

**FY1998
RESEARCH SUMMARY
OF
WATER QUALITY CONTROL DEPARTMENT**

OCTOBER 1999

**WATER QUALITY CONTROL DEPARTMENT
PUBLIC WORKS RESEARCH INSTITUTE
MINISTRY OF CONSTRUCTION**

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**FY1998
RESEARCH SUMMARY
OF
WATER QUALITY CONTROL DEPARTMENT**

**WASTEWATER SYSTEM DIVISION
ADVANCED WASTEWATER TREATMENT DIVISION
SLUDGE MANAGEMENT DIVISION
WATER QUALITY DIVISION**

Synopsis:

Although full content of each research is presented in Japanese in the Annual Reports of Public Works Research Institute, Ministry of Construction, abstract of each research is being published in both Japanese and English. In this Research Summary, researches carried out by four Divisions of Water Quality Control Department in Fiscal 1998 are briefly introduced .

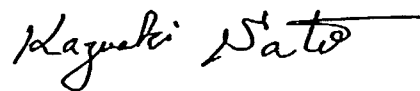
Key Words: Wastewater System, Wastewater Treatment, Advanced Wastewater Treatment, Wastewater Sludge, Water Quality Control

PREFACE

Researches carried out by four Divisions of Water Quality Control Department in Fiscal 1998 are briefly introduced in this Research Summary. Although full content of each research is presented in Japanese in the Annual Reports of Public Works Research Institute, Ministry of Construction (Technical Memorandum of PWRI No. 3661), abstract of each research is being published in both Japanese and English. Since we have several tens of foreign visitors to the Water Quality Control Department each year to exchange views on water quality control engineering each other, English version, though abstract, is considered useful for that.

Researches introduced in this Research Summary of FY 1998 were funded through Research & Study Expenses, Study Funds for National Pollutational Control Research Institutes, Global Environment Research Program Budget, Research Funds for Sewerage & Sewage Purification Programs, Research Funds for River Construction & Improvement Programs, Funds for Construction Technology Research and Development, Applications from Regional Construction Bureaus, and Special Coordination Funds for Promoting Science and Technology.

Although these funds have different purposes in each research from theory to practice, the results are obtained through intensive studies and are all useful to effectively promote water quality control. Hopefully, more intensive exchange of views in water quality control engineering is to be promoted through this Research Summary.



Kazuaki Sato, Director
Water Quality Control Department
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Ministry of Construction

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CHARACTERISTICS OF DEPOSITS IN SEWERS

K.Sasabe, R.Himono, T.Toyoda, T.Horie
Wastewater System Division

Project period: FY1997 - 1999

OBJECTIVES

Sediments in sewers cause such problems as preventing flow, producing bad odor and corroding pipes. Therefore, the design method should be considered not to produce sediments or the maintenance method also be considered to convey once quickly. Here, this study aims to develop a design methodology of sewers preventing the sediments building up. Principle characteristics of sediments and process of sedimentation from examined. Also cause of sedimentation and influence of sediments were.

RESULT

The influence of sediments to sewage property was studied in 1998. This study was focused to the behavior of hydrogen sulfide, which causes various problems are for sewer maintenance and management. This study estimated the amount of sulfide product from sediments, and evaluated the transformation of ones to hydrogen sulfide. Furthermore, it studied the behavior of sulfate-reducing bacteria, which causes the sulfide generation.

(1) Experiment of sulfide generate

For the transformation from sediments change of sulfide amount was measured in experimental reactor and sulfide generation rate was computed. And sample used was raw wastewater of existing treatment plant. Three reactors used were 1000 mm high and 300 mm diameter each. One reactor was for control, and the others were for experiment. The experiment was carried by following procedure.

- ① It places quietly after introducing sample into reactors. Sediments in control reactor was withdrawn.
- ② For other two reactors, wastewater was introduced until the rate of sediments and water became about 1:2 by expectation.
- ③ After confirming accumulation sample was agitated.
- ④ While sample was extracted to seven incubator bottle for each reactor.
- ⑤ Total sulfide and resolved sulfide of each bottle were measured at 0, 30, 60, 90, 120, 150 and 180 minutes later, respectively.
- ⑥ At last, volume, SS, VSS of sediment in each reactor were measured.

By this experiment, hourly change of total sulfide and resolved sulfide were compared and sulfide generation rate was computed. The more sediment was contained; there was more generation speed of the sulfide. The generation rate of total sulfide was 0.93mg/l·hr, 1.28mg/l·hr and 1.39mg/l·hr for 40mm, 100mm and 160mm of sediment quantity respectively. The generation rate of resolved sulfide was also 0.032mg/l·hr, 0.065mg/l·hr for 40mm and 100mm sediment quantity respectively. The difference with sulfide formation speed at the sediment quantity could be confirmed from above. As result, correlation between sediment quantity and sulfide generation rate was confirmed.

(2) Behavior of sulfate-reducing bacteria

Sulfide generation process can approximately be characterized by identifying the relation of

sulfide-reduction bacteria and sulfide generation potential. Under this concept the several condiments of cultivation of sulfide-reducing bacteria were studied in 1998. Three culture method of flask, monotonous and double plate in anaerobic bottle were evaluated to select the most appropriate culture condition and culture method of sulfide-reducing bacteria.

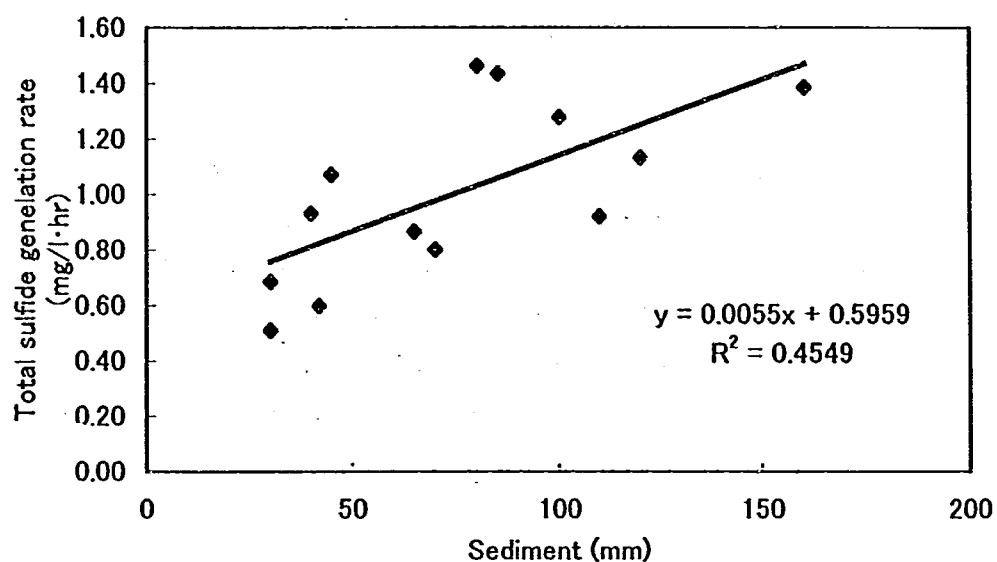


Fig-1 Sulfide generation rate for sediment

SEWERAGE SYSTEM FOR TROPICAL AND SUBTROPICAL COUNTRIES

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Wastewater System Division, Advanced Wastewater Treatment Division

Project period : 1996-2000

OBJECTIVES

The environmental sector in ODA is highly demanded by developing countries in tropical and subtropical regions. The aid on planing and construction of sewerage in the mentioned countries, which is one of the most important works in environmental sector, has been expected more and more. The technology of sewerage originated from Japan is in high standard. However, it is not always appropriate to adopt it in developing countries, considering the respective natural condition, social background, cost, and required standard. Therefore this study aims to establish the sewerage system which is most suitable for developing countries in tropical and subtropical regions.

RESULT

INVESTIGATION ON WASTEWATER COLLECTION SYSTEM AND ARRANGEMENT OF SANITARY FACILITIES

The sanitary facilities (including low-cost sewerage) used in developing countries were examined in terms of adaptability. The developing studies by aid organizations such as JICA, World Bank were collected, and the plans of sanitary facilities and sewerage were examined.

Septic tanks and pit latrines are widely used in the developing countries. In planning of sanitary facilities, the below items should be taken account into.

- Adopt step-wise implementation based on the finance ability, water supply diffusion, etc. without assuming 100% sewerage diffusion in the target year.
- Limit target area, considering that implementation organization has low finance capacity and land planning in the future is not clear, even though study area such as large cities is usually vast.
- Impose sewage works by private fund in land or housing development.

In selection of on-site facilities, the ground water level, infiltration capacity, environmental effect to neighboring drinking water wells and so on have to be considered. Concerning the low-cost sewerage and conventional sewerage, it is required to take account into finance ability, volume of water supply, population density and so on..

APPLICATION OF FACULTATIVE AND AERATED LAGOON PROCESSES

Experiments were conducted using facultative and aerated lagoons which were constructed in Okinawa prefecture to clarify treatment capacities of the lagoons, appropriate loading and operation conditions for better treated water quality.

1) Facultative lagoon

The facultative lagoon was operated at the HRT of 70 days and the BOD surface loading of $7.4 \text{ g}/(\text{m}^2 \text{ d})$. Average influent and effluent water quality and removal ratio are shown in Table 1. 90% removal of influent total BOD was achieved, but the number of coliform group in the effluent was higher than 3,000 CFU/mL. As for seasonal change of treated water quality, DO concentration decreased lower than 5 mg/L when water temperature dropped to 15°C (Figure 1). Even under the condition of low water temperature and low DO concentration, soluble BOD concentration in the effluent was kept lower than 15 mg/L, but the number of coliform group in the treated water showed a little high level.

2) Aerated lagoon

The aerated lagoon was operated at the HRT of 7 to 15 days with a supplementary filter for the reduction of SS concentration in the effluent. It was necessary to provide a sedimentation part in the lagoon for a longer filtration period and stable SS removal, and with continuous aeration, BOD and SS concentration in the effluent was lower than 3 mg/L.

Table 1 Average treatment efficiency of facultative lagoon

	Influent	Effluent	Removal ratio (%)
T-BOD [mg/L]	228	23	90
D-BOD [mg/L]	120	9	93
T-COD(Cr) [mg/L]	432	144	67
D-COD(Cr) [mg/L]	112	43	62
SS [mg/L]	197	46	77
Coliform Group [CFU/mL]	300,000	770	100
NH ₄ -N [mg/L]	26.64	1.35	95
PO ₄ -P [mg/L]	2.63	0.10	96

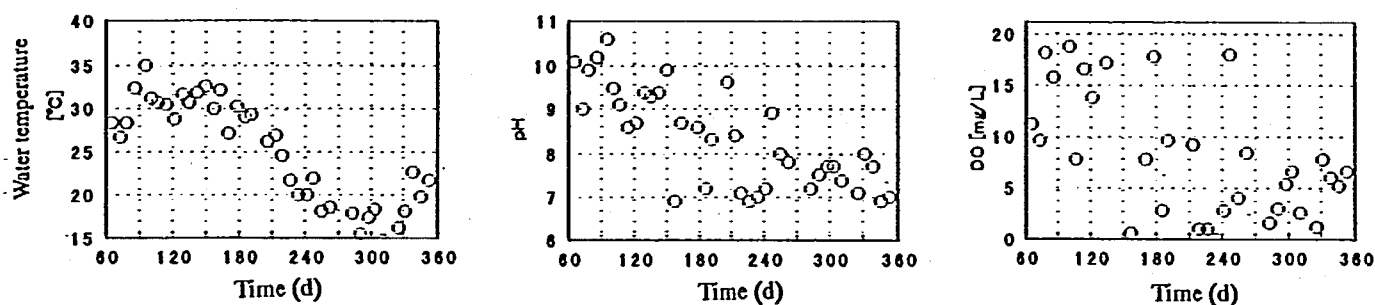


Figure 1 Effluent water temperature and DO concentration

REHABILITATION OF SANITARY SEWERS

K. Sasabe, R. Himono, T. Toyoda and T. Horie

Wastewater System Division

Project period : 1997-2001

OBJECTIVES

Most cities adopt separate sewer systems since sewerage projects have been implemented in recent years in Japan. According to years passing after construction in separate system, various troubles become to be appeared. These troubles are, for instance, infiltration and inflow of rain water and underground water (I/I), corrosion of concrete pipe and piling up of sediments. Peculiar troubles to the separate sewer are included in these. It is probable that the occurrence of these troubles increases rapidly coping with aging of facilities.

Based on this situation, this study aims to clarify the cause of troubles which are not elucidated enough by now in sanitary sewers. Moreover, this study also aims at the examination of effective counter measures concerning principle troubles of sanitary sewers.

The sulfide generation mechanism of sanitary sewer of gravity flow system was tried to elucidate on touching the hydrogen sulfide by field study. As regards infiltration to sanitary sewer, the relationship between infiltration situation and precipitation was investigated by measuring flow rate and amount of rainwater at connecting point of public sewerage with regional sewerage system, and the characteristics were examined.

RESULT

1. The investigation of sulfide generation in sewers

We researched into sulfide generation at K pumping station and at its upstream sewer in A regional sewerage system, respectively. When the sanitary sewage was stored in sewer, sulfide generation was observed. And when the stored sanitary sewage was drained by pumping, it was also observed.

The sulfide generations observed in the investigation was categorized into two cases by measuring SS concentration and sulfide concentration. In the first case, SS sedimented in sewer was rolled up when flow veracity of sanitary sewage became high. We defined the solids sulfide which excluded soluble sulfide from total sulfide. There was the positive correlation between total sulfide concentration and SS concentration in sanitary sewage. And there also was the positive correlation between solids sulfide concentration and SS concentration. Almost 70% of total sulfide, which was included in sanitary sewage was transferred into soluble sulfide. Soluble sulfide is possibly supposed to be volatile easily, and transfer into hydrogen sulfide in the air. In the second case, when sanitary sewage was stored in sewer and its flow veracity lowered, SS concentration declined and the sulfide concentration increased. The sulfide generation rate was $0.73\text{mg-S/l}\cdot\text{hr}$ as of total sulfide in gravity flow system. In the previous investigation, the sulfide generation rate in pressure mains was estimated about $6.8\text{mg-S/l}\cdot\text{hr}$. Though sulfide generation rate of gravity system was smaller than one of pressure mains, the sulfide concentration in sewers was high enough and retention time of sewage was longer. Therefore it may lead to causes of corrosion of sewers facilities and odors, etc..

2. Investigation of I/I(Infiltration/Inflow) in A regional sewerage system

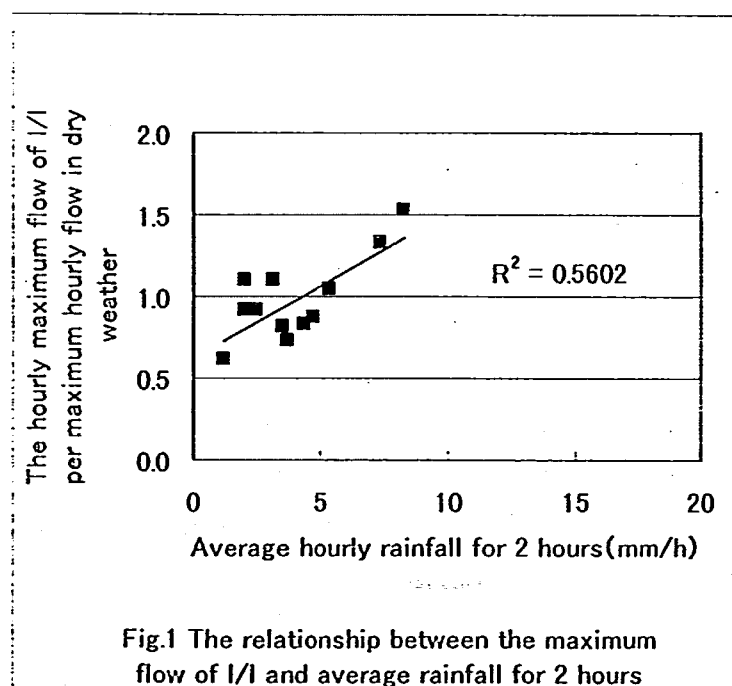
2.1 The measuring method of I/I

We investigated I/I in A regional sewerage system in 1998. Here, the administrator of municipal sewage works installs flowmeter at each connecting point of public sewer with regional sewerage system. Rainfall amount was measured at regional wastewater treatment plant, pumping station and station of AMeDAS(Automated Meteorological Data Acquisition System) of Meteorological Agency respectively. The investigation was executed between April through September which is a rainy season. We used the data of sewage flows at 5 connecting points and amount of rainfall at 3 observation points. The data were available at hourly intervals.

On the measuring method of I/I, the fundamental approach is described in "I/I prevention measure guidelines in the sewer JSWA". Amount of I/I in rain event is defined as the supplemented flow in wet weather flow to the average flow of dry weather flow. The underground water which infiltrates into sewer continuously, is already included in dry weather flow.

2.2 Characteristics of I/I according to analytical result.

Especially, the most serious effect to sewerage system is the high intention of maximum hourly flow caused by I/I such as flooding. Among 5 areas investigated, the maximum hourly flow of I/I almost is equal to the maximum hourly flow in dry weather. And the maximum hourly flow of wastewater in rain event reaches at almost 1.4 to 2.2 times of maximum hourly dry weather flow. It is shown that a certain rate of rain water into sewer, since the flow of I/I per rainfall amount and area is well proportional. Then, the relationship between the maximum flow of I/I and average hourly rainfall for 2 hours is shown in figure1. It shows that I/I is proportional to the rainfall amount for the last 2 hours and I/I has generated very rapidly.



COST REDUCTION OF PIPE SYSTEM

K. Sasabe, R. Himono and T. Yoshida

Wastewater System Division

Project period : 1998-1999

OBJECTIVES

Among the infrastructures of Japan, the sewerage even is delayed one as compared with western countries in a term of sewerage coverage. Further promotion of sewerage construction has also been required at present. And it is urgently necessary to reduce the unit construction cost since the finance situation of national/local governments are deteriorated. The pipe system cost amounts to about 70% of all sewerage work cost including collection system and treatment works. Accordingly, cost reduction of the pipe system is very important in order to reduce the whole sewerage works cost. In order to reduce the cost of pipe system, the following measures can be considered. We analyze the construction cost of pipe system on traditional design method, and find out the issues which should be solved coping with the development of technology. As a result, it should reexamine the background of the conventional design criteria.

As it needs to grasp the cost reduction potential of pipe system, we make a comparison study of construction cost of newly developed pipe system with conventional ones. Firstly we decompose the construction cost of pipe system into each facility of man-hole, pipe, etc., and analyze the contribution of earth coverage of pipe in some specified treatment areas. Then we establish the cost calculation model and cost reduction effect.

RESULT

(1) The investigation of cost reduction methodology of pipe system of local governments

We sent out questionnaires of the cost reduction methods of pipe system to local governments. According to them, 17 out of 19 cities have taken some cost reduction methods. The other 2 cities replied that they would take the cost reduction methods in near future. The most prevalent method is to review the standard requirement change of their own design manual of manhole. It is apparent that this method is the most effective among cost reduction factors. There are 2 techniques of the cost reduction of manhole. The first technique is to make shorter the distance between manholes. The other is to adopt a newly developed manhole, which is smaller than conventional ones and can also reduce the material cost of manhole. In addition, they revised the minimum diameter of polyvinyl chloride pipe to $\phi 150\sim 100\text{mm}$ from $\phi 200\text{mm}$ for the reduction of material cost. The problem, which is common to review the design guidelines of pipe, is how to coordinate with maintenance sectors.

Therefore we also sent out the questionnaires for maintenance methods of pipe system. Every cities are executing maintenance (inspection, dredging, repair and reconstruction) of pipe system. Some cities are doing up to the maintenance of house inlet and lateral. We estimate the unit price of maintenance of pipe system from past records to build Life Cycle Cost (LCC) of pipe system. As results, saved unit price was estimated as 673yen/m of

inspection, 1,206yen/m of dredging and 142,660yen/m of repair and reconstruction respectively. If we will choose some cities that have many data of maintenance of pipe system available, we are able to estimate LCC of pipe system.

(2) The analyzed features of construction cost for pipe system

①The ratio of pipe length classified by pipe diameter in treatment areas

About 90% of the pipe length of sanitary sewer is small pipe which diameter ranges 400mm or less.

②The ratio of pipe length classified by pipe construction method

The open cut method accounts for 91%, the pipe jacking method (contained the small-diameter jacking method) for 8 % and the shield tunneling method for 1 % of all pipe length respectively. Generally, pipe jacking method and shield tunneling method tend to be adopted as pipe diameter is large.

③Average unit price of pipe construction cost classified by pipe construction method and pipe diameter

Average unit price of pipe construction cost (direct construction expenses bases) is shown in figure1. It is proven that the unit price of the pipe jacking method and the shield tunneling method rapidly increase as pipe diameter is over 1000mm.

④The ratio of pipe construction cost classified by pipe construction method and pipe diameter in treatment areas

Whole pipe construction cost in treatment area basis is approximately allocated for 50% to open cut method of pipe diameter less than 300mm, 30% to pipe jacking method (includes small-diameter jacking method) of pipe diameter less than 900mm, 10% to open cut method of pipe diameter larger than 350mm and 10% to pipe jacking method and shield tunneling method of pipe diameter larger than 1,000mm respectively.

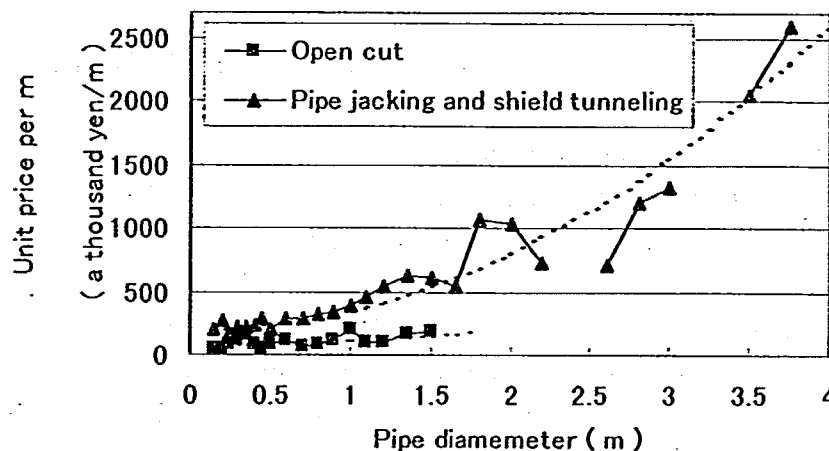


Fig.1 Unit price of pipe construction cost per m (direct construction expenses bases)

BENEFIT ANALYSES OF SEWAGE WORKS

K.Sasabe, S.Okamoto and T.Yoshida
Wastewater System Division

Project period: 1998-1999

OBJECTIVES

At present, it is strongly requested to secure the efficiency and transparency of social infrastructure provision, and to accomplish the accountability of public works as the administration. And it becomes an important matter to evaluate public works by clarifying the effectiveness and measuring its benefit. Then, the object of this research is to establish a reasonable evaluation technique for the effect of sewage works.

In FY 1996 and 1997, we conducted several researches to optimize a reasonable evaluation technique for the effects provided by sanitary sewers as a part of sewage works. In FY 1998, in order to evaluate the effect of sewage works, we conducted three researches. First, we investigated values of water environment especially in view of water quality, since the water quality improvement in water bodies is a principal effect by sewage works. Secondly, we estimated the value of quality improvement of nearby water body by using contingent valuation method (CVM). Thirdly, we conducted a case study applying hedonic pricing method (HPM) to evaluate sewage works comprehensively and peered the applicability of HPM.

RESULTS

(1) The Values of Water Environment

In order to evaluate the effects of sewage works, we abstracted values of water environment from existent material and we especially focused on the values of water quality.

The effect of water quality improvement in public water bodies varies with using patterns of water body, and it is thought that not only direct water use but also indirect environmental use of water body has a strong relation with water quality.

And we classified practicable water-related activities and fauna that closely correspond to biochemical oxygen demand (BOD), with reference to existent materials. For example, where BOD ranges 5 ppm to 10 ppm, practicable activities are taking a walk, rowing a boat, etc., and inhabitant fishes are carp, crucian carp, etc. Where BOD is about 2 ppm, swimming is practicable, and inhabitant fishes are chars and a kind of trout.

(2) Benefit Appraisal of Water Quality Improvement by CVM

We appraised the benefit of water restoration, which is one of the major effects of sewage works, by using CVM. CVM is a technique of measuring benefits and uses a questionnaire to elicit people's preference for public goods by finding out what they would be willing to pay for specified improvement in them. We conducted this research in Azuma Town and Mitsukaido City in Ibaraki Prefecture, and the appraised water bodies range two patterns: (i) only streams in each municipality, and (ii) both streams and rivers in each municipality. And we set the

scenarios of water quality improvement in accordance with 'Setting of Water Quality Ranks' (Table 1). Table 1 is based on the result of '(1) The Values of Water Environment'. The sample size is 1,200 and the used research procedure is by mail.

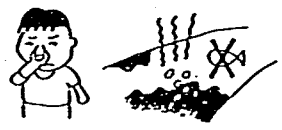
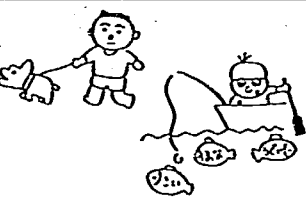
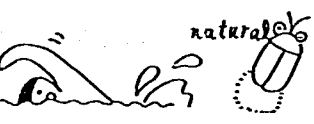
The result is as follows. In case that the appraised water body is only streams, the mean willingness to pay (WTP) are 2,190 yen/month/family for rank C, 2,360 yen/month/family for rank B, and 3,290 yen/month/family for rank A. And in case that the appraised water body is both streams and rivers, the mean WTP are 2,430 yen/month/family for rank B and 2,660 yen/month/family for rank A.

(3) Benefit Appraisal Applying HPM

We conducted a case study of applying HPM to appraisal of Miyagawa regional sewerage project in Mie Prefecture. HPM is a comprehensive benefit appraisal method focusing on land prices.

The difference of estimated land price between sewerred land and unsewerred land, calculated by multiple regression, was approximately 7,600 yen/m².

Table 1 Setting of Water Quality Ranks

Water Quality Rank		Appearance, practicable activities, and inhabitant fish	Image
bad ↓ good	D	The riverbed is black and there is a smell of rotten eggs. There is no fish.	
	C	There may be a somewhat unpleasant smell, but we can take a walk along the river. And we can enjoy fishing crucian carp, carp, and <i>Zacco temminckii</i> . If there is plenty of water in the river, it seems that we can enjoy rowing boats.	
	B	We can enjoy water bathing such as catching fish or insects. Ayus and reared fireflies can inhabit the river.	
	A	If there is plenty of water in the river, we can enjoy swimming. Natural fireflies can inhabit the river	

UTILIZATION OF URBAN STORMWATER IN SEWERAGE

K. Sasabe, H. Yamashita and T. Toyoda

Wastewater System Division

Project period : 1998-2000

OBJECTIVES

Recently, people recognize the importance of the water resources through the experience of drought or large scale natural disasters such as the Hanshin-Awaji great earthquake. And it is important that urban areas have autonomous water resources, instead of depending on distant resources. The main reasons for this are that dam and weir construction are both extremely costly, and require many years to complete. More over, pipe lines may be damaged by earthquakes. In these circumstances, it is possible to utilize treated effluent or stormwater as a substitute water resource.

In this study, we focus on the stormwater utilization in urban areas. We will make investigation into mass balances of stormwater in urban areas, required quantity and quality of water for each utilization purpose, and transformation of stormwater quantity and quality on various unit processes such as inlets, pipes, storage facilities, and so on. And finally, through these investigations, we will propose the method of urban drainage planning for utilizing rainwater.

The main results obtained in FY 1998 are as below.

RESULTS

SELECTION OF THE AREAS WHICH ARE SUITED FOR UTILIZATION OF RAINWATER

We collected the data related to utilization of rainwater. To put it in the concrete, the data which we collected is divided into three categories. The first one is the data about city demography such as population and number of households. The second one is about meteorology such as average yearly rainfall and average yearly temperature. The last one is about water resources such as user fee for drinking water and water consumption.

We analyzed this data and reached the conclusion that an area would be suited for utilization of rainwater when its population density is high, and its degree of satisfaction to water resources is low. For example, prefectures which face the Pacific or the Inland Sea come under the suited ones (Fig. 1). These areas will have great merits to promote utilization of rainwater.

QUANTITY TRANSFORMATION IN STORMWATER SYSTEM

In urban areas, quantity and quality of runoff vary with the difference of the land usage. So, it is important to make clear how much quantity and quality of the rainwater will change while it flows on the various surface conditions. In this fiscal year, we focused on the quantity of stormwater, and examined its transformation by using computer simulations.

As an example, we chose the real drainage basin which is 39.5 ha wide and served by a combined sewer system. The data (rainfall intensity, flow rate) was already taken several years ago. We calculated the runoff volume by two methods as shown below.

- (1) The drainage basin has one runoff coefficient (overall type)
- (2) Each mesh (10m * 10m) has an individual runoff coefficient based on land usage (distribution type)

We made a comparison between the two (Fig. 2). When we compare the flow rate at the end of the drainage basin, the difference between the two would be so small that we could choose the easier method (1). But we reached the conclusion that a distribution type model would be needed when we want to know conditions inside the drainage basin or to predict the effect of on-site infiltration/storage facilities.

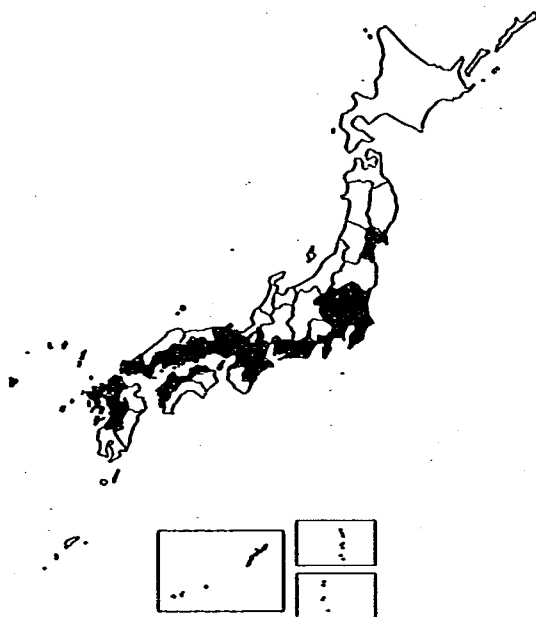


Fig. 1 The areas suited for utilization of rainwater

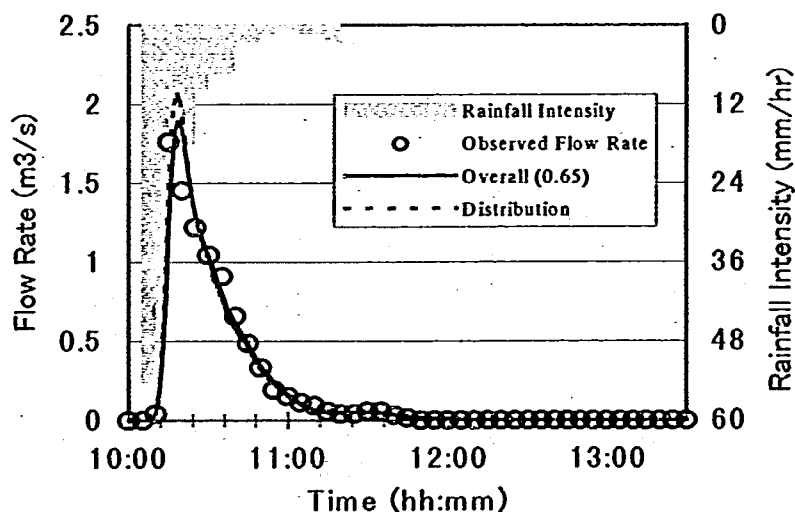


Fig. 2 Comparison between an overall model and a distribution model

DISINFECTION ALTERNATIVES AND THEIR BY-PRODUCTS

Y. Suzuki and T. Hatatsu

Advanced Wastewater Treatment Division

Project period : 1996-1999

OBJECTIVES

To secure safety of treated wastewater in terms of pathogens, much chlorine dosage is needed, but this may lead to the formation of toxic substance such as THM. Therefore, other means of disinfection such as UV radiation and ozon have to be studied to have safer treated wastewater, because those are thought to produce less toxic substances and have higher disinfection efficiency.

In this research, disinfection experiments will be conducted using chlorine and ozone to evaluate their disinfection efficiency and toxic substance formation.

In this year, we evaluated the influence of water quality on by-products formation, the effect of activated carbon to remove by-products and the influence of mixing strength on the chlorine disinfection.

RESULTS

- 1) In chlorine disinfection, the number of coliform group decreased with the increase of Ct value. In secondary effluent, coliform group survival ratio was $10^4 \sim 10^5$ at Ct value of 150mg-Cl $\cdot$ min/L. In case that ammonia was added to secondary effluent, disinfection effect was lowered. Conversely, in case that sea water was added to secondary effluent, disinfection effect was improved.
- 2) In chlorine disinfection, with ammonia nitrogen existence in secondary effluent, by-products formation was decreased. When ammonia nitrogen existed 1mg-N/L, THM formation was reduced to half of that with ammonia nitrogen of 0.1mg-N/L (Figure-1). On the other hand, in the case that sea water or humic acid was contained, TOX and THM formation increased in comparison with the secondary effluent.

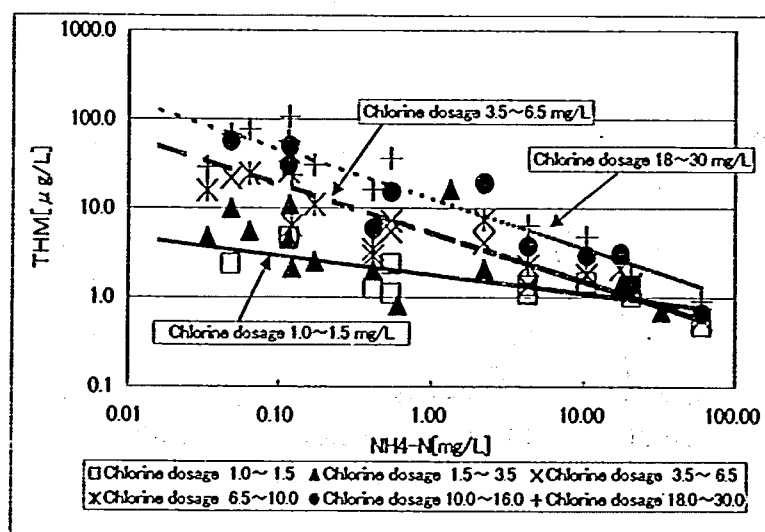


Figure-1 Relation between ammonia nitrogen concentration and THM formation

- 3) In ozonation, aldehyde and bromine acid ion was formed as ozon dosage increased. With sea water, bromine and aldehyde formation was increased, and higher TOX and THM was formed.
- 4) With activated carbon, chlorine and bromine were removed effectively, but not aldehyde. Because aldehydes formed by disinfection were formaldehyde and acetaldehyde, whose removal rate with activated carbon was low.
- 5) There was a tendency that disinfection effect became large as mixing intensity increased. The tendency was significant if higher disinfection effect was aimed at (Figure-2). When sludge was contained in secondary effluent, disinfection effect decreased. Especially, if the sludge was of short SRT, disinfection effect decreased significantly.

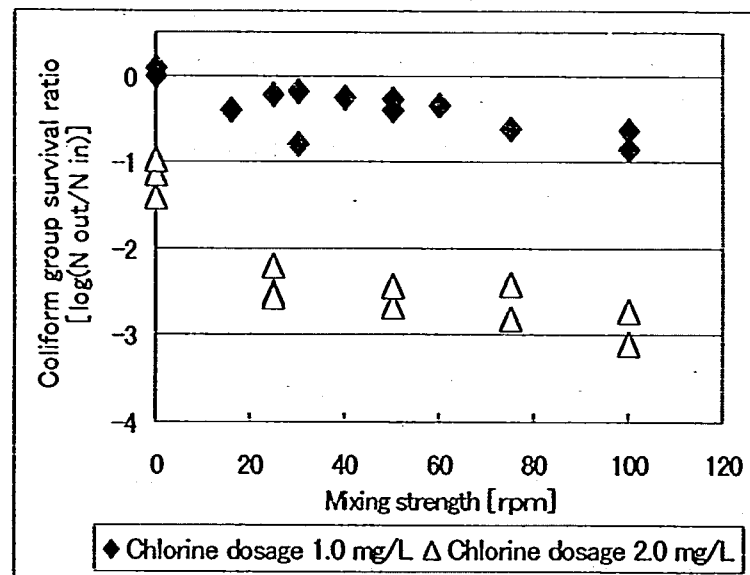


Figure-2 Influence of mixing strength on the chlorine disinfection

FATE OF PATHOGENS IN NATURAL WATERS

Y. Suzuki, M. Ogoshi, M. Suwa and T. Hatatsu

Advanced Wastewater Treatment Division

Project period : 1998-2001

OBJECTIVES

Construction of wastewater systems has improved public health and decreased the occurrence number of water-borne disease. However, recently, new water-borne diseases are emerging. At the same time, occasions that people contact treated wastewater are increasing, because the number of wastewater treatment plants upstream of rivers is increasing and wastewater reuse is in progress. Consequently, there is a need that treated wastewater quality standards are reviewed for the safer water system. For that, however, many have to be clarified about the fate of pathogens in natural water and this research study deals with this topic.

In this year, we did a literature survey and a basic experiment which investigated the relation between water quality and death rate of microorganisms.

RESULTS

1) *Escherichia Coli* and Coliform group in the physiological saline showed two kinds of fluctuation patterns in 30day period. In case that water temperature was about 20°C and 30°C, the bacteria increased by $10 \sim 10^2$ in the early period irrespective of shaking of culture, and after that the bacteria remained at the same level. On the other hand, in case that water temperature was about 4°C, the bacteria didn't increase and decreased as time passed. This was thought to be because the low temperature caused stress to the bacteria. Also, if temperature is suitable bacteria can grow, even if nutrient is included in very small quantity.

2) In secondary effluent, if the water temperature was about 4°C, *Escherichia Coli*, Coliform groups, *Pseudomonas* didn't increase and decreased as time passed. On the other hand, in case that water temperature was about 20°C and 30°C, the bacteria increased in the early period, after that the bacteria decreased. There was a tendency that the growth and death rates became large as the temperature increased.

3) Ultraviolet(UV) disinfected water showed almost the same fluctuation pattern of microorganism as secondary effluent. It was considered that there were few changes in water quality with UV disinfection. On the other hand, chlorine disinfected water and ozon disinfected water enlarged death rate of *Escherichia Coli*.

4) Fluctuation patterns of bacteria in secondary effluent and influent resembled among almost all cases, with the exception of that of *Clostridium*, in which higher existence was observed in influent which caused more anaerobic conditon. It was considered that there are few differences in the effect on death rate between the secondary effluent and influent.

5) Seawater showed higher death rate of bacteria than other samples water.

6) Figure-1 shows fluctuation of Coliform group without the addition of microorganisms.

In chlorine disinfected water, ozon disinfected water and UV disinfected water, Coliform group was not detected at the beginning, but its number increased while left at 20°C. The reason of this was considered to be that the sample volume was insufficient at the beginning or bacteria that had lost proliferation ability recovered after a time.

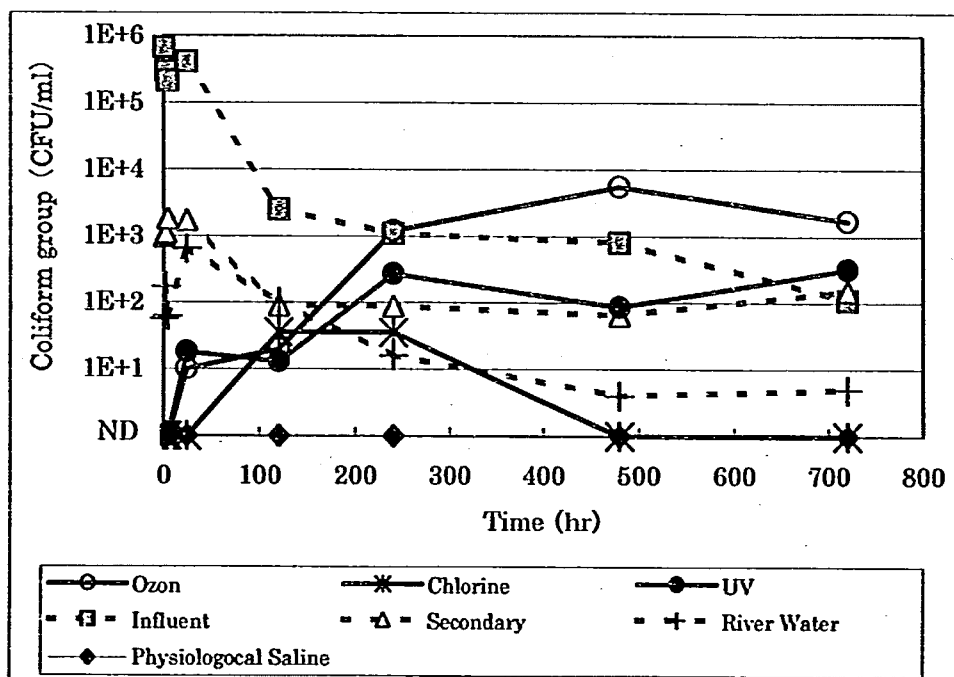


Figure-1 Fluctuation of Coliform group

(Culture condition : 20°C, Not shaking, Shield light)

TECHNOLOGIES CONTROLLING GREEN-HOUSE EFFECT GAS EMISSION FROM SEWERAGE SYSTEM

K.Sakai, Y.Suzuki, K.Yogi, S.Ochi and I.Harada

Advanced Wastewater Treatment Division and Sludge Management Division

Project period : 1998-1999

OBJECTIVES

Global warming is becoming one of the most serious environmental problems we have ever met. Although carbon dioxide is one of the responsible agents causing green-house effect, methane and nitrous oxide are no less important in controlling global warming. In fact, the effects of methane and nitrous oxide on global warming on the unit mass basis for 20 years after are reported around 60 and 270 times as high as the carbon dioxide, respectively.

This research is aiming at the development of technologies to reduce the emission of the green-house effect gases, such as methane and nitrous oxide, from the sewerage treatment facilities consisting of wastewater treatment processes and sludge treatment processes. The purpose of research also includes the estimation of reduction effect of green-house gases.

METHOD

1) Wastewater treatment process

Methane balances in wastewater treatment processes were compared between a conventional activated sludge process and a A/O process using a pilot plant with the capacity of 35 m³/d, to clarify the effect of a A/O process to reduce methane emission, which had been observed in the last year's survey.

2) Sludge treatment process

In FY1998 a life cycle costing(LCC) analysis of some working fluidized bed incinerators was conducted on the assumption that incineration temperature was raised for C 50 degrees to reduce the emission of nitrous oxide. The conditions of incinerators were set in 2 types. One was to be assumed that each incinerator had been operated retroactively at higher temperature than designed one (it will hereinafter be abbreviated 'existing incinerators'). Another condition was on the assumption that designed incinerating temperature itself had been raised('improved incinerators' hereinafter). Moreover, the reduction of green-house effect and unit cost were estimated.

RESULTS

1) Wastewater treatment process

The ratio of the amount of methane emission from a wastewater treatment process to the influent dissolved methane was 1.7 for the activated sludge process and almost 1 for the A/O process. The reason of this difference is that methane was produced in the first cell of the activated sludge process but not in the anaerobic cell of the A/O process. Further research is needed to clarify the methane production mechanism in wastewater treatment processes together with the function of Poly-P microorganisms.

2) Sludge treatment process

Some fundamental data concerned with necessary costs for the reduction of green-house effect caused by sludge incinerators were obtained through the study. The summary of the study in FY 1998 is as follows.

(1) Maximum increasing rates of total cost(TC) of repairing and of supplement fuel at existing incinerators were estimated at 81.5% and 45.8% respectively, however, these of electricity and chemicals were very small(Fig.1). Increasing rates of whole costs at existing incinerators were 10 ~ 15%, which were mainly originated by repairing. On the other hand, calculated increasing rates of TC at improved incinerators were 4.1 ~ 7.3%, which operation occupied mostly.

The reduction effects of green-house gases were estimated at 0.62 ~ 1.54t-CO₂/t-sludge on a dried solid basis, and the reduction rates were 24 ~ 45%. It was also confirmed that improved incinerators were more advantageous than existing incinerators from the viewpoint of costs.

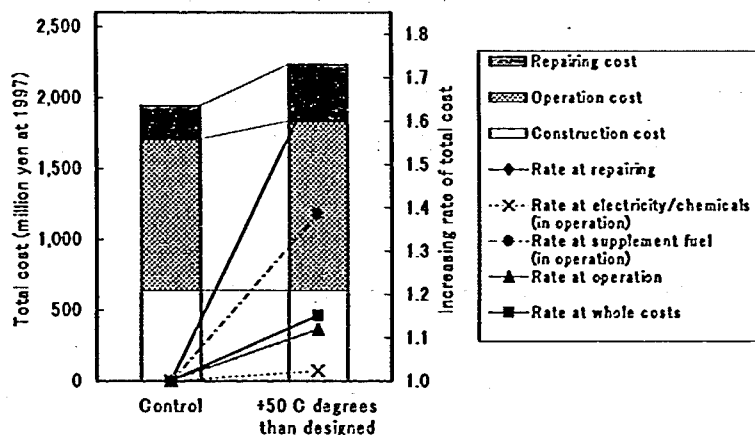


Fig. 1 Change of Total Cost at an Existing Incinerator

OPTIMIZED SYSTEM FOR WASTEWATER TREATMENT AND RESOURCES RECOVERY

Y. Suzuki and H. Shigemura

Advanced Wastewater Treatment Division

Project period:1995-1998

OBJECTIVES

The purpose of this research is to propose optimized systems for wastewater treatment and resource recovery. For that, mass balances and energy consumption of existing wastewater treatment systems are investigated to evaluate the processes and the systems. With this results, improvement and development of each process and combination of the processes are investigated, and optimized systems are proposed for requested types.

RESULTS

(1) ANALYSIS OF THE MASS BARANCES OF TREATMENT PLANTS

Comparing COD_{Cr} balances in two wastewater treatment plants (C and M) which differ in the way of SS removal before biological treatment, the effect of the SS removal method was evaluated. COD_{Cr} balances in two plants are shown in Figure 1. C treatment plant utilized conventional gravity sedimentation, and M treatment plant was equipped with a solid – liquid separation tank using filtration media. The ratio of sludge produced to the influent COD_{Cr} was bigger in M plant than in C plant, and that of CO₂ was reverse. This was because high suspended solid removal rate was performed in the solid – liquid separation tank and COD_{Cr} entering aeration tank was small in M plant.

This result shows the solid – liquid separation tank increase the production of sludge, which may lead to the increase of methane gas formation if anaerobic digestion is applied to sludge treatment.

(2) IMPROVEMENT OF DENITRIFICATION WITH ADDITION OF HYDROLYZED RAW SLUDGE

The flow diagram of the system with a raw sludge hydrolyzing tank and a centrifugal solid –liquid separator is shown in Figure 2. Raw sludge from the primary sedimentation tank was mixed for 30 hours in sludge hydrolyzing tank and, after centrifuge, separation liquid was supplied to the anoxic tank. Without the addition of separation liquid, denitrification was not often completed when oxidized nitrogen inflow load was above 1.5mg g-MLSS⁻¹ h⁻¹. However, with the addition of separation liquid, denitrification was completed in almost all cases when oxidized nitrogen inflow load was below 3mg g-MLSS⁻¹ h⁻¹ (Figure 3). The addition of separation liquid promoted complete denitrification.

(3) PROPOSAL OF SYSTEMS APPROPRIATE FOR REQUESTED TYPES

From the results past, treatment processes and systems appropriate for requested types shown below are proposed; (1) reuse of sewage sludge as fertilizer, (2) low energy consumption, (3) reduced emission of green –

house effect gas and (4) high removal rate of nitrogen and phosphorus.

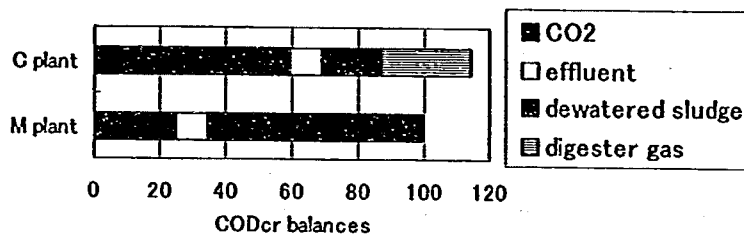


Figure 1: The CODcr balances of C and M treatment plants
(calculating CODcr in raw sewage to 100)

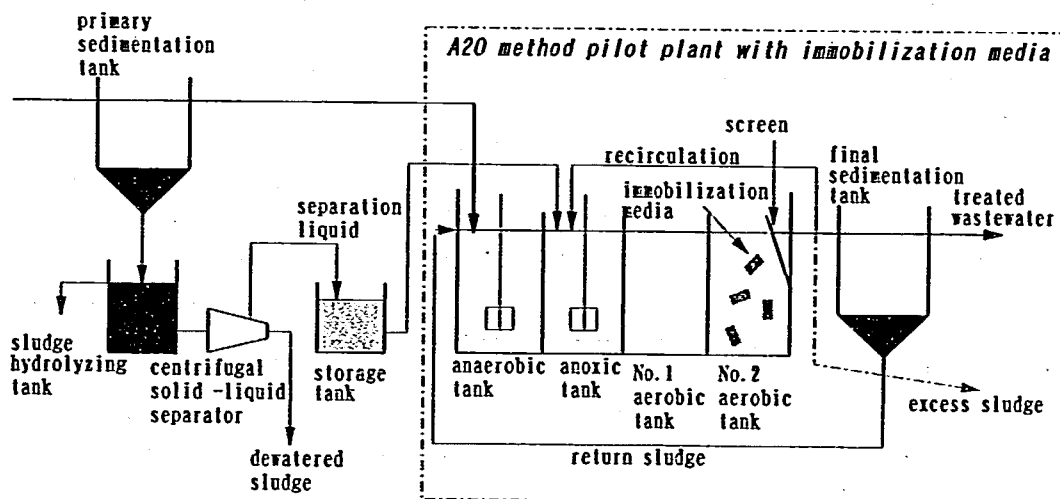


Figure 2: The diagram of the pilot plant for the addition of separation liquid

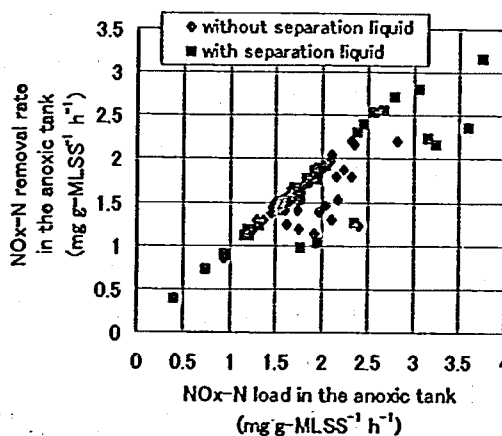


Figure 3: The denitrification rate in the anoxic tank with and without the addition of separation liquid

EVALUATION OF WASTEWATER REUSE SYSTEM

Y. Suzuki and M. Ogoshi
Advanced Wastewater Treatment Division

Project period : 1998 - 1999

OBJECTIVES

Reclaimed wastewater has become one of the important alternative water resources for many urbanized areas in Japan. From the first official announcement of the draft about the reclaimed water quality standard in 1981, the number of wastewater reclamation and reuse facilities increased year by year. And the tendency was accelerated by the additional draft in 1990, which mentioned the reclaimed water quality for the landscape irrigation and recreational use. The recent utilization rate of this new water resource is around 1% of the total secondary effluent, and most of inhabitants accept these reuse facilities friendly. It seems that water reuse is in the introduction of real popularization, though the national standard for water quality and design criteria is not established formally. The reclaimed water should be given a correct position as a permanent water resource in the area after the fair evaluation about rationality of the water reuse system.

This study aims at proposing an evaluation method which assess the water reuse system synthetically. In FY1998, we have conducted a research about the actual state and cost of reclaimed municipal wastewater reuse facilities all over Japan. And also made investigations about the actual water quality in 10 water reuse systems to see the water quality change in actual reuse facilities.

RESEARCH ON THE ACTUAL STATE AND COST

1) Outline of the research

According to the statistics of sewage works FY1996, there are 163 reclaimed wastewater reuse facilities in Japan. We have sent out questionnaires to these 163 facilities and requested to answer about specifications of their water reuse system, construction costs of the system, reclaimed water quality, and so on. Major headings of the questionnaire are indicated in Table 1. In addition, we made a field survey about the quality of recycled water and reclamation process.

2) Result of the research

Recovery rate of questionnaires were 99.4%, but the rate of effective answer to each questions were much lower, particularly, about the cost. Table 2 shows overall replying rates in major items of the questionnaire.

Figure 1 indicates the contribution of each reuse category to the total amount of reclaimed municipal wastewater based on the replied daily supply from 104 plants. Snow melting is the largest use based on a sum of daily supply and agricultural irrigation is the third largest. However, these uses are seasonal while the other uses are daily. So that the order of the contribution will change in the base of annual

Table 1. Major Headings of The Questionnaire

1. General descriptions	Plant name; Comment for water reuse; Attached papers (leaflet, etc.)
2. Outline of the water reuse	Background; Objects; Reclamation processes; Main user; The date of supply started
3. Supply water amount	Planned; Supplied in FY 1997
4. Reclamation plant	Annual construction and mending costs; Specifications of the reclamation plant; Operational conditions
5. Pipeline installations	Annual construction and mending costs; Specifications
6. Operation and maintenance	O&M system; O&M costs; Charge of reclaimed water use
7. Reclaimed water quality	Planned water quality; Control target; Actual water quality

Table 2. Recovery Rate to the major items of The Questionnaire

General descriptions	Plant name	99.4
Outline of the reuse	Objects	91.4
	Reclamation processes	91.4
	Main user	89.6
	The date of supply started	84.0
Supply water amount	Planned value	30.7
	Supplied in FY 1997	70.6
Reclamation plant	Specifications	62.0
	Annual construction cost	46.0
	Annual mending cost	33.1
	Annual construction cost	45.4
Pipeline installations	Specifications	46.0
	Annual construction cost	45.4
	Annual mending cost	24.5
O & M	O & M cost	35.0

supply. Anyway, river aesthetic, snow melting, landscape or recreational irrigation and agricultural irrigation are four major uses of reclaimed wastewater in Japan.

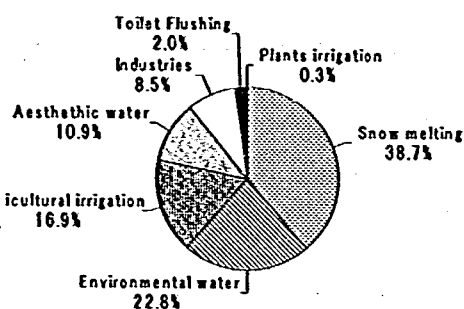


Fig. 1 Rate of Amount for Uses

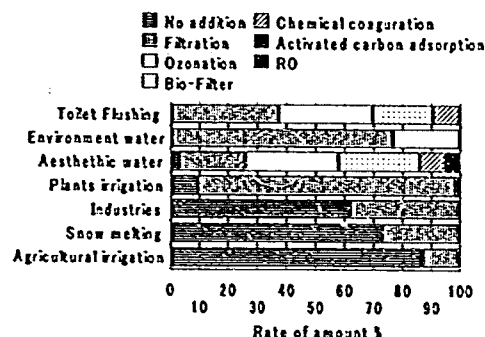


Fig. 2 Object and Reclamation Process

Figure 2 shows the contribution of

reclamation process to the amount of daily supply for each use. In the figure, no addition means that the disinfected secondary effluent is used as the reclaimed wastewater, and this is common in agricultural irrigation and snow melting. Filtrate of secondary effluent occupies a large part in the use for river aesthetic and landscape irrigation. Ozonation and biological treatment are used mainly to make reclaimed water for toilet flushing and for environmental and recreational use.

The cost of wastewater recycle consists of three large categories, the repayment cost, the repairment cost and the O/M cost. The repayment cost were calculated from the construction cost, the durable years of each equipments and the daily supply capacity. The repairment cost and the O/M cost were calculated from the replied data and the daily supply. Table 3 is a result of average cost estimation in every reclamation process group.

Table 3 Estimated Average Reclaimed Water Cost (yen/m³)

Process	Chlorination	Filtration	Filtration-Ozonation	Ozon-Bio-Filtration	Coagulation-filtration-Ozonation	Activated carbon adsorption	RO
Repayment cost	5.6	13.4	34.8	55.3	48.9	63.4	872
Mending cost	0.4	0.7	2.1	2.1	1.7	4.9	40
O & M cost	4.2	5.2	24.2	23.6	42.3	50.0	312
Total cost	10.2	19.3	61.1	80.9	92.8	118.3	1224

According to Table 3, the construction cost occupied a major part of the recycle cost in every group. The average prime cost of water is about 180 yen/m³ (by JWWA PR data in the home page), which is higher than the cost of reclaimed water in Table 3, except the membrane process. Hence, the water recycle is considered as a profitable work.

As the result of the field survey, relationship between the water quality and the reclamation process was made clear as shown in Figure 3. Ozonation does not improve SS and TOC in Figure 3, though it was expected to eliminate some organics. Thus the ozonation process in the water reclamation system should be considered as the special process for color removal or disinfection.

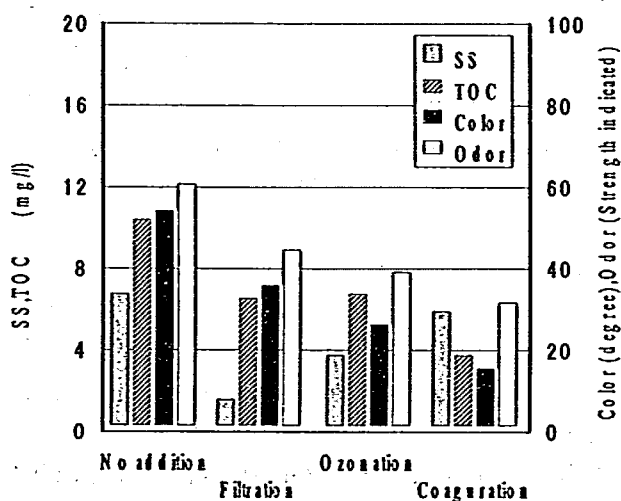


Fig. 3 Water quality and reclamation process

CONCLUSIONS

The reclaimed municipal wastewater were mainly used for snow melting in winter, river aesthetic, agricultural irrigation in summer, and landscape or recreational water. About half of these reclaimed water was chlorinated secondary effluent. Especially for snow melting and agricultural irrigation, it was more than 90%. Advanced treatment process were common in the use for toilet flushing, river aesthetic, and landscape or recreational water. As a result of cost estimation, the average wastewater reuse cost is lower than the average tap water cost in most of the reclamation process.

RISK MANAGEMENT OF PATHOGENS IN SEWERAGE SYSTEM

Y.Suzuki , M.Ogoshi and M.Suwa
Advanced Wastewater Treatment Division

Project period : 1998-2001

OBJECTIVES

Japan experienced an outbreak of cryptosporidiosis in 1996 in Ogose town, Saitama Prefecture, in which about 9,000 people were infected. The major cause of this outbreak is thought to be that several small wastewater treatment plants are located upstream of the source water of the town and *Cryptosporidium* oocysts multiplied in a loop composed of tap water, wastewater and source water without being removed in the water and wastewater treatment processes. During an outbreak high number of oocysts are discharged with fecal from human being. From the viewpoint of risk reduction, wastewater treatment plants must be prepared for an outbreak, because a high concentration of oocysts flows into wastewater treatment plants, causing an increased concentration in the treated wastewater. Also, as our microbiological knowledge is accumulated, pathogenic protozoan and viruses are detected more often in both raw wastewater and treated wastewater. Therefore, it is necessary to upgrade the removal level of treated wastewater for the safety of human health.

This study investigates the source of viruses and protozoan and also develops pathogen reduction methods during an outbreak.

RESULTS

In FY 1998 we investigated the detection method of *Cryptosporidium* oocysts in sewage and river water. The effects of pretreatment, the way of concentrating samples and removal methods of suspended matter from concentrated samples on the recovery of oocysts were evaluated. Furthermore, oocysts removal efficiency of an activated sludge process was evaluated, then a coagulant dosing method to improve oocysts removal was investigated. Also, we investigated the detection method of viruses in sewage. Results are shown below.

DETECTION METHOD OF OOCYSTS

As for river water sample with high SS concentration, centrifuge was effective as the concentration method, but in other cases membrane filter concentration was more appropriate. Magnetic beads were useful to separate oocysts and suspended matter in case of raw sewage, but in most cases a sieve was efficient.

REMOVAL OF OOCYSTS OF ACTIVATED SLUDGE TREATMENT

- 1) The oocyst removal capacity of the activated sludge was evaluated by conducting batch experiments and data of eight-hour aeration were used for the evaluation. Fig.1 shows the relationship between oocyst concentration in the supernatant and number of oocyst removal by 1 g of activated sludge. These two parameters showed correlation, and the relation was expressed as formula (1).

$$R = 1,039 \cdot C^{0.90} \quad (1)$$

R : number of oocyst removed by 1g of activated sludge (oocyst / g-MLSS)

C : oocyst concentration in the supernatant (oocyst / L)

- 2) Removal of 2log of oocyst are produced at the activated sludge treatment that continues. It was estimated that an activated sludge process can remove oocysts by 2 log.
- 3) To improve oocyst removal efficiency of an activated sludge treatment, poly-aluminum-chloride (PAC) was dosed in activated sludge. As dosed PAC increased, the oocyst concentration in the supernatant decreased. An additional 90 percent removal can be expected if PAC is dosed above 10 mg-AL/L.
- 4) No distinct relationship between oocyst removal ratio and turbidity removal ratio in the treated water with the addition of PAC was observed (Fig.2).

IMPROVING VIRUS DETECTION IN SEWAGE

- 1) Virus recovery ratio from sewage was improved by changing the condition of elution from membrane filters.
- 2) Virus detection efficiency from sewage was improved by removing toxic substance in the sewage with membrane filter.
- 3) Recovery ratio was not affected by the decreased number of membrane filters to concentrate viruses.

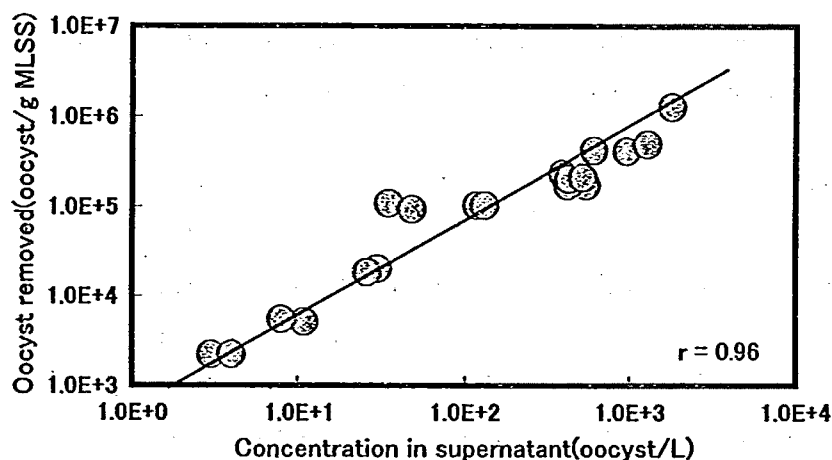


Fig.1 Relationship between oocyst concentration in supernatant and number of oocysts removed by activated sludge

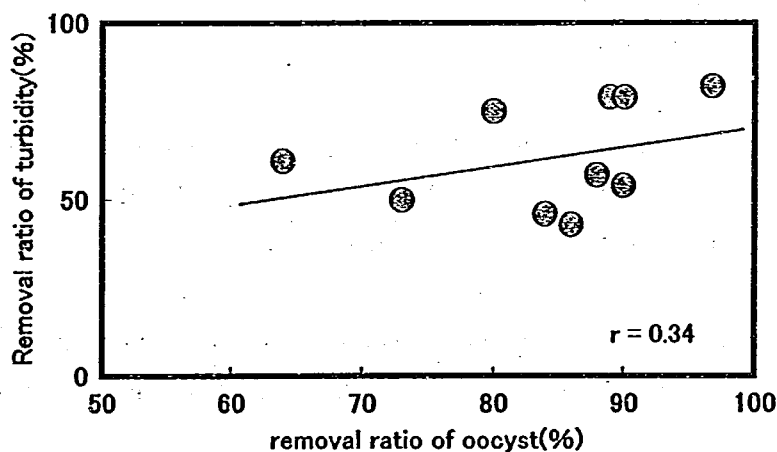


Fig.2 Relationship between removal ratios of oocyst and turbidity after PAC addition

ENERGY SAVING OF NITROGEN AND PHOSPHORUS REMOVAL SYSTEMS

Y. Suzuki, H. Shigemura and T. Hara
Advanced Wastewater Treatment Division

Project period: 1998-2001

OBJECTIVE

Because nitrogen and phosphorus removal systems consume more energy than conventional activated sludge systems, the load to the global environment in the form of green house effect can increase with the improvement in treated water quality. For the purpose of reducing energy consumption of nitrogen and phosphorus removal systems, we investigated operation and design methods from the view point of improving energy efficiency of each processes and total system.

RESULTS

- (1) From investigation of two wastewater treatment plants, about 10% of total energy consumption were occupied by that of the continuous mixing in the anaerobic tanks and the anoxic tanks.
- (2) MLSS concentration in the anaerobic tank with intermittent or slow mixing decreased considerably in the upper layer because of sedimentation of sludge. In anoxic tanks, MLSS and oxidized nitrogen ($\text{NO}_x\text{-N}$) concentrations were almost the same at every depth of the tanks. The reason of this is that the sludge does not easily sediment because of the formation of nitrogen gas with denitrification.
- (3) Complete stop of mixing affected denitrification and phosphorus removal performance (Figure 1 and 2). Using intermittent aeration mixing, denitrification was completed if the load was maintained at proper level, but the denitrification rate was smaller than that of continuous mixing. In the laboratory scale experiments with continuous mixing, denitrification rates and phosphorus removal rates decreased if activated sludge is separated because of slow mixing.
- (4) The overall volumetric oxygen transfer coefficient (K_La) with immobilization media was smaller with the increase of media addition when aeration gas flowrate was small. However, when aeration gas flowrate was large, K_La increased with the increase of media addition.
- (5) Heterotrophic bacteria grew on the surface of immobilization media with addition of organic matters, and, in the condition of low dissolved oxygen concentration, the nitrification rate of the media decreased considerably (Figure 3).

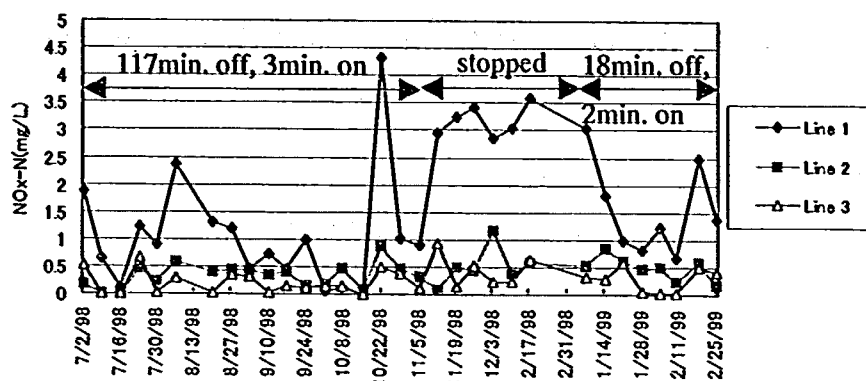


Figure 1: NO_x-N concentrations in the anoxic tanks

(The arrows show the mixing conditions of intermittent aeration in the anoxic tank of Line 1.

The anoxic tank of Line 2 and 3: continuous mixing

The treatment method is anaerobic – anoxic – aerobic methods.)

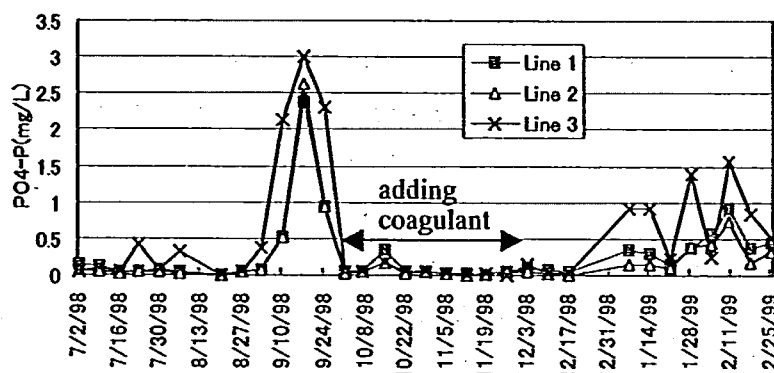


Figure 2: Phosphate phosphorus concentrations at the exits of aerobic tanks

(In the anaerobic tanks, the mixing methods of Line1, 2 and 3 were intermittent aeration mixing, continuous mixing and stopped mixing, respectively.

The treatment method is anaerobic – anoxic – aerobic methods.)

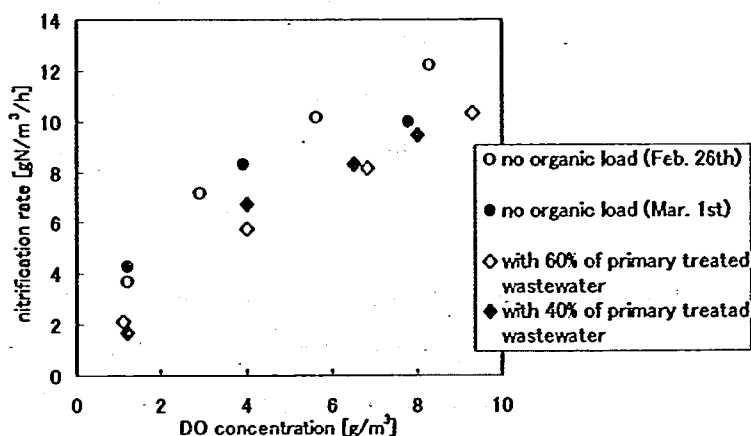


Figure 3: The effects of dissolved oxygen (DO) to the nitrification rate after adding organic matters
(batch experiments)

CONTROL OF PATHOGENIC MICROORGANISMS IN WASTEWATER SYSTEM

M. Ozaki, S. Ochi and T. Kitamura

Sludge Management Division

Project period: 1997-2000

OBJECTIVES

Cryptosporidiosis occurred by water supply in 1996 in Ogose Town, Saitama, Prefecture and more than 8,000 people were affected. Although the first cause of this outbreak cannot be specified, the circulatory system of *Cryptosporidium* formed between the treated water of the wastewater treatment plant (WWTP) and the water supply plant is the supposed cause of this outbreak, because the WWTP is located upper stream of the water supply plant intake.

According to the spread of sewerage systems, WWTPs tend to be located in upper stream areas. The ratio of treated water in environmental water bodies has increased year by year. In order to decrease the risk of infection, *Cryptosporidium* must be removed or inactivated at the WWTP. Furthermore, sanitary treatments of sewage sludge is important. This study aims to control pathogenic microorganisms in wastewater treatment systems.

In FY 1998, we investigated the physical and chemical characteristics of *Cryptosporidium parvum* oocysts. We measured the specific gravity and zeta potential of oocysts. The experiments carried out were chemical precipitation and adsorption by activated sludge of oocysts.

METHODS AND RESULTS

(1) Specific gravity of oocysts

Specific gravity of oocysts was measured by isopycnic banding. The flotation liquid used was PERCOLL. The PERCOLL were diluted with distilled water and prepared at a specific gravity of 1.00, 1.04, 1.05, 1.06, 1.07, 1.08. Five milliliters of the each flotation liquid was put into each 15ml tube. Next, 1550 oocysts were laid on the surface of each flotation liquid. Afterward, these tubes were centrifuged and 4.5ml off the top was discharged. We counted the number of oocysts in the remaining liquid. As a result, the specific gravity of oocysts ranged from 1.05 to 1.06.

(2) Zeta potential of oocysts

We measured the zeta potential of oocysts in the wastewater by the microelectrophoresis method. The results are shown in Figure 1. The zeta potential of oocysts in the wastewater was taken as the isoelectric point at pH2. The zeta potential of the oocysts was decreased as the pH value increased. The oocysts zeta potential was -20mV at pH7.

(3) Chemical precipitation of oocysts

We carried out chemical precipitation experiment of the oocysts in the wastewater in order to obtain basic data. The coagulant used in this experiment was polyaluminium chloride (PAC). The PAC dose was 1.56, 7.80, 46.8, 78.0, 156 mg-Al/L. Experimental conditions were rapid-mixing time of five minutes, a slow-mixing time of 15

minutes and settling time of 20 minutes. The results are shown in Figure 2. Zeta potential of flock was the isoelectric point at dose PAC46.8mg-Al/L. The pH value under this condition was 6.5. The suspended solid concentration in the supernatant was at the lowest level at 6mg/L. The number of oocysts in the supernatant under this condition was the lowest level and removal efficiency of the oocysts was 98.4%.

(4) Adsorption by activated sludge of oocysts.

We carried out an activated sludge batch experiment in order to obtain basic data on adsorption to activated sludge of oocysts. This experiment was used six 30ml tubes. The mixing ratios of activated sludge and primary effluent were 9:1 as volume. This mixed liquid was put into 20ml into each tube. Next, 1.3×10^5 oocysts were added in each tube. Immediately, we started to mix by rotary shaker. One tube was taken at intervals of 5, 15, 30, 60, 120, 240 minutes and settled for five minutes. Next, we counted the number of oocysts in the supernatant. The results are shown in Figure 3. Removal efficiency of oocysts by activated sludge was increased as the mixing time increased. Removal efficiency was 90% and 99.6% at a mixing time of five minutes and four hours.

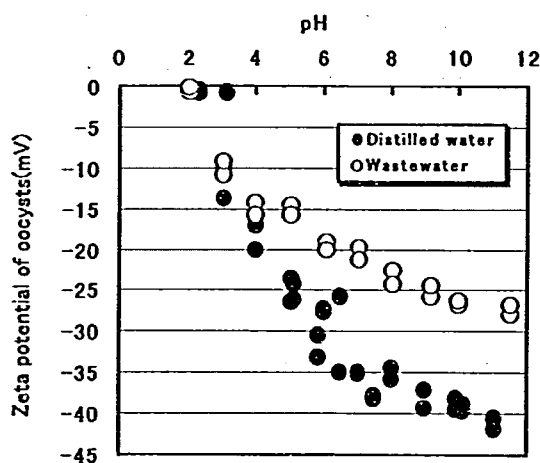


Fig.1 The relationship between pH value and Zeta potential of oocysts in distilled water and in wastewater

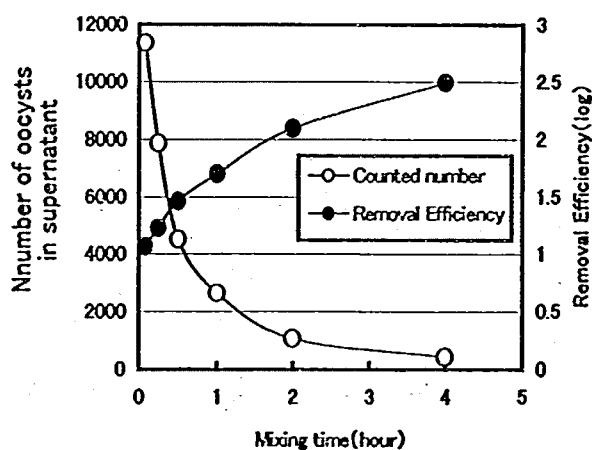


Fig.3 Result of adsorption by activated sludge of oocysts

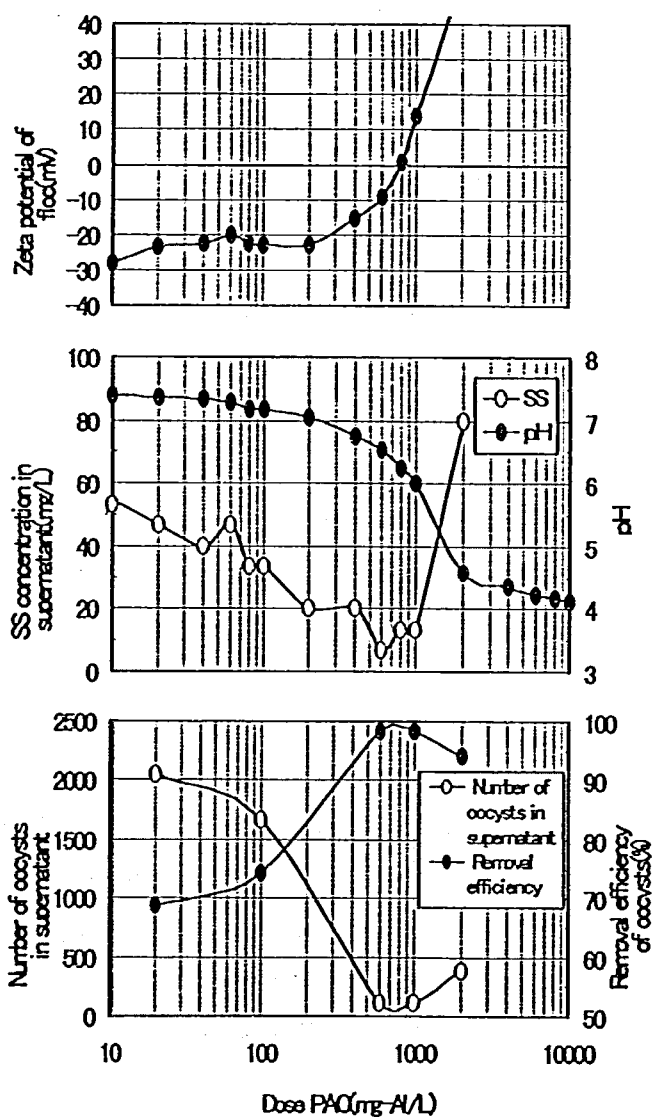


Fig.2 Result of chemical precipitation of oocysts

CONTROL OF HEAVY METALS ON SLUDGE TREATMENT PROCESS

Masaaki Ozaki, Tadao kubo

Project period;1998-2000

OBJECTIVES

Small quantities of hazardous substances, such as heavy metals which are included in gray water and industrial waste, flow into a sewage treatment plant. Some of the hazardous substances are decomposed or transformed into harmless substances with biological processing, but a part still subsists in sludge. Such hazardous substances need to be reduced as much as possible for the advance of the reuse of sewage sludge.

This study aims at the development of method to improve sewage sludge in quality, which may enable sludge to be utilized as raw material of recycled products in safety. It is, therefore, necessary to research the behavior of such hazardous substances in the sludge treatment processes. This study will contribute to the progress of technology to control them.

In FY 1998, a survey to grasp the behavior of heavy metals in the sludge incineration furnace and a study to control the dissolution of metals from recycled products were conducted.

RESULTS

SURVEY REGARDING THE BEHAVIOR OF HEAVY METALS IN THE INCINERATOR

We have performed many leaching tests on sludge incineration ash and recycled product. In the tests, it was often observed that selenium and arsenic dissolved from the samples, and the results in some case were not suited for the standard.

In the sludge incinerator, selenium and arsenic are in the state of a gas, because the temperature is higher than their evaporation temperature. So, they are discharged as exhaust gas from the furnace, but they solidify on the surface of fly ash as the gas temperature goes lower in the gas treatment process such as heat exchanger, cyclone, and cooling tower. Recently, use of the bug filter to improve the efficiency of fly ash collection is increasing. The bug filter collects fly ash at a low temperature of around 200°C to protect the filter. This range is lower than the evaporation temperature of selenium and arsenic, so it is considered that selenium and arsenic of high density are included in the fly ash collected by the bug filter.

Figure1 shows the ratio of metals distributed to each matter discharged from the incinerator of two different systems. The ratio is shown with the percentage to its content in dewatered sludge. Substances of which the

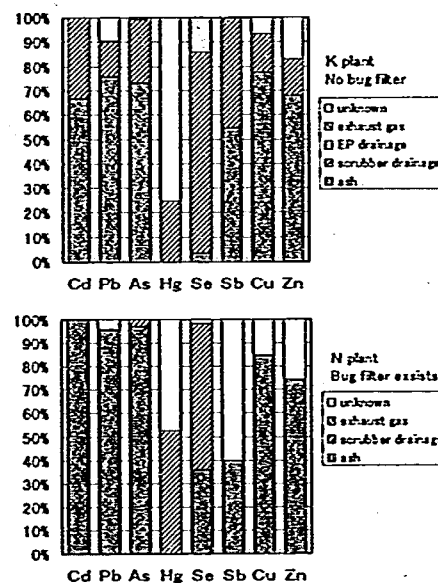


Fig.1 Ratio of Distribution

distribution ratio to ash was high were cadmium, lead, arsenic, copper, and zinc, but mercury, selenium were only slightly distributed to ash. From the viewpoint of difference of gas treatment process, on the other hand, more selenium and arsenic were distributed to ash collected by the bug filter, as expected at the beginning.

Selenium was distributed to ash collected by the bug filter, because the bug filter was operated at a lower temperature than the sublimation point of selenium oxide (SeO_2).

And it was also observed that a large amount of selenium passed the bug filter, most of which was collected in the scrubber to drainage, then returned to the water treatment process. Such a phenomenon is generally known in the case of mercury, and it is one of serious problems in some sewage treatment plants.

RESEARCH REGARDING THE CONTROL OF METALS DISSOLVING FROM SPHERE ASH

"Sphere ash" is a recycle product made from incineration ash discharged from a fluidized-bed incinerator. Incineration ash passes the flame of 1500° to 2000°C in the sphere forming furnace, and the surface of ash is melted to form spheres due to surface tension.

Sphere ash has such a characteristic as the fly ash which is used as a cement additive, and it is a better raw material than incineration ash, so it is expected to be a way to reuse sewage sludge. Sphere ash also achieved better results on leaching tests than incineration ash, because its surface is melted to glass.

However, the delay of solidification were observed in some tests on mortar which contained sphere ash. It was guessed that some substances, such as phosphorus and metals known to cause the delay of solidification, dissolved from sphere ash. Therefore, some leaching tests in $\text{Ca}(\text{OH})_2$ saturated solution, similar to the condition in mortar, were performed. It was then found that the surface of sphere ash was broken, calcium in the solution was absorbed, and metals such as kalium, sodium, and aluminum dissolved from sphere ash. In the tests, phosphorus dissolved from sphere ash was hardly detected in the solution. To see the images of EPMA of sphere ash after the test in a $\text{Ca}(\text{OH})_2$ saturated solution, calcium and phosphorus existed in similar position. From these results, it is conjectured that the delay of solidification was related to the lack of calcium caused by a reaction involving calcium and phosphorous. In a high pH solution such as mortar, a complicated reaction involving calcium arises on the surface of sphere ash, and the surface made of glassy material is broken, then calcium is combined with phosphorous contained in the ash.

We tried to control these reactions by adding $\text{Ca}(\text{OH})_2$ to ash before it is formed to sphere ash, because the phenomenon was not observed in the case of ash to which

$\text{Ca}(\text{OH})_2$ was added in the dewatering process. Figure2 shows that $\text{Ca}(\text{OH})_2$ addition of about 5% can control the reaction sufficiently.

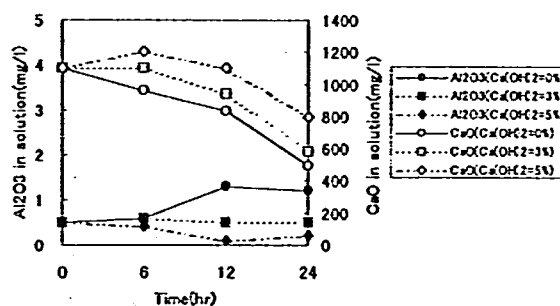


Fig.2 Leaching test in $\text{Ca}(\text{OH})_2$ saturated solution

SLUDGE TREATMENT RESPONDING TO SLUDGE PROPERTY CHANGE

M. Ozaki, S. Ochi and Y. Kitamura

Sludge Management Division

Project period : 1996 - 1999

OBJECTIVES

For the future, it is predicted that introducing advanced wastewater treatment processes in the sewerage systems will increase. In addition, there are many people who are eager to apply a garbage grinder - disposer in their homes for convenience. Therefore, the quality / quantity of sewage sludge through the wastewater treatment processes will change. Especially, the change of sewage sludge by garbage inflow will appear to the primary sludge which will increase the quantity and contain more the cellulose.

This study aims to construct sewage sludge treatment systems which can respond to changing sludge properties or quantities without a extensive rebuilding of the facilities and moreover recovery the resources or energy they contain.

RESULTS

In FY 1998, The influence of garbage inflow for the anaerobic digestion process and the compost process were investigated by laboratory - scale experiments on the supposition that the inflow of garbage will reach maximum in the future.

MIXTURE CONDITION OF GARBAGE

Two kinds of the garbage were prepared for the experiments, one was the Law - Garbage in which the raw wet-garbage is ground, and the other is Stabilized - Garbage in which the foregoing of the raw-garbage is aerobic digested by a 30 ° C - 24 hr condition on the assumption of stabilization in the flow of the pipe system. Then, the part of the garbage was mixed with sewage sludge by yield value per capita that is 250 g - wet/person/day of garbage and 70 g-total solids /person/day of sewage sludge. The source of garbage is a refectory of PWRI.

ANAEROBIC DIGESTION PROCESS

The experiments of anaerobic digestion were carried out using three units of equipment equipped with the same volume of reactor to 100 L and operated under condition with the digestion temperature to 35 ° C and 55 ° C, and the HRT (Hydraulics Retention Time) to 10, 15 and 20 days. The sewage sludge in which the garbage was mixed was easy to be digested than the usual case (Figure 1). Then, digested garbage was effectively connected with the generation of digestion gas (Figure 2).

COMPOST PROCESS

The experiments of compost were carried out by batch processing in the thermostatic chamber set to 30 ° C. In the composting of the sewage sludge in which garbage was mixed, composting periods were more abounding

than usual case (Figure 3), however there was no large effect on quality and the property of the products.

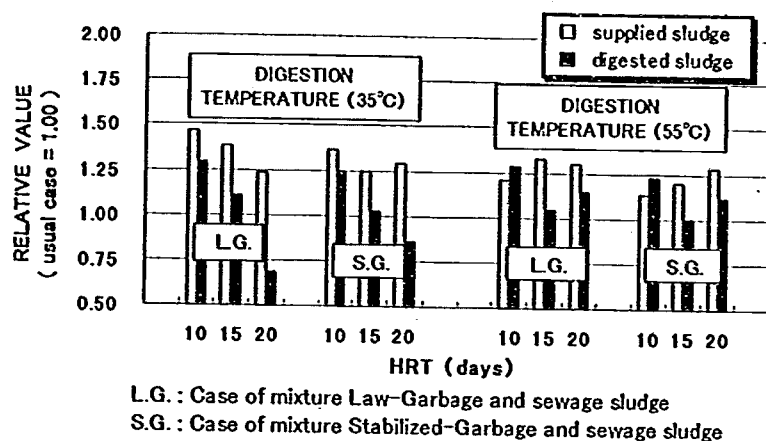


Fig. 1 Relative Comparison of Supplied Sludge and Digested Sludge by Anaerobic Digesting Mixture of Garbage and Sewage Sludge

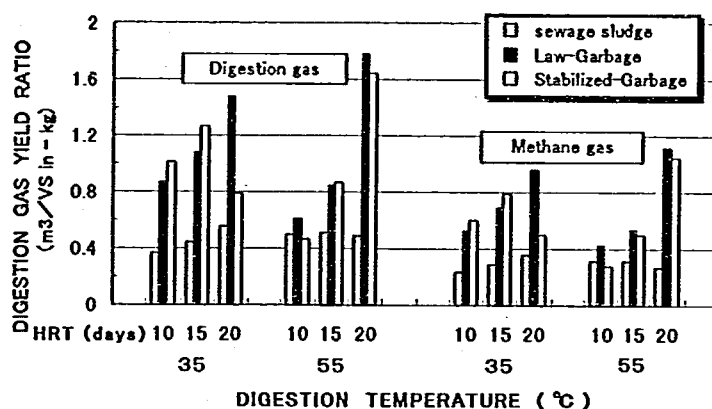


Fig. 2 Yield Ratio of Digestion Gas per Unit of Digested Sewage Sludge and Digested Garbage

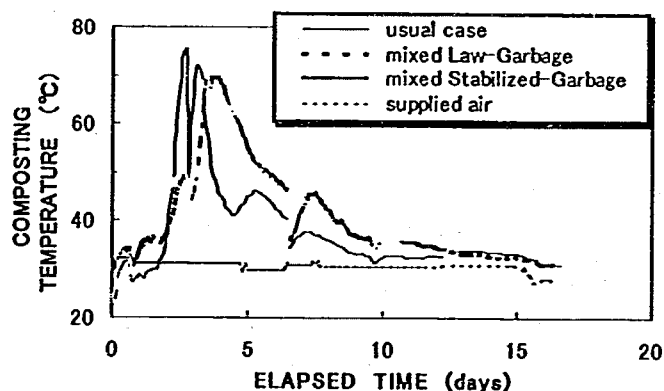


Fig. 3 Change of Temperature According to composting Mixture of Garbage and Sewage Sludge

CENTRALIZED SLUDGE TREATMENT SYSTEM FOR MEDIUM AND SMALL CITIES

M. Ozaki, T. Kubo, T. Ishizaki
Sludge Management Division

Project period : 1996-1998

OBJECTIVES

With the increase of sewerage systems in medium and small cities, it will be very important in the future to treat, dispose of and utilize sewage sludge which is generated in these cities. In general, there is not so much sludge generated in these cities, and the construction of sludge treatment facilities in each sewage treatment plant is inefficient and not economical. So, it is important to collect sewage sludge efficiently. It is also necessary to treat and dispose of collected sludge, and to promote the beneficial use of sewage sludge because of limited landfill sites.

This study aims to develop a centralized sludge treatment system for medium and small cities through the investigation and evaluation of beneficial use for medium and small sewage treatment plants.

RESULTS

In FY 1998, we investigated (1) odor substances for different bulking agents, and (2) discharge rates of VOCs (Volatile Organic Compounds) from compost facilities in sewage treatment plants.

ODOR SUBSTANCES FOR DIFFERENT BULKING AGENTS

Organic materials generated from agriculture, forestry, stock raising and the food industry were used as bulking agents in sewage compost facilities. The purpose of bulking agents is to improve moisture and pore content. But I felt that the odor of sewage sludge mixed with coffee grounds was better than the odor of sewage sludge mixed with no bulking agents and except for coffee grounds. So, we carried out a fermentation experiment for different bulking agents to confirm odor control on a laboratory scale. There were four cases as follows; blank (BL) mixed sewage sludge and compost product, case 1 (C1) mixed sewage sludge, chaff (generated from agriculture) and compost product, case 2 (C2) mixed sewage sludge, bark (generated from forestry), case 3 (C3) mixed sewage sludge, coffee grounds (generated by the drink industry) and compost product. Initial moisture content was conditioned to be about 60% in all cases.

We analyzed the sulfur compound of hydrogen sulfide (H_2S), methyl mercaptan (MM), methyl sulfide (DMS) and dimethyl disulfide (DMDS) regulated by the Offensive Odor Control Law. H_2S and DMDS were not detected in all cases. Change of MM concentration is indicated in Fig.1. C1, C2 and C3 were not detected over ten days and BL was not detected over 13 days. And it seemed that fermentation temperature was related to the MM concentration. So, we carried out regression analysis between the MM concentration and fermentation temperature. The results of this analysis indicated in Table 1. We considered that all cases had high correlativity, and in the case of the same temperature, the MM concentration decreased in order as follows; C1, BL, C2, C3. Next, the change of DMS concentration is indicated in Fig.2. Detectable period of the case of mixed bulking agents was shorter than the case of no mixed bulking agents. We carried out regression analysis for DMS

concentration and fermentation temperature. The results of this analysis are indicated in Table 2. The correlation coefficient of DMS was not as high as MM, but we considered that there was correlativity between the DMS concentration and fermentation temperature. In the case of the same fermentation, the DMS concentration decreased in order as follows; BL, C1, C2, C3. So, it was obvious that there was an effect of odor emission control by adding bark and coffee grounds.

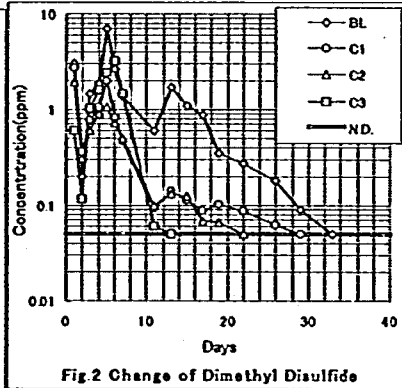
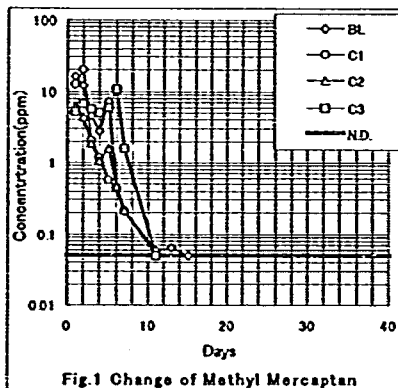


Table-1 The results of regression analysis(MM)

	a	b	R ²	n
BL	8.0×10^{-16}	9.0	0.69	9
C1	3.0×10^{-17}	9.9	0.83	9
C2	2.0×10^{-17}	9.8	0.88	9
C3	1.0×10^{-19}	11	0.91	9

$$Y = a \cdot X^b \quad [Y: \text{MM concentration (ppm)}, X: \text{temperature (}^\circ\text{C)} (40 \leq X \leq 70)]$$

Table-2 The results of regression analysis(DMS)

	a	b	R ²	n
BL	1.0×10^{-8}	4.8	0.62	14
C1	4.0×10^{-9}	4.9	0.63	15
C2	6.0×10^{-10}	5.3	0.75	14
C3	5.0×10^{-12}	6.3	0.65	10

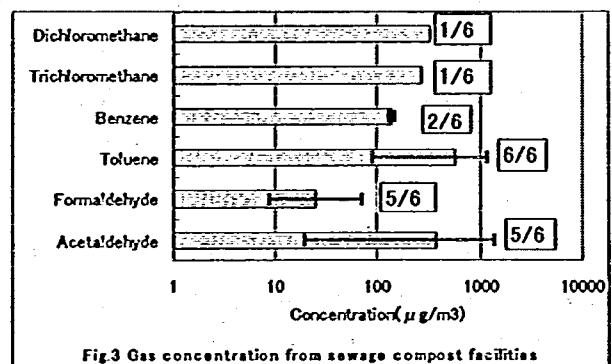
$$Y = a \cdot X^b \quad [Y: \text{DMS concentration (ppm)}, X: \text{temperature (}^\circ\text{C)} (35 \leq X \leq 70)]$$

DISCHARGE RATES OF VOCs FROM SEWAGE COMPOST FACILITIES

We investigated 14 substances of VOCs from compost facilities in three sewage treatment plants. The results of this investigation are indicated in Fig.3. The straight lines are average concentration over not detected (ND). The denominator at the right side of the straight line is the sample number and the numerator is the number over ND. Six substances of investigation target substances were detected, and we compared the gas concentration with environmental quality standard and so on.

①Dichloromethane: This substance's management concentration (on the workshop where organic solvents and so on were used) by the Labor Safety Sanitation Law is 100ppm. This investigation concentration $330 \mu\text{g}/\text{m}^3$ was under 1/1,000 of the management concentration. ②Trichloromethane: This substance's management concentration is 10ppm. This investigation concentration $270 \mu\text{g}/\text{m}^3$ was about 1/200 of the management concentration. ③Benzene: This substance is one of the substances under the Air Pollution Control Law, and the strictest environmental quality standard in outlets from the discharge facilities of benzene is $50 \text{mg}/\text{m}^3$. This investigation's highest concentration $150 \mu\text{g}/\text{m}^3$ is about 1/330 of the standard. ④Toluene: This strictest standard on the sit boundary by the Offensive Odor Control Law is 10ppm, and the management concentration is 50ppm. This investigation's highest concentration $1.16 \text{mg}/\text{m}^3$ is about 1/30 of the odor standard, and is about 1/170 of the management concentration. ⑤Formaldehyde: General environmental concentration is from $0.9 \mu\text{g}/\text{m}^3$ to $21.7 \mu\text{g}/\text{m}^3$. This investigation's highest concentration $710 \mu\text{g}/\text{m}^3$ is the same figure as the general environmental concentration. ⑥ Acetaldehyde: This strictest standard on sit boundary by the Offensive Odor Control Law is 0.005ppm. This investigation's highest concentration $1.36 \text{mg}/\text{m}^3$ is about fourteen times the odor standard.

So, through comparing with environmental quality standards, we consider that the discharge gas concentration from compost facilities has no influence on human health.



CO-COMPOSTING OF SLUDGE WITH OTHER ORGANIC MATERIALS

M. Ozaki, I. Harada and S. Ochi

Sludge Management Division

Project period : 1997-1999

OBJECTIVES

For many years sewage sludge, principally made by composting, has been used on agricultural and green lands as fertilizer in Japan. In the future, the number of sewage treatment plants will increase in small cities of which hinterlands are agricultural and green lands, where sewage sludge can be used as fertilizer. Farmers using organic fertilizer, however, desire better products, which need improving in order to promote effective utilization of sewage sludge. A simple composting is also hoped for to prevent costs from rising.

Therefore, the purpose of this study is to develop composts that combine sewage sludge with other organic materials or bulking agents which have advantageous characteristics and to suggest a simple composting method that can be adopted by small wastewater treatment facilities.

METHOD

In FY1998 we investigated a co-composting from some different viewpoints for the second year running.

- (1) Fermentation experiments of sewage sludge mixed with grass were carried out on a laboratory scale to identify the permeability of composts. After materials were put into cylindrical compostors 4.7 liter in volume, compulsory aeration and mixing every one - nine days were practiced during fermentation for 46 days. Permeability coefficients were measured in addition to temperature and chemical components.
- (2) Large-scale experiments of sewage sludge with grass added as a bulking agent were conducted for the purpose of considering adequate initial conditions. The wind-low type by a self-driving compost turning machine was applied. The mixing ratios of sewage sludge and grass were adjusted to between 1:0.20 and 1:0.05 on a dried solids (DS) basis. Initial moisture content was regulated at about 65%.
- (3) We investigated a combined composting of sewage sludge and cattle dung to confirm the fermentation in the case of applying dewatered sludge and return compost to the wind-low type. The recirculation ratios of return compost were set as 30% and 90% on a DS basis. Dried material was used as sewage sludge in the former and only dewatered sludge was applied in the latter. The mixing ratio of sewage sludge and cattle dung was adjusted to 1:1 on a DS basis and initial moisture content was regulated at about 65% in both piles.
- (4) Fertilizer response tests of combined composts with different mixing ratios of sewage sludge and cattle dung were conducted. We cultivated cabbage, sugar beets and adzuki beans on the experimental farms. Harvested weight and absorption ratios of fertilizer components were measured so that desirable application rate of fertilizer would be estimated.

RESULTS

Some fundamental data concerned with co-composting of sewage sludge with other organic materials were obtained through this study. The summary of the study in FY 1998 is as follows.

(1) Grass had the effect of keeping free air space (FAS) of the mixture in the first stage. Permeability coefficients of the composts mixed with grass decreased as time proceeded, however, permeability of only sewage sludge improved through fermentation (Fig.1). The relationship between bulk densities and permeability coefficients also became clear in the case of using grass as a bulking agent.

(2) In the large-scale fermentation experiments of sewage sludge adopting grass, it was estimated that the mixing ratio of grass to sewage sludge on a DS basis was set up over 0.2 and the bulk density was conditioned less than 0.6t/m^3 even if dried sludge was applied in order to control the initial moisture content.

(3) Aerobic fermentation over 65°C , which the temperature reached after one week from the start of the experiment, was observed in the combined compost of dewatered sludge and cattle dung added return compost when applying the wind-low type (Fig.2). It is necessary to investigate the suitable condition such as the recirculation ratio of return compost to activate fermentation of composts.

(4) Fertilizer response tests showed that the compost in which mixing ratios of sewage sludge and cattle dung was 9:10 on a DS basis had more of an effect to increase the harvested weight of all crops than that of 5:10 (Fig.3). The possible reducing quantities of chemical fertilizer application were estimated if combined composts of sewage sludge and cattle dung were utilized.

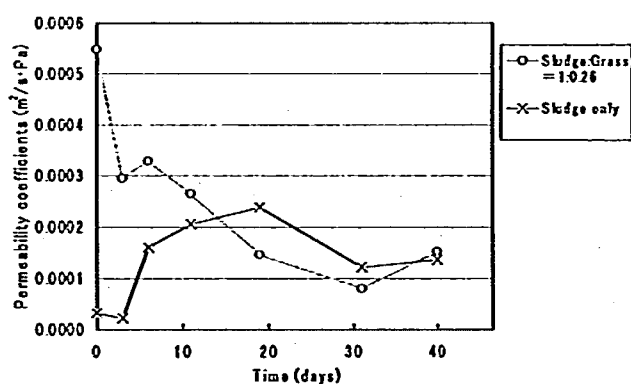


Fig. 1 Change in permeability of sludge compost mixed with grass

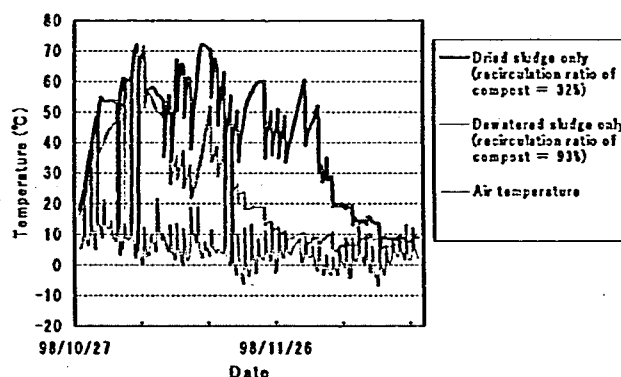


Fig. 2 Temperature trend in combined composting of sludge and cattle dung applied return compost

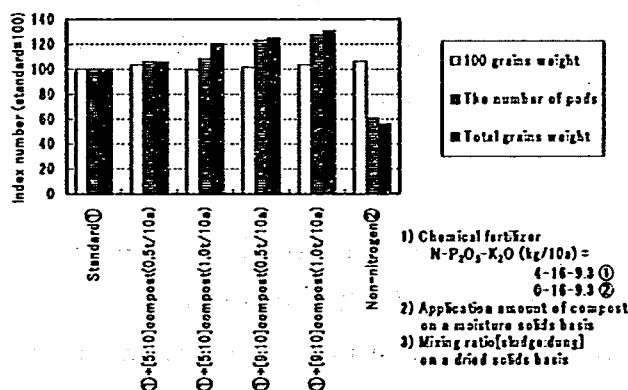


Fig. 3 Adzuki bean yield in applying combined composts of sludge and cattle dung

EMISSION VALUE FOR UNIT MATERIAL PRODUCTION USING LCA OF SEWERAGE SYSTEM

M. Ozaki, I. Harada, T. Kubo and T. Ishizaki

Sludge Management Division

Project period : 1998-2000

OBJECTIVES

Sewerage systems, which preserve the water quality of public water bodies, cause environmental loads. For example, the discharge of global-warming gases and electricity consumption result from construction, operation, maintenance and disposal of sewerage. Therefore, it is desired to build sewerage systems in which environmental loads are reduced as much as possible.

The purpose of this study is to determine the unit value of environmental loads quantitatively caused by sewerage systems and to establish an evaluation method for optimizing sewerage systems in terms of environmental loads. Life cycle assessment (LCA) analysis is applied to estimating environmental loads in the study. Still most of the study was conducted as joint research with the Japan Sewerage Works Agency, the Association of Water and Sewage Works Consultants Japan, and the Japan Sewage Treatment Plant Constructors Association.

METHOD

In FY 1998, we investigated life cycle inventory (LCI) analysis applicable to sewerage systems and tried calculating environmental loads for the first year running. A stacking method, which could represent the variety of sewerage systems in detail, was used as inventory analysis. Carbon dioxide (CO₂) and energy were selected from environmental loads because these databases were relatively improved as typical indexes. As for the objects of LCI analysis, practical sewer systems and treatment plants were chosen to estimate environmental loads suitable to the actual condition. Sewerage system was divided into two categories which consisted of public works/architecture structures and mechanical/electric plants. On the other hand, construction, operation/maintenance, scrapping and reuse were included in a life cycle of the study. But, final disposal of sewerage facilities and CO₂ discharged directly from sewage and sludge were not considered.

RESULTS

Some fundamental data concerned with environmental loads caused by sewerage systems were obtained through the study. The summary of the study in FY 1998 is as follows.

(1) CO₂ load of sewer construction by the cut and cover tunneling method was estimated as $1.4 \sim 1.5 \times 10^3 \text{ kg-CO}_2/\text{m}$ on average of collecting area. Body construction occupied more than 90% in public works

structures at a treatment plant. CO₂ load at a large-scale public works structure was less than that at a small one, however, the calculated construction loads of architecture buildings per floor area indicated almost the same values, which were approximately 800kg-CO₂/m². It was also confirmed that a branch sewer had the most effect on CO₂ loads caused by construction of public works/architecture structures (Fig. 1).

(2) Operating load occupied more than 95% in both CO₂ and energy discharged by mechanical/electric plants of a standard activated sludge treatment plant to the extent of sludge dewatering during a life cycle (Fig. 2). The remaining 5% was mostly due to materials and the unit environmental loads per treatment ability were estimated as 0.329kg-CO₂/m³ and 6.96MJ/m³. The results of calculation for a sludge incinerator also showed a similar tendency. From the viewpoint of facilities, the amount of loads caused by the wastewater treatment process was approximately equal to that of sludge treatment at a standard activated sludge treatment plant, however, the influence of aeration became larger at an oxidation ditch. As for the material load, a simplified estimating method focused on the investigation of main facilities could be applied.

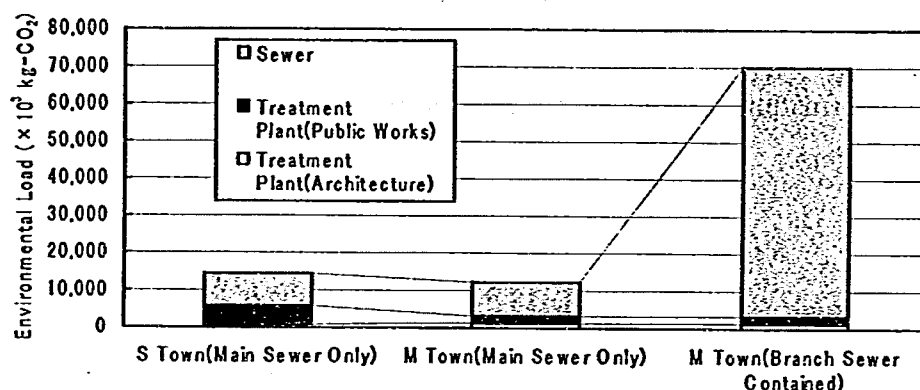


Fig. 1 CO₂ Load Caused by Construction of Public Works/Architecture Structures

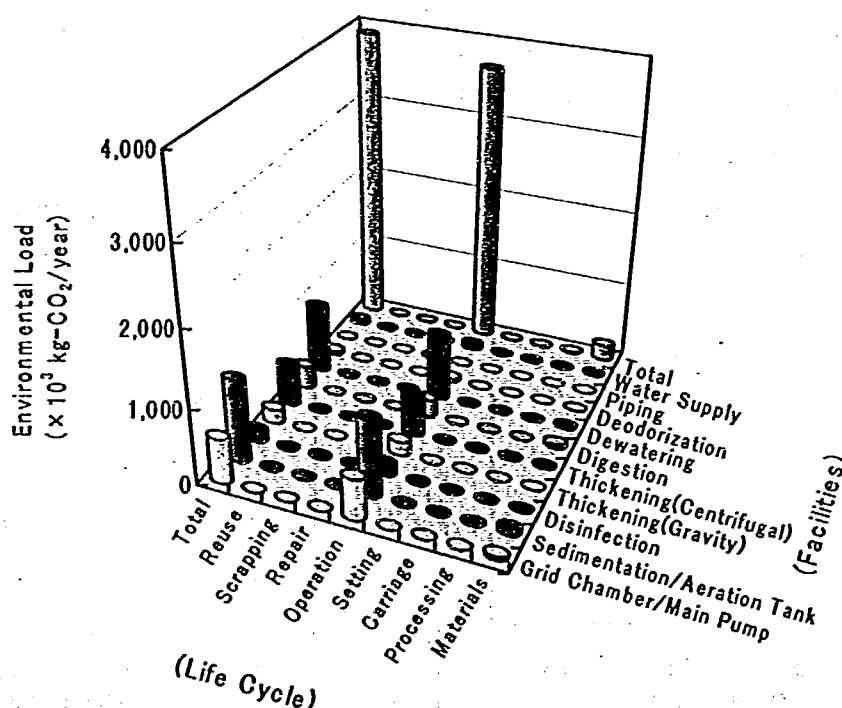


Fig. 2 LC-CO₂ at Mechanical/Electric Plants of Standard Activated Sludge Treatment

FATE OF ORGANIC COMPOUNDS IN RIVERS UTILIZED FOR DRINKING WATER RESOURCES

M.Shirasaki, H.Tanaka and Y.Okayasu

Water Quality Division

Project Period : FY1995-1998

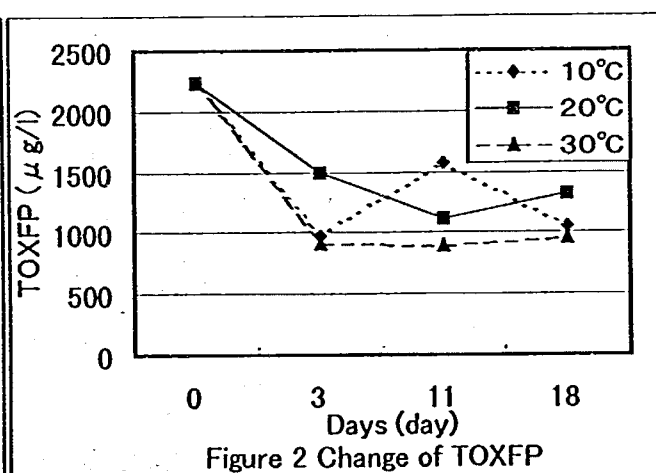
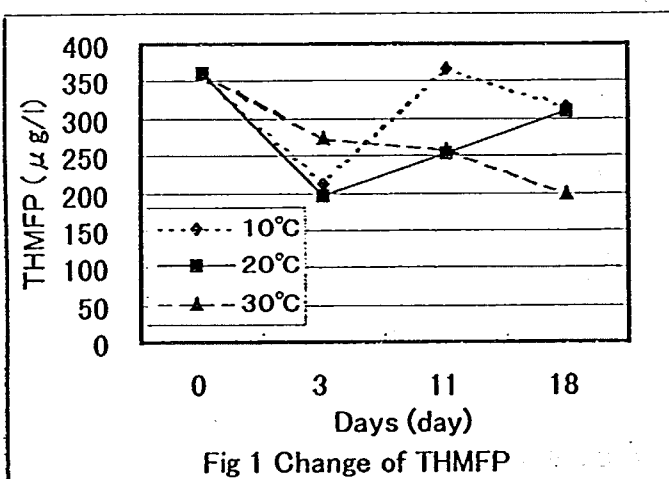
INTRODUCTION

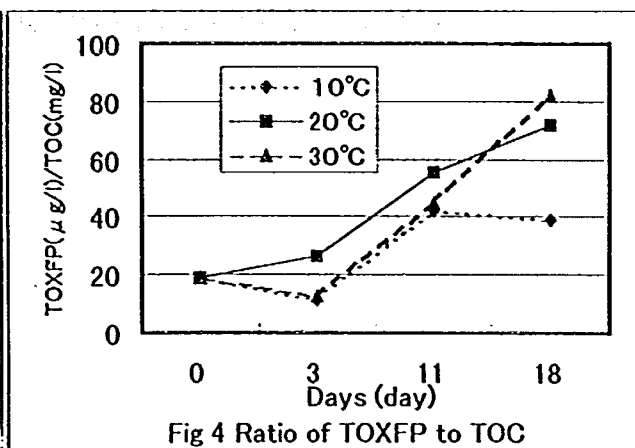
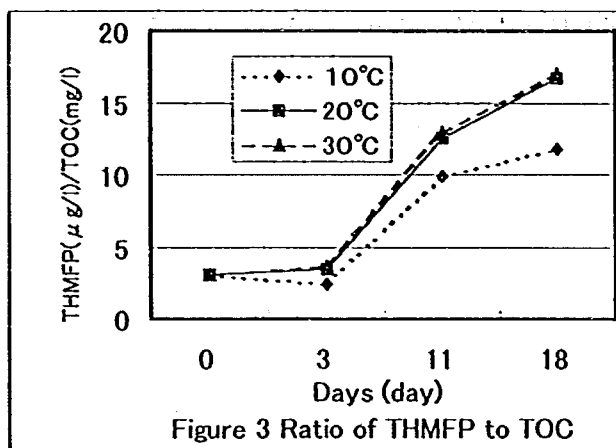
In order to plan effective countermeasures for public water supply facing the difficulty in controlling trihalomethane (THM) at tap, it is necessary to predict trihalomethane formation potential (THMFP) concentration in the designated waters. When we predict THMFP concentration, it is necessary to understand not only the amount of THMFP load discharged from various sources on watershed but also the fate of THMFP in rivers and stagnate waters. So we conducted the study to understand the formation and decay process of disinfection by-product formation potential (DBFP) in natural waters.

RESULTS

(1) Research on the decay process of DBFP

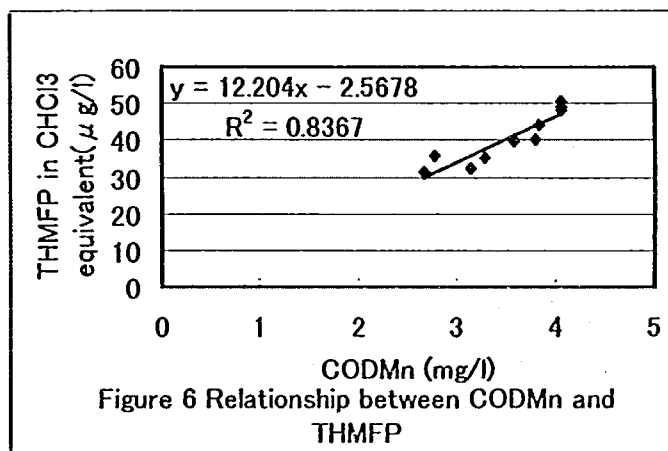
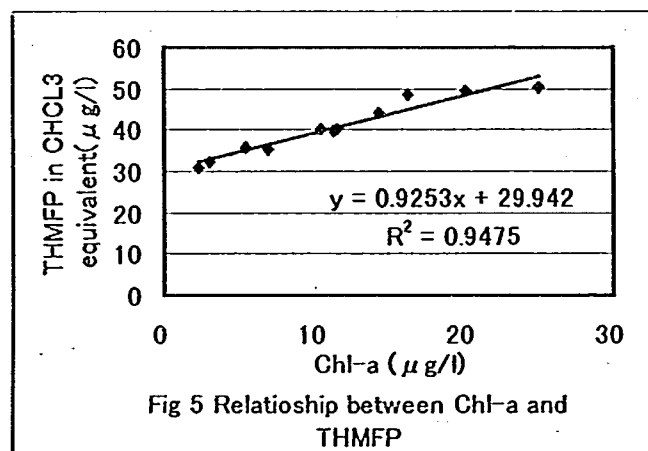
In order to understand the influence of water temperature on decay process of THMFP and TOXFP, and the relationship between TOC, BOD and THMFP, TOXFP, we experimented at three different water temperature 10°C, 20°C and 30°C. In this experiment, origin of pollutant was from domestic waste. The influence of water temperature on change of water quality was not clear. (as shown in Figure 1 and Figure 2) And the decay rates of THMFP and TOXFP were smaller than those of TOC and BOD. (as shown in Figure 3 and Figure 4) As a result when the fates of THMFP and TOXFP are predicted, the organic matter index such as TOC and BOD can not be used for surrogate indexes of THMFP and TOXFP.





(2) Analysis on the water quality data in Tone River

We have analyzed water at 11 sampling points along the Tone River. The data of water quality were averaged between September in 1996 and January in 1999. When we studied the relationship between Chl-a and THMFP as well as that and TOXFP, we found the relationships were almost linear. (as shown in Figure 5) In same way, the relationships between COD_{Mn} and THMFP as well as that and TOXFP were almost linear. (as shown in Figure 6) In this analysis, in order to remove the effect by molecular weight of bromine compound, we change THMFP into $CHCl_3$ equivalent.



MANAGEMENT OF HAZARDOUS SUBSTANCES IN SEWERAGE

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Water Quality Division

Project period: FY1996-1999

OBJECTIVES

Many chemical substances are indispensable for making human life comfortable and convenient, but some of them are suspected to have large toxicity to human and ecological health. At present, only a small number of them are regulated for discharge to public waters on the basis of Water Pollution Control Law and Sewerage Law in Japan.

Management of such chemical substances is quite important in sewerage systems, which play a role of returning treated wastewater to public waters. It is necessary to get information about identifying and quantifying chemical substances in untreated and treated wastewater, predicting their fates in wastewater treatment plants and estimating effectively for their risk to human and ecological health, which result in establishing methodology for managing hazardous chemical substances in sewerage system.

In FY 1998, we studied on endocrine disrupting chemicals (EDs) for the reason that EDs problem become emerging social concerns. We conducted field surveys of nonylphenol (NP) and nonylphenol ethoxylates compounds (NPEO) in the experimental wastewater treatment plant applying the conventional activated sludge process (ASP) which is popularly applied in urban areas in Japan. NP is a biodegradation product of nonionic surfactant NPEO and has been known as a typical EDs. In addition, we conducted field surveys of 9 types of EDs and related substances which have been detected in wastewater on the field surveys by Ministry of Construction in FY 1998 in the experimental wastewater treatment plant.

RESULTS

This study in FY 1998 can be summarized as follows:

(1) Mass balance of NP and NPEO in the experimental wastewater treatment plant

We measured NP and NPEO concentrations in influent and effluent wastewater and withdrawn sludge, and then estimated mass fluxes of NP and NPEO that entered into and emitted out of the treatment process. All the samples were concentrated with solid phase extraction and were measured with HPLC. NPEO was separately measured NP1-4EO group and NPnEO group. Where ethoxylates number of NP1-4EO is from 1 to 4 and that of NPnEO is greater than or equal to 5.

Mass balances of NP and NPEO are shown in Figure-1. 13 % of NP, 5.6 % of NP1-4EO and 13 % of NPnEO were estimated to be emitted out of the treatment process compared with their entering mass fluxes.

(2) Field surveys of endocrine disrupting chemicals in the experimental wastewater treatment plant

We conducted field surveys of NP, NP1-4EO, bisphenol A, diethylhexyl adipate, diethylhexyl phthalate, di-n-butyl phthalate, 17 β -estradiol and estrogen-like activities in wastewater at the experimental wastewater plant applying the conventional ASP. Results of the surveys are shown in Table-1. Concentration of NP, bisphenol A, diethylhexyl adipate, diethylhexyl phthalate, di-n-butyl phthalate and 17 β -estradiol in influent were 13 $\mu\text{g/l}$, 1.0 $\mu\text{g/l}$, 0.07 $\mu\text{g/l}$, 10 $\mu\text{g/l}$, 1.5 $\mu\text{g/l}$ and 0.037 $\mu\text{g/l}$ respectively. All the concentrations of the EDs in influent were with in the range of the EDs concentrations in the nation-wide surveys by Ministry of Construction in FY 1998.

Concentration of NP1-4EO, NPnEO and estrogen-like activities in influent were 14 $\mu\text{g/l}$, 42 $\mu\text{g/l}$ and 0.038 $\mu\text{g/l}$ respectively.

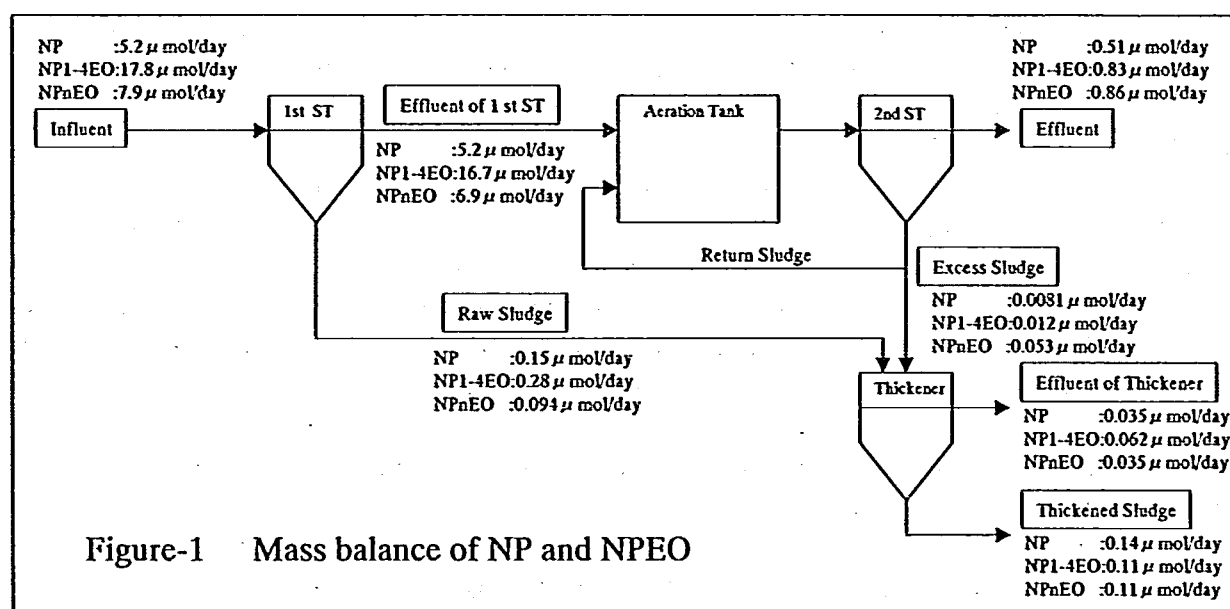


Table-1 Results of the Surveys

unit : $\mu\text{g/L}$

	Influent	Effluent of 1st ST	Effluent	Raw Sludge	Excess Sludge
① NP	13	8.8	1.2	150	18
② NP1-4EO	14	18	0.5	340	160
③ NPnEO (n $\geq$ 5)	42	32	2.4	530	120
④ bisphenol A	1.0	0.89	0.036	6.4	11
⑤ diethylhexyl adipate	0.07	0.09	0.05	1.1	0.57
⑥ diethylhexyl phthalate	10	6.4	1.2	800	830
⑦ di-n-butyl phthalate	1.5	1.5	0.1	17	10
⑧ 17 β -estradiol	0.037	0.033	0.009	0.36	0.15
⑨ estrogen-like activities (as the 17 β -estradiol equivalent)	0.038	0.035	0.0066	—	—

APPLICATION OF BIOSENSORS TO WATER QUALITY MONITORING IN SEWERAGE

H.Tanaka, M.Shirasaki and Y.Okayasu
Water Quality Division

Project period:FY1995-1998

OBJECTIVES

BOD₅ is one of the most popular tests used for water quality management in sewerage and rivers. However, a BOD₅ test takes five days to get the results. Thus, BOD₅ cannot be measured as real time data or as feedback data for wastewater treatment. Because a number of staff in charge of water quality management are eager to monitor BOD of influent and effluent at wastewater treatment plants, PWRI developed a prototype BOD sensor which consists of an immobilized microbial film and a DO probe under "the Biofocus Project." This survey is aiming at development of a BOD monitoring system for secondary effluent from wastewater treatment plants.

METHODS & RESULTS

1. Selection of the microorganism applied to the receptor of the BOD sensor

The BOD sensor applied the microorganisms (so called S-1 strain) which had been isolated from a discharge channel receiving secondary effluent. However, it was observed that the activity of the microorganisms applied to the receptor of the BOD sensor was very small. Therefore, five species in strains of microorganisms were newly isolated from secondary effluent in Soseigawa wastewater treatment plant in Sapporo. And the oxygen consumption rate for standard solution was measured by the sensor system consisting of the microorganism. As a result, so called SO-1 strain turned out to be the best one applied to the receptor of the BOD sensor.

2. Understanding characteristics of degradation by SO-1 strain applied to BOD sensor

BOD₅ value of various samples was compared with the oxygen consumption rate in the BOD sensor consisting of the SO-1 strain. Both are not mutually related (Fig.-1). It seemed to be caused by difference in components of organic compounds in sample (Fig.-2). The SO-1 strain and samples filtered with a membrane filter were set in Coulometer and the oxygen consumption was observed (Fig.3). It could be understood that such characteristics are hardly changed even if a term for measurement of the BOD sensor is extended.

3. Studying methods to preserve the microorganisms

Methods to preserve the microorganisms was studied. The following three method were examined a refrigerating method, a freezing method and a freeze-drying method. As a result, the freeze-drying method turned out to be effective.

4. Developing a portable type of a BOD sensor

A portable type of a BOD sensor was developed. To evaluate the device, BOD₅ value of sample were compared with the oxygen consumption rates in terms of the BOD sensor output. Both are mutually related (Fig.-4). The results of testing samples, secondary effluent in Soseigawa wastewater treatment plant, showed that the standard solution for calibration needs to be improved if GGA is used. (Fig.-5).

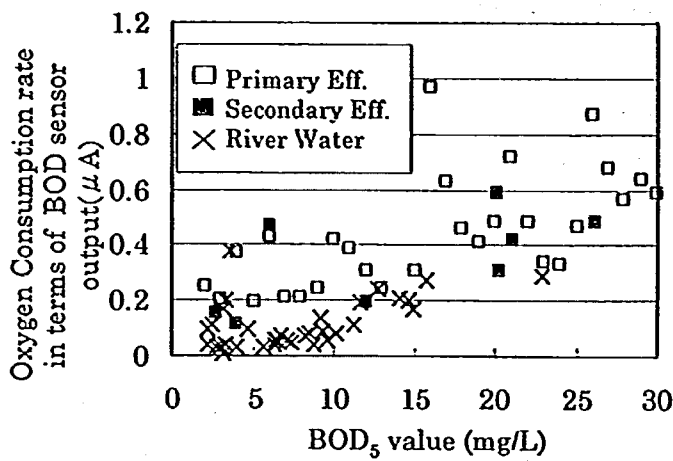


Fig.-1 Comparison of oxygen consumption rate in BOD sensor output with BOD₅ value in various sample

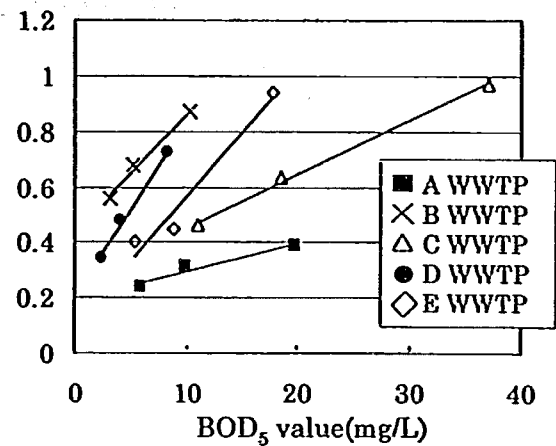


Fig.-2 Comparison oxygen consumption rate in BOD sensor with BOD₅ value of diluted primary effluent

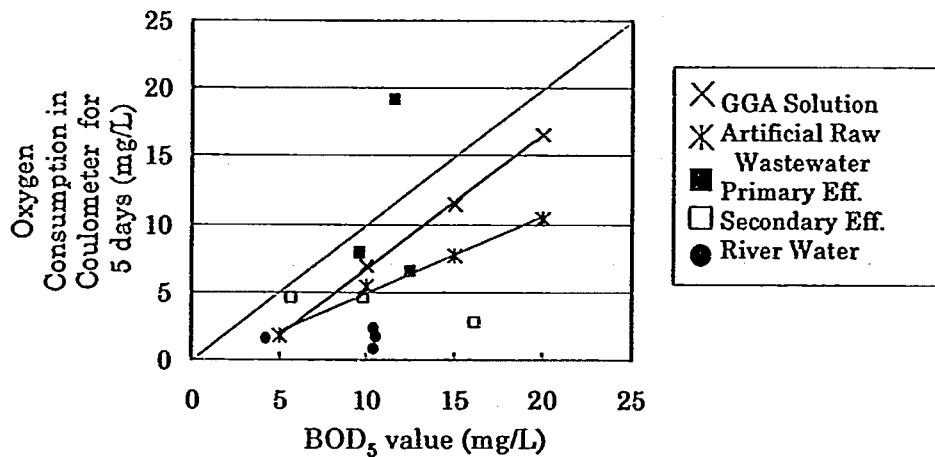


Fig.-3 Comparison of oxygen consumption in Coulometer for 5 days with BOD₅ value

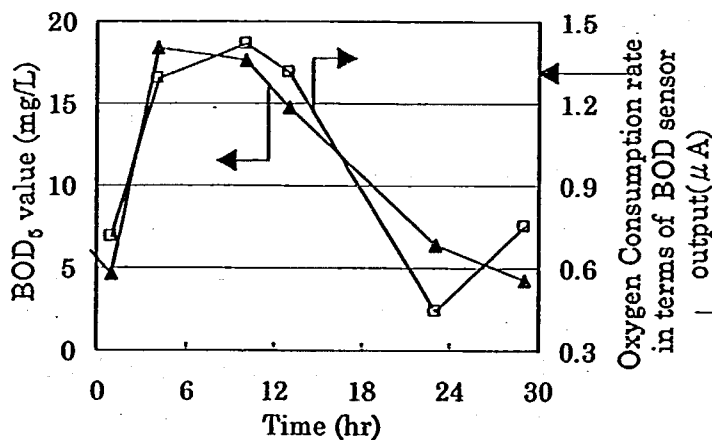


Fig.-4 Comparison of oxygen consumption rate in BOD sensor with BOD₅ value

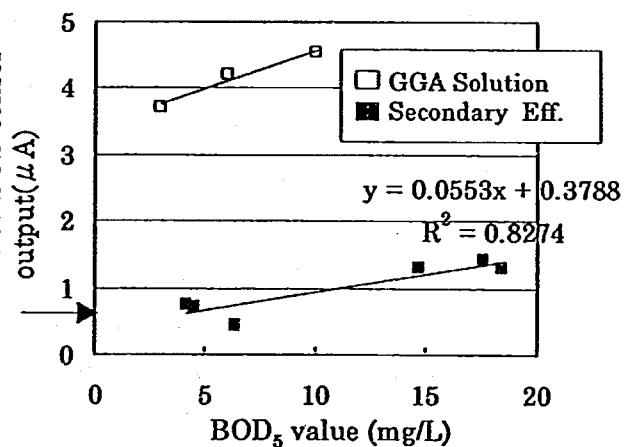


Fig.-5 Comparison of oxygen consumption rate in BOD sensor with BOD₅ value

FATAL PREDICTION OF VOLATILE ORGANIC COMPOUNDS IN ACTIVATED SLUDGE PROCESS

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Water Quality Division

Project Period:1996-1999

OBJECTIVES

Chlorinated organic compounds have become a matter of increasing concern in the field of water quality management due to their small biodegradability and large toxicity. However, only a small number of organic compounds in production are regulated for discharge to public waters in Japan. In December 1993, nine volatile organic compounds (VOCs) most of which are chlorinated organic compounds were supplemented for the effluent standard. Industrial discharges to sewerage systems must be set up pretreatment facility in order to observe the effluent standard on the regulated VOCs if necessary. However, the rest of VOCs, commonly utilized in home and industry, might be wasted to public sewers as sewage. Seventy percent of urban wastewater is now discharged to public sewers and biologically treated in wastewater treatment plants.

Thus, the fate of these compounds in biological treatment processes, particularly in the activated sludge process (ASP) which is popularly applied in urban areas in Japan, should be identified. If necessary, countermeasures should be taken in public sewerage. As the first step of control of such trace compounds in the activated sludge process, this study is aiming to identify the fate of VOCs in the activated sludge process.

RESULTS

This study in FY 1998 can be summarized as follows:

1) Field Survey of VOCs

We conducted field survey of 22 types of VOCs in wastewater at actual treatment plant applying the conventional ASP. Eleven VOCs consisting of dichloromethane, chloroform, benzene, 1,2-dichloroethane, trichloroethylene, toluene, trans-1,3-dichloropropene, 1,1,2-trichloroethane, m,p-xylene, o-xylene and p-dichlorobenzene were detected in influent. Six VOCs consisting of dichloromethane, chloroform, toluene, m,p-xylene, o-xylene and p-dichlorobenzene were detected in primary effluent. Eleven VOCs consisting of 1,1-dichloroethylene, trans-1,2-dichloroethylene, cis-1,2-dichloroethylene, chloroform, 1,1,1-trichloroethane, tetrachlorometane, 1,2-dichloroethane, trichloroethylene, toluene, trichloroethylene and m,p-xylene were detected in secondary effluent. However, all the concentrations of VOCs were lower than environmental water quality standards or guideline values for items for monitoring.

2) Mass balance of VOCs in the experimental wastewater treatment model

We measured VOC concentrations in influent wastewater, effluent wastewater, wasted gas and

withdrawn sludge, using experimental facilities simulating the ASP. And then estimated mass fluxes of VOCs with respect to water, air and sludge that entered into and emitted out of the treatment process. VOCs whose mass balances were estimated were dichloromethane, benzene, toluene, m,p-xylene and o-xylene. (see Fig.1)

There resided 39% of dichloromethane, 12% of benzene, 8% of toluene, 3% of m,p-xylene and 8% of o-xylene in the effluent, and 55% of o-xylene in excess sludge if influent mass fluxed of individual VOCs are assumed 100%. 46% of dichloromethane, 2% of benzene, 16% of toluene, 10% of m,p-xylene and 22% of o-xylene were withdrawn as the raw sludge that generates in the primary settling tank. 3% of dichloromethane, 3% of toluene, 2% of m,p-xylene and 12% of o-xylene were withdrawn as the excess sludge that generates in biological process. The mass fluxes of VOCs that were purged into the air could be estimated to be 28%, 25%, 24%, 18% and 22% of the influent mass fluxes of dichloromethane, benzene, toluene, m,p-xylene and o-xylene respectively.

The total mass fluxes emitted into the environment of benzene, toluene, m,p-xylene and o-xylene that have been reported to show relatively large biodegradability were estimated to be only 31%, 46%, 31% and 64% of the influent mass flux, respectively.

3) Biodegradation test of VOCs

We conducted biodegradation test of VOCs by Coulometers which can automatically measure respiration rate of activated sludge administered with the VOCs for 14 days. VOCs tested were dichloromethane, benzene, toluene, o-xylene, m-xylene and p-xylene.

Degradation rate of VOCs for 14 days were 7%, 52%, 60%, 34%, 51% and 59% of dichloromethane, benzene, toluene, o-xylene, m-xylene and p-xylene.

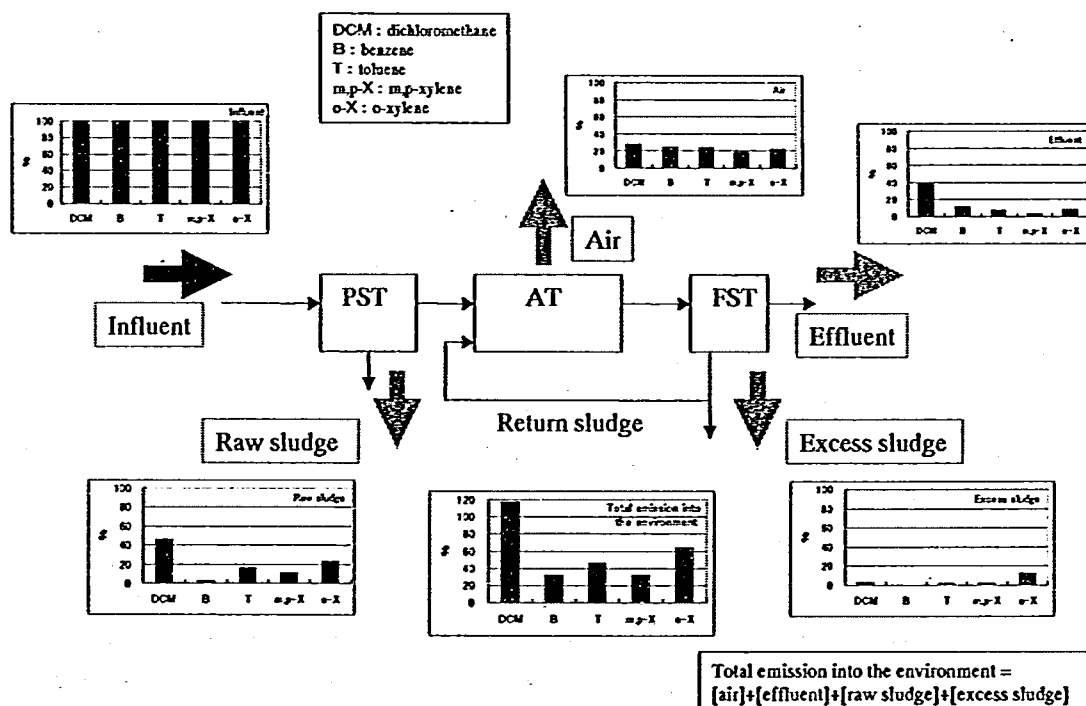


Figure-1 Mass balance

BIOASSAYS FOR EVALUATING EFFECTS OF TREATED WASTEWATER ON ECOSYSTEMS

H. Tanaka, A. Takahashi, T. Higashitani and Y. Yakou.

Water Quality Division

Project period:FY1996-1999

OBJECTIVES

The role of sewerages has been becoming more important from the view of restoration of aquatic ecosystems as well as water quality improvement in public waters. Due to recent their development in Japan, it is necessary to evaluate the effect of treated wastewater on ecosystems in receiving waters from various aspects, but the methodologies for evaluation have not been established yet.

The purpose of this study is to identify the positive and/or adverse effect of sewage treatment on ecosystems in receiving waters based on biological evaluation methods. Many bioassays are expected to be useful to evaluate the toxicity of effluents to aquatic organisms because they are relatively simple, cost-effective and able to be conducted for a short term.

In FY 1998, we aim to develop several methods using bioassays for evaluating aquatic toxicity, and apply them to evaluation of toxicity of sewage, treated sewage and its receiving waters.

RESULTS

APPLIED BIOASSAYS

We use some bioassays. The first is a bacterial luminescence inhibition test using *Vibrio fischeri*, i.e., MICROTOX^R acute toxicity test(Bioassay A).The bacteria are very sensitive to many toxic compounds. The second is a microplate growth inhibition test using green algae, *Selenastrum capricornutum*(Bioassay B). Algae are important primary producers in an aquatic ecosystem. The third is a determination of the inhibition of the mobility test using water flea (Bioassay C). The fourth is Aquatic Organisms Environment Oiagnostics(AOD Test) using small fish , *Tanichthys albonubes* (Bioassay D).The fifth is AOD Test using the small Crustacea , *Paratya Compressa improvisa* (Bioassay E).The last is a teratogenisity test using embryos of the African claw frog, *Xenopus laevis*(Bioassay F). Frogs are one of important higher consumers in the aquatic.

APPLICATION OF BIOASSAYS TO EVALUATION OF SEWAGE SAMPLES

Six bioassays (Bioassays A,B,C and E) were applied to sewage , treated sewage and river water that discharged effluent at five different sewage treatment plants (STPs). The results based on the two bioassays showed that the toxicity of sewage decreased by biological treatment in all the STPs. However, the toxicity of disinfected effluents differed among the STPs. The toxicity of the effluents evaluated with bioassay A showed higher than of untreated sewage in plant a applying high-dose chlorination, while no significant increases of toxicity were observed in the other STPs applying low-dose chlorination(Plants B and D) as well as ozonation (Plants C). The similar tendency among the STPs was observed for Bioassay b for the dechlorinated samples. The results of bioassays are shown in Table. 1.

COMPARISON OF BIOASSAYS' SENSITIVITY TO SAMPLES IN A STP

The toxicity of the influent and effluent from ten STPs that major treats industrial wastewater evaluated with six bioassays (Bioassay A, B, C, D, E and F) as shown in table 2. The results based on detect ratio, bioassay A, B, C and D are more sensitive to influent than others. Similer ,bioassay D and E are more sensitive to effluent than others.

Table 1 Evaluation of toxicity unit of sewage samples *

STP	Test Method sample	Bioassay A			Bioassay B		
		1996	1997	1998	1996	1997	1998
A	Influent	3.37	2.38	0.4	0.82	0.54	0.24
	Secondary effluent	0	0	0	0.16	0.36	0
	Chlorinated effluent	7.63	6.21	2.67	1.7	1.06	0.84
	River Water **	3.64	4.94	0.94	0.84	0.11	0.63
B	Influent	3.35	6.84	3.23	2.06	1.91	0.82
	Secondary effluent	0	0	0	0	0.001	0.01
	Chlorinated effluent	0	0	0	0.06	0.02	0.07
	River Water ***	0	0	0	0.74	0.7	0
C	Influent	—	2.71	3.63	—	1.5	0.89
	Secondary effluent	—	0	0	—	0.61	0.55
	Ozonated effluent	—	0	0	—	0.33	0.01
	River Water ****	—	0	0	—	0.24	0.01
D	Influent	—	6.08	3.54	—	1.1	0.62
	Secondary effluent	—	0	0	—	0.4	0.11
	Chlorinated effluent	—	0.5	0	—	0.67	0.001
	River Water *****	—	0	0	—	0.58	0.14

* Results of bioassay A,B:TU=100/EC50, —:no date

** water is discharged by STP only*** STP discharge is about 8l

**** water is discharged by STP or***** STP discharge is about

Table 2 The comparison of bioassay sensitivity to STP influent and effluent

Sample		Test Method					
		Bioassay A	Bioassay B	Bioassay C	Bioassay D	Bioassay E	Bioassay F
Influent	STP E	ND	0.65	ND	1.33	0.53	—
	STP F	ND	0.41	ND	0.77	0.43	—
	STP G	ND	0.96	ND	2.27	1.33	—
	STP H	ND	0.27	ND	1.27	0.48	—
	STP I	ND	1	ND	0.77	0.63	—
	STP J	ND	0.08	ND	1.33	1.08	1.9
	STP K	1.59	ND	ND	1.33	0.53	0.47
	STP L	ND	0.05	ND	0.91	0.91	—
	STP M	ND	0.08	ND	0.77	0.71	1.24
STP N	ND	0.43	ND	1.33	1.33	—	
Average		1.59	0.44	—	1.21	0.8	1.2
Detect Ratio		1/10	9/10	0/10	10/10	10/10	3/3
Effluent	STP E	ND	0.43	ND	ND	ND	—
	STP F	ND	ND	ND	0.07	ND	—
	STP G	ND	ND	ND	ND	ND	—
	STP H	ND	ND	ND	0.43	1.27	—
	STP I	ND	ND	ND	ND	ND	—
	STP J	ND	ND	ND	0.13	0.13	ND
	STP K	ND	ND	ND	ND	0.15	ND
	STP L	ND	0.38	ND	0.15	0.13	—
	STP M	ND	ND	ND	ND	0.06	ND
STP N	—	ND	ND	ND	ND	—	
Average		—	0.4	—	0.2	0.35	—
Detection Ratio		0/10	2/10	0/10	4/10	5/10	0/3

*Results of bioassay A,B:TU=100/EC50, —:no date, ND:not detect

EFFECTS OF SEWERAGE IN WATERSHED

H.Tanaka, K.Komori, M.Shirasaki, and K.Taketoshi

Water Quality Division

Project period: FY 1996-2000

OBJECTIVES

In recent years, sewerage systems are being constructed steadily in Japan. Therefore, the water discharged through sewerage systems is increasing and has occupied the major part in water circulation in the watersheds, partially in urban areas. The greater water flow through the artificial water circulation that is affected by human activities, water supply and sewerage systems becomes, the more water quantity and quality of the rivers are affected by such artificial water circulation.

Considering this situation, we must comprehensively manage quantity and quality of water from the view of watershed in order to protect the water environment. Although we need to grasp how and what extent the artificial water circulation affects on the whole water circulation in the watersheds, we have not yet reached the answers to clarify the questions up to this present. Therefore, as the first step to materialize the comprehensive water management, we have investigated the effects of sewerage systems on the circulation of water and various pollutant loads in watersheds at present. Further, we will try to predict them under the development of sewerage systems in the future.

METHODS

As an example of watersheds that are affected by artificial water circulation, we investigated the characteristics of discharge loads and flow rates in the Ohtsu River since 1996. In this year we investigated on rainy days besides fine days. The Ohtsu River is one of the rivers flowing into the Lake Teganuma that is located in northwest of Chiba Prefecture. Now the Lake Teganuma is the most polluted lake in Japan due to the advance of urbanization in its watersheds. The reasons we selected this river are that the sewerage systems are now under construction in the watershed of this river and that we had investigated pollution runoff in the same watershed in the 1980s.

We set three observation points along the Ohtsu River. Those points are shown in Figure 1 and the backgrounds of those points are also shown in Table 1.

One was set up at the main stream, and the other points were set up at the tributaries. Avoiding the effects of backwater by the weir of the direct purification plant of the river, we had to set up three observation points upstream of the backwater area. However, dividing three

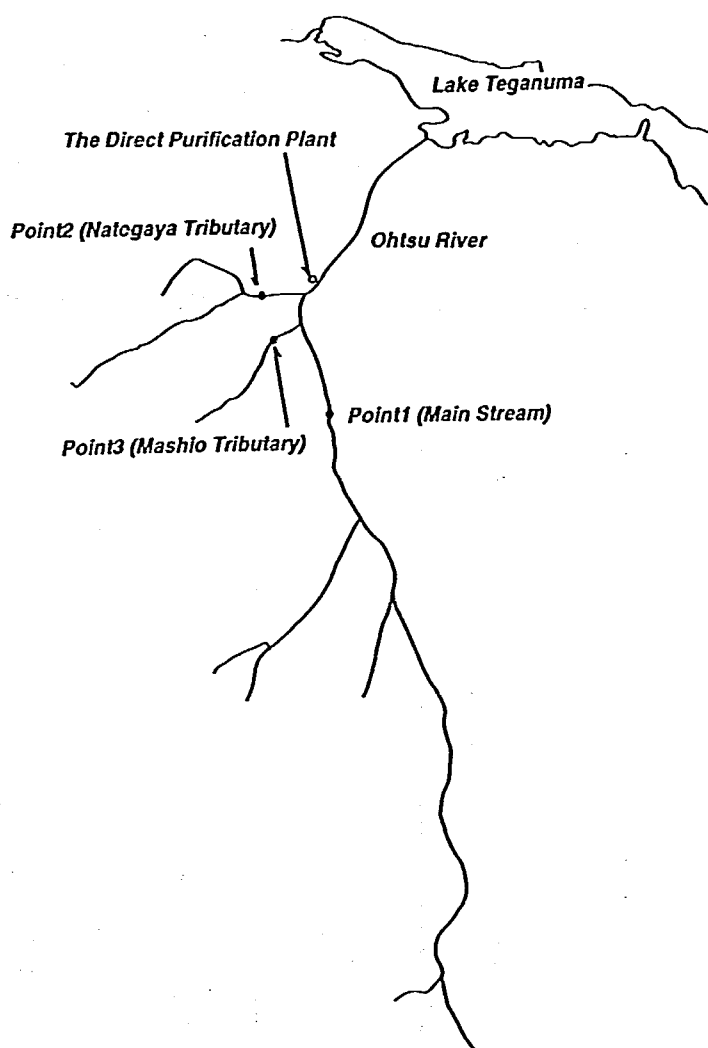


Fig.1 Observation points on the Ohtsu River

Table 1 Background of observation points (1994)

Observation Point	Population Density (people/ha)				Ratio of Land Use (%)				Area of Watershed (ha)
	All	Treated by Sewerage Systems	Treated by Septic Tanks	Non-treated Domestic Waste	Urbanized Area	Paddy Field	Farm and Others	Woods	
Ohtsu River (Main Stream)	45.65	9.17	28.89	30.77	48.08	5.72	36.53	9.67	2,400
Natogaya (Tributary)	83.49	62.66	17.55	19.45	79.39	0.00	11.85	8.76	437
Mashio (Tributary)	59.93	9.05	48.20	33.49	67.88	0.78	16.50	14.85	424
Total	52.58	16.33	29.88	29.60	54.85	4.31	30.62	10.22	3,261

observed points, enables us to get the total flow rates and pollutant loads discharged from the watersheds.

We observed flow rate and water quality at each observation point. Flow rates (Q_s) were calculated from water levels (H_s) observed by the flow gauge every five minutes and H-Q curve where it can be obtained from the relationship between water levels and flow rates that can be measured from velocities of the stream and cross section areas at many occasions. Regarding the fluctuation of water quality, we sampled the river water every hour and then analyzed about BOD, COD_{Mn} , TOC, NH_4-N , NO_2-N , NO_3-N , K-N, T-N, PO_4-P and T-P concentrations in laboratory. Discharge loads were calculated from the flow rate and the water quality.

RESULTS

Observation in fine days

We have observed the discharge loads and flow rates in fine days. We compared the differences in flow rates and pollutant loads among three watersheds are divided by watershed areas. As results of the observation in fine days, in the watershed where sewerage systems are developing, the specific flow rates and specific pollutant loads are smaller than those of the watershed where sewerage systems are not installed well enough.

We have observation data in different seasons for three years. The results of those observations suggested that discharges and pollutant loads from not only the non-point source but also the point source depending upon season. So if we want to catch the precise discharge loads, we must observe many times.

Observation in rainy days

We also observed the discharge loads and flow rates in rainy days. We compared the difference of flow rates and pollutant loads between the observation in 1980s (1987-1989) and 1990s (1996-1999). Fig.2 shows the relationships of specific flow rates and specific pollutant loads, and those of specific flow rates and the ratios of runoff due to individual rainfall events between the observation of 1980s and 1990s. As results of the observation in rainy days, on the contrary in fine days, the results of the observation in 1990s when sewerage systems were more installed, the specific flow rates and specific pollutant loads became larger than those of 1980s when sewerage systems were less installed. But we did not find the difference in the ratios of runoff to rainfall between the results of the observation in 1980s and 1990s.

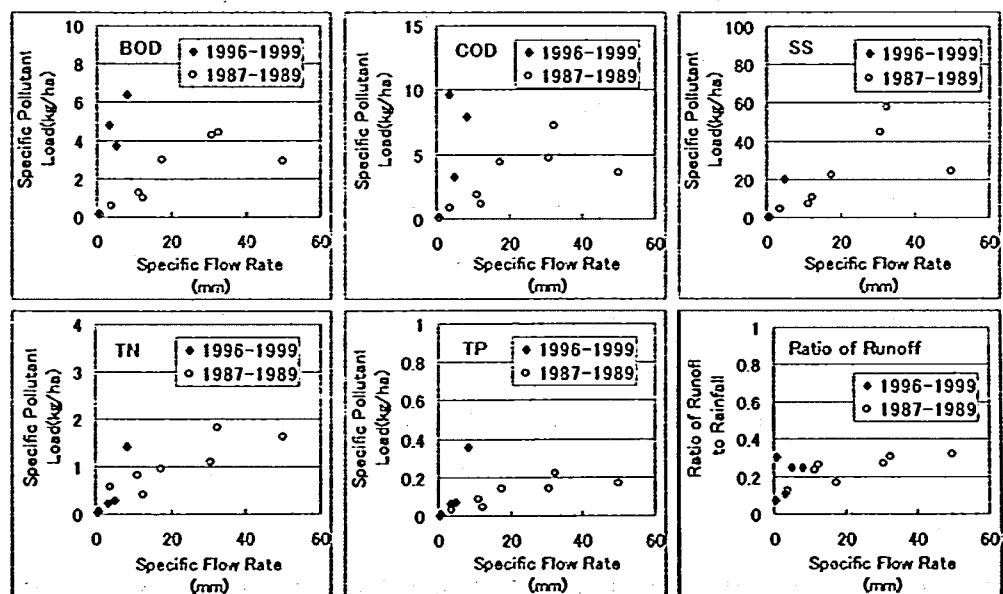


Fig.2 Relationship between Flow Rates and Pollutant Loads, Ratios of Runoff

COUNTERMEASURES AGAINST SPILL ACCIDENTS IN RIVERS

M.Shirasaki, H.Tanaka and Y.Okayasu

Water Quality Division

Project Period:FY1997-1999

INTRODUCTION

Many water quality accidents in river are caused by oil spill. River administer must forecast water quality to do countermeasure when oil spill accidents happen. But forecast model about oil outflow in rivers has not been established yet. So we research the existing forecast model about oil spill. Besides we research application of fluorometric analyzer to detect oil spill.

RESULTS

(1) Comparison oil position in center of river with that in side of river

We compared oil position in center of river with that in side of river by using particle tracking survey. In case we did not take sheer into consideration, oil position in side of river was much the same as that in center of river. Even if we took sheer into consideration, oil position in side of river was much the same as that in center of river as oil carried through center of river was spread toward side of river by effect of dynamic stretch. This is because diffusion coefficient of oil stretch is large. As a result though flow velocity in side of river is slow, oil arrives at the side of river at the almost same time as at the center of river as long as effect of dynamic stretch continues.

(2) Research on application of fluorometric analysis to oil analysis

As we referred to analysis method of environment agency we measured the sensitivity of each kind of oil to fluorometric analysis. As a result the most sensitive oil to fluorometric analysis was C-heavy oil, the second was A-heavy oil, the third was gasoline and kerosene and light oil were relatively less sensitive. (as shown in Figure 1) Extent of quantitative analysis by n-hexane extracts analysis method is said to be from 0.5 to 50mg/l according to public notice of environment agency. In measurement by fluorometric analysis the sensitivity is high in less concentration than above extent.

Besides, according to the result of addition and collection experiment done 5 times, concentration of which was 0.001, 0.01, and 0.1mg/l, change coefficient was under 10% and collection rate was from 57% to 140%. (as shown in Table 1)

So there is possibility that fluorometric analysis is appropriate with regard to measurement of oil in small concentration.

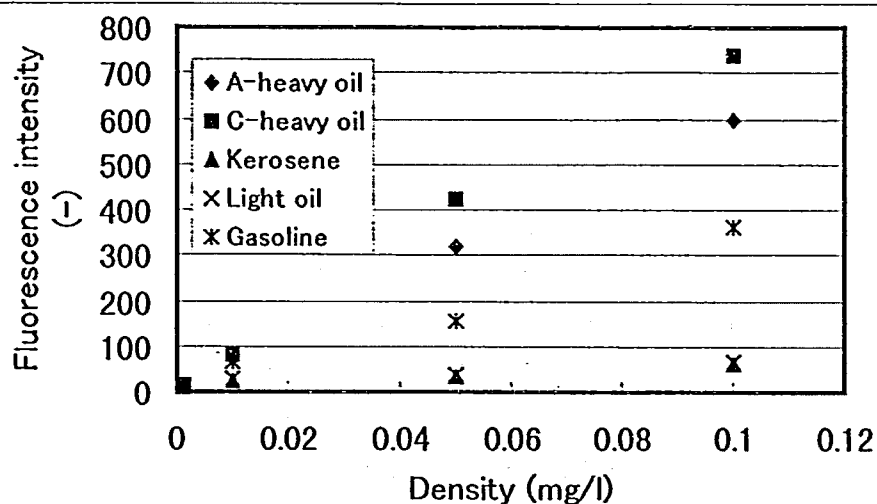


Figure 1 Relationship between each oil density and fluorescence intensity

Table 1 Result of additional and collection experiment

		Density (mg/l)		
		0.001	0.01	0.1
A-heavy oil	Collection rate (%)	110	92	69
	Change coefficient (%)	5.77	3.18	2.94
C-heavy oil	Collection rate (%)	81	68	97
	Change coefficient (%)	6.68	1.65	0.81
Light oil	Collection rate (%)	70	57	69
	Change coefficient (%)	7.82	9.19	1.42
Kerosene	Collection rate (%)	104	79	72
	Change coefficient (%)	9.91	6.64	2.83
Gasoline	Collection rate (%)	140	67	100
	Change coefficient (%)	7.54	3.38	3.62

EFFECTS OF WATER QUALITY OF RIVERS ON AQUATIC ECOSYSTEM

H. Tanaka, A. Takahashi, T. Higashitani and Y. Yakou

Water Quality Division

Project period:1996-1999

OBJECTIVES

The Basic Environment Law and the Outline of Environment Policy recently issued insist a new idea that conservation and restoration of the diversity of ecosystem in rivers and in urban area should be prioritized. However few information is available on effect of water quality on structure of aquatic biota. Therefore, the purpose of this research is to obtain biological data and water quality data to understand their relation and to investigate methodology for discussing of water quality to protect aquatic ecosystem.

In FY 1998, we continued to collect the fundamental data relating to water quality and aquatic biota in rivers receiving discharge from sewage treatment plants (STPs).

RESURTS

PERIPHYTIC ALGAE AT THE DISCHARGED POINT OF STPs

For grasp in relation between water quality and aquatic biota, field survey was carried out at four seasons(spring, summer, autumn and winter) in four rivers. Each river is receiving effluent from a domestic STP. All or almost flows of these rivers consist of effluents from STPs. Therefore, difference in water quality of the rivers can be regarded as difference in water quality of STP effluent. Incidentally three STPs discharging to River A, B and D apply disinfection by chlorination following activated sludge, while the other STP discharging to River C applies disinfection by ozonation following activated sludge. Dominant periphytons at each discharge point are showed in Table 1.

In River A receiving effluent with high-dosage chlorination showed great effect by chlorination because *Chlorolobion* occupied a majority in the population of periphytic algae at all seasons and number of periphytic algae was few. But in rivers where no significant dosage of chlorination or ozonation is applied in STPs *Chlorolobion* was not majority. This tendency was quite similar to the results of last two years. Therefore, high-dosage chlorination in a STP affects structure of periphytons to large extent.

THE EFFECT OF EFFLUENT FROM STPs

Rivers B and E have original flow of water upstream of confluence with STP discharge, and quality of river water is changed by STP discharge. Water quality and species of the periphytic algae observed at upper reach of the confluence, waterway from the STP and lower reach downstream of the confluence are showed in Tables 2 and 3.

The predominant periphytic algal species are different between the upper and the lower reaches. Some factors causing such this difference were supposed to be for example, water speed, riverbed form and water quality. In this case, water speed and riverbed form are almost same but water quality was very different between the upper and the lower reaches. Thus, these results suggest that some relation between water quality and periphytic algal species are expected to exist.

Table 1 Observed Species of the Periphytic Algae in Rivers A to E at the Discharged Point of STPs

		spring	Summer	autumn	winter
A river	the most predominant		<i>Chlorolobion</i>	<i>Chlorolobion</i>	<i>Chlorolobion</i>
	the second predominant		<i>Scenedesmus</i>	<i>Stigeoclonium</i>	<i>Scenedesmus</i>
	the third predominant		<i>Stigeoclonium</i>	<i>Scenedesmus</i>	<i>Stigeoclonium</i>
	Number of species		6	5	7
B river	the most predominant	<i>Phormidium</i>	<i>Gomphonema</i>	<i>Phormidium</i>	<i>Stigeoclonium</i>
	the second predominant	<i>Stigeoclonium</i>	<i>Stigeoclonium</i>	<i>Chlorolobion</i>	<i>Phormidium</i>
	the third predominant	<i>Gomphonema</i>	<i>Phormidium</i>	<i>Gomphonema</i>	<i>Gomphonema</i>
	Number of species	12	15	12	13
C river	the most predominant	<i>Achnanthes</i>	<i>Stigeoclonium</i>	<i>Stigeoclonium</i> sp.	<i>Navicula</i>
	the second predominant	<i>Stigeoclonium</i>	<i>Navicula</i>	<i>Achnanthes</i>	<i>Nitzschia</i>
	the third predominant	<i>Nitzschia</i>	<i>Achnanthes</i>	<i>Navicula</i>	<i>Stigeoclonium</i>
	Number of species	10	6	6	10
D river	the most predominant	<i>Phormidium</i>	<i>Chlorolobion</i>	<i>Chlorolobion</i>	<i>Chlorolobion</i>
	the second predominant	<i>Chlorolobion</i>	<i>Phormidium</i>	<i>Phormidium</i>	<i>Phormidium</i>
	the third predominant	<i>Gomphonema</i>	<i>Stigeoclonium</i>	<i>Stigeoclonium</i>	<i>Stigeoclonium</i>
	Number of species	11	16	10	14

Table 2 Quality of river water (Summer)

	(mg/l)	upper reach	waterway from STP	lower reach
B river	DO	14.5	9.1	8.5
	BOD	1.1	0.9	1.2
	TOC	1.79	3.63	4.11
	T-N	5.4	7.5	7.8
	T-P	0.0	0.3	0.3
	Total-Chlorine	—	ND	ND
D river	DO	10.1	6.0	7.4
	BOD	2.7	0.9	2.6
	TOC	6.09	4.77	5.81
	T-N	2.1	7.7	7.0
	T-P	0.4	0.1	0.2
	Total-Chlorine	—	ND	ND

—: no date, ND: not detect

Table 3 Observed Species of the Periphytic Algae at Rivers B and E

		upper reach	waterway from STP	lower reach
B river	the most predominant	<i>Homoeothrix</i>	<i>Gomphonema</i>	<i>Homoeothrix</i>
	the second predominant	<i>Stigeoclonium</i>	<i>Stigeoclonium</i>	<i>Stigeoclonium</i>
	the third predominant	<i>Nitzschia</i>	<i>Phormidium</i>	<i>Phormidium</i>
	Number of species	19	15	20
D river	the most predominant	<i>Navicula</i>	<i>Chlorolobion</i>	<i>Scenedesmus</i>
	the second predominant	<i>Scenedesmus</i>	<i>Phormidium</i>	<i>Navicula</i>
	the third predominant	<i>Oedogonium</i>	<i>Stigeoclonium</i>	<i>Stigeoclonium</i>
	Number of species	19	16	22

EVALUATION METHODS OF CONTAMINANTS DISCHARGED FROM URBAN WASTEWATER AFFECTING SOURCE WATER OF DRINKING WATER SUPPLY

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OBJECTIVE

Development of sewerage systems has increased the amount of urban water returning to natural waters through sewerages and the number of sewage treatment plants located upstream. This results in increase in portion of treated wastewater and/or stormwater discharged from sewerages to the amount of rivers that are used for source water of drinking water supply in the downstream. We have not yet understood whether and, if so, to what extent low biodegradable and trace pollutants that are concerned about drinking water quality and that may be included in the discharge from sewerages has affected source water of drinking water supply. Polyaromatic hydrocarbons (PAHs) are one of such concerned pollutants that are small amount, low biodegradable and toxic organic compounds, and have been recently reported to exist in source water of drinking water supply. But to what extent they pollute source water and where they come from are little known. The objective of this research is, therefore, to establish methods for evaluating such biodegradable, bioaccumulative, suspected-chronic toxicants on the basis of chemical analyses using GC-MS, etc. as well as biological assays applying mutagenicity tests, etc.

RESULTS

(1) Literature reviews were conducted on PAHs. PAHs are originated from fallout from the atmosphere, influent wastewater, urban stormwater, leachate from soil, etc. As regulations of PAHs in drinking water and ambient water, the USEPA has already regulated 16 substances as priority pollutants and benzo(a)pyren for drinking water, and the WHO has recommended that benzo(a)pyren be below 0.7 μ g/L in drinking water guideline, but no regulation or guideline exists in Japan with respect to drinking water and ambient water. A wide range of PAHs concentrations, such as tens ppt to tens ppb, in drinking water has been reported in United State, etc. A wide range of PAHs concentrations such as tens ppt to tens ppb, increase in PAHs concentration during rainy events, and 2 logs-removal during wastewater treatment have been reported in wastewater although the number of studies on sanitary sewage is limited. It has been reported that PAHs concentrations in urban stormwater range hundreds ppt to tens ppb and that some ppb was found in combined sewer overflows and the number of the studies with respect to urban stormwater is relatively large in the US.

(2) Analysis methods of benzo(a)pyren among PAHs in wastewater, treated wastewater and sewage sludge were examined. Accuracy, precision and recovery rates of analyzing the substance were studied by adding the substance to actual sample. The testing methods examined in

wastewater were selected based on the analysis methods proposed by Japan Environment Agency in 1998 and the references of existing studies. The examination revealed that solid phase extraction method is superior to solvent extraction method based on the results of recovery rate as shown in Table 1.

Table1. Accuracy of Analysis Methods of Benzo(a)pyren in Wastewater and Treated Wastewater

	Distilled water		Influent Wastewater		Secondary effluent	
	Recovery rate*	Variance	Recovery rate*	Variance	Recovery rate*	Variance
Solvent Extraction Method	91.5%	4.3%	57.5%	9.2%	96.9%	4.9%
Solid Phase Extraction Method	46.4%	6.0%			55.8%	5.6%

*Ratio of a concentration actually observed by an analysis method to a known concentration of the substance added to a sample

Experiment results on analysis accuracy and recovery rate of the substance added to sludge revealed that heating reflux methods with alkaline and ethanol is superior to supersonic extraction method with acetone as shown in Table 2.

Table 2. Accuracy of Analysis Methods of Benzo(a)pyren in Sludge

Pretreatment Methods	Added concentration	Measured Concentration without any chemical addition	Recovery rate	Variance
Supersonic Extraction with Acetone	5μg/L	0.26μg/L	14.9%	8.6%
Heating Reflux Methods with Alkaline and Ethanol	5μg/L	1.13μg/L	56.6%	4.1%

The former method could attain 120% for recovery rate, 5μg/wet-kg for detection limit, and 15μg/wet-kg for quantification limit.

(3) Because PAHs concentrations of influent wastewater range tens ppt to tens ppb, and 99% reduction are expected in wastewater treatment, we can estimate that PAHs concentration in final discharge from wastewater treatment plants are at large hundreds ppt that are at the same level of PAHs concentration regulated in drinking water. Therefore, PAHs in the final discharge from sewage treatment plant may be insignificant. But PAHs concentration in stormwater may be concerned because PAHs concentrations are reported to be same as the level of untreated wastewater and because no or little treatment is conducted for stormwater. Profound attention may be necessary when groundwater recharge with stormwater is planned to be carried out.

(4) It is assumed that analysis be conducted at 0.1 ppb level of accuracy if water samples will be examined in order to know the sate of contamination and that establishment of analysis methods applied to sludge be essential. Therefore, the study on improving and assuring analysis methods of benzo(a)pyren in wastewater and sludge that were conducted in this year are considered to be quite meaningful.