added is considerably large.

(2) Coagulating sedimentation

In coagulating sedimentation, calcium hydroxide ($Ca(OH)_2$) was used along with aluminum sulfate ($Al_2(SO_4)_3$) which was employed as an emulsion breaker, and the pH value was set to 8.5 from experience. Then, the effect of coagulating sedimentation was examined. The residual oil content of the separated supernatant was 11.2 ppm in the actual wastewater, 10.2 ppm in FC-1, 10.5 ppm in EE-56, 12.5 ppm in GC, and 16.6 ppm in the mixed wastewater, which made it clear that secondary treatment would be needed.

Concerning COD, it remains in the quantity of several hundreds ppm in every type of wastewater, and consequently secondary treatment is required.

(3) Activated carbon adsorption

The fluidized bed method was adopted as the means of adsorbing activated carbon. The oil content was 2ppm or less after treatment in all cases, and the SS, COD and BOD values were all exceedingly lower than the effluent standards. Consequently, the effect of the activated carbon adsorption method was fully displayed. For the purpose of recycling of activated carbon, the spherical method was used.

The pH value of treated water is in the vicinity of 9, and so the pH needs to be adjusted in the one method used.

The pH value of treated water is in vicinity of 9, and so the pH needs to be adjusted in cases where the treated water is discharged.

Table-2 Results of the activated carbon treatment

	External appearance	pH	SS (ppm)	COD(ppm)	BOD (ppm)	Oil content
Actual wastewater	colorless, transparent smell transparency 30 or more	8.8	0	21.4	2	0.2
FC-1	colorless, transparent smell transparency 30 or more	11.6	0	66	34	0.5
EE-56	colorless, transparent smell transparency 30 or more	9.9	5	123	123	0.6
GC	colorless, transparent smell transparency 30 or more	9.9	0	37	6	1.4
Mixed wastewater	colorless, transparent smell transparency 30 or more	9.8	5	87	73	0.8

(4) Research on dehydration

Table-3 shows items including the amount of cake produced and makes it clear that the volume of sludge is remarkably large.

The volume of sludge produced is 200 ℓ per 1 m^3 of raw water in the actual wastewater, 450 ℓ per 1 m^3 of raw water in FC-1, 470 ℓ per 1 m^3 of raw water in EE-56, 300 ℓ per 1 m^3 of raw water in GC, and 460 ℓ per 1 m^3 of raw water in the mixed water.

Table-3 Dehydration efficiency of the sludge

	Slurry concentration (ppm)	Sludge Volume (ℓ/m^3)	Amount of cake (Kg/m^3)	Water of cake (wt %)	content efficiency of cake
Actual wastewater	3,300	200	12.5	62.8	good
FC-1	27,300	450	49.0	58.1	〃
EE-56	28,867	470	53.8	58.2	
GC	6,543	300	23.9	65.0	〃
Mixed wastewater	23,000	460	49.3	60.7	〃

Note) Diatomite (sludge volume x 0.015) is contained in the cake as a body-feed aid.

4.Construction cost

Table-4 Construction cost

	100 ℓ/hr	500ℓ /hr	5 m^3 /hr	Regenerative furnace and incinerator
Common temporary construction costs	(yen) 900,000	(yen) 1,000,000	(yen) 1,300,000	(yen) 1,200,000
Structure construction costs	1,000,000	1,300,000	2,200,000	5,300,000
Machinery and equipment costs	11,300,000	13,200,000	19,100,000	76,500,000
Electric and instrumentation work expenses	8,800,000	8,800,000	9,800,000	3,600,000
Test run adjustment work expenses	1,800,000	1,800,000	1,800,000	2,700,000
Design costs	3,000,000	3,100,000	3,400,000	8,800,000
Construction expenses and other expenses	4,400,000	4,700,000	5,500,000	12,800,000
(yen) Total	(yen) 31,200,000	(yen) 33,900,000	154,000,000	

5.Running cost

The following table shows the running cost per 1m^3 .

Table-5 Running cost

100 ℓ/ hr	500 ℓ/ hr	5 m^3 / hr
362 yen / m^3	237 yen / m^3	218 yen/m^3

Note) Sludge treatment expenses and activated carbon cost are excluded from the above expenses.

6.Construction area and operation personnel

Table-6 Construction area and operation personnel

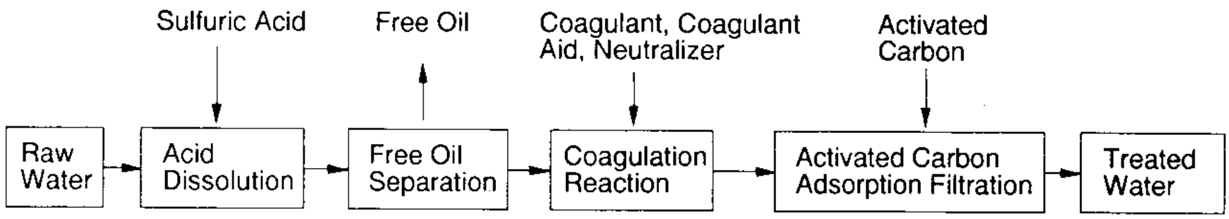
	100ℓ/hr	500ℓ/hr	5 m^3 /hr	Dehydrator and regenerative furnace
Construction area	100 m^2	150 m^2	600 m^2	1,200 m^2
Operation personnel	1 person	1 person	1 person	2 persons

C-4. Coagulating Filtration Method (entrusted to Fuji Kasui Kogyo)

1. Outline

The oil-contaminated emulsified wastewater is to be transformed into free oil by adding an emulsion breaker, and effective conditions are to be found by selecting a coagulant. Finally, treatment with an adsorbent mainly composed of activated carbon and by filtration is to be conducted, and simultaneously an economical treatment method that can attain the value equal to and below the effluent standard is to be examined.

2. Flow sheet



3. Treatment method

As to the raw water, the emulsion oil is transformed into free oil with sulfuric acid on the side of acidity. After that, the separated liquid coagulates with chemicals such as a coagulant, etc. and sediments. After the supernatant is adsorbed by the activated carbon, it is dehydrated together with the activated carbon by filtration with a diatomite precoat filter. The filtrate is discharged.

4. Samples and properties

Table -1 shows the properties of raw water.

Table -1 Sample and properties

	External appearance	pH	SS (ppm)	COD(ppm)	BOD (ppm)	Oil content
Actual wastewater	milk white	6.5	160	1,150	5,100	12,500
FC-1	milk white	11.0	148	8,484	3,470	33,500
EE-56	milk white	9.5	354	6,666	3,370	27,000
GC	milk white	10.5	680	13,440	6,120	44,000
Mixed wastewater	milk white	10.5	304	18,988	2,450	31,750

5. Results of the research [Results of the beaker test]

(1) Treatment by acid dissolution

Table-2 shows the sesults of the optimum treatment by acid dissolution.

Table-2 Results of acid dissolution

	pH	SS (ppm)	COD (ppm)	BOD (ppm)	Oil content	Recovered free oil (vol %)	Sulfuric acid addition volume (vol %)
Actual wastewater	0.3	130	900	4,200	5,800	0.2 - 0.5	0.5
FC-1	0	120	743.5	210	1,900	3.0 - 3.5	1.0
GC	0.1	250	482.5	204	1,350	2.0 - 2.5	1.0
EE-56	0.4	332	840	255	1,010	3.0 - 3.5	1.0
Mixed wastewater	0.8	170	509.5	240	900	3.0 - 3.5	1.0

(Examination)

(i) The beaker tests were conducted under the condition that the sulfuric acid addition amounts were 0.5%, 1.0% and 2.0%. Addition of large quantities of sulfuric acid obviously increased the amount of free oil recovered. In consideration of corrosion of a device with acid and subsequent treatment, the amount of sulfuric acid to be added, however, was restricted to 0.5% in the actual wastewater, and the 1.0% in other cases. At that time, the pH value was not more than 1.0 respectively.

(ii) The amount of free oil recovered was 0.2 to 0.5% in the actual wastewater, and 2.0 to 4.0% in other types of wastewater. The oil content removal rate was about 55% in the actual wastewater, and 95% and over in other cases.

(iii) Though the effect of acid dissolution can be substantially recognized, such a matter as corrosion of materials needs to be examined in future.

(2) Coagulation treatment

Table-3 Comparison of coagulant

	Coagulant					
	J-70		$Al_2(SO_4)_3$		$FeCl_3$	
	Addition amount (ppm)	Oil content (ppm)	Addition amount (ppm)	Oil content (ppm)	Addition amount (ppm)	Oil content (ppm)
Actual wastewater	4,500	25.0	4,000	24.0	3,500	25.0
FC-1	2,000	18.0	1,000	15.0	1,500	17.0
GC	500	50.0	500	44.0	500	47.0
EE-56	2,000	59.0	1,500	54.5	1,500	46.0
Mixed wastewater	1,000	65.0	1,000	41.0	1,000	41.0

Note 1) The amount of coagulant aid (AKOFLOC -100) to be added is 0 ppm in the case of J-70, and 10 to 20 ppm in the cases of $Al_2(SO_4)_3$ and $FeCl_3$.

Note 2) The component of J-70 is not known, but is thought to be a mixture of metallic salt and activator. The manufacturer of J-70 is PETROLITE Co.

(Examination)

(i) As to a coagulant and the amount of it to be added, 4,000ppm of $Al_2(SO_4)_3$ in the actual wastewater, 1,000ppm of $Al_2(SO_4)_3$ in FC, 500ppm of $Al_2(SO_4)_3$ in GC, 1,500ppm Fecl3 in EE-56, and 1,000ppm of $FeCl_3$ in the mixed wastewater could attain the lowest oil content concentration. Accordingly, the coagulants mentioned above were determined as optimum coagulants.

(ii) The oil content removal rate after the treatment by acid dissolution varies from 93% to 99%, which is sufficiently recognized as effective, but secondary treatment is necessary since the value equal to and below the standard is not yet attained.

(3) Activated sludge treatment

Table-4 and Table-5 show the results of the activated sludge treatment.

Table-4 Results of the oil content treatment according to the amount of activated carbon to be added (preparatory experiment)

Wastewater \ Oil content \ Activated carbon addition amount	Oil content before addition of activated carbon (ppm)	Addition of activated carbon					
		ppm 250	ppm 500	ppm 1000	ppm 1500	ppm 2000	ppm 3000
		Oil content (ppm)	Oil content (ppm)	Oil content (ppm)	Oil content (ppm)	Oil content (ppm)	Oil content (ppm)
Actual wastewater	24.0	1.9	2.8	2.2	-	-	-
FC-1	15.0	1.6	1.4	1.1	-	-	-
EE-56	44.0	4.3	2.8	3.6	-	-	-
GC	46.0	17.0	8.3	5.1	3.8	1.3	0.9
Mixed wastewater	41.0	4.3	4.3	2.6	-	-	-

Table-5 Results of the treatment by adding the optimum amount of activated carbon Wastewater

	External appearance	pH	SS (ppm)	COD (ppm)	BOD (ppm)	Oil content (ppm)	Activated carbon addition amount
Actual wastewater	colorless, transparent	6.5 - 7.0	8.0	126.2	93	2.6	250
FC-1	colorless, transparent	6.5 - 7.0	12.0	216.8	60	0.8	250
EE-56	colorless, transparent	6.5 - 7.0	20.0	380.0	40	3.5	500
GC	colorless, transparent	7.5 - 8.0	15.0	144.2	55	1.2	2,000
Mixed wastewater	colorless, transparent	7.5 - 8.0	14.0	188.2	80	4.2	500

Note) Average values are shown for the oil content and COD.

(Examination)

(i) As shown in Table-4, it was made clear that the optimum amount of activated carbon to be added was soughly 250 ppm in the actual wastewater, 250 ppm in FC-1, 500 ppm in GC, 2,000 ppm in EE-56, and 500 ppm in the mixed wastewater.

(ii) Table-5 shows that as for SS, BOD and the oil content, considerably lower values than the effluent standards are attained, but the treatment of COD is still a future subject since the standard is not met as to COD.

(iii) Besides, it will be a problem that the quantity of activated carbon used is 10 to 40 times that of the oil content which needs to be treated.

(4) Research on dehydration

Table-6 shows the results of the sludge-related treatment.

Table-6 Dehydration efficiency of sludge

	Sludge production (g/ raw water)			Water content after sludge dehydration (%)	
	After coagulating sedimentation treatment	After activated carbon treatment	Total sludge volume	After coagulating sedimentation treatment	After activated carbon treatment
Actual wastewater	25	4.5	29.5	68	54
FC-1	27	4.5	31.5	65	53
EE-56	29	5.0	34.0	66	54
GC	25	6.0	31.0	70	57
Mixed wastewater	25	5.0	30.0	68	57

(Examination)

(i) The sludge production is in the vicinity of 30 g/. Concerning the water content of cake after precoat dehydration, it is low in the case where the sludge has undergone activated carbon treatment. This appears to be caused by the fact that the activated carbon contains a large amount of water.

(ii) Reuse of the sludge as a precoat agent is possible in regard to a sludge treatment method, but disposal of it by incineration appears to be appropriate in consideration of the aspect of cost.

(5) Construction cost

Table-7 Construction cost

100m³/ hr	0.5 m³/ hr	5 m³ / hr
4,000,000 yen	7,000,000 yen	12,000,000 yen

(6) Running cost

The running cost per 1 m^3 in the actual wastewater treatment is shown in the following table.

Table-8 Running cost

	Item \ Capacity	100 / hr	0.5 m^3/ hr	5 m^3 / hr
1	H_2SO_4	60 (yen)	60 (yen)	60 (yen)
2	$Al_2(SO_4)_3$ or $Fecl_3$	90	90	90
3	$Ca(OH)_2$	70	70	70
4	Polymer coagulant aid	1.25	1	1
5	Powdery activated carbon	50	50	50
6	Diatomite	50	50	50
7	Electric power cost	250	80	20
8	Water charges	37.5	7.5	3.75
Total		608.75 (yen)	408.5 (yen)	344.75 (yen)

(7)Construction area and operation personnel

Table-9 Construction area and operation personnel

	100 ℓ / hr	0.5 m^3 / hr	5 m^3 / hr
Construction area	50m^2	100m^2	200m^2
Operation personnel	1 person	1 person	1 person

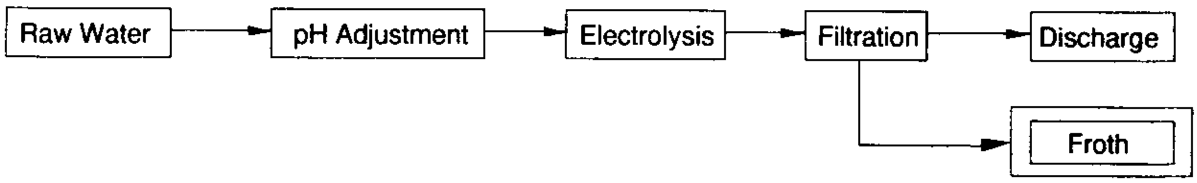
D. Electrolytic Method

D-1. (entrusted to Daiki Gomu Kogyo)

1. Outline of the research

The aims of this research is as follows: to treat oil-contaminated emulsified wastewater mainly composed of water-soluble cutting oil agents, to conduct experiments and research into treatment conditions such as materials of the electrodes, equipment covering a reaction tank, subsequent treatment, etc., and to clarify effects and problems the treatment would have.

2.Flow sheet



3.Samples and properties

Table-1 Composition of the samples

Sample / Item	EE-56	FC-1	GC	Mixture	Actual waste liquid
External appearance	milk white	milk white	milk white	milk white	milk white
pH	9.3	8.8	8.0	9.1	6.7
SS (ppm)	25	126	64	85	1,310
COD (ppm)	12,160	11,490	8,396	11,050	1,318
BOD (ppm)	9,300	5,600	5,600	7,450	1,470
n-Hex (ppm)	49,200	40,100	35,200	44,300	3,520

4. Results of the research

(1) Research into electrolytic conditions

As a result of the examination of various primary electrolytic factors mentioned below, the optimum treatment conditions for the samples are as shown in Table-2.

Table-2 Optimum conditions and state of electrolysis

Item \ Sample	EE-56	FC-1	GC	Mixture	Actual waste liquid
pH before electrolysis	4.0	2.0	4.0	4.0	4.0
COD before electrolysis (ppm)	12,160	11,490	8,396	11,050	1,318
Current density (A / dm^2)	0.8	0.8	0.6	0.8	0.32
Electric current (A)	20	20	16	20	8
Voltage (V)	15.6	13.5	16.7	15.1	17.0
Distance between (mm)	15	15	15	15	15
Retention time (min/ ℓ)	7.0	6.5	3.5	6.5	3.5
Rise in water temperature	30℃	40℃	20℃	30℃	10℃
pH after electrolysis	10.0	10.0	7.0	10.0	7.0
COD after electrolysis (ppm)	550	447	383	642	97.5

Note) • Electrolyzer volume 10ℓ
• Electrodes (+) iron, (-) stainless
• The lowest value is shown as for the COD after electrolysis, and average values for other items.

Dischargeable treated water can not be attained by treatment conducted under electrolytic conditions that are supposed to be optimum, so that secondary treatment such as filtration is necessary.

a. pH adjustment
Electrolysis was conducted after the pH value had been adjusted to 2, 4 and 6 respectively.
The value achieving a high COD removal rate then was determined as the optimum pH.

b. Electrodes
After iron and aluminum had been compared and studied as a soluble anodic material, iron which was economical was chosen since the both showed little difference in terms of efficiency.

c. Optimum current density
It was recognized that a difference in the current density hardly affected the treatment capability within the range of these experiments. In consequence, the current density was decided in consideration of economical elements and the conductivity of liquid.

d. Distance between the electrodes
The factors to be examined are a degree of voltage rise and consideration given to maintenance.

e. Coulometric concentration (AHr / ℓ)
As a result of the examination of the aforementioned items (a) to (d), the current and electrolysis time were not regarded as an independent factors, but were regarded as the produced coulometric concentration and indicated as

(2) Electrolyzer

The operation of electrolysis is of batch type having 3 unit operations, namely liquid supply, electrolysis, and discharge of treated liquid. To realize continuous treatment as a whole, the treatment is to be automatized by combining some electrolyzers and staggering time since the volume of an electrolyzer is not limited.

(3) Froth treatment

As in the case of the froth produced in these researches, filtration and flotation are thought of as separation methods which are effective against products with slight precipitating ability. This time, filtration by a leaf test , in which a precoat filter was assumed, was examined. Table-3 and Table-4 show the results.

Table-3 Results of the analysis of treated water (filtrate)

Item \ Sample	EE-56	FC-1	GC	Mixture	Actual waste liquid
External appearance	colorless, transparent	colorless, transparent	colorless, transparent	colorless, transparent	colorless, transparent
pH	9.5	9.8	7.3	10.0	6.8
SS (ppm)	4	10	24	1	5
COD (ppm)	574	651	372	584	1,145
COD average removal rate (%)	95.2	94.5	95.6	94.7	91.4
BOD (ppm)	680	1,100	281	705	83.7
BOD average removal rate (%)	92.8	80.8	95.0	90.5	94.3
n-Hex (ppm) BOD average n-Hex average removal rate (%)	49,200 120 99.8	40,100 183 99.8	35,200 95.5 99.2	44,300 149 99.7	3,520 24.6 99.3

Table-4 Filtration capacity and properties of cake

Item \ Sample	EE-56	FC-1	GC	Mixture	Actual waste liquid
Treatment capacity ($\ell/m^2 \cdot Hr$)	1,200	905	455	600	830
Wet cake rate (%)*	4.42	3.4	0.5	4.8	0.4
Water content (%)	21.4	30	53	48	48
Low heat value (cal / g)	6,860	5,170	6,020	6,760	6,680

Wet cake rate = Weight (W_1) of dehydrated cake (before drying) / Filtrate volume (W_2) x 100%

As shown, the n-Hex, COD and BOD values as to the treated water (filtrate) are not satisfactory, and consequently subsequent treatment such as the activated carbon treatment is required.

(4) Elucidation of the reaction mechanism

Though not yet elucidated sufficiently, the principle of this treatment method is generally as mentioned below.

The cation and anion in the wastewater are not necessarily equivalent, and most of particulates are negatively electrified. The particulates, which adsorb hydrated ions, form the electric double layer (?), and its É*f* potential and hydration cause mutual repulsion among particles, which maintains the stable state of suspension.

The electrolyzer has the following actions on the wastewater.

1. When the wastewater is placed in the electric field, the particles lose electrons (negative) at the anode and are electrically neutralized, thus weakening their repulsive force.

2. The particles are also electrically neutralized by the metal ions eluted from the anode. The particles are gathered by the Brownian movement, and are associated (?) and coagulated by the Van der Waals force.

3. The eluted metal ions (in the case of Me2+) are reacted with the water molecule to be hydroxide. That is,

At the Anode,

$$Me \rightarrow Me^{2+} + 2e$$

$$Me^{2+} + 2H_2O \rightarrow Me(OH)_2 + 2H^{-1}$$

At the cathode,

$$2H^{-1} + 2e \rightarrow H_2 \uparrow$$

$$Me + 2H_2O \rightarrow Me(OH)_2 + H_2 \uparrow$$

The hydroxide made by dissolving metal as mentioned above has capability of several times as much as that of the hydroxide made by hydrolyzing metallic salts. And, it adsorbs and coagulates fat and oil and soluble BOD components besides particulates.

5. Construction cost and running cost

Table-5 Construction cost

(Unit : yen)

Contents of equipment	100 ℓ/Hr	500 ℓ/Hr	5,000ℓ /Hr
Electric instrumentation equipment	1,300,000	1,800,000	4,300,000
Electrolytic treatment equipment	1,950,000	4,050,000	9,000,000
pH adjustment equipment	400,000	500,000	700,000
Filtration equipment	2,800,000	4,000,000	7,800,000
On-site construction	350,000	450,000	700,000
Total	6,800,000	10,800,000	22,500,000

Table-6 Running cost

(per m^3 of liquid concentrate)

Item	Unit price	100 ℓ/Hr	500ℓ/Hr	5,000 ℓ /Hr
Electric power for electrolysis	5.00 (yen/kWh)	7.2 (kW/m^3) 36.00	6.2 (kW/m^3) 31.00	5.1 (kW/m^3) 25.50
Chemical-N	30.00 (yen/kg)	150 (g/m^3) 4.50	150 (g/m^3) 4.50	150 (g/m^3) 4.50
Fe electrode consumption cost	100 (yen/kg)	340 (g/m^3) 34.00	290 (g/m^3) 29.00	243 (g/m^3) 24.30
Sulfuric acid	20.00 (yen/kg)	495 (g/m^3) 9.90	495 (g/m^3) 9.90	495 (g/m^3) 9.90
Chemical-M	7.00 (yen/kg)	200 (g/m^3) 1.40	200 (g/m^3) 1.40	200 (g/m^3) 1.40
Filtration aid	50.00 (yen/kg)	900 (g/m^3) 45.00	800 (g/m^3) 40.00	800 (g/m^3) 40.00
Miscellaneous power	5.00 (yen/kg)	1.1 (g/m^3) 5.50	0.9 (g/m^3) 4.50	0.9 (g/m^3) 4.50
Total	yen/m^3	136.30	120.30	110.10

6. Plottage

Table-7 Floor space occupied

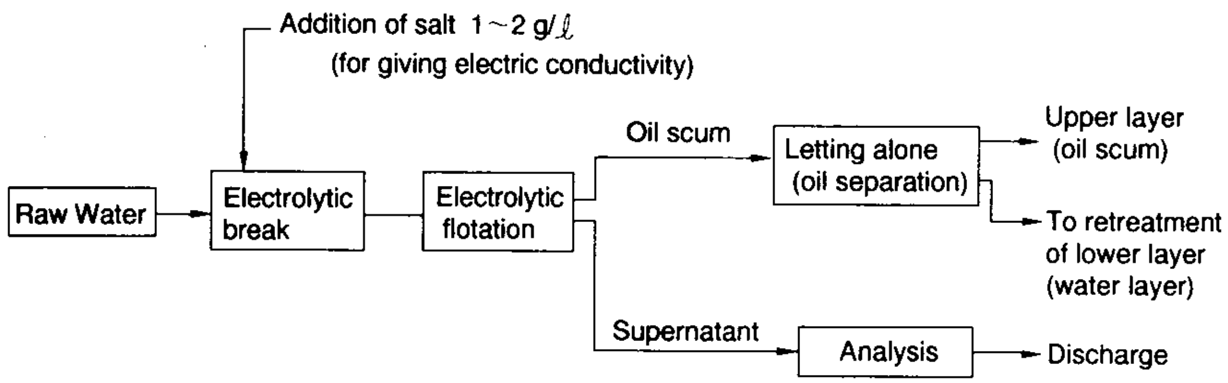
100 ℓ/Hr	2.20M × 2.40m × 2.50MH	5.28 m^2
500 ℓ/Hr	4.00M × 4.00m × 3.20MH	16.00 m^2
5,000 ℓ/Hr	6.00M × 4.60m × 4.30MH	27.60 m^2

D-2. Electrolytic Method (entrusted to Mitsui Metal Engineering)

1. Outline of the research

The aims of this research are as follows: to treat oil-contaminated wastewater by electrolysis, to investigate emulsion break, flocculation, floc flotation, etc., and to examine technical and economical problems for the purpose of realizing a treatment that can attain a value equal to or below the effluent standard.

2. Flow sheet



3. Methods of experiment

(1) Batch test

Electrolytic break and flotation are conducted simultaneously. Salt is added to the raw water in the ratio of 2g/R, and a direct current is applied at the current density of 0.5A/R. After the liquid in the vicinity of the cathode is sampled at regular intervals, analyses are made of such matters as the oil content, COD,BOD and pH to find out the time and the amount of electricity required for electrolysis.

(2) Continuous test

The retention time for a tank required for continuous treatment is set based on the data of the batch test . The current of the electrolytic break tank is set to 0.5A/R, and analyses are made of such matters as the oil content, COD, BOD and pH to find out various conditions required for electrolysis.

4. Samples and properties

Table 1. Samples and properties

Items to be analyzed	Tint	Oil content	COD	BOD	pH	
Property	milk white, opaque	*34,150 ppm	*5,440 ppm	*7,066 ppm	8.5	*analytical average value of 3 samples
Analytical method	-	JIS • K 0102 • 18	JIS • K 0102 • 13	JIS • K 0102 • 16	JIS • K 0102 • 8	

Note) The samples are the emulsified wastewater offered by the corporation.

5. Results of the research

(1) Research on emulsion break

(i) Examination of materials of the anode and cathode

① Material of the anode

The electrode made of special Al alloy was employed: it prevents the Alumite phenomenon (formation of an oxidative film) that has tended to happen to the conventional Al electrode. It also prevents the voltage rise caused by the adhension of slime, and can be used continually over a long period of time.

② Material of the cathode

The relation between the electrolysis time and treated liquid's oil concentration was examined by means of SUS27, Al, Fe, Ni, Zn and Cu. As a result, it was concluded that material with lower hydrogen overvoltage could attain a higher oil content removal rate and that Fe was favorable in terms of cost.

③ Consumption of the anode

Special Al alloy (for electrolytic break) ... 0.334 g/Hr (theoretical consumption)
(Exchange is required at intervals of 6 to 12 months.)

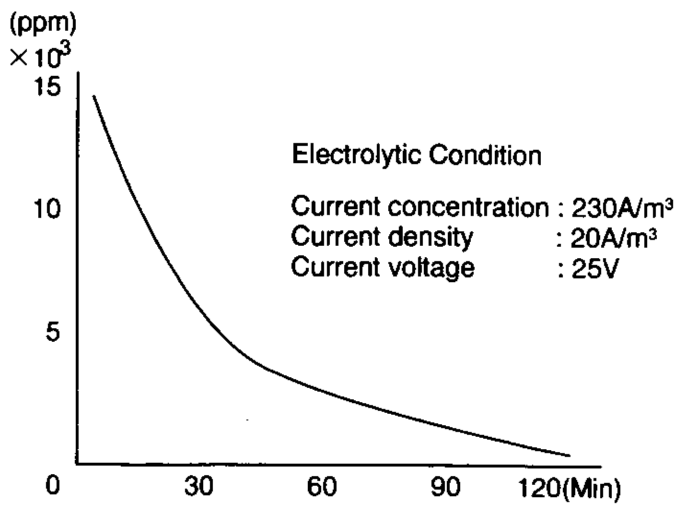
(ii) Examination of the optimum bath voltage, bath current, distance between the pole plates and electrolysis time

① Optimum bath voltage

The maximum is 30V in consideration of such matters as safety in operations, electric power cost, and the price of a rectifier. In case of the voltage not less than 30V, addition of salt is necessary to lower the voltage. (The addition amount is examined in a separate item.)

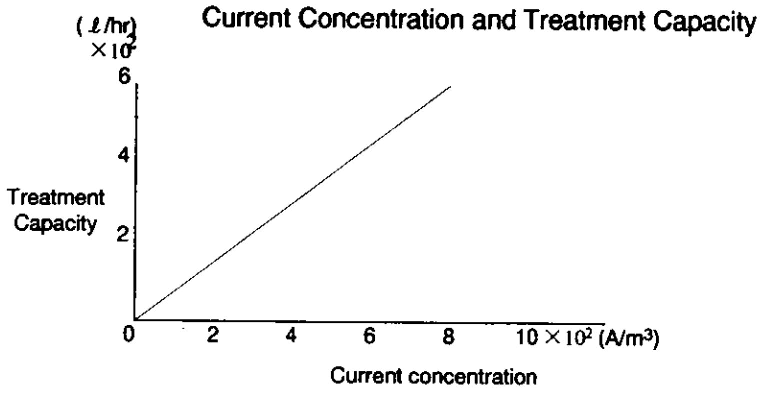
② Bath current (electrolytic current) and electrolysis time

Oil Content in the Wastewater and Electrolysis Time



It took 120 min to enable the oil concentration to reach the vicinity of 5 to 10 ppm. The required time is nearly proportional to the current concentration as a result of the experiment.

③ Current concentration and treatment capacity



The current concentration and flow rate of liquid are changed, and the condition that enables the oil content concentration in the wastewater after the electrolytic treatment to range from 5 to 10 ppm is plotted.
As a result of this experiment, the relation between the current concentration and treatment capacity is almost directly proportional.

(iii) Examination of addition agent and its optimum addition amount
As a result of the examination conducted in (ii)-①, in the case where the bath voltage is in excess of 30V, in the freshwater particularly, an addition agent needs to be added with the object of lowering the voltage. Salt is the most suitable as the addition agent since it is cheap and makes electrolytic break easy. The addition amount ranges from 0.5 kg/m^3 to 3 kg/m^3 on the average, and it is to be increased or decreased if necessary.

(iv) Examination of the optimum pH value
There is no need to stick to the optimum pH value particularly as long as pH is situated within the range which does not cause dissolution of aluminum hydroxide (pH 5.0 - 9.5).

(2) Research on floc formation and flotation

(i) Examination of addition agent and its addition amount
The colloidal particles of aluminum hydroxide made out of aluminum at the anode by electrolysis carry extremely peculiar properties, and are electrified in the opposite way (negatively) from the floc made out of aluminum sulfate and PAC. Accordingly, use of cationic coagulants (e.g. SUMIFLOC #NP) is suitable. The addition amount ranges from 5 to 20 g/m^3 and the pH value ranges between 6.7 and 8.5.

(ii) Shape and volume of the flocculation tank
The structure and volume are to be determined in consideration of the two points, namely the optimum retention time of 7 to 20 min and the air agitation method that causes little destruction of floc.

(iii) Distance between the pole plates and voltage in the flotation tank

① Anode

The structure which does not hinder the flotation of floc is required. The material is carbon.

② Cathode

The cathode is to be horizontally placed at the bottom of the tank. The material is iron.

③ Distance between the pole plates

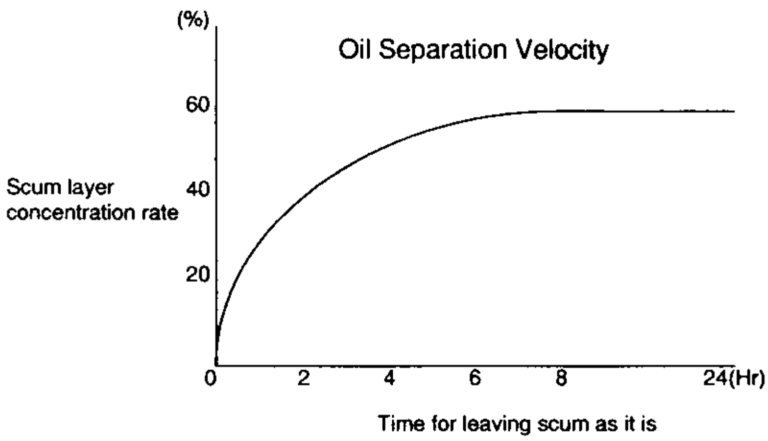
30 ~ 50 mm

④ Bath voltage

30V at maximum

(3) Research on scum

Oil separation is conducted by leaving scum as it is. The separated oil content can be incinerated.



Scum analytical value

(The scum in the upper layer has been left as it is for 24 hours.)

External appearance blackish brown, state of paste, odorless, fluid	
Water content	22 wt% (average value out of 3 tests)
Oil content	66.5 wt% (average value out of 3 tests)
Heat value	6,317 Kcal/kg (assumption based on n-hexane content)
Dehydration efficiency	
Forced filtration can not be used since free oil passes through meshes of a filter paper. Gravity filtration by leaving scum as it is is suitable.	

6. Results of the treatment

Table-2 Results of the treatment

	Item \ Sample Name	Diluted FC.1 Solution by Factor of 25		Diluted Yushiroken GC 1 Solution by a Factor of 25		Diluted Yushiroken EE56 Solution by a Factor of 20		FC-1, GC ,EE56 Mixed liquid	
Properties of wastewater		Liquid concentrate	Diluting Liquid	Liquid contentrate		Liquid contentrate	Diluting Liquid	Liquid contentrate	Diluting Liquid
	Tint	Milk white opaque		Milk white opaque		Milk white opaque		FC-1 : 1 GC- : 1 EE-56 : 2	ⓐ : 1 ⓑ : 1 ⓒ : 1
	Oil content (ppm)	7690	1538	1076		1076	992		
	COD (ppm)	10855	2171	7180		7180	2618		
	p H (ppm)	9.0	-	9.3		93			
	Dilution rate	Dilution by a factor of 5		No Dilution		Dilution by a factor of 5		Mixure of 3 rinds	
Treatment Conditions	Corrent concentration (A/)	05	05		05	05	05		05
	Electorlytic Voltage (V)	2.2	2.2		12	16	16		19
	p H Adjustment	9.0	7.6 HCl		8.0	7.5	7.5		93→73
	Salt Addition Amonut (g/)	2.0	(2/5+2)		2.0	2.0	(2/5)		2.0
	Item \ Sample	Treatment of diluting liquid		Treatment of liquid concentrate		Treatment of Diluted liquid		Treatment of Mixture of 3 kinds after dilution	
Results of Analysis	Electrolysis time (min) \ Item to be analyzed	OIL content (ppm)	COD (ppm)	OIL content (ppm)	COD (ppm)	OIL content (ppm)	COD (ppm)	OIL content (ppm)	COD (ppm)
	0	1538	2171	1076	7180	992	2618	3642	3400
	40	17	176	-	-	-	-	-	-
	60	14	175	-	-	-	-	-	-
	70	-	-	-	-	24	145	-	-
	79	-	-	-	-	-	-	20	265
	80	-	-	-	-	11	152	-	-
	90	5	165	-	-	-	-	-	-
	100	-	-	92	545	6	154	-	-
	105	-	-	-	-	-	-	5	176
	110	-	-	63	413	-	-	-	-
	120	-	-	28	438	-	-	-	-

7. Conclusion

The aforementioned results show that secondary treatment such as the activated carbon treatment is required since it is difficult to attain the effluent standard by this method of treating the oil-contained wastewater.

8. Construction cost, construction area, operation personnel and running cost

Construction cost, construction area, operation personnel and running cost

Items \ Treatment capacity	0.1 m^3/hr	0.5 m^3/hr	5 m^3/hr
Construction cost (yen)	5,000,000	7,000,000	19,000,000
Construction area (m^2)	6	10	40
Electrolyzer proper (m^2)	3	5	20
Others (m^2)	3	5	20
Operation personnel (persons)	1	1	1
Chemical compounding (hr)	1	1	1
Adjustment (hr)	1	1	1
Running cost (yen / m^3)	745	696	617
Electric power (yen)	120	101	92
Electrode consumption (yen)	520	490	420
Chemical to add (yen)	105	105	105

D-3. Electrolytic Method (entrusted to Seisui Kogyo)

1. Outline of the research

The aim of this research is to elucidate various problems relative to electrochemical purification of the oil-contaminated emulsified wastewater mainly composed of water-soluble cutting oil agent (equivalent to the type JIS-K-2241-1970-W-1). Attention was especially paid to the following.

(1) Electrolytic conditions

(i) Oil separation for reducing the load of oil content on the electrolyzer

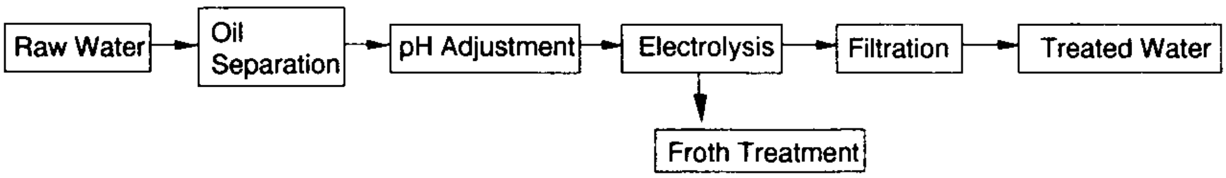
(ii) Electrolytic pH

(iii) Various conditions including the current amount concentration (A•Hr /r)

(2) Froth treatment and disposal

(3) Advanced treatment for the liquid treated by electrolysis

2. Flow sheet



3. Results of the research

(1) Electrolytic conditions

(i) Oil separation for reducing load of the oil content on the electrolyzer

With the object of reducing the load of the oil content on the electrolyzer, emulsion break with sulfuric acid was planned, and oil separation by gravity was studied. However, no remarkable effect was observed.

(ii) Electrolytic pH

A difference in the pH value presented by electrolysis does not produce a noteworthy change in the treated water, and adjustment of the presented pH value to slight acidity is rather desirable in terms of a rise in the pH value of electrolyte.

(iii) Various conditions including the current amount concentration (A•Hr / ℓ)

Various conditions including the current amount concentration were examined by employing 3 types of electrodes, namely the cage type electrode , the inclined plate type electrode, and the cage type electrode and inclined plate type electrode combined. The results are shown in Tables 1, 2 and 3.

In all methods, 5ppm or less of n-Hex and 120ppm or less of COD can not be attained only by the electrolytic treatment.

The required current amount concntreation is vastly different depending on the method. That is,

Cage type electrode 0.40 - 1.60 AHr/r

Inclined plate type electrode 0.20 - 0.59 AHr/r

Cage type + inclined plate type electrode 0.16 - 1.15 AHr/r

As indicated above, the difference is remarkable. As for this matter, elementary researches are further needed.

Table-1 Treatment effect presented by the cage type electrode

ITEM / SAMPLE	LIQUID CONCENTRATE			TREATED LIQUID						
	pH	n-Hex	COD	n-Hex REMOVAL RATE	RESIDUAL n-Hex	COD REMOVAL RATE	RESIDUAL COD	A.Hr/l	CURRENT (A)	VOLTAGE (V)
		ppm	ppm	%	ppm	%	ppm			
EE-56	500	41000	21680	99.8	25	93.8	1271	1.60	2	23
FC - 1	500	47640	13690	99.8	31	85.3	1725	1.10	4	17
G C	500	29600	16640	99.8	25	96.3	453	0.40	2	24
MIXTURE	500	35820	15620	99.8	30	92.8	1234	1.00	2	21
ACTUAL WASTE WATER	500	3210	6970	99.8	279	62.0	2720	0.90	4	20

Table-2 Treatment effect presented by the inclined plate type electrode

ITEM / SAMPLE	LIQUID CONCENTRATE			TREATED LIQUID						
	pH	n-Hex	COD	n-Hex REMOVAL RATE	RESIDUAL n-Hex	COD REMOVAL RATE	RESIDUAL COD	A.Hr/l	CURRENT (A)	VOLTAGE (V)
		ppm	ppm	%	ppm	%	ppm			
EE-56	500	42610	21960	98.1	7970	92.4	1680	0.59	2	30
FC - 1	500	33070	13340	99.8	630	84.6	2050	0.42	2	25
G C	500	32680	11960	99.8	322	95.3	568	0.20	2	50
MIXTURE	500	34280	12930	99.9	297	90.5	1230	0.53	2	28
ACTUAL WASTE WATER	500	3210	6970	91.9	2590	68.7	2180	0.32	2	26

Table-3 Treatment effect presented by the cage type electrode and inclined plate type electrode combined

ITEM / SAMPLE	LIQUID CONCENTRATE			TREATED LIQUID						
	pH	n-Hex	COD	n-Hex REMOVAL RATE	RESIDUAL n-Hex	COD REMOVAL RATE	RESIDUAL COD	A.Hr/l	CURRENT (A)	VOLTAGE (V)
		ppm	ppm	%	ppm	%	ppm			
EE-56	490	45400	24200	99.9	60	95.0	1212	1.15	32	38
FC - 1	515	32800	13300	85.6	1000	88.0	1590	1.15	32	32
G C	500	24380	13080	99.9	121	94.4	727	0.16	22	40
MIXTURE	490	36200	18600	99.9	122	93.6	1190	1.15	32	35
ACTUAL WASTE WATER	505	3210	6970	95.8	1360	71.6	1980	0.44	40	24

Note) The pH values have been adjusted

(2) Froths

Concerning the froth produced by electrolysis, its production varies from 125 to 400R per 1 m^3 of liquid concentrate and its dehydration efficiency is poor. Accordingly, it appears that its treatment and disposal need to be studied further for the future. As for dehydrated froth, it is almost autogenously combustible.

(3) Advanced treatment for liquid treated by electrolysis

In electrolytically treated liquid, n-Hex varies from 10 to 800 ppm and COD ranges between 500 and 2,700 ppm, so that further treatment is necessary. Filtration with activated carbon and multi-layered sand was carried out as advanced treatment. The result is shown in Table-4.

Table-4 Treatment effect presented by the activated carbon and sand layer filtration

ITEM	ELECTROLYCALLY			RUNNING WATER AMOUNT		TREATED WATER				
SAMPLE	pH	n-Hex	COD	SV	SV	pH	n-Hex	REMOVAL RATE	COD	REMOVAL RATE
EE - 56	8.85	ppm 60	ppm 1212	% 44	% 10.7	8.20	ppm 0.8	% 99.9	ppm 767	% 36.7
FC - 1	8.75	1000	1590	8.8	22.0	8.10	3.0	97.0	740	53.5
GC	6.60	121	727	19.0	42.0	7.20	1.5	87.6	194	73.3
MIXTURE	8.60	122	1190	13.5	33.0	8.15	3.8	68.9	1010	15.1
ACTUAL WASTE LIQUID	7.30	1360	1980	8.2	20.0	7.55	3.0	97.8	804	59.4

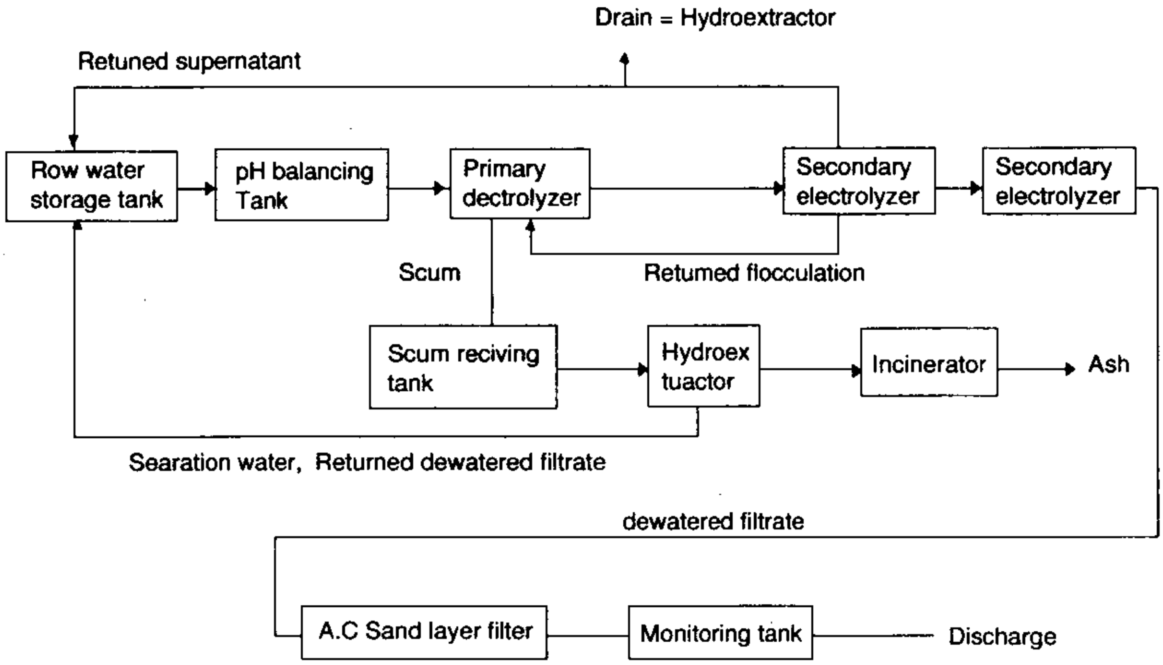
Note) SV = A · C+SAND

The satisfactory result that n-Hex ranged from 0.8 to 3.8 ppm was obtained by employing activated carbon and sand layer filtration. However, selection of activated carbon which is excellent in terms of the adsorption and removal of n-hex and COD is desirable for the future since COD ranges from 194 to 1,010 ppm.

4. Construction of an actual plant

(1) Flow sheet

The following figure shows a basic flow sheet for the oil-contaminated emulsified wastewater mainly composed of water-soluble cutting oil agent.



(2) Construction cost

Table-5 Construction cost

×1,000 yen

	100l/Hr batch	100l/Hr continuous	0.5 m^3/Hr	2 m^3/Hr
Electrolytic	1,230	1,835	2,447	10,628
Dehydration and Incineration	2,660	2,660	3,843	10,469
Total	3,890	4,495	6,290	21,097

Breakdown

(i) Electrolytic equipments

×1,000 yen

	100ℓ/Hr batch	100ℓ/Hr continuous	0.5 m³/Hr	2 m³/Hr
Civil engineering and construction related work	80	90	150	2,275
Machinery related work	660	1,105	1,380	2,816
Piping related work	45	55	80	630
Electric related work	40	40	90	1,260
Instrumentation related work	300	400	510	2,200
Fixed work	50	50	110	200
Varopis expenses	55	95	127	1,247
Total	1,230	1,835	2,447	10,628

(ii) Dehydration and incineration

×1,000 yen

	100ℓ/Hr batch	100ℓ/Hr continuous	0.5 m³/Hr	2 m³/Hr
Civil engineering and construction related work	20	20	80	350
Machinery related work	2,500	2,500	3,500	8,770
Piping related work	15	15	40	70
Fixed work	20	20	40	50
Various expenses	105	105	183	1,229
Total	2,660	2,660	3,843	10,469

(3) Plottage

Table-6 Plottage

	100ℓ/Hr batch	100ℓ/Hr continuous	0.5 m³/Hr	2 m³/Hr
Electrolytic	8 m²	6.5 m²	14 m²	110 m²
Dehydration and Incineration	10 m²	10 m²	12.5 m²	80 m²
Total	18 m²	16.5 m²	26.5 m²	190 m²

(4) Running cost

Table-7 Running cost

CAPACITY				100ℓ/Hr		0.5m^3/Hr		2m^3/Hr	
TREATMENT QUANTITY				800ℓ/D		4m^3/D		40m^3/D	
		UNIT PRICE		USAGE	COST Yen/D	USAGE	COST Yen/D	USAGE	COST Yen/D
Electric Power	For Electrolysis	5Yen/Kwh	maxEE-56	19.48	97.4	4870	487.0	9740	4,870
			min GC	8.0	40	200	200	400.0	2,000
	For power	5Yen/Kwh	—	16.0	80	80	80	110.0	550
98%H_2So_4 FOR pHCONTROL (Kg/D)		16Yen/Kwh	maxACTUAL WASTE LIQUID	0.98	15.68	78.4	78.4	49.0	784
			min GC	0.222	3.55	18.56	18.56	11.6	185.6
Al ECTRODE MATERIAL (Kg/D)		320Yen/Kwh	maxMIXTURE	0.188	60.16	300.16	300.16	9.38	3,001.6
			min GC	0.054	1728	0.268	85.76	2.68	8,576
FILTRATION SAND (ℓ/D)		11Yen/	—	22	242	11.0	121	110.0	1,210
ACTIVATED CARBON (ℓ/D)		160Yen/	—	2	320	10.0	1.600	100.0	16,000
LABOR COST (ℓ/D)		5000Yen/ℓ	—	1		1		2	
TOTAL			max	597.44 yen/D 746.8 yen/m^3		2666.56 yen/D 666.64 yen/m^3		26415.60 yen/D 660.39 yen/m^3	
			min	485.03 yen/D 606.29 yen/m^3		2105.32 yen/D 526.33 yen/m^3		20803.20 yen/D 520.08 yen/m^3	

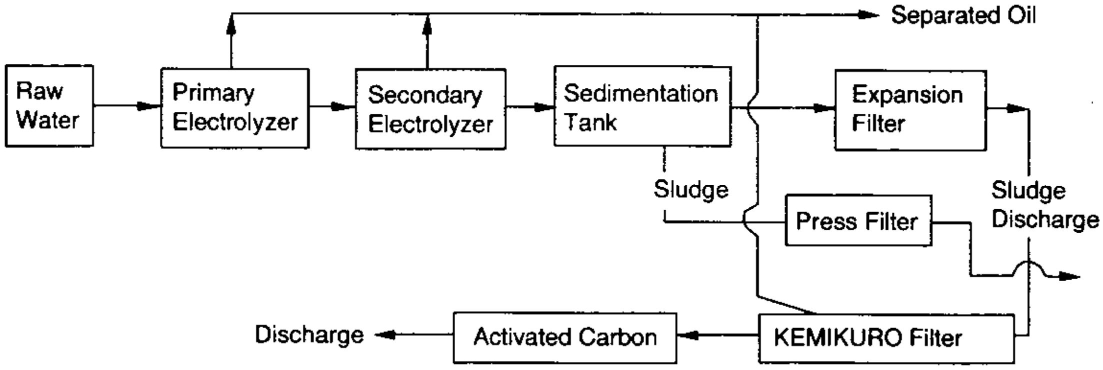
D-4. *Electrolysis Method (entrusted to Mekku Kogyo)*

1. Outline of the research

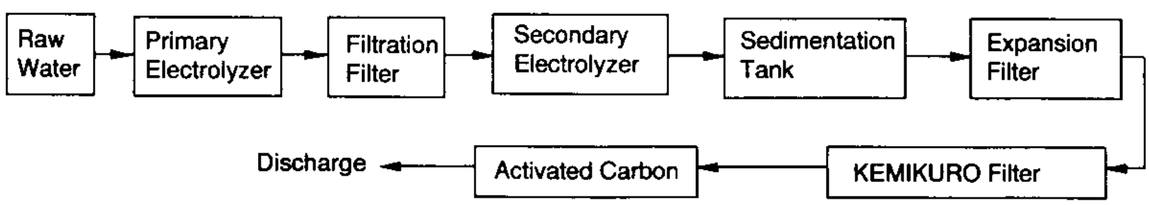
In this method aimed at treating the oil-contaminated emulsified wastewater, the oil separation and coagulation effects are to be enhanced by means of electrolysis, and then secondary treatment by filtration and activated carbon adsorption is to be carried out. As for the method, various examinations were conducted so that economical conditions could be found.

2. Flow sheet

(1) Actual wastewater treatment flow sheet



(2) Beaker test flow sheet (adopted for the synthetic wastewater)



3. Sample properties

Properties of the sample are shown in Table-1.

Table-1 Samples and Properties

	External appearance	pH	SS (ppm)	COD (ppm)	Oil content (ppm)
Actual wastewater	cloudy	9	-	-	47,122
FC-1	cloudy	8	325	11,925	20,888
GC	cloudy	8	370	10,426	25,994
EE-56	cloudy	8	200	13,282	36,638
Mixed wastewater	cloudy	8	283	11,852	34,508

Note) BOD was not analyzed.

4. Results of the research

(1)Examination of the primary electrolysis

(i) Oil content removal

Primary electrolysis is aimed at ereatingan emulsion break, but has little effect on the actual wastewater. However, an oil content removal rate ranging from 80 to 90% was attained in other types of wastewater.

(ii) No particular examination of such matters as bath voltage and bath current was conducted, but the appropriate values appear to be on the order of 3V and in the vicinity of 2A respectively with such an item as running cost in view.

(iii) Set pH

It was made clear that emulsion break was effectively carried out when pH was set on the side of acidity in the case of GC, and on the both sides of acidity and alkaline, namely twice, in the cases of the actual wastewater, FC-1, EE-56 and the mixed wastewater.

(iv) Electrode

Ti electrode and TiPbo2 electrode were used. These electrodes have good conductivity and resistance to corrosion, and can compare with Pt electrode in terms of chemical stability. (The result of their use in a sulfuric acid solution for 2 years has been given.) Slight corrosion was recognized at the edge of the TiPbo2 electrode this time. These electrodes are cheaper than Pt.

(v)Current and the amount of product

Though the current and the quantity of product are generally proportional, the proportional relation did not apply to the emulsified oil-contaminated wastewater. By turning on electricity only for a certain period of time, the reaction was rapidly accelerated, showing similarities to catalytic reaction.

(2)Examination of the secondary electrolysis

(i) The aim of the secondary electrolysis is, by using Al electrode, to flocculate the contained surfactants, etc. which have been turned into low molecular substances by the primary electrolysis. However, the secondary electrolysis is not necessarily required since chemical feeding also appears to be possible. The reason is that the use of Al electrode produces $Al_2(SO_4)_3$ and $AlCl_3$ as reaction products, and these products take the lead in flocs in the same manner as the general addition of chemical.

(ii) Set pH

It was clarified that pH set to 3 or 4 promoted flocculation effectively.

(3) Sedimentation tank and separated oil tank

(i) It is probable that floc is classified into precipitating and floating types, and consequently the tank which is capable of coping with both is considered essential.

(ii) The separated oil tank removes the residual water content, so that one serving as a surge tank as well as a separator is desirable.

(4) Filtration

(i) The expansion filter is equipment for SS removal and removes about 90% of SS.
The KEMIKURO filter, equipment for oil content removal, attains 5ppm or less oil content, which conforms to the effluent standard. However, about 200ppm of the COD remains, which is not within the range of the standard. Consequently, subsequent treatment is required. As for the amount of BOD, it is about 20ppm, and so the standard is fully met.

(5) Activated carbon adsorption

Activated carbon adsorption removes the oil content, enabling the oil content value to be 1ppm or less. However, COD does not always comply with the standard, so that conditions for the use of activated carbon, etc. need to be examined in future.

(6) No particular examination of sludge has been conducted.

[Table of result of each treatment process]

Table-2 Result of theTreatment by Primary Electrolysis

	SS (ppm)	COD (ppm)	Oil content (ppm)
Actual wastewater	945	2,454	33,450
FC-1	90	452.3	1,532
GC	210	521.3	384
EE-56	115	535.3	166.8
Mixed wastewater	141	646	6,213

Note) BOD was not analyzed.

Table-3 Result of the Treatment by Secondary Electrolysis

	SS (ppm)	COD (ppm)	Oil content (ppm)
Actual wastewater	810	213	3,004
FC-1	290	-	-
GC	145	-	-
EE-56	85	-	-
Mixed wastewater	132	-	-

Table-4 Result of the Treatment with an Expansion Filter

	SS (ppm)	COD (ppm)	Oil content (ppm)
Actual wastewater	50	-	364
FC-1	70	460.5	70
GC	45	813	16
EE-56	55	525	8
Mixed wastewater	54	475	9.2

Table-5 Result of the treatment with a KEMIKURO Filter

		SS (ppm)	COD (ppm)	BOD (ppm)	Oil content (ppm)
Actual wastewater	6.8	50	203	15	2
FC-1	7.1	-	247.7	25	5
GC	6.8	-	163.6	12	3
EE-56	6.8	-	175.7	16	2
Mixed wastewater	6.8	-	163	19	5

Table-6 Result of the Treatment by Activated Carbon Adsorption

	External appearance	pH	SS (ppm)	COD (ppm)	BOD (ppm)	Oil content (ppm)
Actual wastewater	slight yellow	6.8	50	2	4	0.5
FC-1	yellow	7.1	65	174.5	14	0.7
GC	slight yellow	6.8	15	29.8	6	1
EE-56	light yellow	6.8	70	117.2	4	0.6
Mixed wastewater	yellow	6.8	53	119	8	1.2

6. Construction cost

Table-7 Construction Cost

	100 /hr	500 /hr	5 m^3/hr
Equipment proper	1,896,000 yen	2,096,000 yen	9,326,000 yen
Machinery related cost	690,000	690,000	1,430,000
On-site expenses	257,000	257,000	624,000
Various expenses	199,000	199,000	372,000
Total	3,042,000 yen	3,242,000 yen	11,752,000 yen

7. Running cost

Table-8 Running Cost

100 /hr	500 /hr	5 m^3/hr
29.36 yen		

Note) Activated carbon cost is not included.

8. Construction area and operation personnel

Table-9 Construction Area and Operation Personnel

	100 /hr	500 /hr	5 m^3/hr
Plottage	10 m^2	10 m^2	100 m^2
Main area	3.5 m^2	3.5 m^2	48 m^2
Operation personnel	1 person	1 person	1 person

E. Comparison of each method

1. Comparison of result for oil-contaminated wastewater.

The Example of comparison of raw water and treated water according to each company is shown as below.

A. Nippon Yuka Kogyo
B. Mitsubishi Kakoki Kaisha, Ltd.
C. Mitsui Engineering & Shipbuilding Co., Ltd.
D. Fuji Kasui Kogyo
E. Daiki Gomu Kogyo
F. Mitsui Metal Engineering
G. Seisui Kogyo
H. Mekku Kogyo
I. National Research Institute for Pollution and Resources
J. Government Industrial Research Institute, Osaka

Table-1 Example of Actual Wastewater from Among the Oil-contaminated Emulsified Wastewater

Item / Company	Raw water					Treated water					Reference
	pH	COD (ppm)	BOD (ppm)	N-Hex (ppm)	SS (ppm)	pH	COD (ppm)	BOD (ppm)	N-Hex (ppm)	SS (ppm)	
A	8.4	9,130	18,600	20,500	-	7.5	96	94.3	13.1	15.3	( ) : After sand Filtration
B	8.4	6,900	894	25,000	-	7.3 (6.9)	624.5 (580)	212.5 (200)	82.5 (50)	81.5 (30)	( ) : After sand Filtration Average value is Used for Treated water
C	7.9	3,230	3,800	2,686 (3,120)	569	8.4 (9.6)	675 (16.3)	65.4 (1.8)	11.1 (0.2)	2.2 (0)	( )For Ran water : Value by IR ( )For Treated water : After Activated Carbon Treatment
D	6.5	1,150	5,100	12,500	165	6.5	124 (126)	250 (93)	24.0 (2.6)	13.0 (8.0)	( ) : After Activated Carbon Treatment
E	6.7	1,318	1,470	3,250	1,310	6.8	114.5	83.7	24.6	5	
F	8.5	5,440	7,066	34,150	-	-	379	439	25	-	
G*	7.7	6,970	-	3,210	-	7.3 (7.6)	1,980 (840)	-	136 (3)	-	( ) : After Activated Carbon Sand Filtration Treatment
H	9.0	-	-	47,122	-	6.8 (6.8)	203 (2)	15 (4)	2.0 (0.5)	50 (50)	( ) : After Activated Cabon Treatment Others : After Kemikuro(?) filter
I	9.8	-	-	10,200	-	7.4 ~ 8.4	2,590 ~ 4,510	763 ~ 4,190	44 ~ 76	100 ~ 300	Water quality of Treated water Varies with Type of Aosorbent
J*	7.9	2,970	2,000	3,626	-	-	500	-	5 ~ 150	-	Water quality of Treated water Varies with Type of Aosorbent

Note) A~D : Physical and Chemical Miethod, E~H : Electrolytic Method, I~G : Adsorption Method

* G and J represent D Industrial Wastewater. (Wastewater from car manufaoturing plants)

2. Comparison of facility construction cost

The construction cost of up to secondary treatment according to each company is as below.

Table-2 Comparison of the Construction Cost

(Unit : 1,000 yen)

Physical and chemical treatment method				Electrolytic method			
Company	0.1 m^3/H	0.5 m^3/H	5 m^3/H	Company	0.1 m^3/H	0.5 m^3/H	5 m^3/H
A	2,000	2,600	4,700	E*	6,800	10,800	22,500
B	15,100		15,800	F*	5,000	7,000	19,000
C	31,200	33,900	43,100	G*	1,835	2,447	18,000 ~ 20,000
D	4,000	7,000	12,000	H	3,042	3,242	11,752

Note) Incineration facility for froths is not included. (*) : Secondary treatment is not included.

3. Running cost

The running cost per 1m^3 of liquid concentrate is as follows.

Table-3 Comparison of the Running Cost

Adsorbent treatment method		Physical and chemical treatment method	Electrolytic method
(Adsorbent use cost)		A. 960 - 3,720 yen	E. 110 yen
NYUKATORE No1. and No.2	1,550 - 5,200 yen	B. 484	F. 617
B-20	9,350 - 27,500	C. 218	G. 200 - 340
TAICLEAN	1,500 - 4,200	D. 295 - 341	H.
GUREZIN	1,650 - 4,675		
MONMORIRONAITO	750		
(including chemical cost)			

Note) The running cost on the scale of 5 m^3/H is shown as for the physical and chemical treatment method and the electrolytic method. Chemical cost varies with the kind of waste liquid. Activated carbon use cost is not included.

4. Required plottage

The required plottage according to each company is shown as below.

Table-4 Required Plottage

Physical and chemical treatment method				Electrolytic method			
Company	0.1 m^3/H	0.5 m^3/H	5 m^3/H	Company	0.1 m^3/H	0.5 m^3/H	5 m^3/H
A☆	1.0 m^2	2.8 m^2	18.9 m^2	E	5.3 m^2	16 m^2	27.6 m^2
B☆	15		28	F◎	6	10	40
C	100	150	600	G※	16.5	26.5	190
D	50	100	200	H	10	10	100

Note) ※: An incineration facility is included. ☆: Surrounding vacant land is not taken into consideration.
◎: The area of pits is not included.

5. Operation personnel

Table-5 Operation Personnel

Unit : operation personnel / time to spend on facility for 1 day

Physical and chemical treatment method				Electrolytic method			
Company	0.1 m^3/H	0.5 m^3/H	5 m^3/H	Company	0.1 m^3/H	0.5 m^3/H	5 m^3/H
A	1 person/4H	1 person/4H	1 person/4H	E	1 person/4H	1 person/4H	1 person/4H
B	1 person/2H	1 person/2H	1 person/2H	F	1 person/2H	1 person/2H	1 person/2H
C	1 person/8H	1 person/8H	*3 persons/8H	G	1 person/8H	1 person/8H	1 person/8H
D	1 person/8H	1 person/8H	1 person/8H	H	1 person/8H	1 person/8H	1 person/8H

Note) * : An incinerator and dehydration related equipment are included.

F. Reference (Bubble Association Method ... entrusted to the Cargo Transport Research Society)

1. Outline of the research

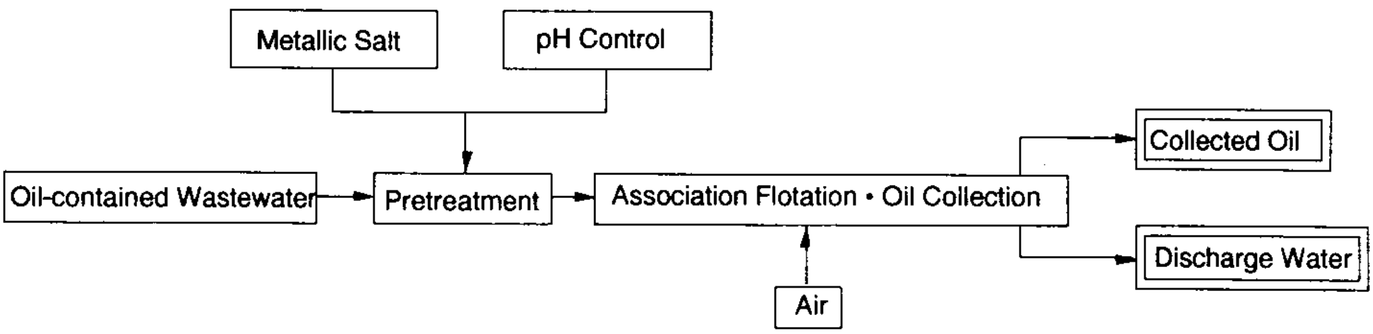
This method is considered effective in removing a fine particle oil drop which is conventionally seen as a problem in terms of the oil-contaminated wastewater treatment. As for the method, various matters related to the processes from pretreatment to subsequent treatment, which include liquid properties of wastewater, the amount of liquid and draft volume at the time association flotation, filtration equipments, etc., are to be clarified.

Note) What is the bubble association method?

It is a method derived from the experience that when oil-contaminated wastewater was agitated with bubbles, a fine-grained oil drop was gradually turned to a coarse-grained one by the bubbles and floated to separate.

The mechanism of turning the oil drop to a coarse grain is regarded as a process by which the fine grained oil drop is associated with others to become an oil drop and floats on the surface of the water at either the stage of oil drop coagulation on the gas liquid interface between the bubbles and water layer or the stage of bubble breaking on the surface of the water.

2. Flow sheet



3. Samples and properties

Experiments were made on the oil -contaminated wastewater mentioned below.

(1) For a laboratory .... About 1g of heavy oil A was dropped and agitated for about 30 min. (water volume : 1r)

(2) Actual wastewater ...... Oil-contaminated wastewater from a certain hot rolling mill

(3) Oil-contaminated emulsified wastewater....... diluted solution of cutting oil agent FC-1 manufactured by Daido Kagaku Kogyo by a factor of 25

Table-1 Actual wastewater composition example and experiment setting example

Experiment No.	N-H extraction (ppm)	SS (ppm)	COD (ppm)	TOC (ppm)	Contents of experiment		
					Treatment amount m³/hr	Air volume m³/min	Liquid properties
1	101	310	9.4	88.2	1	0	
3	57.9	44.0	14.3	60.5	2	0.3	
5	7,850	648	35.2	566	1	0.5	$CaCl_2$ 0.01% pH 7.5
6	756	620	32.9	681	2		

Note) Table-1 is an example that describes the liquid concentrate analytical value and experiment setting conditions concerning the actual wastewater(b)from among the oil-contaminated wastewater to be studied.

4. Results of the research

The elementary experiment confirmed that treatment of the sample (c)(oil-contained emulsified wastewater) by bubble association was impossible. That is to say, in the case of emulsification, the existence of added surfactant prevents the mutual contact and coagulation of oil particles, and consequently bubble association (?) can not turn the oil drop to a coarse grain. The following description, accordingly, presents the results of the experiment on treatment of the wastewater containing floating oil and dispersed oil.

(1) Research on liquid properties (beaker test)

As shown in Figure-1, Figure-2 and Table-2, the association and flotation speed of dispersed oil drops is markedly accelerated by the pH of water layer or addition of inorganic salt at the time of bubble association and when the wastewater is left as it is .

Wastewater left as it is

Table-2 Residual oil content concentration when the wastewater is left as it is (5 days later)

Liquid properties	pH 3.1	pH 4.0	pH 4.99
Oil content concentration	113 (ppm)	47.5	75.0
pH 6.3	pH 7.0	pH 9.0	pH 11.2
57.5	180	105	106
$CaCl_2$ 0.1%	$Al_2(SO_4)_3$ 0.1%	NaCl 3%	Seawater
77.5	37.5	36.5	46.3

Note) The initial concentration is in the order of 500 ppm in every case.

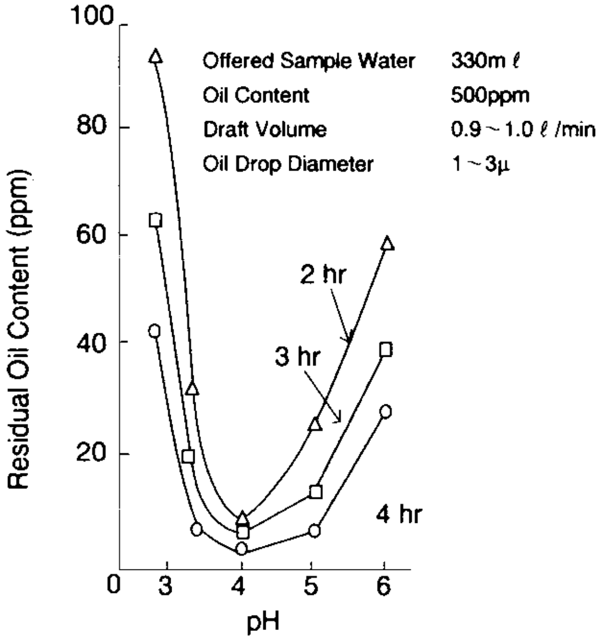


Figure 1 Influence of pH
(at the time of draft)

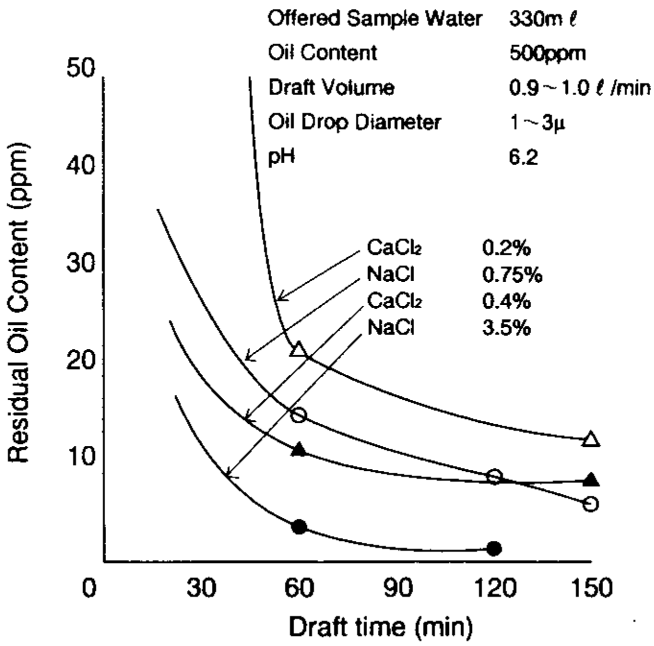


Figure 2 Influence of inorganic salt
(at the time of draft)

(2) Research on bubble association

The effect of oil content treatment by bubble association is affected by the air amount besides the aforementioned primary factors related to liquid properties and the optimum unit amount varies with the composition of liquid concentrate. Consequently, research is required under a variety of circumstances.

Table-3 Oil content removal by bubble association (primary treatment)

Experiment No.	1	3	5	6
Liquid concentrate concentration (ppm)	101	57.9	7,850	756
Liquid treated by bubble association (ppm)	68	14.5	43.0	53.0
Oil content remaining rate (%)	67.3	25.0	0.5	7.0

An excess of air leads to the strong effect of liquid agitation with bubbles and the unfavorable tendency of dispersed oil drops coagulated on the gas liquid interface of bubbles to peel off.

(3) Others

(a) Secondary treatment (filtration)

The result of filtration with a pressure filter is shown as an example in Table-4.

Table-4 Oil content removal by filtration (secondary treatment)

Experiment No.	1	3	5	6
Primary treatment liquid concentration (ppm)	68	14.5	43.0	53.0
Secondary treatment liquid concentration (ppm)	16.4	3.1	24.6	18.6
Oil content remaining rate (%)	24.1	21.4	57.2	35.1

As indicated in the table, the wastewater with high SS content is not completely treated, and so some measures including settling of the wastewater at the stage of pretreatment need to be examined from this time on.

(b) Filler

Lightness of a material, compact in volume, smoothness on the surface, and shape that allows distortion of flowing of bubbles and water are the required factors for filler. According to these conditions, net-shaped based on the expanding method were selected. (Other materials for comparison are polyurethane foam, plastic corrugated cardboard and anthracite.)

(c) Collection equipment for floating oil

In cases where floating oil content is minimal, shaking on the surface of the liquid caused by bubbles greatly deteriorates the effect of collecting the floating oil with an oil collection belt. Consequently, thoughts need to be given to such matters as stabilization of an oil layer by overflow and the operational procedure in which oil is collected after the oil layer is made thicker.

V. Conclusion

This committee has applied itself closely to the examination aimed at elucidating various technical and economic problems, in order to realize the treatment for oil-contaminated emulsified wastewater containing water soluble cutting oil agents. The oil-contaminated emulsified wastewater is discharged by the metal-products manufacturing industry, and the nonferrous metals and nonferrous metal alloy rolling industries. The treatment is aimed at attaining a value equal to or below the effluent standard stipulated by the Water Pollution Control law. As seen in the interim report, each treatment methods had problems to be solved, and on that account, the research into various treatment methods was entrusted to 13 companies through the Environmental Pollution Control Service Corporation. The reports on the research were examined, and generally the following results were obtained.

1. Electrolytic method

The electrolytic treatment is very effective, but the standard stipulated by the Water Pollution Control Law is not satisfied in every method. The activated carbon treatment as secondary treatment and a method such as filtration with a special filter as a supporting means are effective. In this case, not only removal of the oil content but that of COD (chemical oxygen demand) arising from an addition agent for cutting oil is extremely difficult.

2. Salting-out method

The initial object is not attained only by salting out, necessitating activated carbon treatment in addition. Removal of COD is not sufficient.

3. Coagulation method

In all cases, namely coagulating sedimentation, coagulating flotation, and coagulation and sand filtration, the target value is not attained only by primary treatment. Activated carbon filtration or activated carbon adsorption is required as secondary treatment. Though there is a fluidized bed type activated carbon adsorption method in which COD is removed by activated carbon filtration, the economical aspects still need to be examined. The method of filtration by adding activated carbon as an adsorbent appears to be relatively easy.

4. Adsorption method

As primary treatment, adsorption by using MONMORIRONAITO which is a special adsorbent is recognized as effective. Treating the special adsorbent is very costly.

5. Bubble association method

The bubble association method is considerably effective in cases of wastewater containing dispersed oil. It has little effect on the oil-contaminated wastewater mainly composed of emulsifying oil.

6. Grain size distribution measurement

The grain size distribution generally ranges from 1 to 10m and mostly from 2 to 3m . There is no particularly big change when the water is left standing on standing.

7. Sludge treatment

(1) Every treatment method produces sludge in considerably large quantities. In this case, emulsion break by acid dissolution or salting out aimed at partially separating the oil content greatly reduces the amount of sludge. The production eminently varies with the kind and amount of the chemical to be added.

(2) Since the filtration and dehydration efficiency of the sludge is not very good, a precoat filter is suitable.

(3) The heat of the sludge ranges between 4,000 and 10,000 cal/kg, and so the sludge is almost autogenously combustible.

8. Others

(1) Though accurate comparison of the construction cost is difficult since the adopted estimate range is not necessarily the same from company to company, the cost tends to be higher when a stronger treatment effect must be obtained.

(2) The running cost for the adsorbents (except for MONMORIRONAITO) is extremely high. As for other treatment methods, the running cost is relatively low provided that only a primary treatment is employed.

(3) All methods require approximately the same

(4) The required plottage greatly varies with the method.

Based on the above-mentioned results, the following can be said, in summary :

1) Considerably effective treatment is possible by employing the electrolytic and coagulation methods, but secondary treatment is necessary in both of the methods.

2) Activated carbon treatment and filtration with a special filter are effectual as secondary treatment.

3) In simultaneous removal of the oil content and COD by the activated carbon method as secondary treatment, the removal of COD is attended by equipmentywith remaining problems if economical aspects are taken into consideration.

4) Though the fluidized bed type activated carbon filtration method has a great effect as secondary treatment, problems yet remain if it is as a of considered ad method for small-

to-medium-sized enterprises, since its construction cost is high and the activated carbon needs to be recycled.

5) Though the secondary treatment with a special filter is easy and economical, it is not very effective in terms of COD removal and involves problems of maintenance including clogging.

The following issues were indicated by the results, and it appears that sufficient examination of them for the future is needed.

1) Disposal of the scum produced by primary treatment and disposal of the separated oil also need to be examined.

2) Development of secondary treatment needs to be expedited with stress laid on new technology including the activated carbon treatment. In the case of the activated carbon treatment in particular, selection of cheap and efficient activated carbon is required with priority given to technical examination of the durability of the activated carbon's activity and regeneration of the activated carbon.

3) In the case of the electrolytic method, such issues as prevention of a film from being produced on the electrodes and checking of the degree of the electrodes' consumption due to long-term continuous use need to be examined by conducting research based on long-term continuous running.

4) To thoroughly establish the compact and economical technology suited to small-to-medium-sized enterprises, development of the comprehensive technology including scum disposal, separated oil disposal and secondary treatment is needed. To this end, the combustion method needs to be studied from a new point of view.

5) The results of the examination conducted this time tell that the removal of oil content and COD involves many problems which are considerably difficult. Consequently, judging from the viewpoint of pollution control, some consideration needs to be given to the kind and amount of the surfactant which is added to cutting oil and is a causal substance of COD. It appears that the consideration of those issues will make the treatment much easier.

Closing statement

As mentioned above, it has been made clear that the oil-contained emulsified wastewater containing water-soluble cutting oil, which is one of the most difficult types of wastewater to treat, can be treated to the target level of water quality by a primary treatment composed of coagulation a electrolytic methods and a secondary treatment composed of the activated carbon method. Although development of new emulsion breakers is in progress at this time and favorable results of the development are anticipated, there are still lot of problems to be solved for the future. It appears that the most effective treatment method has not yet been determined, and only an examination of the results of the research commissioned is reported this time.

Appendix 1

Various Oil-contaminated Wastewater Treatment Methods

I Physical Treatment Method

1. Gravity separation

(1) Natural separation

① API oil separator
② PPI oil separator
③ CPI oil separator

(2) Coarsening separation

① Coalescer
② ON type oil separation system
③ WOSEP
④ Polypropylene

2. Filtration

(1) KEMIKURO filter

(2) Ceramic filter

(3) Deep filter tank

3. Adsorption

(1) Activated carbon

(2) WOSEP

II Physical and chemical treatment method

1. Coagulating sedimentation method

2. Coagulating flotation method

3. Flotation method

4. Electrolytic method

(1) Flotation separation method
(2) Sedimentation separation method

5.Photooxidation method

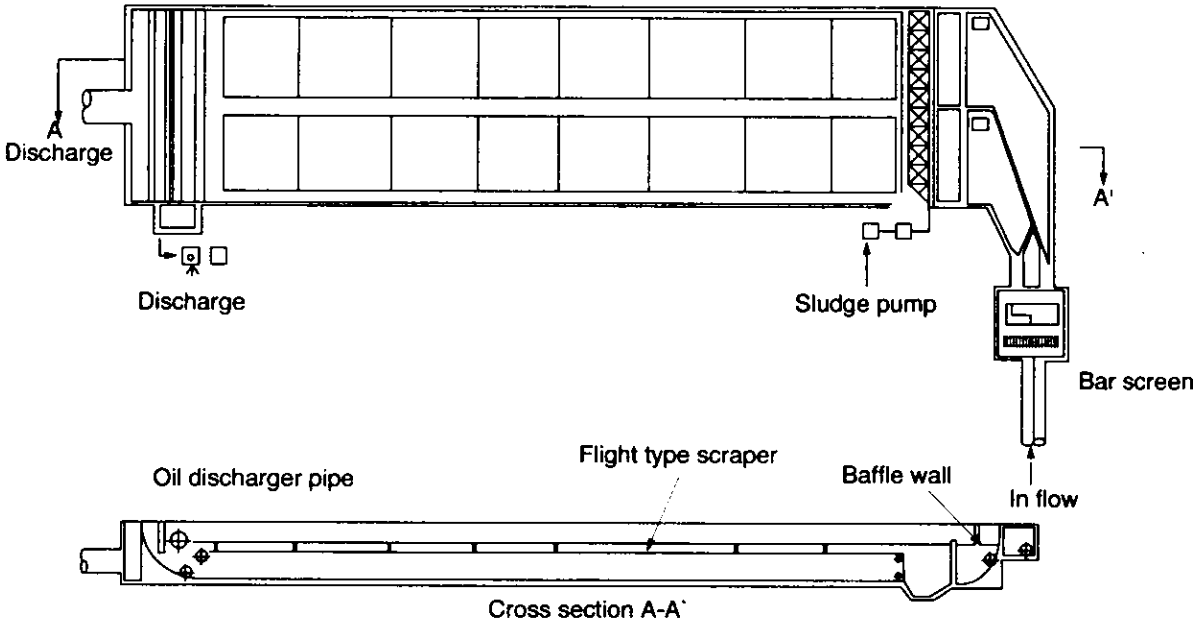
III Biochemical treatment method

IV Combustion method

V Treatment method of each company

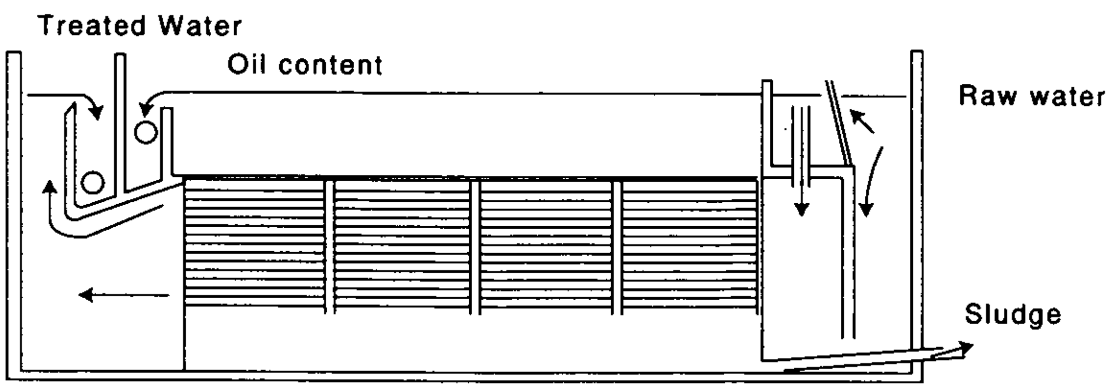
I-1.-(1)- ① API oil separator

This is an overflow type oil separator based on the API manual, and many of the separators are conventionally employed. The critical particle diameter of oil content is around 150m . The suspended matters which are contained in the oily water and easily settle can be removed. The separator is used as pretreatment for other treatment equipments since a fair amount of residual oil is contained in the treated water . A schematic diagram of the separator is shown on the next page.



I-1.-(1)- ② PPI oil separator

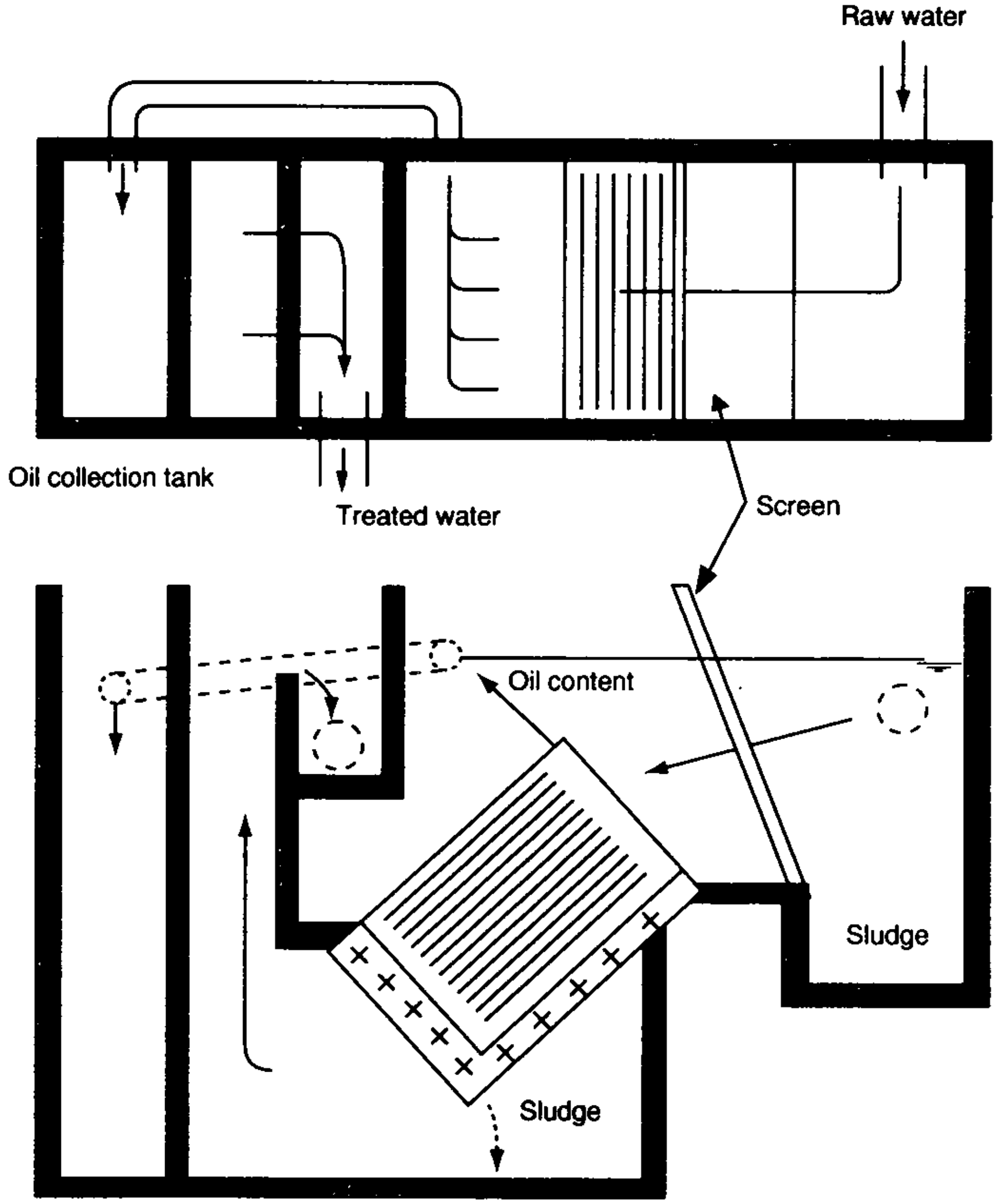
This is an improved API oil separator. Many inclined plates are inserted in the flowing direction, so that the separation effective area per free water surface of the equipment can be increased, and the efficiency of the equipment can be improved by the flow rectification effect. The critical particle diameter is around 60m, and the required area for the equipment can be decreased sharply as compared with API. A schematic diagram is shown below.



I-1.-(1)- ③ CPI oil separator

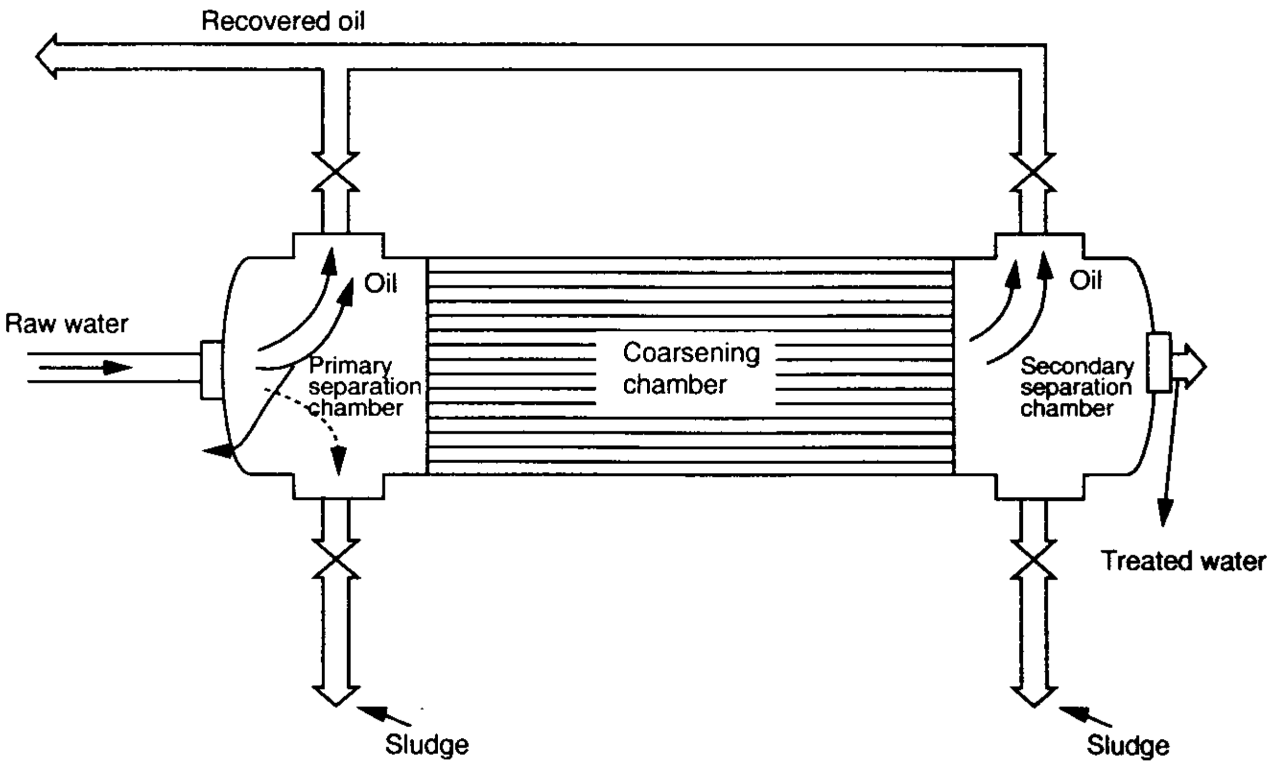
This is a further improved PPI oil separator in which the corrugated iron inclined plates are inserted. The critical particle diameter is around 60m like in the case of the PPI oil separator, so that the installation area can be smaller.

There are MWS oil separator and TPI oil separator as an improved oil separator of this type. A schematic diagram is shown below.



I-1.-(2)- ① Coalescer (coarsening equipment)

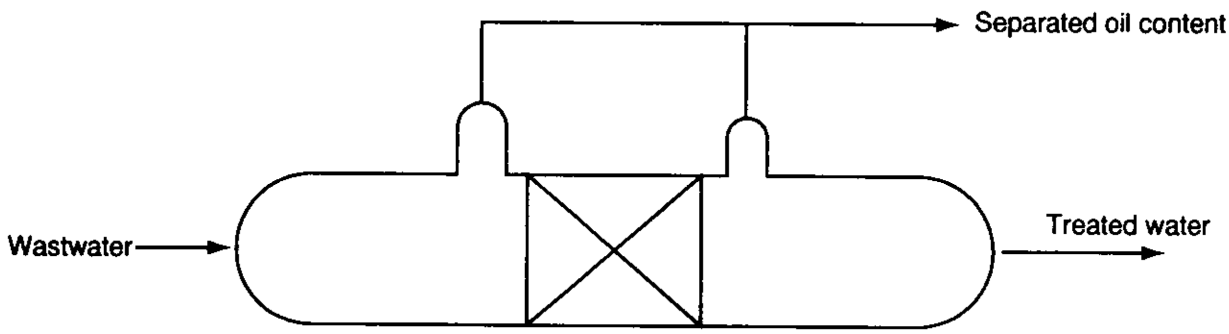
The coalescer is an oil separator based on the coarsening method which was developed by Mitsubishi Heavy Industries, Ltd. Since the coalescer has high separation efficiency and is compact and easy to operate as compared with conventional treatment equipment, it is widely used at such places as domestic oil refining plants, thermal power plants, and vessel waste oil treatment facilities. The critical particle diameter is 10m, and there are some cases where treatment that can attain the value of 10ppm and less is possible only by the coalescer. The coalescer consists of a primary separation chamber, a secondary separation chamber and an oil basin. The coarsened elements which are oilproof and corrosion-resisting materials are accumulated and filled in the coarsening chamber. In contrast to the conventional oil separators which simply separate by means of the flotation speed owned by oil particles, the coalescer is characterized by the fact that it gathers inflowing fine oil drops at numberless coarse grain elements in the coarsening chamber, coarsens them, and increases the flotation speed steeply to conduct separation. A schematic diagram is shown below.



I-1.-(2)- ② ON type oil-contaminated wastewater treatment equipment

A Treatment method

Fine oil drops in the water are absorbed by an oil adsorption separation agent (a solid produced by processing raw oil in a peculiar way and molding it) and are recovered by natural separation as large oil drops. A schematic diagram is shown as below.



B Characteristics

(a) The oil content is completely removed.

(b) The equipment is simple and requires the least construction cost and area.

(c) The equipment applies to every type of oil and enables a wide range of application, which is efficient.

(d) The operation is automatic and human hands are not needed.

(e) The equipment is flexible enough to cope with a steep change in the volume and concentration of raw water.

(f) The durability of the adsorption separation agent varies form 1 to 3 years.

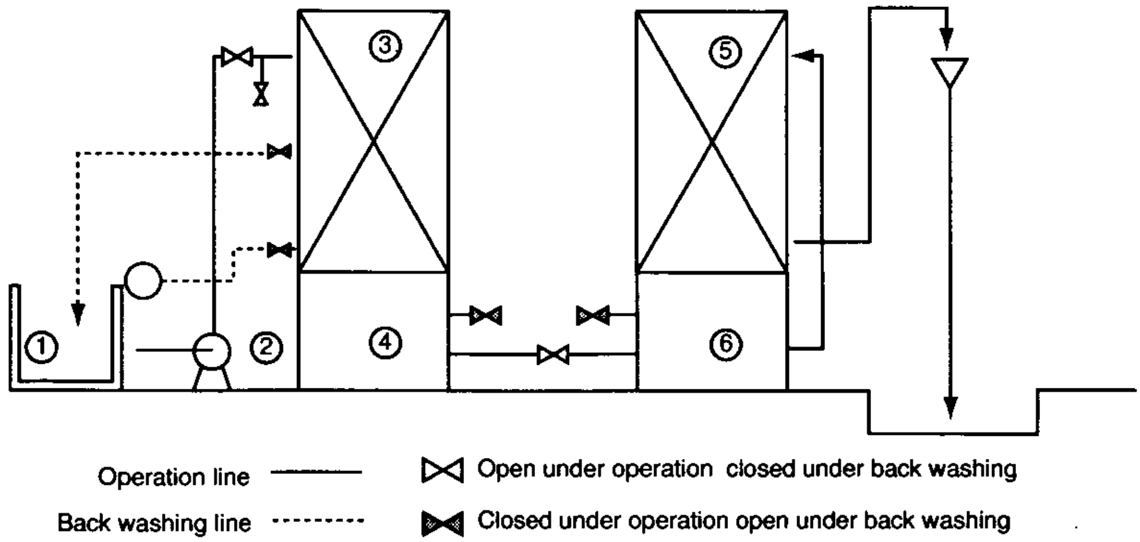
(g) The running cost ranges between 2 and 3 yen/m^2.

(h) Reuse of water oil is possible.

I-1.-(2)- ③ WOSEP

A Treatment method

The oil-contaminated wastewater is stored in the raw water tank ①, and after the oil content and sludge have setlled and roughly separated in the tank, the wastewater is supplied to this equipment. The oil countant and sludge are supplied from the raw water tank ① to the sludge filter ③ by means of the pump ②, and once in, they are captured and removed by WOSEP filling material (a cube sugar-size cut piece of the oleophilic felt oil adsorption material for which a special polymer is used). At the same time, the fine oil content is adsorbed and coarsened when going through the filter. The coarsened oil flows together with the mother water into the decanters ④ and ⑥, and here the coarse grained oil floats and separates. Most of the oil contained in the wastewater is removed here and discharged by a batch method at the upper nozzles of the decanters ④ and ⑥. The separation of oil by coarsening and settling calmly, which uses the filter and decanters, works as a buffer against a change in the oil concentration of raw wastewater and equalizes the oil concentration of the wastewater flowing into the oil adsorption tower ⑤. As the wastewater further flows in to the oil adsorption tower ⑤ and (flows) down through WOSEP filling material inside the tower, a trace amount of oil content is adsorbed and removed by the filling material and is discharged at the bottom of ⑤ to the outside of the equipment. Since long-term running of the sludge filter ③ causes accumulation of sludge, the sludge in the filter is periodically discharged by back washing. A operation is carried out based on the back washing mechanism. The schematic diagram is shown as below.



B Characteristics

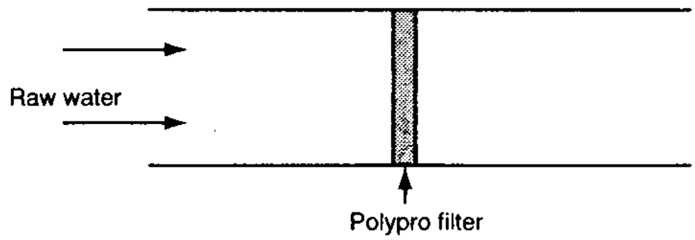
(a) Suspended oil particles and sludge can be almost perfectly removed.
(b) The range of applicable oil types is wide, which is efficient.
(c) The equipment has sufficient flexibility to absorb a sharp change in the raw water concentration.
(d) Since the treatment is physical, secondary sludge is not produced. Besides, the recovered oil does

not change in quality and can be reused.

(e) Consumption of WOSEP is minimal and incineration of waste WOSEP does not produce toxic gas. Accordingly, subsequent treatment is easy.
(f) The maintenance cost is low.
(g) The compact equipment is light and easy to move, and so it is suitable for individual treatment at a source of oil-contaminated wastewater.

I-1.-(2)- ④ Polypropylene

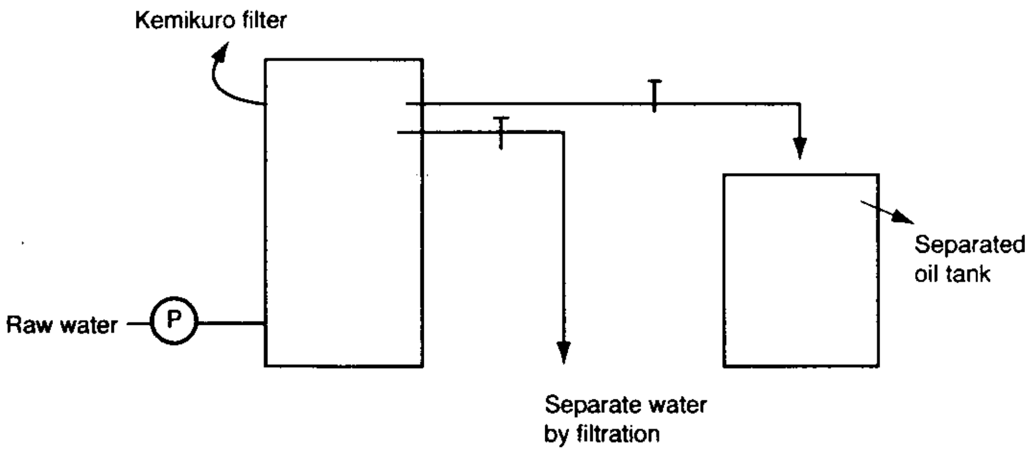
The oil-contained wastewater passes through the filter for which polypropylene is used and the fine particles adhering to the surface of the filter are coarsened when infiltrating and increase their flotation speed to separate.



I-2.-(1) KEMIKURO Filter

A Treatment method

This is a filtration method with a special filter which filters water out of the mixed solution of water and oil, but not oil.

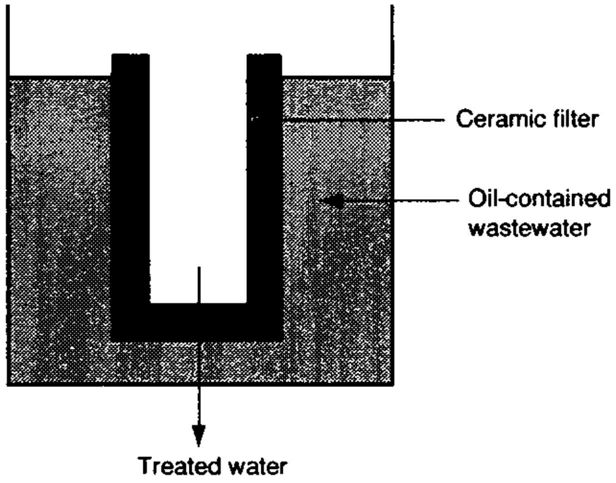


B Characteristics

(a) It is a filter made of cotton under a chemical reaction and has a long life unlike one coated with
such a material as resin.
(b) Since the filter is hydrophilic and repels oil, the filtration resistance to water is small and the filtration
resistance to oil is great. Accordingly, it is suitable for oil separation.
(c) The oil content does not adhere for the most part.
(d) The construction cost is low.

I-2.-(2) Ceramic filter

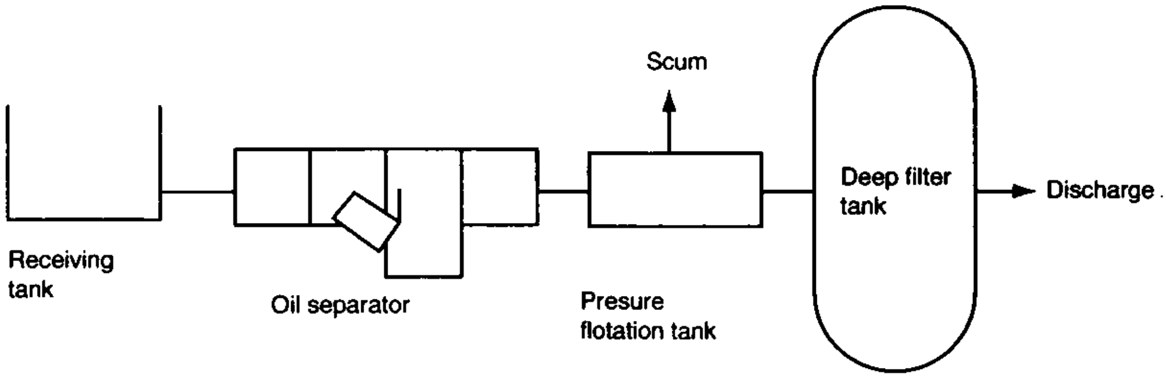
A cylindrical ceramic product with pores infiltrates under the pressure of the natural osmotic pressure level. Back washing is carried out for oil sticking to the surface.



I-2.-(3) Deep filter tank

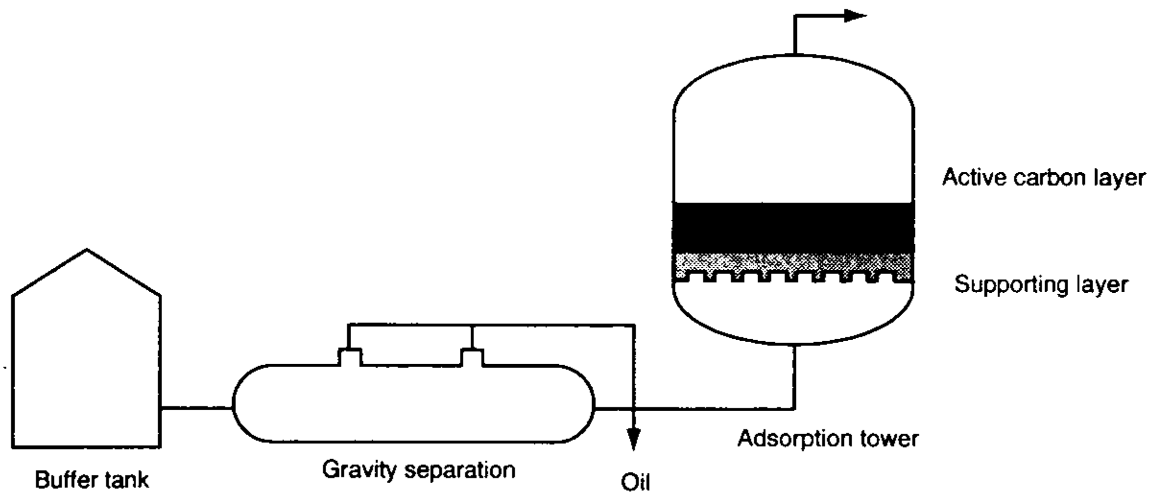
The wastewater from which oil is roughly separated in the receiving tank is extracted at the bottom of the tank and introduced to the process of oil separation. The oil separator as primary treatment, the pressure flotation equipment as secondary treatment, and the filter tank using sands, etc. as fillers as tertiary treatment are employed. As for most of the waste oil, this method enables the oil concentration of wastewater to be 5 ppm and less. The emulsified waste oil can be treated for the most part usually by a combination of flotation and a filter tank.

As tertiary treatment, the reverse osmosis method can also be considered.



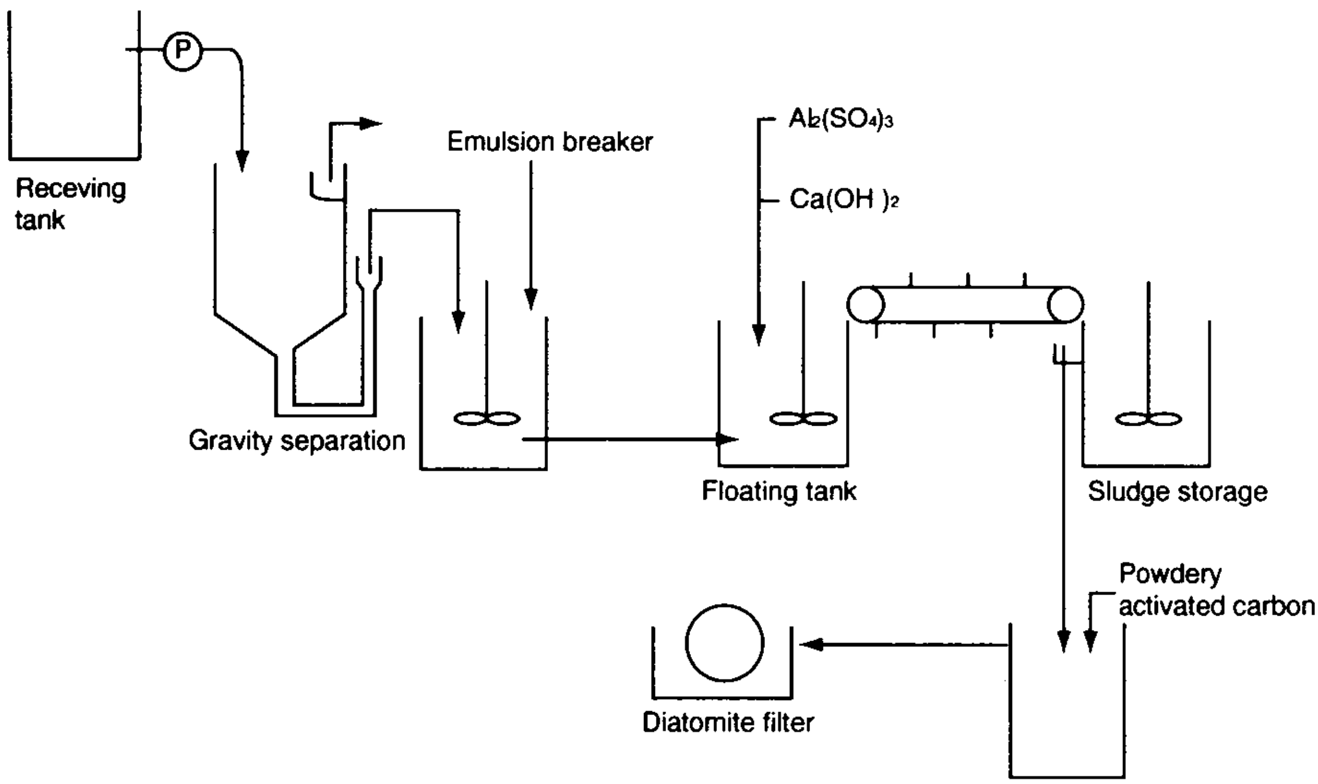
I-3.-(1) Activated carbon adsorption method (1)

Adsorption and removal are carried out by using granular activated carbon. (fluidized bed)



I-3.-(1) Activated carbon adsorption method (2)

An emulsion breaker is added to the separated water after gravity separation, and pressure flotation follows. Powdery activated carbon is added to the treated water, and the water is dehydrated by means of a diatomite filter.



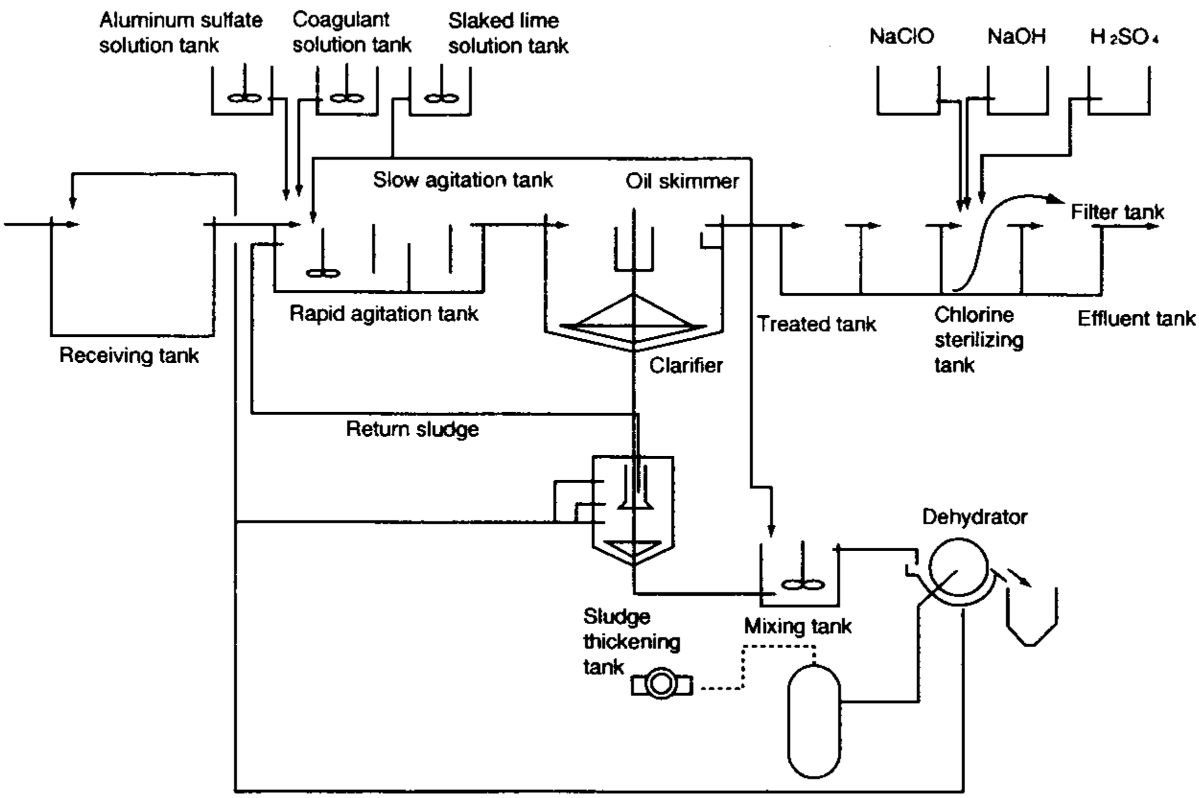
I-3.-(2) WOSEP

The same as I-1.-(2)- ③.

II-1. Coagulating sedimentation method

Aluminum sulfate or another type of coagulant is added to the wastewater. Flocs produced

Coagulating Sedimentation Treatment Method

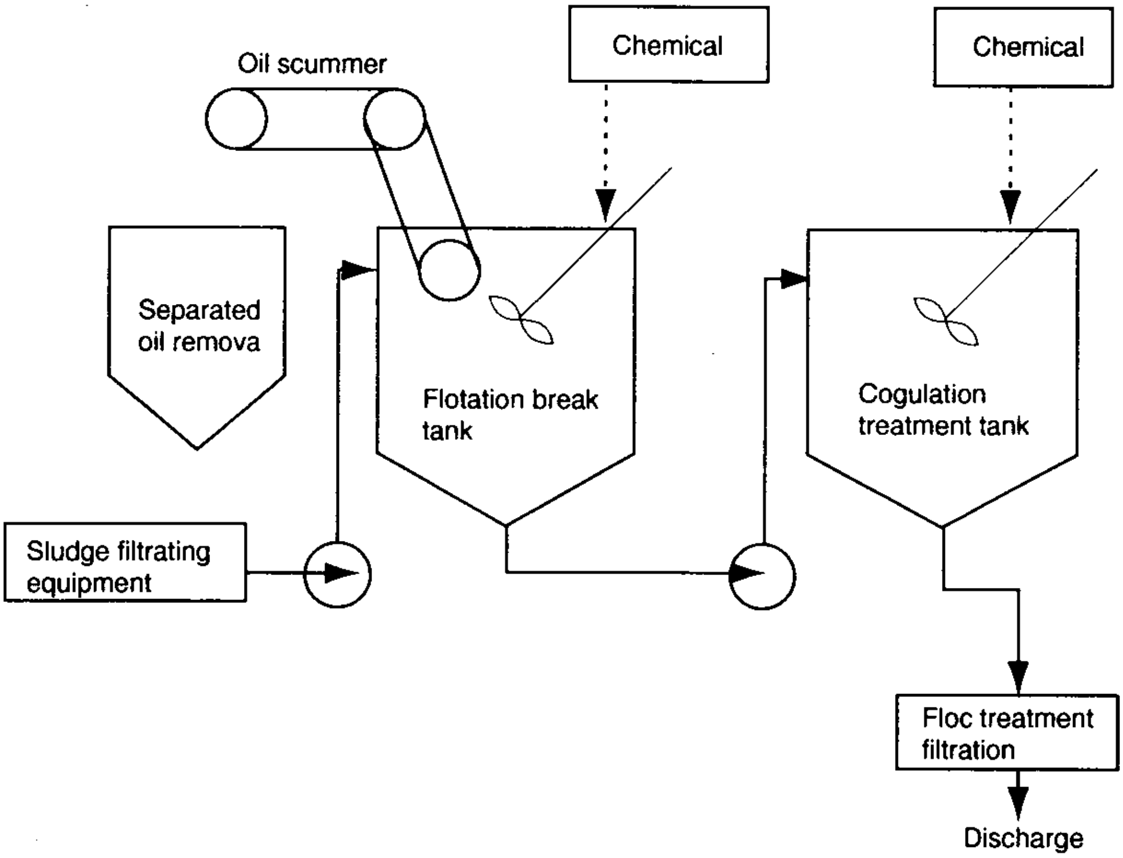


II-1. Coagulating sedimentation method (2) (YUMACLEAN)

A Treatment method

The sludge in the wastewater is removed while the wastewater is introduced to the primary tank, and the oil made free by emulsion break is removed by the oil skimmer. After the lower layer water is moved to the secondary tank, the residual oil content flocculated with a coagulant coagulates and settles.

A schematic diagram is shown below.



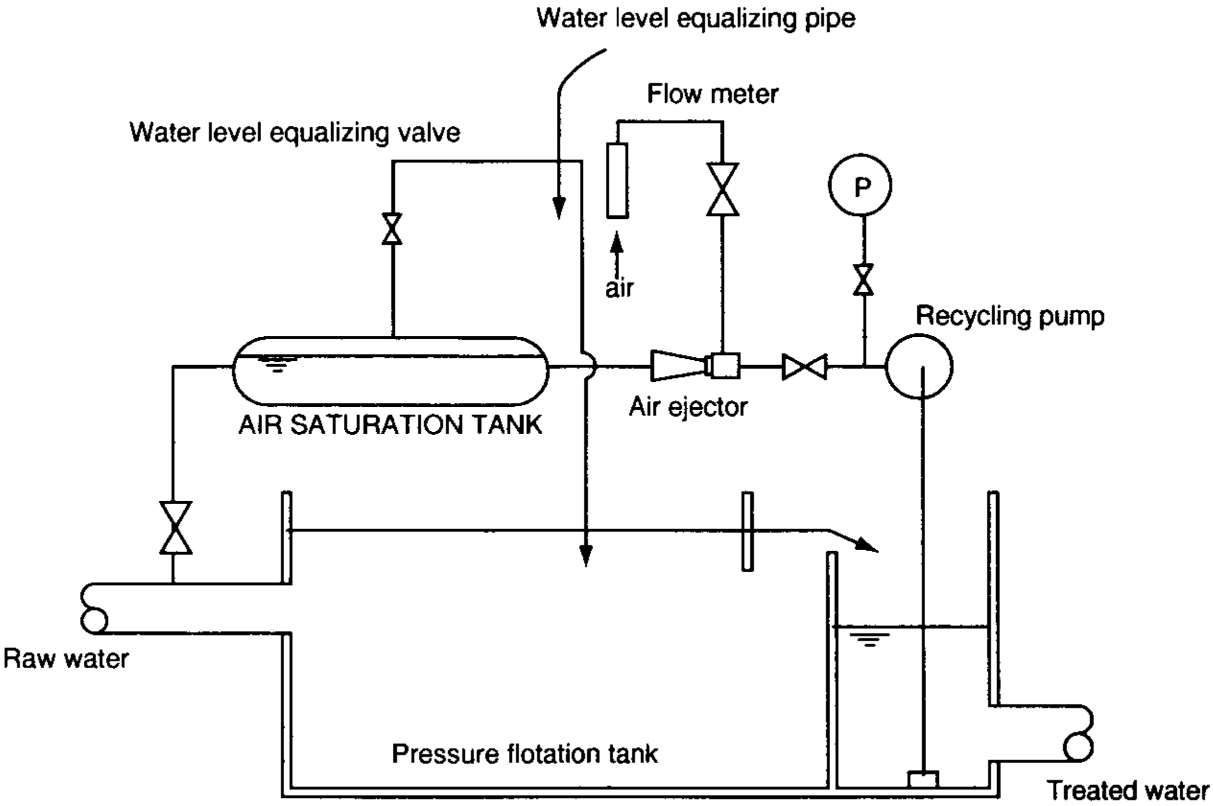
B Characteristics

(a) Being small in size, the equipment does not require much space.
(b) The price is low and the treatment accuracy is high.
(c) Since this is batch type, equipment of the treatment accuracy is stable.
(d) The running cost ranges from 70 to 400 yen/m^3.
(e) The operation is simple and the maintenance is not troublesome.
(f) This equipment is exclusively for the treatment of emulsified oil which is considered the most difficult to treat.

II-2. Coagulating flotation method (1)

This is the method in which the produced floc that is a metallic hydroxide adsorbs, bubbles and the floc floats by the buoyancy. The method brings the wastewater into contact with air and accelerates adsorption to the utmost extent. Small bubbles are made in as large quantities as possible to prevent agitation so that the adsorbed oil can float quickly and can not escape during of flotation.

A schematic diagram is shown below.



II-2 Coagulating flotation method (2) (NYU KATORE)

A Treatment method

NYU KATORE is a separation agent which aims to break the wastewater containing emulsified oil completely and has two types, namely No.1 and No.2.

The oil adhering to NYUKATORE floats.

B Characteristics

(a) The removal rate is high.

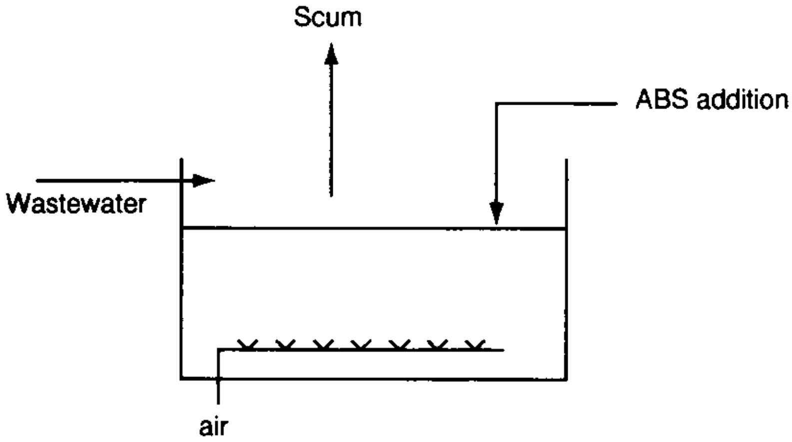
(b) The reaction time is extremely short.

(c) Treatment is possible regardless of the wastewater temperature.

(d) There is no need to control pH.

II-3. Flotation method

By adding the surfactant (ABS) as a foaming agent and aerating, the oil is adsorbed by bubbles and removed.

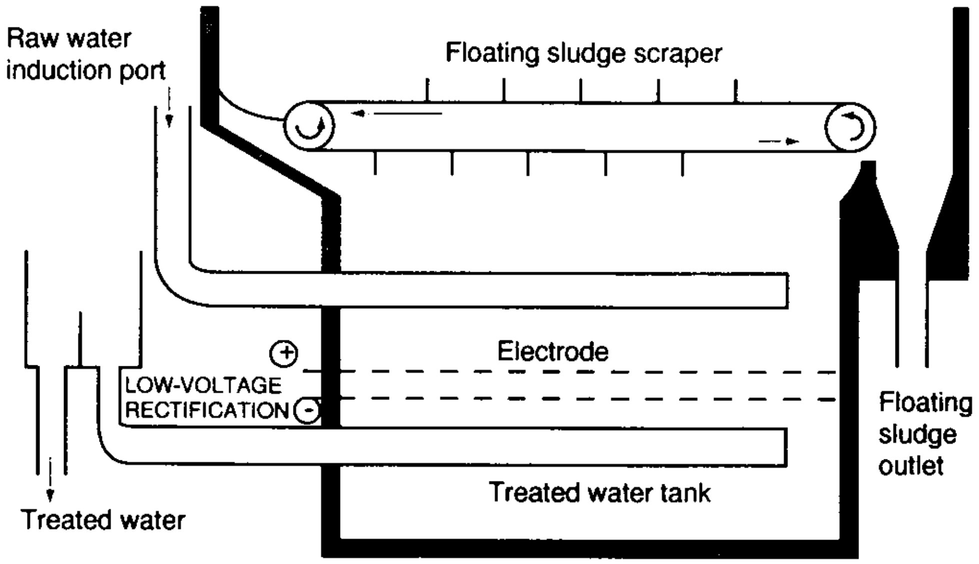


II-4.-(1) Electrolytic flotation separation method (1)

A Treatment method

Flotation is conducted by applying low voltage to the electrodes inside the electrolytic flotation tank and by causing the hydrogen and oxygen bubbles produced by electrolysis to adhere to the suspension. Small bubbles whose capability of adhering to the suspension is large can be obtained in large quantities by a little electricity, and the suspension floats on the surface of the water due to the adhesion of bubbles and is thickened.

The sludge separated and thickened on the surface of the water in the flotation tank is removed by using a seraper. A schematic diagram is shown below.



B Characteristics

(a)Since the diameter of a bubble is small ranging from 50 to 70m in comparison with the pressure flotation method (100 to 150m), and the capability of the bubble to the adhere to the suspension is large, treated water with high degree of clarification can be obtained.

(b)The floating sludge concentration is high.

(c)Side streams necessary for the pressure flotation method are not required, so that the volume and installation area of the flotation tank are small.

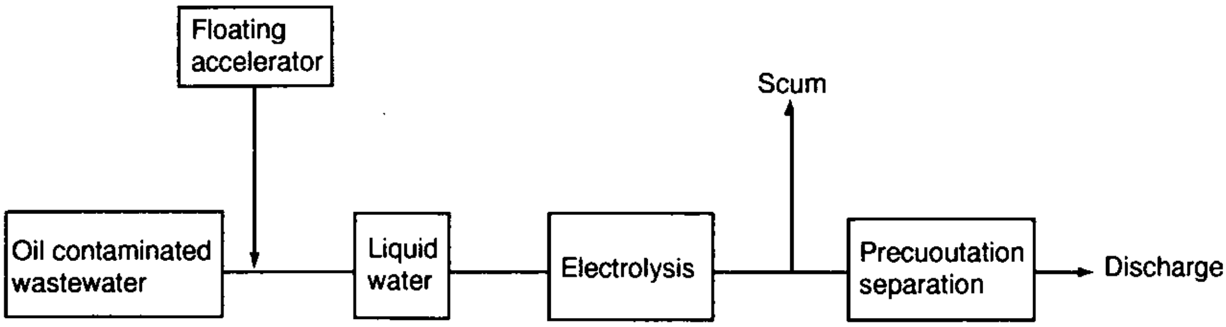
(d)The maintenance and management are easy and unmanned operation is possible.

(e)Structurally, scaling up is easy.

II-4.-(1) Electrolytic flotation separation method (2)

A Treatment method

Oil flotation is conducted by forcebly breaking emulsion by electrolysis and with colloidal hydrogen bubbles which are secondarily produced at the time of electrolysis.



B Characteristics

(a) The floor area of a tank is 1/20 to 1/10 that of a conventional thickener and the like.

(b) Only solid-liquid separation is possible by conventional sedimentation and pressure flotation methods,
but this method separates ions, too.

(c) Simultaneous removal of heavy metal is possible.

(d) Since the colloidal hydrogen bubbles with low specific gravity are used, the clarification level is
remarkably high and the separation efficiency is high as compared with a conventional separation
method.

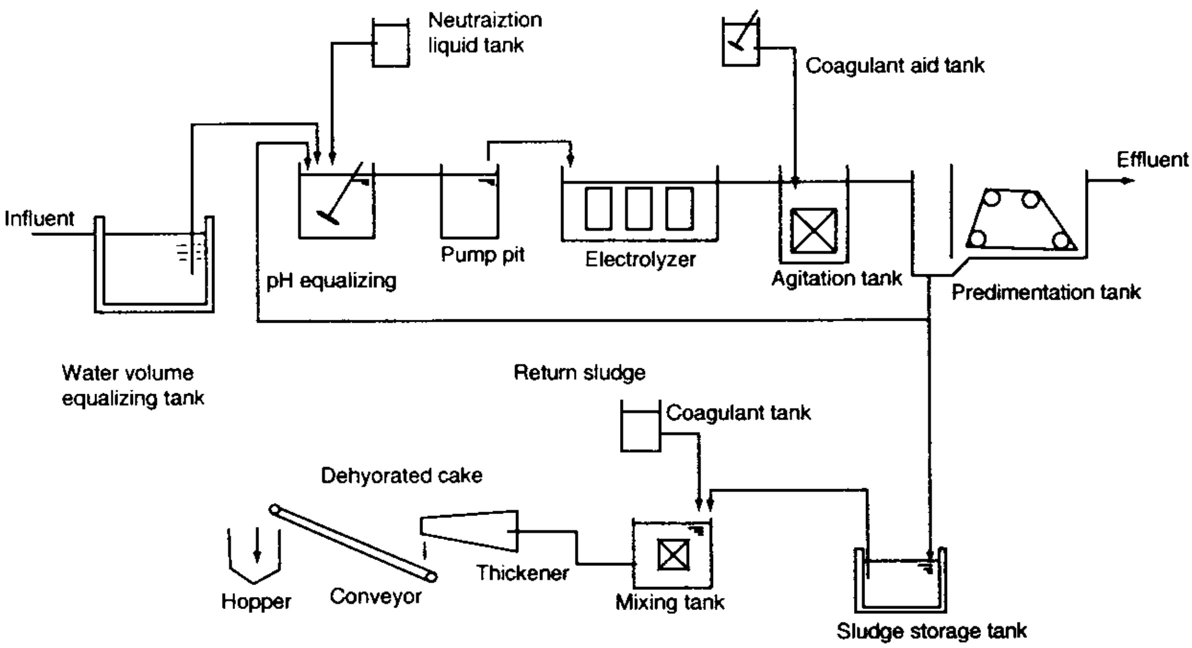
(e) A rise or fall in the wastewater concentration can be controlled by increasing or decreasing the voltage density, so that a change in the treated water can be easily dealt with.

II-4.-(2) Electrolytic sedimentation flotation method

A Treatment method

Direct current electricity with high current and low voltage is applied to the electrodes made of special aluminum plate, and elution of aluminum is caused by the electrode reaction. Then, water of the wastewater is decomposed to produce hydrogen and oxygen, so that the treatment is available. Polluted particles in the water adsorb the aluminum ion produced by electrolysis, and accordingly the polluted particles which have been negatively electrified become neutral electrically, lose their mutual reacting power, coagulate and settle.

A schematic diagram is shown as below.



B Others

Other electrolytic methods include one with a catalyst and one that treats oil and ABS separately.

II-5. Photo-oxidation method

A Treatment method

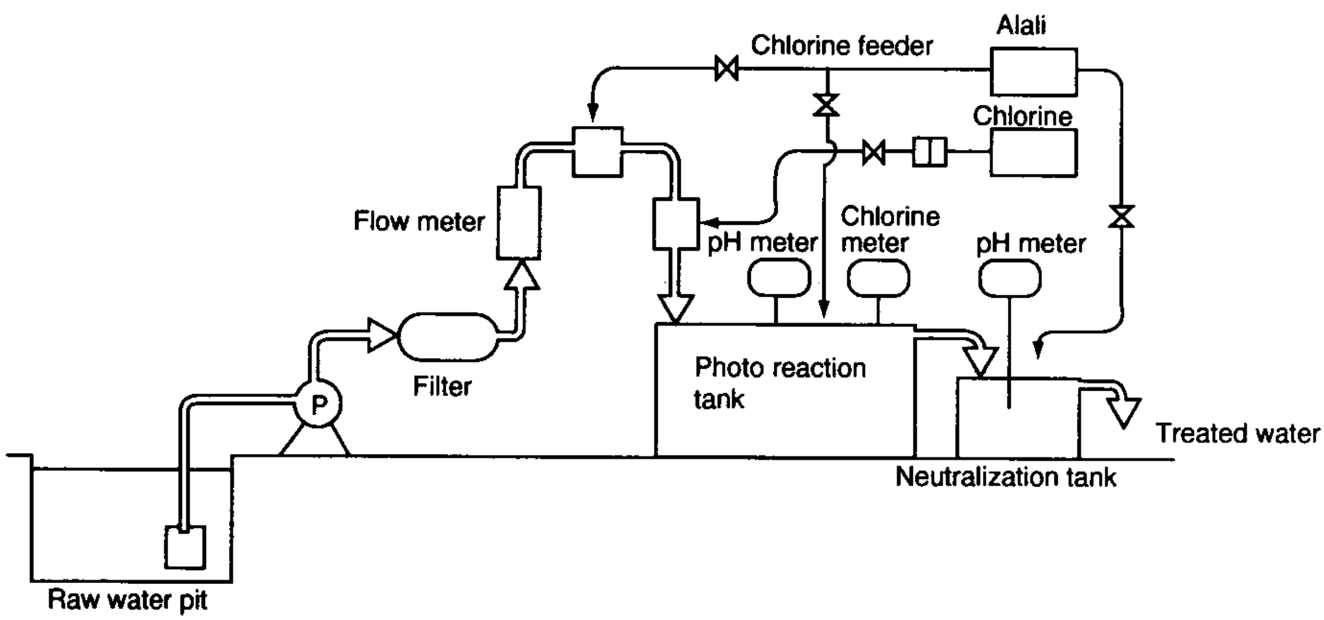
This method aims to decompose and treat polluted matters in the wastewater by strong oxidation power which is composed of both a light and an oxidizer. The method usually employs chlorine which is cheap as an oxidizer and ultraviolet rays as a light.

As for the oil-contained wastewater, the strong oxidation power also makes oxidative degradation of dissolved matters and a trace amount of oil possible.

B Characteristics

(a) The oxidation power is very strong.
(b) Advanced treatment is possible.
(c) The range of applicability of the method is wide.
(d) An equipment for the method can be compact.

Outline of Flow

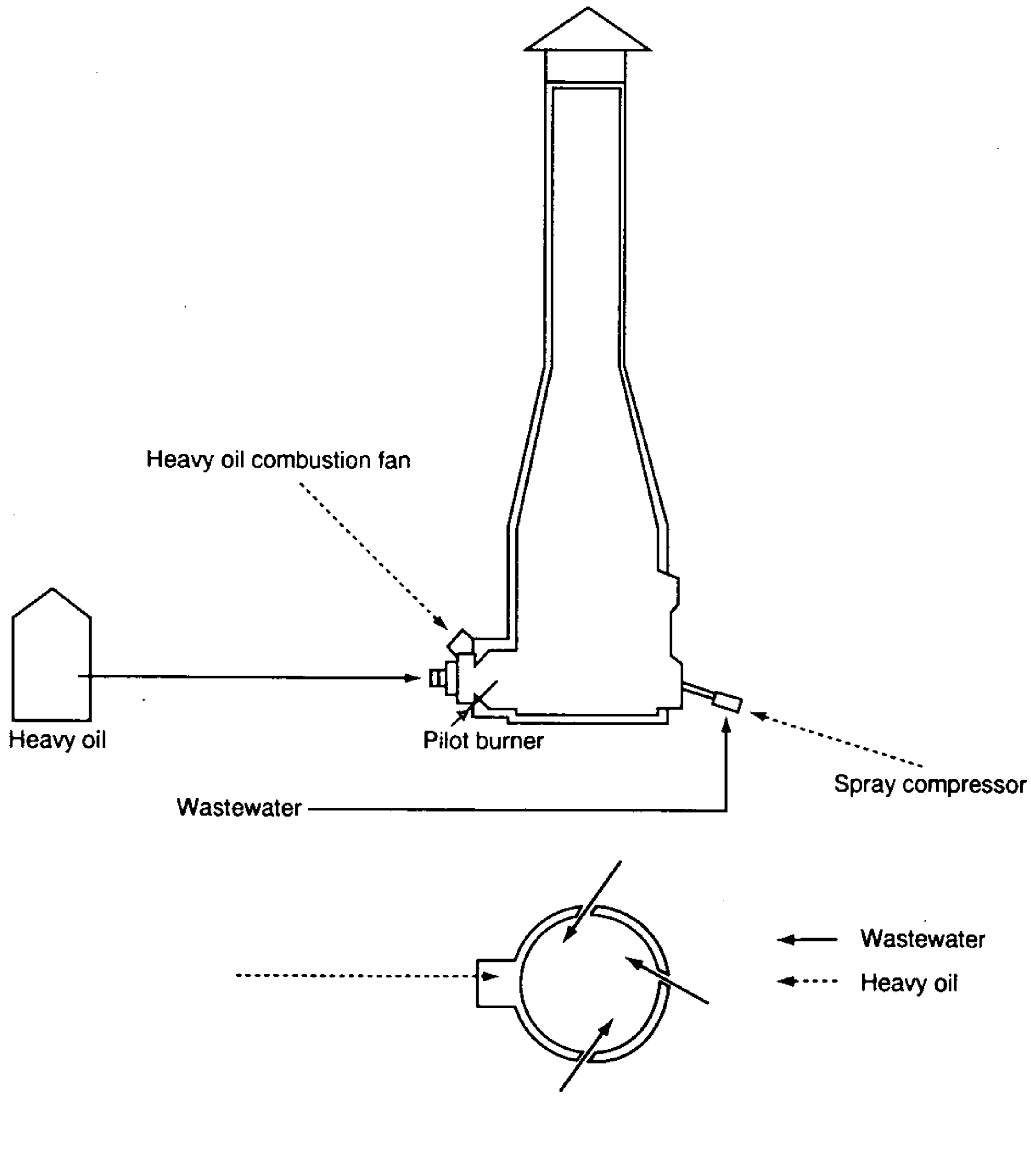


III Biochemical treatment method

The biochemical treatment achieves the purification action seen in the natural world for a short time by breeding microorganisms under certain conditions and is represented by the activated sludge method with aerobic microorganisms.

IV Combustion method

The wastewater is atomized with air by using supplementary fuel, so that it is fed into a furnace and burned.



V Treatment method of each company

(No special order is observed.)

Company name	Treatment method	Reference
Toyo Rayon Engineering	WOSEP	
Chiyoda Corp.	PPI oil separator, CPI oil separator	
Mekku Kogyo	Electrolytic flotation method, Kemikuro filter	
Orugano	On type oil-contained wastewater treatment, Activated carbon adsorption method	(ON type) Joint development with Nippon Oil Co., Ltd.
Mitsubishi Kakoki Kaisha, Ltd.	TPI oil separator, Pressure flotation method, Deep filter tank	
Sumitomo Envirotech	Electrolytic flotation method	
Mitsui Metal Engineering	Electrolytic flotation method	
Nippon Kihatsuyu	API oil separator, PPI oil separator, CPI oil separator	Cooperation with Ltd. sludge method Imamura Mfg
Mitsubishi Heavy Industries	Coarsening equipment (Coalescer), Activated Cooperation	
Ishikawajima-Harima Heavy Industries Co., Ltd.	MWS oil separator, Flotation method, Filter, Polypropylene filter	
Noritake Co., Ltd.	Ceramic filter	
Fuji Kasui Kogyo	Activated carbon adsorption method	
Kurita Water Industries, Ltd.	Combustion method	
Ebara Infiruko	Activated sludge method, Pressure flotation method, Reverse osmosis method	
Mitsui Engineering & Shipbuilding Co., Ltd.	Activated sludge method, Coalescer, Activated carbon adsorption method	
Chugai Furnace Kogyo	Combustion method	
Okumura Machinery Mfg	Coagulating sedimentation method	
Nippon Risui Kagaku Research Institute	Electrolytic sedimentation method with catalyst	
Sannetsu	uma clean (Coagulating sedimentation)	
Tochigi Fuji Sangyo	Electrolytic sedimentation method	
Mitsui Mining & Smelting Co., Ltd.	Nyu Katore	
Toho Rayon Engineering	Photo oxidation method	

Appendix 2

August 28, 1972

Mr. Toshio Eguchi
Chief Director
Environmental Pollution
Control Service Corporation

Osamu Katsuki
Chairman
Committee on Oil-contained
Wastewater Treatment Technology

Interim Report on the Oil-contaminated Wastewater Treatment Technology

As a result of the varied examination of the above-mentioned subject conducted by this committee, among a number of presently advocated technical methods of treating the oil-contaminated wastewater mainly composed of water-soluble cutting oil agent, the ones mentioned below appear to be economically promising. However, they still have problems to be solved for the future, and accordingly we ask you to conduct the investigation assigned as per attached outline and to submit the results to this committee by February 15, 1973.
The oil-contaminated wastewater caontains floating oil and dispersed oil, or sometimes a large amount of waste oil, or emulsifying oil. Accordingly, we also ask you to arrange documents concerning those types of wastewater and to present treatment methods with the aforementioned report.

Description

1. Electrolytic method
2. Salting-out method
3. Use of coagulation method and adsorption method in combination
4. Adsorption method
5. Bubble association method
6. Grain size distribution measurement

Appendix

Outline of the Research Study Commissioned on Oil-contaminated Wastewater Treatment Technology

I Purpose of the Research Study Commissioned

The purpose is to elucidate technical and economic problems in order to develop treatment for oil-contaminatd emulsified wastewater discharged by the metal-products manufacturing industry, the general machinery and equipment manufacturing industry, and the nonferrous metal and nonferrous metal alloy rolling industries.

II Contents of the Investigation and Researches

1. Electrolytic method

(1) Research on the electrolytic treatment

The relevance of such variation factors as the structure of the electrolyzer, electrolytic conditions, electrode materials, the kind and amount of addition agent, and sludge flotation or sedimentation treatment conditions to the properties of treated water and of sludge is to be made clear.

(2) Research on sludge dehydration

The dehydration efficiency of sludge and the combustibility of dehydrated sludge are to be clarified.

2. Salting-out method

(1) Research on the salting-out treatment

The relevance of such variation factors as chemical amount, air volume, and agitation conditions for a reaction tank to the properties of treated water and of sludge is to be made clear.

(2) Research on sludge dehydration

The dehydration efficiency of sludge and the combustibility of dehydrated sludge are to be clarified.

(3) Research on filtration

The efficiency of filtration with a rotary drum (vacuum dehydrator) is to be made clear.

3.Use of coagulation method and adsorption method in combination

(1) Research on the coagulation treatment

The relevance of such variation factors as the kind and amount of coagulant, treatment conditions, and sludge separation methods to the properties of treated water and of sludge is to be clarified.

(2) Research on the adsorption treatment

The relevance of such variation factors as the kind and amount of adsorbent and treatment conditions to the properties of treated water, and an adsorbent recycling method are to be made clear.

(3) Research on sludge treatment

The dehydration efficiency of sludge and the combustibility of dehydrated sludge are to be clarified.

4. Adsorption method (B-20, NYUKATORE, MONMORIRONAITO)

(1) Research on the adsorption treatment

The relevance of such variation factors as the kind and amount of adsorbent, treatment conditions, and a means of recovering saturation adsorbent to the properties of treated water and of saturation adsorbent is to be made clear.

(2) Research on treatment of saturation adsorbent

The combustibility of saturation adsorbent is to be clarified.

5. Bubble association method

The relevance of such variation factors as the structure of the separation tank, a means of recovering floating oil, air amount, and the retention time to the recovered floating oil and treated water is to be made clear.

6. Grain size distribution measurement

The grain size of oil drops is to be measured by using an automatic grain size distribution measuring device.

III Object of the research study commissioned

The object is to be the oil-contained emulsified wastewater containing water-soluble cutting oil agent.

IV Period of the research study

October 10, 1972 - January 31, 1973

V Parties entrusted with the research study

1. Electrolytic method

(1) Nippon Risui Kagaku Research Institute

(2) Mitsui Metal Engineering

(3) Daiki Gomu Kogyo

(4) Mekku Kogyo

(5) Seisui Kogyo

2. Salting-out method

Nippon Yuka Kogyo

3. Use of coagulation method and adsorption method in combination

(1) Mitsui Engineering & Shipbuilding Co., Ltd.

(2) Fuji Kasui Kogyo

(3) Mitsubishi Kakoki Kaisha, Ltd.

4. Adsorption method

(1) Government Industrial Research Institute, Osaka

(2) National Research Institute for Pollution and Resources

5. Bubble association method

Cargo Transport Research Society

6. Grain Size Distribution Measurement

Ishikawajima-Harima Heavy Industries Co., Ltd.

VII Contents of the report of research study commissioned

1. Resultant data of the research study

(1) Treatment conditions of all sorts

(2) Analytical values of raw wastewater and of wastewater in every treatment process

(pH, N-Hex soluble content, COD, BOD, SS)

(3) Sludge

(a) Production volume
(b) Dehydration efficiency
(c) Combustibility (heat value)

(4) Others

2. Examination

Examination based on experimental data

3. Facility to treat oil-contained wastewater in the capacity of 100 ℓ /hr, 0.5m^3/hr and 5m^3/hr respectively (8 hours per day)

(1) Flow sheet

(2) Construction cost

(3) Running cost

(4) Construction area

(5) Others