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**FY1999
RESEARCH SUMMARY
OF
WATER QUALITY CONTROL DEPARTMENT**

NOVEMBER 2000

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

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FY1999
RESEARCH SUMMARY
OF
WATER QUALITY CONTROL DEPARTMENT

by

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 1999 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 1999 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.3761), 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 1999 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.



Eiichi Nakamura, Director
Water Quality Control Department
Public Works Research Institute
Ministry of Construction

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CHARACTERISTICS OF DEPOSITS IN SEWERS

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Wastewater System Division

Project period: FY1997 - 1999

OBJECTIVES

Sediments in sewers cause such problems as deteriorating flow rate, producing bad odor and corroding concrete pipes. Therefore, the design method should consider not to produce sediments, or the pipe maintenance method also should consider to cleans then appropriately. Hence, this study objects to develop a design methodology of sewers preventing the sediments from building up. Principal characteristics of sediments and processes of sedimentation were investigated. Also cause of sedimentation and influence of sediments were investigated by field survey through and by analyzing substance change in experimental pressured sewer.

RESULT

1. The questionnaire research of sediments

The questionnaire research sediments was conducted in a series since 1997 to investigate the charge of the expose to sewer cleansing, disposal of sediments and methodology and standard of sewer cleaning.

1.1 Extracted municipalities of research

Researched municipalities were same as ones researched in 1997, because of comparing the change between both researches.

1.2 Result

1) Disposal quantity, Cleaning expenses of the sediment

Disposal quantity of sediments, sewer length of cleaning and expenses of sewer cleaning at each year of past eight years were collected through questionnaire. Change of sewer length, disposal sediments and expenses of sewer cleanings is shown in Fig-1.

The disposal quantity of sediment decreases since 1992. Sewer lengths of cleaning also increase until 1998. Tendency of changes hotwire in disposal quantity of sediments and sediment length is contrary.

It is supposed that sewer cleaning and maintenance has properly been done as importances of sewer management become apprised in recent years. Those in 1999 are declined, and it is apprised financial restriction for sewer maintenances. As for the cleaning expenses, there is shift like the cleaning extension. The change of expenses of sewer cleaning tends to be some as sewer length of cleaning.

2) Sewer cleaning standard

Sewer cleaning standard for sediment in respective municipalities were summarized through questionnaire. Approximate 20% of studied municipalities have developed cleaning standards for sediments, and 50% of designated cities and other core cities with above. Sewer cleaning standard in studied municipalities is almost targeting the accumulated depth of sediments, however numerical value of depth is 5 to 20% of sewer diameter among them. Prevalent index of depth is 10 to 20% of sewer diameter, and this index aims to preserve flow in

sewer from clogging. Regarding such municipalities without developing cleaning standard, almost all has developed plural criteria. 36% of municipalities sets criterion of “focusing sewer cleaning where sediments is frequently experienced”. 30% of “disposing sediments when sewer inspection is done”, and 28% of “area based sewer cleaning in every some years by rotation”. A few of criteria are by “complaints to foul odor or sewer leakage” and “other”.

It asked a cleaning frequency per pipe. Cleaning term of respective sewer is averaged in every 11.3 years.

2. The sulfide formation by the sediments

Since sediments in sewers is supposed of cause some effects to sewer quality, sulfide formation by sediments was experimented in a view point of sewer quality change.

2.1 Experiment

Experiment was conducted by using reactor equipment of two reactors of $\phi 300\text{mm} \times 1000\text{mm}$ and effluent grit chamber of Kasumigaura Wastewater Treatment Plant, and by procedure as follows.

- (1) Introduce to sewage equipment and precipitate sediments.
- (2) After sedimentation, sewage one reactor is agitated controlled not to sediments.
- (3) The other reactor is not agitated. Sewage is introduced at constant flow velocity by pump, and circulated in two reactors.
- (4) With the pump, it introduces a sanitary sewage at the constant flow velocity and the circulation flow has a sanitary sewage in the reactor at it.
- (5) It samples three in a constant interval flow surface of water of not agitated reactor, and one of the center of agitated reactor. It samples every 0, 20, 40, 60, 90, 120, 150, 180 minutes with the franc bottle. It measures total sulfide, resolve sulfide, T-COD, S-COD.
- (6) It agitates sewage of after sediment reactor, which was accumulated 180 minutes later. It samples and measures total sulfide, resolve sulfide.
- (7) As for each column, it measures SS, VSS.

2.2 Experiment result

Sulfide formations between both reactors were analyzed, and agitated reactor tended to much produce sulfide than reactor without agitation. There was no significant change in amount of sediments. Sewage was agitated after 180 minutes of sediment, it produced 2 to 2.5 times of sulfide of generally produced in public sewers. Therefore, sulfide formation potential to sewage with sediments was detected larger one without sediments.

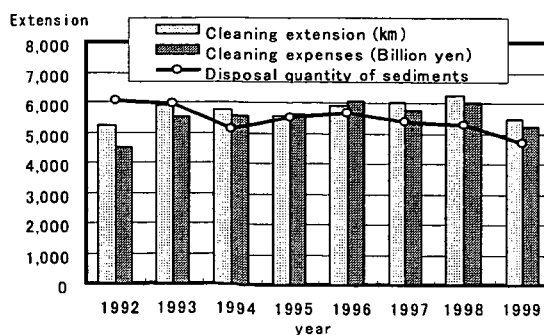


Fig-1 Change of sewer length, disposed sediments and expenses of sewer cleanings

COST REDUCTION OF PIPE SYSTEM

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Wastewater System Division, System Development Division

Project period : 1998-1999

OBJECTIVES

Among the infrastructures of Japan, the sewage work is especially delayed compared to other western countries. Therefore the further development of sewerage construction is needed urgently. It is necessary to reduce the construction cost since the financial situation of the central and local governments are deteriorated. The pipe system accounts for about 70% of whole sewerage construction cost including collection and treatment system. The cost reduction of pipe system is extremely important from the viewpoint of the whole cost reduction. In this context, we examined measures on the cost reduction through analyzing construction cost as well as the current design guideline of pipe system.

RESULT

INVESTIGATION ON MANHOLE INSTALLATION AND PIPE SLOPE

(1) Modification of manhole installation

In the design guideline of the sewerage facilities, it is prescribed that manholes should be installed at some spots and some interval to maintain the pipe adequately. In order to reduce the cost of manhole installation, there are two methods. The first is to reduce the number of installations through making distances between manholes farther and to adopting bending pipes; the second is to substitute the new-developed manhole, which is smaller than the conventional one and a man cannot enter inside. We proposed a new feasible design method based on the above cost reduction measures and estimated cost reduction ratio compared to the conventional one, with minimizing the difficulty of maintenance due to modification of manhole installation.

(2) Flattening the pipe slope

It is desirable to lay the pipe as flat as possible in order to cut the construction cost by reducing the soil covering. However, in case of flat pipe, sediment is likely to accumulate at bottom of the pipe. In the design guideline for sewerage facilities, it is prescribed that the minimum velocity should be greater than 0.6 m/sec to prevent deposition of suspended solids. The theory is based on the condition that sewage flow is steady, although real flow of branch pipes is unsteady. In this context, we examined the feature of real flow and the current design method by local governments to consider the possibility of adopting a new design method. However, it became clear that the current design method should be retained for the time being.

ANALYSIS ON CONSTRUCTION COST OF PIPE SYSTEM

(1) Analysis on pipe construction cost in treatment areas classified by construction method and pipe diameter

In treatment areas, small pipe of diameter less than 300 amounts to about 75% of whole pipe length (Fig.1). The pipe of diameter less than 300 mm by open cut method accounts for about 50% of the whole pipe construction cost in treatment areas (Fig. 2). The pipe of diameter less than 900 mm by pipe jacking method accounts for about 30% (Fig. 2). Therefore it became clear that the technological development related to the small diameter pipe construction contribute to whole cost reduction.

(2) Analysis on pipe construction cost in treatment areas by cost estimation system

The temporary work such as earthwork, retaining work and vertical shaft work amounts to the large portion of the whole construction cost in treatment areas. In the open cut method, more than 50% of the whole cost result from the temporary work (fig 3).

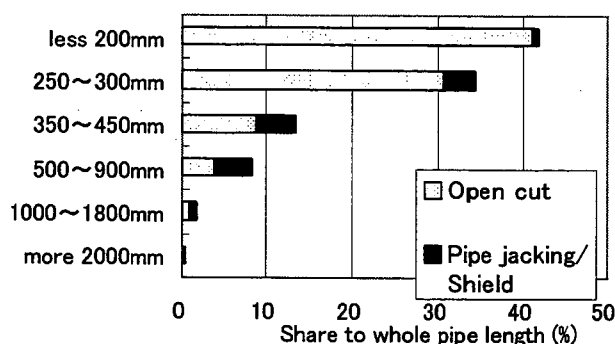


Fig. 1 Pipe length classified by construction method and pipe diameter in treatment areas

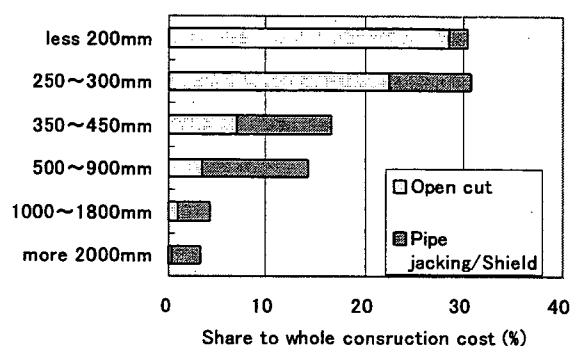


Fig.2 Pipe construction cost classified by construction method and pipe diameter

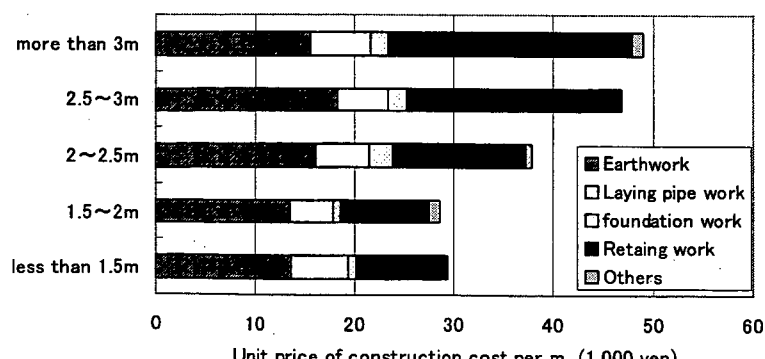


Fig. 3 Cost of 200~250 mm diameter (open cut) classified by soil covering

REHABILITATION OF SANITARY SEWERS

Y. Inoue, 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 of separate sewer system, various troubles become to be appeared. These troubles are, for instance, infiltration and inflow of rainwater and underground water (I/I), corrosion of concrete pipe and piling up of sediments. Peculiar troubles to the sanitary 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.

RESULT

I/I of rainwater frequently takes place in almost all sanitary sewers in Japan. We thought that I/I of rainwater is an inevitable event. Therefore, we sent out questionnaires based on a uniform standard about I/I of rainwater to almost all treatment plants that adopt sanitary sewer system in order to prove this hypothesis in September and in December 1999 and summarize the current situation. There were 763 respondents of treatment plants consisting of 112 plants of regional sewerage systems, 477 plants of public sewerage systems, 168 plants of specific environmental protection sewerage systems and 6 plants of specific industrial waste control sewerage systems, and all of these respondents describing the details of wastewater flow and rainfall. There also are 909 respondents describing experienced troubles and countermeasures related to I/I of rainwater issues.

(1) Outline of sewage influent flow increased at rainy event.

When we appraised sewage influent flow increased at rainy event, a standard measure was necessary. The daily average flow and daily maximum flow, which appraise an increased flow caused by rainfall event, were substituted for daily average flow and daily maximum flow in dry weather day in 1988 respectively.

I/I ratio of rainwater (the average daily) was defined to be equal to "sewage influent flow in a rain day" decided by "average daily flow in dry weather day". I/I ratio of rainwater is used to reveal the correlation of sewage influent flow between in dry weather day and in rainy day. Fig.-1 shows the distribution of I/I ratio of rainwater obtained by respondents. In almost investigated plants, I/I ratio of rainwater (the average daily) is 1.5 or more. This means that sewage influent flow in rain day increase 50% or more of sewage influent flow of dry weather day. I/I of rainwater is a characteristic phenomenon in rainfall events, and it reveals rainwater infiltration to sanitary sewer.

(2) The factors effecting I/I of rainwater

The medium of I/I ratio of rainwater (the average daily) revealed followings,

- ① Total amount of rainfall has the closest correlation to I/I ratio of rainwater.
- ② Moderate correlation factors are age of facilities, area of sewerage system, groundwater level, soils and ratio of a counted for water.
- ③ Irrelevant factors are implemented ratio of served area of storm water drainage system and average length sanitary sewer ,number of manhole and house inlet per 1ha of served area.

(3) Countermeasures and issues of I/I of rainwater

Troubles caused by I/I of rainwater in rainy day vary in collection system through a treatment system. Since torrential damage is brought by far I/I ratio of rainwater, many investigations and repairing sewer system are conducted to eliminate, however, are seldom analyzed concretely by now. It is necessary to grasp quantitatively the respective measures and their effects through inspection of sewer condition to evolution of implemented measures. It is apparent some measure brings is effectively reducing up to 1.86 of I/I ratio of rainwater, however which is far from complete resolution. Comprehensive methodology is expected to establish the countermeasures of I/I of rainwater issues.

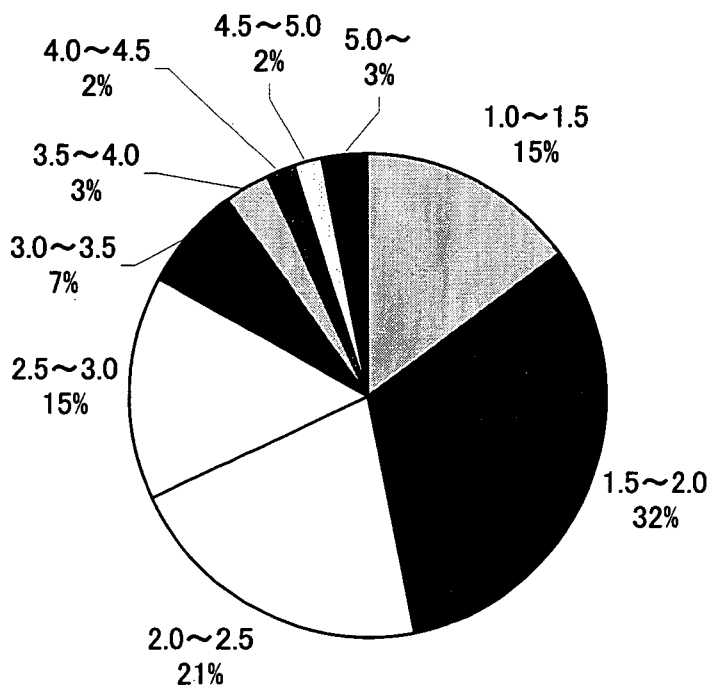


Figure-1 I/I ratio of rainwater (the average daily) of sanitary sewer systems

SEWERAGE SYSTEM FOR TROPICAL AND SUBTROPICAL COUNTRIES

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Wastewater System Division, Advanced Wastewater Treatment Division

Project period : 1996-2000

OBJECTIVES

As a result of rapid economic growth, urbanization and shortage of sanitary facilities, the environmental deterioration became very serious in developing countries in tropical and subtropical regions. To restore this situation, the environmental sector in ODA is highly demanded by the developing countries. The aid on planing and construction of sewerage in the above 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

The conditions of sanitary facilities used in the above developing countries as well as the development studies by aid organizations such as JICA and World Bank were examined. Considering them, we generalized sanitary facilities (including on-site ones) selection and proposed the sanitation technology selection algorithm based on the respective conditions.

Three selection stages (1) on-site system areas or off-site system areas in the planning area, 2) the selection of the appropriate off-site facilities in off-site areas and 3) the selection of the appropriate on-site facilities in on-site areas) are pointed out in the algorithm. As criterions for the selection, population density, condition of water supply, ground water table level, infiltration capacity, investment ability, community participation, condition of existing facilities and so on are adopted.

Prior to the selection, overall goal such as the improvement of public hygiene, urban environment and preservation of water quality in public water bodies should be decided and we are to implement the selection process, taking account of achieving the goal.

In addition, the features on combined sewer system and separate sewer system in developing countries in tropical and subtropical regions were examined.

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 lagoon, appropriate loading and operation

conditions for better treated water quality.

FACULTATIVE LAGOON AND AERATED LAGOON

The facultative lagoon was operated at the HRT of 30 days and the BOD surface loading of 22.7g/(m²·d). The aerated lagoon was operated at the HRT of 5 to 15 days and 100 kg-O₂/d of oxygen were supplied. Results of the survey are summarized in Table 1. The COD removal ratios of both experiment plants were about 60% and the BOD removal ratios about 80% were obtained. High and low water temperature periods were compared, and there were 10% of difference in the removal ratio of organic matter in the lagoon. Also, the removal ratio of the coliform group was high in the period when the photosynthesis was intense.

The removal ratio of organic matter and coliform group was deteriorated, when HRT of the aerated lagoon was shortened. Also, the decay coefficient of the sludge expressed as Formula 1 was 0.1~0.3 ranges using the data of constant MLSS concentration of the aerated lagoon. The decay coefficient was fairly big in comparison with that of a conventional activated sludge process, because the BOD volumetric loading was small, there was much oxygen supply and the DO concentration was high.

$$\text{Decay coefficient of sludge [1/d]} = \frac{\text{Decrease of sludge by decay [mg MLSS/(L} \cdot \text{d)]}}{\text{Average sludge concentration [mg MLSS/L]}} \quad (1)$$

Table 1 Average treatment efficiency of organic matter of the facultative and aerated lagoons.

Facultative lagoon	Removal ratio(%)	Aerated lagoon	Removal ratio(%)
Average of all period	T-BOD 75	HRT on 15 days	92
	D-BOD 76		99
	T-COD 60		68
	D-COD 48		78
Period of high water temperature	T-BOD 84	HRT on 10 days	91
	D-BOD 84		99
	T-COD 59		58
	D-COD 49		76
Period of low water temperature	T-BOD 69	HRT on 5 days (The BOD value, there may be the influence of N-BOD)	76
	D-BOD 67		86
	T-COD 48		54
	D-COD 43		65

BENEFIT ANALYSES OF SEWAGE WORKS

Y. Inoue, R. Uematsu and T. Yoshida

Wastewater System Division

Project period: 1998-2001

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 1999, we conducted a case study to measure WTP (Willingness to Pay) of the residents for water quality improvement in a large river, applying CVM (Contingent Valuation Method), with the aim of benefit appraisal of water quality preservation which sewage works can serve.

METHOD

The technique we applied is a benefit measuring one that uses a questionnaire to elicit people's preference for public goods by finding out how much they would be willing to pay for a specified improvement in them.

We determined Ara River as a large river to be appraised. The river runs through the Kanto district and has much importance in social point of view (Figure-1).

The water quality (BOD) of Ara River was approximately 1 mg/l in the upper reach, 2 mg/l in the middle, and 3~6 mg/l in the lower. And we set the scenario as shown in Figure-2. The elicitation method was a double-bounded dichotomous choice approach, and the presented price was 200, 500, 1000, 2000, 4000 or 8000 yen/month/household.

We supposed that the population to which the benefit would accrue were the residents of the river basin, so we selected eight municipalities in the river basin (as

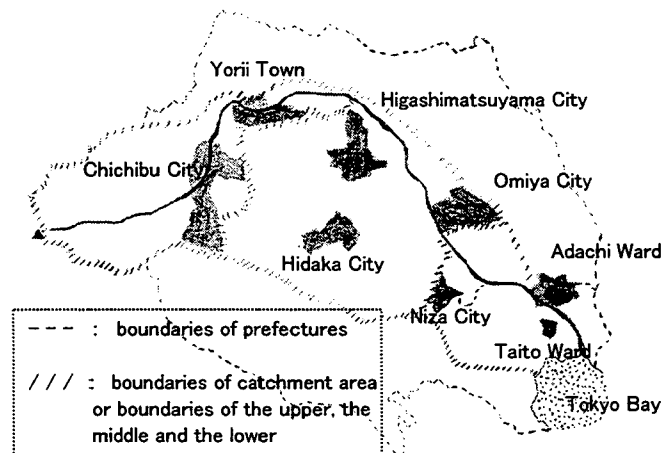


Figure-1 Map of Ara River

Please consider a project of water quality improvement in Ara River. This aim is as follows;	
☐ the middle stream aiming at the condition as clear as the upper. you can see natural fireflies and enjoy swimming with a relief	☐ the lower stream aiming at the condition as clear as the middle ① not only carp, crucians but also bitterlings, daces, ayus can inhabit, which you can enjoy fishing ② there is no odor, you can enjoy catching fish or insects
In order to accomplish this goal, measures for water quality improvement will be taken, such as more advanced wastewater treatment and removal of depositing sludge. And the goal will be accomplished. But this project only improves the water quality with no change of water flow or riverbanks.	
If you have to pay the object tax of ____yen/month/household for this project, do you agree with the project or not?	

Figure-2 WTP question

shown in Figure-1), and sampled 200 residents randomly in each municipality. And we used a mail survey procedure.

RESULTS

The respondents were 40%, composed of 66% male, 19% female, and 15% sex-unknown. And two thirds of respondents were over fifties. These biases might result from the random sampling based on telephone books.

We estimated the WTP by applying a Weibul distribution function to the percent willingness to pay as a function of required payment. The results are shown in Table-1 and Figure-3 shows the estimated function curve in case of the total catchment area. The mean WTP in the total catchment area for water quality improvement of Ara River was estimated at 1,485 yen/month/family. The least WTP in the selected municipalities was that of Hidaka City, which was thought to be caused by the fact that the city was the most distant and many respondents of the city answered there existed alternative water environments. And it was demonstrated that the WTP of the lower catchment area was significantly higher than that of the upper/middle.

We made benefit function, of which the independent variable was the WTP and the dependent variables were attributes of respondents. We found that 'doing fishing in Ara River', 'age', 'income' and 'having sewage sanitarily treated' had a positive effect on WTP, whereas 'no use of Ara River', 'over 1 hour taken to get access to Ara River', 'watching or touching water of Ara River', and 'having a priority other than water quality improvement' had a negative effect on WTP. Next, we made the benefit function employing only 'no use of Ara River' as the dependent variable, and estimated that the WTP for non-use value was thought to be 1,000 yen/month/household.

Before estimating the WTP, 52 data had to be omitted as oppositions. And there were some comments complaining about administration seen in free comment space provided in the questionnaire sheets. It was connoted that a questionnaire should be designed to eliminate the anti-administration mind and elicit truer preference.

Table-1 Estimated WTP

			effective sample number	mean WTP (yen/month /household)
Total	Upper	Chichibu City	66	1,297
		Yorii Town	75	1,459
			141	1,384
	Middle	Hidaka City	57	1,112
		Higashimatsuyama City	63	1,427
		Omiya City	62	1,529
			182	1,358
	Lower	Niiza City	61	1,716
		Adachi Ward	57	1,849
		Taito Ward	55	1,573
		173	1,701	
			496	1,485

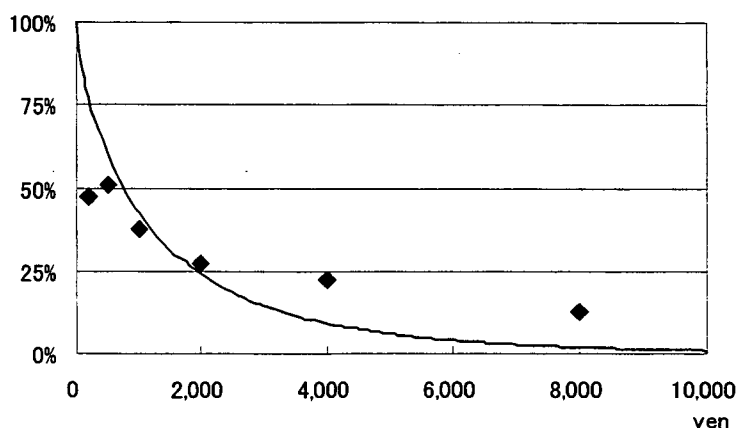


Figure-3 Percent willingness to pay as a function of required payment (total catchment area)

UTILIZATION OF URBAN STORMWATER IN SEWERAGE

Y. Inoue, M. Matsubara and T. Toyoda

Wastewater System Division

Project period : 1998-2000

OBJECTIVES

Utilization of stormwater in urban areas has many effects such as ensuring water resources and urban disaster prevention. In this study, we focus on stormwater utilization in urban areas. Considering stormwater as a resource of sewerage, we will clear technical problems for promotion of stormwater utilization, especially from the viewpoint of sewage works. And we will consider what urban drainage systems should be. We also make investigation into characteristics of pollutant load discharges in wet weather condition to draw up an effective plan for CSO control. More over, explication of hydraulic characteristics in pressurized storm sewers will be one of our main targets. It is necessary for safe and stable collection of stormwater.

The main results obtained in FY 1999 are as follows.

RESULTS

CALCULATION OF STORMWATER QUANTITY AND QUALITY IN URBAN AREA

When we investigate stormwater utilization from the viewpoint of sewage works, we must set water cycle in whole city as our target of investigation. Such benefits as flood prevention and control of pollutant loads brought by stormwater must be evaluated in whole city, too.

Then, as a case study, we calculated stormwater quantity and quality (supply) and water quantity and quality (demand) in a model city, and investigated problems in utilizing stormwater by comparing supply with demand. We used BOD as an indicator of water quality, and selected toilet flushing, garden watering, artificial streamflow, and cooling water as uses of stormwater. If there is no limitation for storage capacity, annual total supply quantity would balance with annual total demand quantity in whole city. It would be important how to determine the capacity of storage facilities (both on-site and off-site) in consideration of construction costs for storage facilities and benefits brought by stormwater utilization. With respect to quality, there would not be a restrictive problem when using a roof runoff only.

DEVELOPMENT OF DISTRIBUTED PWRI LOAD MODEL

To calculate pollutant load discharges in wet weather condition, lumped type models such as PWRI load model have been used. But there are some difficulties in these models; difficulty to apply ones to complicated countermeasure scenarios, impossibility to get calculated results at many points simultaneously, and so on. Therefore, we decided to integrate to change PWRI load model into a distribution type model that is easy to apply and befits the current age.

We conducted field survey at the drainage area served by combined sewer system (168ha) to collect data for model verification. We set 4 monitoring points for sewage quantity, 2 for sewage quality, and 1 for precipitation in this area. Monitoring items for sewage quality were BOD, COD, SS, T-N, and T-P. Sampling of sewage had been made 3 times in dry weather condition and in wet weather condition, respectively. The automatic water sampler, which had been installed in the manhole (Fig.1), had operated in dry weather condition only. Fig.2 shows an example of the results. After this, we plan to review collected data and to investigate model improvements. (In this part, we have conducted joint research with R & D division of Japan Sewage Works Agency)

MANHOLE COVERS "BLOWING-OUT" PHENOMENON

In order to prevent blowing-out of manhole covers and to eliminate accidents caused by entrapped air, it requires that hydraulic characteristics of pressurized storm sewers should be investigated. This time, we sent out inquiries to 13 designated cities to comprehend the present condition and to extract problems to be solved.

The main results obtained by inquiries are as below.

- (1) Manhole covers of combined sewer and storm sewer have some small holes on themselves for ventilation and pressure release, but size or numbers of these holes have not been determined theoretically.
- (2) Pressure release structures have been installed in some cases. But there are no design manuals for these facilities.
- (3) They are expecting that how to extract the dangerous points to be treated, behavior of the entrapped air in a pressurized sewer, and establishment of design manuals for pressure release structures would be made clear.

Through these results, it became clear that explication of behavior of the air lingered in a storm sewer and establishment of countermeasure to exhaust the air safely were critical issues from both practical and technical points of view.

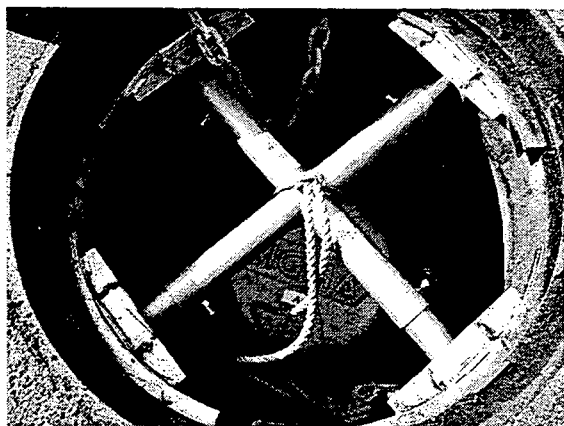


Fig.1 The automatic sampler installed in the manhole

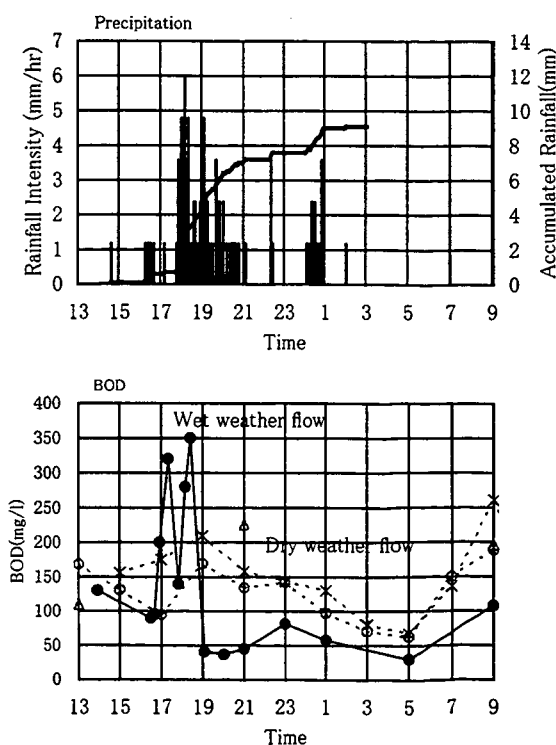


Fig. 2 An example of the filed survey results

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 ozone 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, chlorine and ozone disinfection methods and those followed by activated carbon adsorption, which were intended to remove residual disinfectant and by-products, were investigated to evaluate their disinfection efficiency and toxic substance concentration in the effluent.

RESULTS

- ① The water quality had an influence on the decrease rate of the disinfectant residuals. Chlorine remained longer when ammonia was included in the treated water and chloramine was foamed. The effect of ozonation remained longer when sea water was included in treated water because of residual oxidant produced by ozonation.
- ② In dechlorination with thiosulfate solution, less thiosulfate was needed to reduce the same amount of residual chlorine when the ratio of free-chlorine to total-available-chlorine became high.
- ③ In GAC(granular activated carbon) filtration of disinfected effluent, residual chlorine was removed effectively (Figure-1). THM was decreased with GAC filtration, but the removal ratio decreased as filtration volume increased (Figure-2). In the result of last year, the activated carbon could not remove aldehyde by absorption, but after a few weeks of treatment, aldehyde was removed by biofilm that grew on the activated carbon surface (Figure-3).

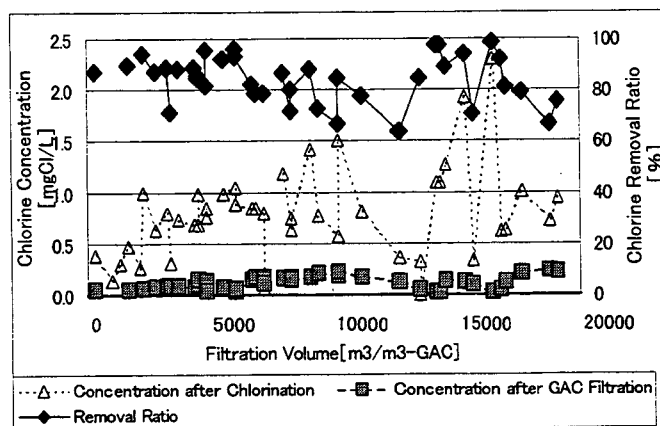


Figure-1 Chlorine Removal by Activated carbon
(After Chlorination)

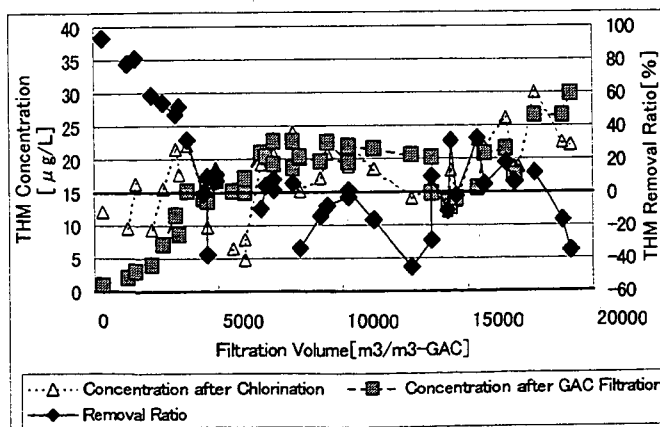


Figure-2 THM Removal by Activated carbon
(After Chlorination)

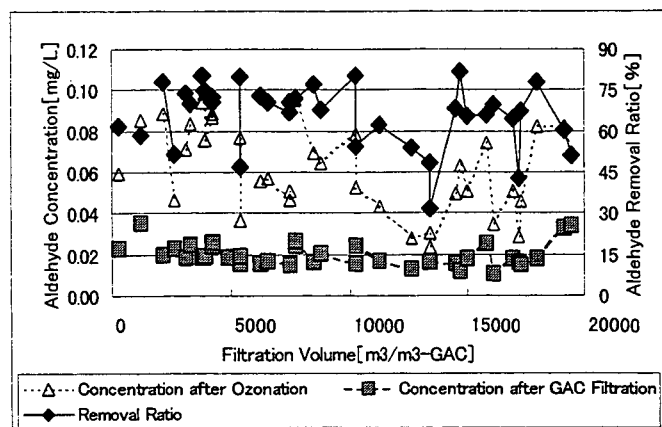


Figure-3 Aldehyde Removal by Activated carbon (Ozonation)

- ④ Even if coliform group survival ratio was 10^{-4} with disinfection, the number of coliform group and *E.coli* increased about 10 times after the activated carbon filtration (Figure-4,5).

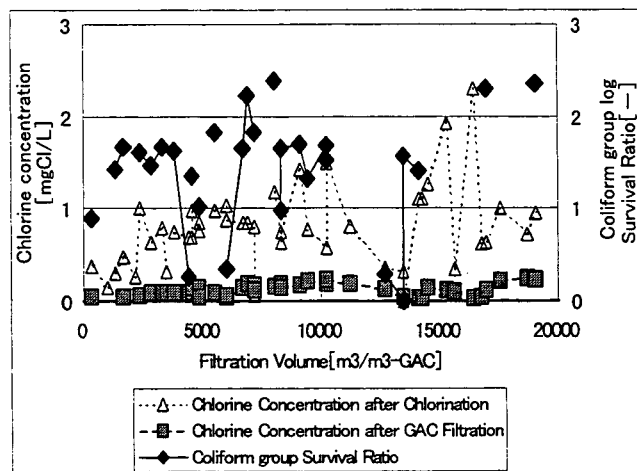


Figure-4 Change of coliform group survival ratio (Chlorination)

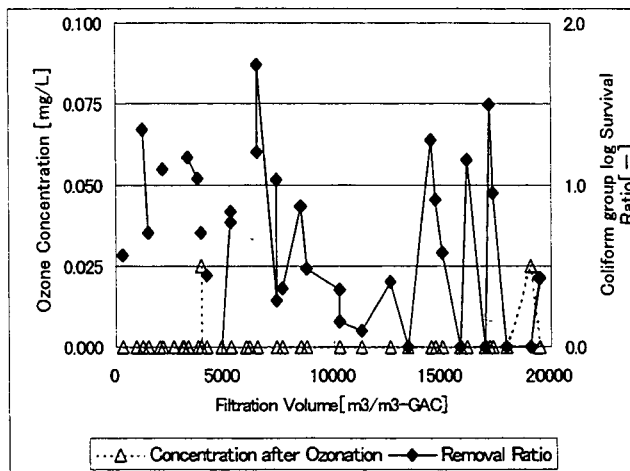


Figure-5 Change of coliform group survival ratio (Ozonation)

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 drought 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 drought 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 treated waste effluent, and most of inhabitants accept these reuse facilities friendly. It seems that water reuse is in the introduction of real popularization, though the official system 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.

Major results of the study before FY1999

The cost of the water re-use through public owned treatment works (POTW) was studied by using questionnaires. And the average re-use cost was estimated relating to the additional treatment processes. The construction, o/m and repair works for distribution pipeline and additional water treatment were included to the estimation.

Results of the study about the benefit of water re-use

The investigation about the benefits, effects and problems of water re-use were made using questionnaires and/or direct hearing to the administrators of 15 water re-use works. These 15 works include major reclaimed water uses such as toilet flushing, melting snow, agricultural irrigation, aesthetic and/or recreational water and river flow augmentation. The benefit of re-use was not grasped well in these 15 works, due to the low recognition to the evaluation of re-use works, the difficulty of evaluation to such uses as aesthetic water and river flow augmentation, and the unclear effect of water saving under the present low saturation level of re-use. The only way of the evaluation of re-use benefit is to compare the price or cost of reclaimed water with that of alternatives such as purchase of water, although it does not evaluate the entire re-use works. In the sense, agricultural irrigation seems to indicate the best performance.

Re-use of reclaimed public sewer for flush toilet has two important problems. One is the competition with on-site recycling and the other is the benefit of individual user, particularly house user. The former problem is

purely economic or financial but the latter one has various sides such as emotional discomfort, inconvenience, frequent troubles, etc. According to the result of this study in fy1998, there are scale merits on the cost of water re-use systems. So, the economical boundary must exist between on-site and wide-area recycling system. And in case of large building, it reflects the comprehensive ability of the municipality to compete with private company.

Results of the study about the pipe corrosion in a water re-use system

The decrease of pressure at the pipe end of reclaimed or miscellaneous water was reported from some apartment complexes in Fukuoka and Tokyo. According to the survey of Fukuoka city, the major phenomena were plugging of service pipe to each residence, and the plugged matter mainly consisted of Fe_2O_3 . Those matter was supposed to come from another part of service pipe, because the main distribution pipe were not corroded in our survey that had been made 2 years before the accident. So, we made study to find the main factor of the pipe corrosion. A model service pipe and actual tertiary effluent were used in the study. The dissolved substances and residual chlorine concentration were arranged in three different levels respectively. The effluent from the model pipe was collected and total concentration of total iron and copper were analyzed. The results of the experiment indicated that the concentration of dissolved inorganic substances was the major factor of the corrosion at the uncoated steel pipe joint. Residual chlorine supposed to accelerate the corrosion not only of steel joint but also of bronze valve and meter (Fig.1). So, the plumbing materials for reclaimed water service pipe must be corrosion proof like the plastics, because it is impossible to stop chlorination from the sanitary point of view.

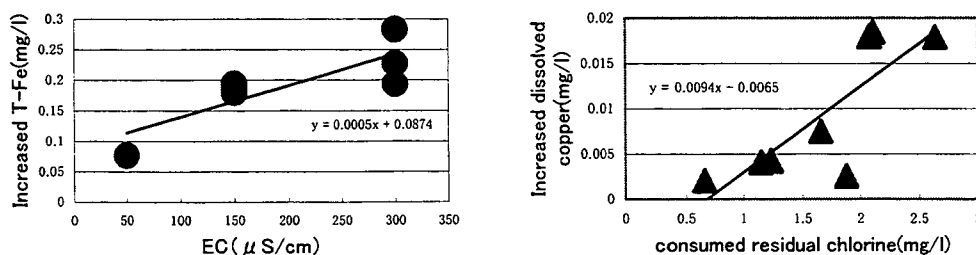


Fig.1 Result of the experiment about service pipe corrosion by reclaimed water

Conclusions

The evaluation of water re-use has many sides, so that it should be made case by case. The users of reclaimed water basically expressed a favorable evaluation to use them ordinary. But the water re-use should be got an economical or financial rationality, even if they are the PR of general attitude to the water environment. From this point, the municipality must put more energies to account the quantitative effect of water re-use. The corrosion and plugging of reclaimed water service pipe was found to be originated from high concentration of dissolved inorganic substances in the reclaimed water. So, the service pipe material should be corrosion proof like the plastics.

EVALUATION OF TECHNOLOGIES TO REDUCE THE EMISSION OF GREEN-HOUSE EFFECT GASES IN WASTEWATER TREATMENT SYSTEM

K.Sakai, Y.Suzuki, H.Shigemura, R.Hiraide, H.Morita, 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(CO_2) is one of the responsible agents causing green-house effect, methane(CH_4) and nitrous oxide (N_2O) are no less important in controlling global warming. In fact, the effects of CH_4 and N_2O on global warming on the unit mass basis for 20 years after are reported around 60 and 270 times as high as the CO_2 , respectively.

Sewerage system is constructed to improve both living environment and water environment. The national government promotes to increase the number of served population by sewerage system. The emission of the green-house effect gases(GHG) from sewage treatment plants is also increasing according to the number of served population and the quantity of sludge to be incinerated. Besides CO_2 caused by electricity and fuels, the emission of N_2O from biological nitrogen removal process and sludge incineration, and CH_4 from biological wastewater treatment process are recognized to be quite important from the results of the researches already done. The purpose of this research is to evaluate the technologies which reduce the emission of GHG from wastewater treatment facilities.

METHOD

From the former research, the introduction of anaerobic or anoxic zones to wastewater treatment process was supposed to suppress the emission of CH_4 . And we have already cleared that the emission of N_2O decreases with the rise of the temperature in fluidized bed furnace receiving polymer-coagulated sludge.

This year, experiments of pilot plant scale were carried out to compare the emission characteristics of GHG from a conventional process, AO process and A_2O process. CH_4 and N_2O were measured using gas chromatography either with direct injection for the samples of exhausted gas from aeration tanks, or with the head space method for the samples of dissolved gas in influent, effluent and mixed liquor of each aeration tank.

The GHG emission and the operation cost were analyzed for the countermeasure of fluidized bed incinerator, and the GHG emission in the future(2010) was estimated. The data of the costs of fuels and furnace improvement were collected from the existing plants in Japan in FY1998 by questionnaire. The cost of GHG reduction was evaluated through the life cycle cost analysis.

RESULTS

The CH₄ emission from the conventional process was higher than the AO and A₂O processes. The ratio of the emitted CH₄ from aeration tanks to the influent dissolved CH₄ was estimated to be 1.7, 1.0 and 0.89 for the conventional process, the AO process and the A₂O process, respectively. The difference of these ratios can be attributed to that the CH₄ was produced in the first cell of the aeration tank of the conventional process, conversely the CH₄ in the anaerobic and anoxic tanks was decreased.

High N₂O emission was observed when NO₂-N concentration was high in the aeration tank (Figure 1). Maintaining low NO₂-N concentration is necessary to reduce N₂O emission, especially in winter.

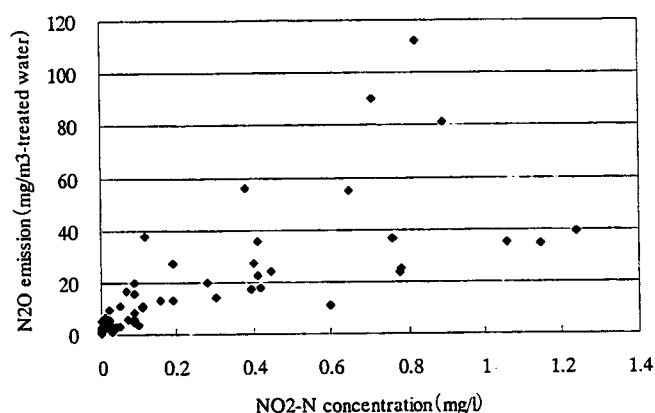


Figure 1 The relationship between NO₂-N concentration and N₂O emission

In FY1998, the GHG emission from sludge incineration facilities was obtained at 437Gg-C/year, and the N₂O emission from the polymer-sludge cake fluidized furnace formed 70% of it. When the combustion temperature of fluidized furnace was raised by an average 35 degree, though the annual GHG emission decreases from 437Gg-C/year to 221Gg-C/year, and the GHG reduction cost was analyzed to ¥ 10600/t-carbon(1\$≐¥110). The GHG emission in the 2010 is estimated to be 725Gg-C/year by 1.7 times for FY1998 in the case of an unchanging combustion temperature. Though the case of a raising combustion temperature, GHG emission was estimated the greatest 317Gg-C/year(Table 1). Therefore, it seems that the GHG emission on FY2010 could be controlled in previous level of FY1998.

Table 1 An estimate of the GHG emission from sludge incinerators in 2010.

	1998	2010	
		Case of Using Present Incinerators	Case of Improving Old Incinerators to Fluidized Bed Furnace
Sludge Weight (10 ³ t-wet/year)	4,220	6,410	6,410
Case of Present Operation			
N ₂ O (Gg-C/year)	374	605	642
CO ₂ from Fuels(Gg-C/year)	63	91	83
Total(Gg-C/year)	437	695	725
Case of Raising Combustion Temperature			
N ₂ O (Gg-C/year)	147	208	192
CO ₂ from Fuels(Gg-C/year)	74	110	104
Total(Gg-C/year)	221	317	296
Reduction Ratio (%)	49.4	54.4	59.2

ENERGY SAVING OF NITROGEN AND PHOSPHORUS REMOVAL SYSTEMS

Y. Suzuki, H. Shigemura and N. Ogura
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 gas increases though the pollutant load to the local environment is reduced. For the purpose of reducing energy consumption of nitrogen and phosphorus removal systems, we investigated operation and design methods to improve energy efficiency of each process and the total system.

RESULTS

- (1) Performance of phosphorus removal was the same both in the cases with continuous mechanical mixing and intermittent mixing with coarse bubble aeration in anaerobic tanks.
- (2) When the anoxic tank was operated in intermittent aeration of a five-minute cycle, the performance of denitrification was as high as that with continuous mechanical mixing. However, the intermittent aeration of a twenty-minute cycle lowered the performance of denitrification in spite of the high water temperature period (Figure 1). When we changed intermittent aeration cycle to 15 minutes after October, the performance was recovered.
- (3) In the laboratory scale experiments to investigate the effect of mixing intensity on phosphorus removal, sludge sedimented below 10rpm of mixing and even higher phosphorus release rate was observed in the lower layer. At 20rpm, the sludge was dispersed uniform, but the total release rate was the same as that of low rpm (Figure 2).
- (4) Generally, when immobilization media were added more, the overall volumetric oxygen transfer coefficient (K_La) with immobilization media became smaller. However, when nitrification proceeded, K_La became higher than that without media (Figure 3). When air flowrate was small, K_La was not so affected by the immobilization media.

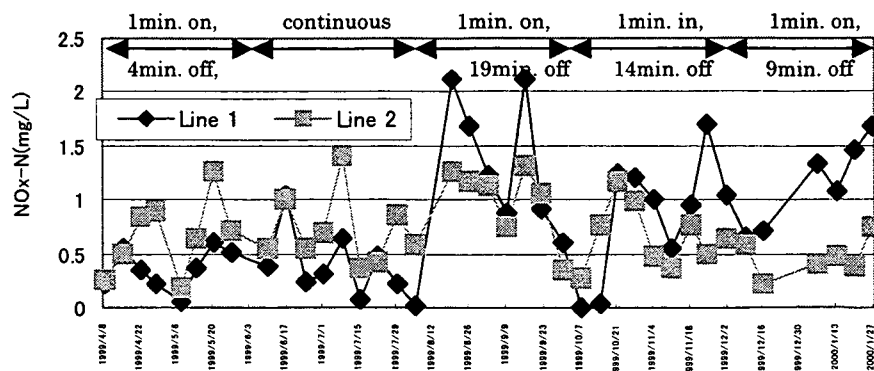


Figure 1: NOx-N concentrations in the anoxic tanks

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

The anoxic tank of Line 2: continuous mixing

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

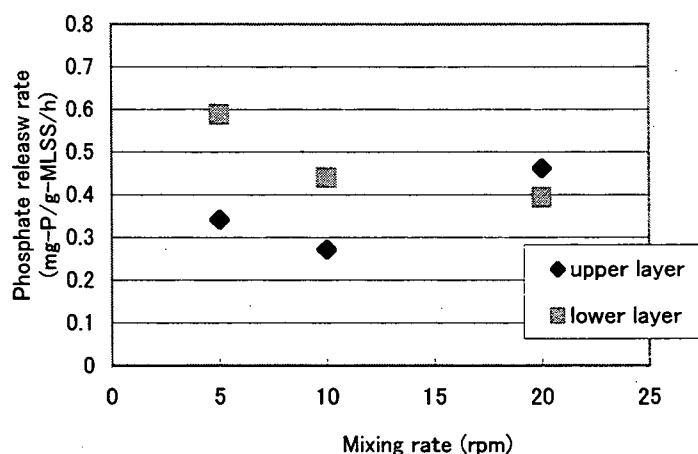


Figure 2: Phosphate phosphorus concentrations in the laboratory scale experiment

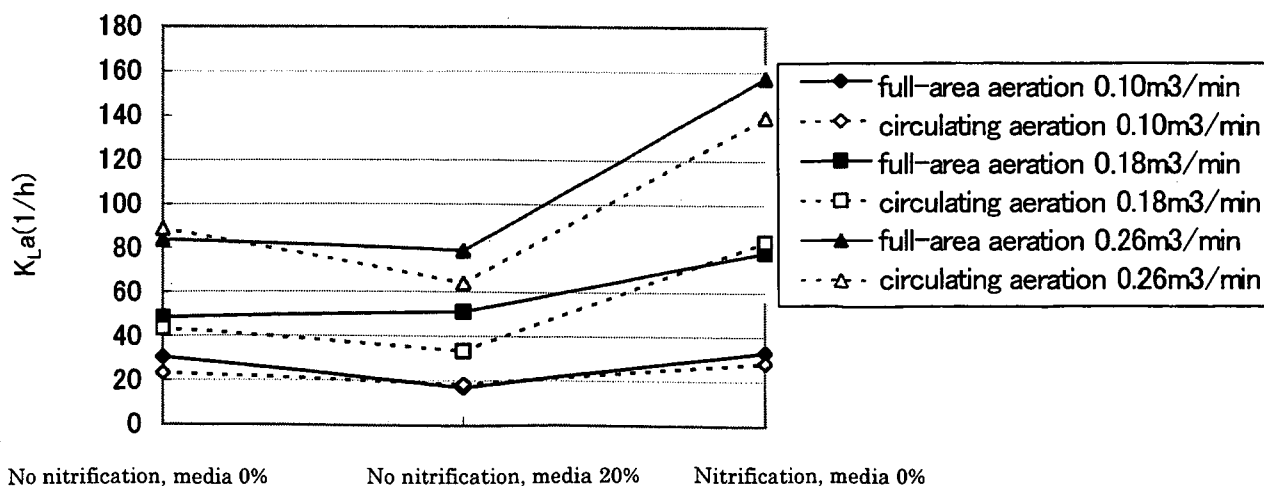


Figure 3: Effect of immobilization media on $K_L a$ value

(continuous flow experiments)

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 evaluated the relationship between the chlorine disinfection level and bacteria proliferation, the behavior of bacteria in contact purification process and the tracer experiment using *E.coli* in a single pass channel.

RESULTS

(1) The relationship between the chlorine disinfection level and bacteria proliferation

we had a chlorine disinfection experiment using *E.coli* as indicator bacteria, and microscopic observation of *E.coli* after 20 hour contact with TSB and nalidixic acid was carried out in addition to the cultivation method, to evaluate the *E.coli* which is alive but dose not have proliferation ability.

In the case of high chlorine dosage (Physiological saline: $>2.0\text{mgCl/L}$, Artificial secondary effluent: $>10\text{mgCl/L}$), the number of *E.coli* in disinfected effluent was 10^0CFU/100mL (survival ratio was $-6\log$), and *E.coli* didn't increase in 480 hours, not showing life function neither. On the other hand, in the case of low chlorine dosage, the number of *E.coli* by cultivation method in disinfected effluent was 10^1CFU/100mL (survival ratio was $-4\log$), but the alive *E.coli* were detected more ($10^2 \sim 10^3\text{CFU/100mL}$). Within 24 hour the number of *E.coli* by cultivation method and microscopic observation did not change, but after 100 hour it increased and reached 10^7CFU/100mL .

In the experiment, *E.coli* growth even in the physiological saline was observed. *E.coli* may have increased using a very small quantity of substrates that remained in water and experiment container.

(2) The behavior of bacteria in contact purification process adapted to river flow

we had an experiment that was intended to make clear that fate of bacteria in a contact purification process, in which bacteria concentration in the influent and effluent was measured together with that in the process.

About 80% of *E.coli* that flowed in were removed in this process. And 99.72% of removed *E.coli* were inactivated.(See Figure-1" The mass balance of the *E.coli* in contact purification process")

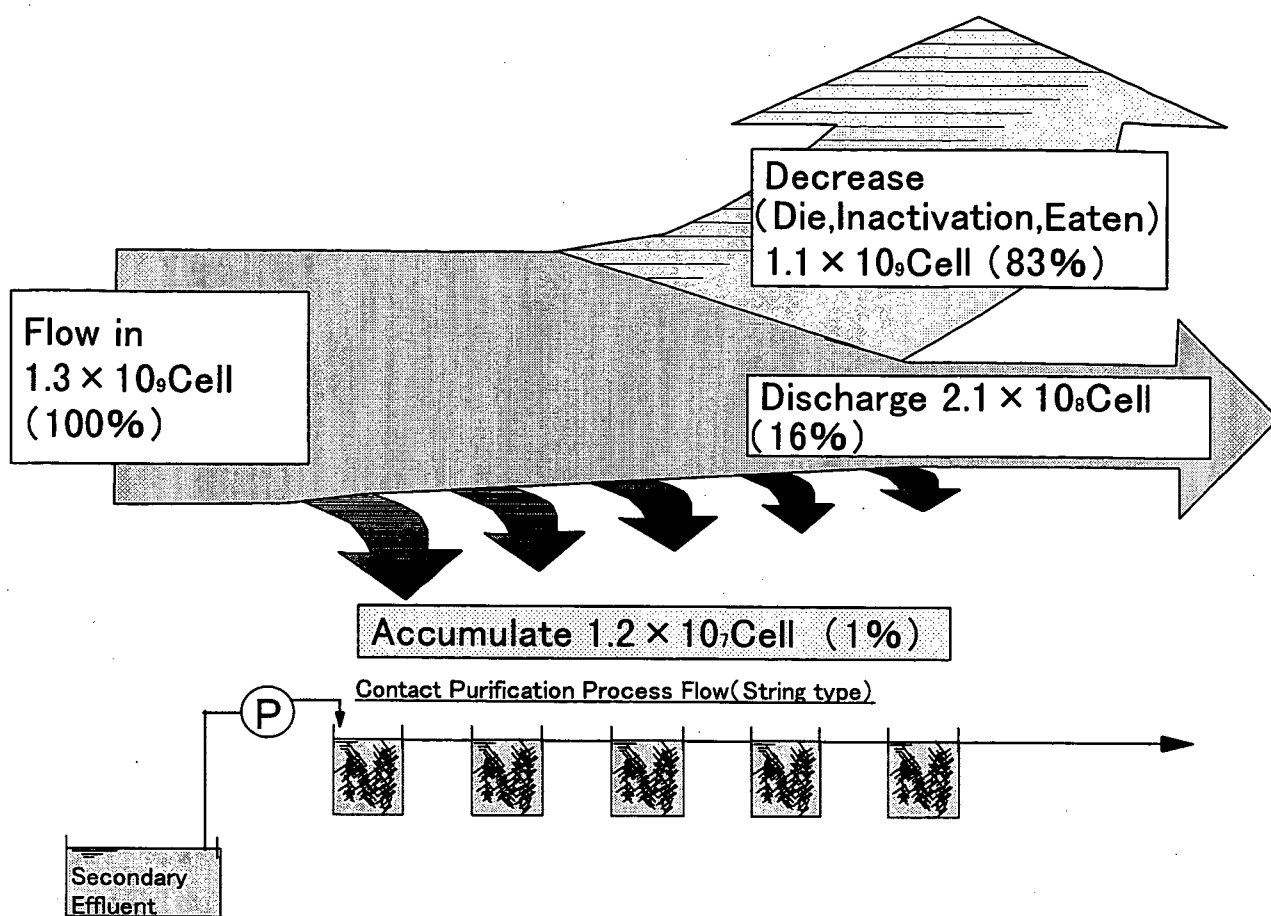


Figure-1 The mass balance of the *E.coli* in contact purification process

RISK MANAGEMENT OF PATHOGENS IN SEWERAGE SYSTEM

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

Project period : 1998-2001

OBJECTIVES

Japan has 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.

METHODS

In FY 1999 we investigated the oocysts removal efficiency of the following processes with experiment facilities receiving municipal wastewater.

- 1) Activated sludge process of continuous flow.
- 2) Activated sludge process of continuous flow with poly-aluminum-chloride(PAC) dosed.
- 3) Sand filtration.
- 4) Sand filtration with PAC dosed.
- 5) Chemical precipitation process of raw wastewater.

RESULTS

REMOVAL OF OOCYSTS OF ACTIVATED SLUDGE TREATMENT

The operation conditions of the continuous activated sludge process were HRT 8 hours, the MLSS concentration 2000 mg/L and return sludge ratio 50 percent. The addition of the inactivated oocysts to primary effluent was 4.0×10^4 oocyst/L, and the PAC was added to the activated sludge at 10mg-AL/L. Fig. 1 shows the removal of the oocysts by the activated sludge process and by that with coagulant addition. The removal ratio about 2 log was obtained by the activated sludge process, and the improvement of the removal ratio by about 3log was observed after coagulant was added, showing total 5 log removal.

REMOVAL OF OOCYSTS BY SAND FILTRATION

The removal experiment of the oocysts by sand filtration was carried out at the filtration rates of 100 and 200 m/day. Secondary effluent of the continuous activated sludge process was used. Also, we experimented coagulant addition of 3 mg/L before the sand filtration. Results of the survey are listed in Table 1. The removal ratio of the oocysts by the sand filtration was 0.5 log, showing almost the same ratio for the filtration rate cases of 100 and 200m/day. However, the removal ratio with the coagulant addition for the both filtration rate cases was improved to 2.6 log.

REMOVAL OF OOCYSTS BY CHEMICAL PRECIPITATION PROCESS OF RAW WASTEWATER

In the chemical precipitation of raw wastewater, coagulant was added to the wastewater, and it underwent 1 minute rapid-mixing and 90 minute settling, and oocyst concentration in the supernatant was measured. The range of the concentration of the coagulant addition was 0 to 20mg/L. High removal ratio was observed at high coagulant concentration, 1log at 5mg/L, 2log at 10mg/L and 3log at 15mg/L. The oocyst removal ratio in the supernatant was correlated to the turbidity and the chemical oxygen demand removal ratio.

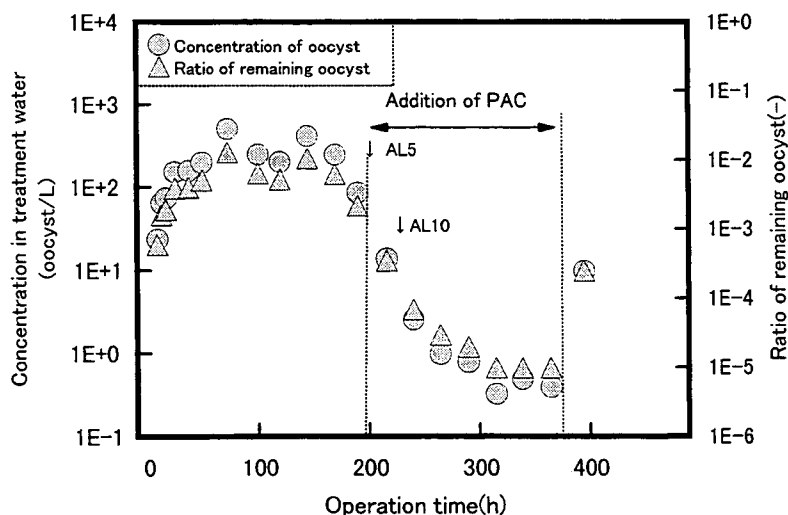


Fig.1 Removal result of the oocysts by the activated sludge treatment and coagulant addition of activated sludge treatment

Table1 The experiment result of sand filtration and coagulant addition sand filtration

	Sand filtration		Coagulant add. sand filtration	
	Conc. of oocyst (oocyst/L)	Removal ratio (log)	Conc. of oocyst (oocyst/L)	Removal ratio (log)
Influent	124	—	199	—
Effluent (100m/d)	34	0.56	0.5	2.6
Effluent (200m/d)	36	0.54	0.5	2.6

BIOLOGICAL DECOMPOSITION OF ENDOCRINE DISRUPTING SUBSTANCES

Y. Suzuki, M. Ogoshi, H. Shigemura, T. Hatatsu and S. Kim

Advanced Wastewater Treatment Division

Project Period: 1999 – 2000

Objectives

Nonylphenol(NP) and 17 β -estradiol(E2) were commonly detected in the final effluent of municipal wastewater treatment plant as the endocrine disrupting substances. So, these two substances are supposed to be degraded insufficiently by activated sludge. This study objects to find the bases of removal and biological degradation of these two substances and also to find special microorganisms that can decompose these materials effectively. The annual targets in fiscal 1999 are as follows.

- 1) To find the special microorganisms which have high metabolizing ability of these two substances.
- 2) To find the part of condensation of these substances in the activated sludge.
- 3) To examine the removal efficiency of these two substances by RO process.

This study project started in 1999, as a part of the comprehensive studies and developments on the water quality risk management in the aquatic environment.

Methods and the results of search

The high NP or E2 metabolizing microorganisms were searched from 7 different kinds of activated sludge. They were collected from 7 municipal wastewater treatment plants where the influent contained comparatively thick NP or E2. A part of the sludge were inoculated into some single substrate culture medium and cultivated for about a month. The supernatant of the culture medium from the culture flask which indicated the growth of microorganisms, were examined to confirm the

reduction of NP or E2. And finally, some kinds of microorganisms were purely separated and the ability was confirmed.

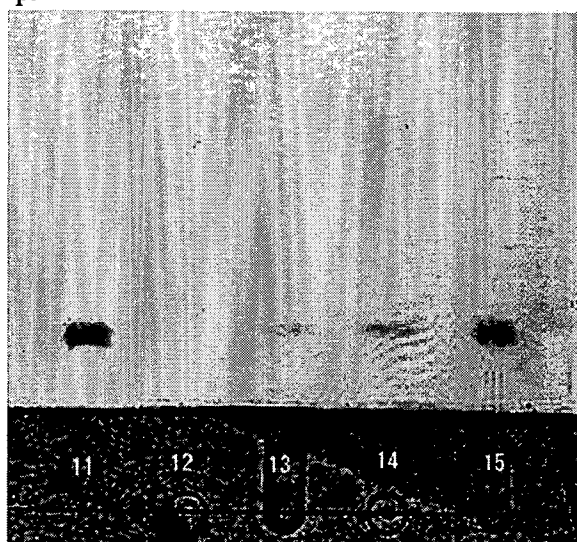
The result of the survey is not satisfactory enough, but we could find that some microorganisms have high E2 metabolizing ability as indicated in Table 1.

Table 1 Result of the E2 metabolizing test by single strains separated from POTW

Strain No.	Initial E2 (mg/L)	Final E2 (mg/L)	Removal rate (%)
F2	7.03	0.02	99.8
F3	7.03	2.52	64.2
F4	7.03	0.31	95.5
T22	7.03	0.38	94.6
T23	7.03	2.49	64.6
T31	7.03	0.12	98.3
T43	7.03	2.04	70.9
T44	7.03	1.54	78.2
T46	7.03	0.9	87.2

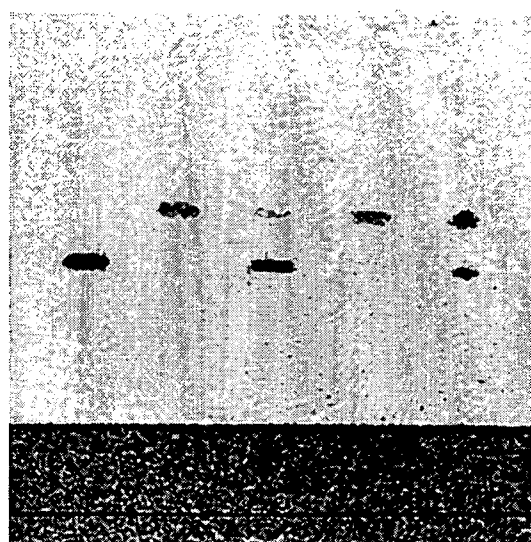
Biological degradation of E2

On the way of searching microorganisms, we have found important phenomena about the E2 degradation. Fig. 1 is an example of the thin layer chromatogram (TLC) of the first accumulation culture medium for E2 metabolizing microorganisms. Two different band patterns were observed, one indicates a clear E2 band, which means E2 metabolizing microorganisms do not exist, and the other dose not indicate clear E2 band, that means E2 has disappeared or has diminished. Fig.2 is an example of TLC of the final pure culture medium of E2 metabolizing microorganisms. Different from fig.1, there are other two different patterns, one indicates a clear band in the upper part of E2 band, which means the degradation of E2 to E1, and the other indicates two bands at E2 and E1, that means the degradation of E2 to E1 is on the way. We could not find any TLC which indicates no band as seen in fig.1 from pure culture medium. So, E2 metabolizing microorganisms can degrade E2 to E1, but they can't degrade E1 anymore. But in the first accumulation culture, E1 was also degraded. Therefore, at least two kinds of microorganisms exist, one degrades E2 to E1 and the other degrades E1, however the final product of this reaction chain has not been identified.



The E2 band is almost lost in 12 to 14.

Fig.1 TLC of accumulated culture medium



(Lower bands are E2 and upper bands are E1)

Fig.2 TLC of pure culture medium

Other results

About the condensation part of NP or E2 in the activated sludge, some extraction methods were examined. But the results were insufficient to compare which extraction is most effective. From this, NP and E2 are supposed to exist inside of activated sludge or firmly bound with protein of the cell.

The basic removal efficiency of some RO membranes was also examined by using bench scale experimental equipments. The removal rate of NP depended on the permeable pressure, but E2 removal was not influenced by pressure.

TREATMENT METHODS OF ENDOCRINE DISRUPTERS

Y. Suzuki and H. Shigemura
Advanced Wastewater Treatment Division

Project period: 1999-2001

OBJECTIVES

Recently, the effects of endocrine disrupters on human health and ecosystem are worried about, and this problem is often reported by mass media. In sewage treatment plants, it is necessary to investigate the fate of endocrine disrupters in the treatment facilities in order to reduce the endocrine disrupters in the influent. In this research, we investigated the fate of endocrine disrupters in conventional activated sludge and A²/O processes using pilot plants. Also, we investigated the removal of endocrine disrupters by ozonization and active carbon adsorption which can be adapted as tertiary treatment.

RESULTS

(1) REMOVAL OF ENDOCRINE DISRUPTERS BY BIOLOGICAL TREATMENT

In both of the pilot plants, 17beta-Estradiol and Nonylphenolethoxylate were removed well, but the removal of benzophenone was not good. The removal ratio of 17beta-Estradiol was more than 90%, which was different from the existing data of 70% removal with biological treatment. Nonylphenol and Benzophenone were removed more in the A²/O process than in the conventional process. (Figure 1)

(2) CONCENTRATION OF ENDOCRINE DISRUPTERS IN ACTIVATED SLUDGE

We measured the concentration of endocrine disrupters in the sludge of the conventional process. Nonylphenolethoxylate ($n \geq 5$) was concentrated well in sludge, but 17beta-Estradiol was hardly contained in sludge. (Figure 2)

(3) REMOVAL OF ENDOCRINE DISRUPTERS BY OZONIZATION

Removal of Nonylphenol and Nonylphenolethoxylate by ozonization was experimented. The higher dosed ozone concentration was, the more endocrine disrupters were removed. Especially, when dosed ozone concentration was above 10mg/L, the concentration of Nonylphenol and Nonylphenolethoxylate was nearly 0mg/L (Figure 3). Therefore, dosing ozone above 10mg/L is necessary to remove endocrine disrupters completely by ozonization.

(4) REMOVAL OF ENDOCRINE DISRUPTERS BY ACTIVE CARBON ADSORPTION

Endocrine disrupters were removed well by active carbon adsorption. There were little endocrine disrupters deriving from adsorption column made of Poly-vinyl chloride.

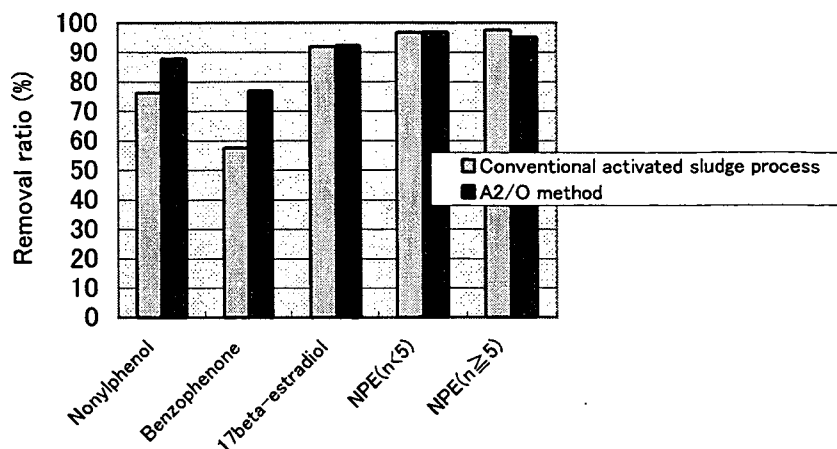


Figure 1: Removal of endocrine disrupters by biological treatment

NPE: Nonylphenolethoxylate

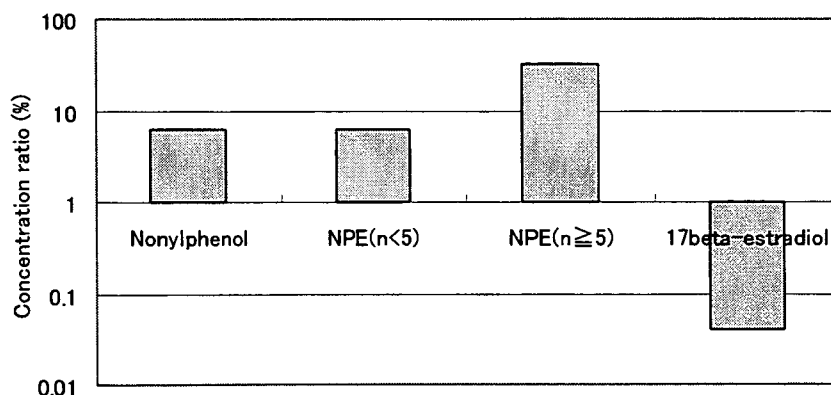


Figure 2: Concentration of endocrine disrupters in sewage sludge

NPE: Nonylphenolethoxylate

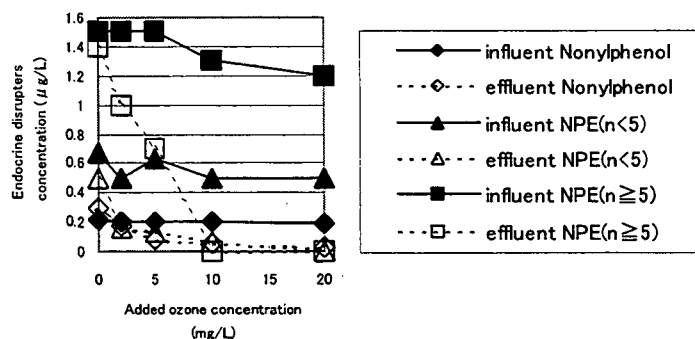


Figure 3: Removal of endocrine disrupters by ozonization

NPE: Nonylphenolethoxylate

CO-COMPOSTING OF SLUDGE WITH OTHER ORGANIC MATERIALS

H. Morita, I. Harada, and H. Saino
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 surrounded by hinterlands that are agricultural and green lands, where sewage sludge can be used as fertilizer. Farmers using organic fertilizer, however, desire better products, which means that improvements are necessary to promote the effective utilization of sewage sludge. It is also hoped that simple composting will prevent costs from rising.

Therefore, the purposes of this study are 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 FY1999 we investigated large-scale co-composting from varying viewpoints for the third consecutive year.

- (1) We conducted large-scale composting experiments of sewage sludge with grass added as a bulking agent in order to consider the appropriate amount of aeration. The wind-low type by a self-driving compost turning machine was applied and sewage sludge was turned five times a week. (In one case, this was done three times a week.) Aerations were adjusted between 0 and 100 L/min·m³.
- (2) We tried to use return compost to adjust the moisture content. We investigated the combined composting of sewage sludge and cattle dung, or the mixed composting of sewage sludge and grass to confirm the fermentation in a case where dewatered sludge and return compost was applied to the wind-low type. The recirculation ratios of return compost were set as 35% and 65% in grass mixed compost and 50% and 80% in cattle dung combined compost. These ratios were set referring to the result of FY1998. In cases which included more return compost, the moisture contents were higher (Lower cases were 62% or 64%, higher cases were 68% or 70%).
- (3) Hearings were held to investigate actual composting facilities. The hearings were conducted at facilities constructed with government subsidies. The hearings investigated the costs of construction, costs of running, scale of facilities, the amount of products, qualities of products, and so on.

RESULTS

Some fundamental data concerned with the co-composting of sewage sludge with other organic materials

were obtained through this study. The summary of the study in FY 1999 is as follows.

- (1) The aeration helps fermentation at the primary stage, but the fermentation temperature fell quickly and fermentation was prevented when we continued aeration (Fig.1). So we focused on the bulk density, and estimated that the bulk density when we should stop aeration was between 0.50 and 0.55.
- (2) It was estimated that the moisture content of the mixture was a condition of less than 65% even when return compost instead of dried sludge was applied in order to control the initial moisture content. We confirmed the fermentation in a hard winter. But we should turn the mixtures with great care because their temperature might drop suddenly, and we should make fairly big piles of mixtures because we must control the heat radiation of the mixtures.
- (3) It was clarified that the driving cost per the amount of products tended to be lower at the composting facilities where other materials were added to the sewage sludge. It was also clearly shown that while the contents of the heavy metals in composts fell far below the level stipulated by laws governing fertilizers, the contents of the copper and zinc occasionally exceeded the recommended regulations (Fig.2).

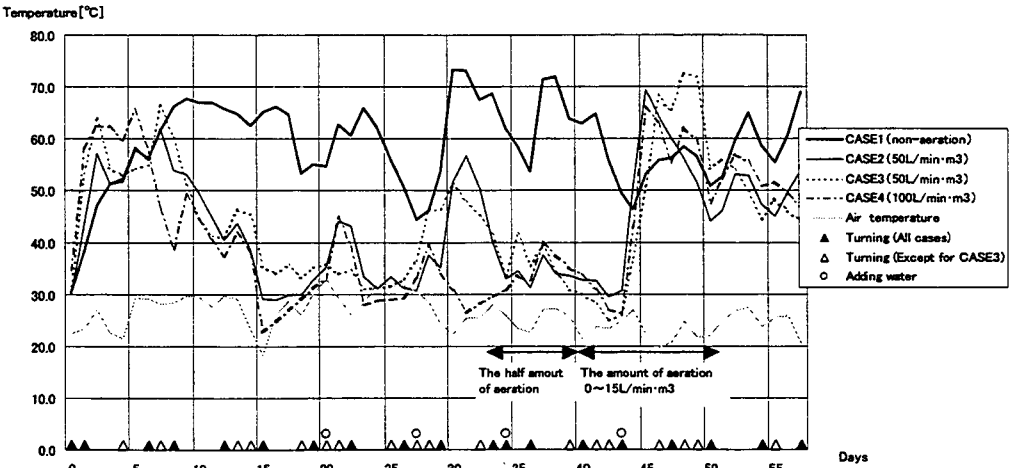


Fig.1 Temperature trend in composting with aeration

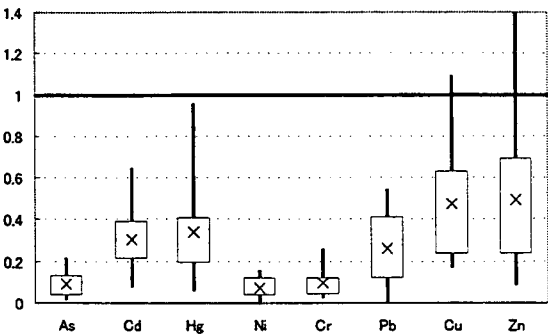


Fig.2 Contents of heavy metals in composts
(Regarding regulations as 1)

SLUDGE TREATMENT RESPONDING TO SLUDGE PROPERTY CHANGE

H. Morita, S. Ochi and Y. Kitamura

Sludge Management Division

Project period : 1996-1999

OBJECTIVES

It is predicted that advanced wastewater treatment processes will be introduced in sewerage systems with increasing frequency in the future. In addition, many people are eager to install a garbage grinder - disposer in their homes for convenience. Therefore, the quality / quantity of sewage sludge passing through wastewater treatment processes will change

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

METHOD

In FY 1999, we analyzed the change of concentration and magnitude of sewage and swage sludge by an increased pollutant load for the wastewater treatment process assuming the garbage inflow to reach maximum, based on that the information had already cleared according to The Study On The Effect Of Sewage Works On Residential Circumstance (*Annual Report Of Research And Investigation On Sewage Works, PWRI, FY1987_FY1989*) and The Study On The Effect Of Garbage Grinder On Design And Operation Of Nutrient Removal Processes (*Annual Report Of Research And Investigation On Sewage Works, PWRI, FY1996*). The treatment capacity and specification of existing facilities for the quantitative analysis were quoted from The Guideline For Plan And Design Of Sewerage Facilities (*Japan Sewage Works Association, 1994*) and The Manual Of Design For Advanced Wastewater Treatment Facilities (*The Advanced Wastewater Treatment Committee, 1994*).

RESULTS

WASTEWATER TREATMENT PROCESSES

It was estimated that the flow rate of sewage inflow will increase to 1.1 times the present level, and that this will increase the concentration of various substances in the water: 1.2 times for SS, 1.5 times for BOD, 1.5 times for soluble BOD, 1.4 times for COD, 1.1 times for total nitrogen and 1.2 times for total phosphorus. Therefore, the quantity of oxygen that must be supplied to the aeration tank for wastewater treatment will also increase from the present levels. Specifically, 1.36 times for the conventional activated sludge process, 1.43 times for the oxidation ditch process, 1.18 times for the recycled nitrification/denitrification process, 1.27 times for the anaerobic/oxic process, and 1.36 times for chemical addition process.

SLUDGE TREATMENT PROCESS

The sludge treatment process must treat the quantity and quality of inflow sludge that is predicted to change to the conditions shown in Table 1 from the present conditions shown in Table 2. It was estimated that we will be able to cope with this changed range of sludge load without the extensive rebuilding of the facilities

In this case, the item sludge quantities in Table 1 and Table 2 is represented by the quantity per unit of the present inflow rate of wastewater. Accordingly, the value shown multiplied by the present inflow rate obtains the actual sludge quantity in each time under each set of conditions.

Table 1 Sludge quantity and sludge quality conditions that sludge treatment processes must handle in the future to achieve the maximum garbage inflow.

The source	Kinds	Sludge quantities		Sludge qualities	
		Flow rate of solids (kg TS/m ³ /day)	Flow rate of fluids (m ³ /m ³ /day)	VS/TS (kg/kg (%))	Concentration (kg TS/m ³)
Conventional activated sludge process	Primary sludge	0.120	0.0092	82	13.0
	Excess activated sludge	0.175	0.0292	85	6.0
	Mixed sludge	0.295	0.0378	84	7.8
Recycled nitrification/denitrification process	Excess activated sludge	0.147	0.0246	85	6.0
	Mixed sludge	0.267	0.0338	84	7.9
Anaerobic/oxic process	Excess activated sludge	0.173	0.0288	73	6.0
Chemical addition process	Excess activated sludge	0.208	0.0347	72	6.0
	Mixed sludge	0.328	0.0439	76	7.5
Oxidation ditch process	Excess activated sludge	0.219	0.0235	86	9.3

Table 2 Present sludge quantities and qualities that must be handled by sludge treatment processes.

The source	Kinds	Sludge quantities		Sludge qualities	
		Flow rate of solids (kg TS/m ³ /day)	Flow rate of fluids (m ³ /m ³ /day)	VS/TS (kg/kg (%))	Concentration (kg TS/m ³)
Conventional activated sludge process	Primary sludge	0.081	0.0081	77	10.0
	Excess activated sludge	0.132	0.0220	82	6.0
	Mixed sludge	0.213	0.0301	80	7.1
Recycled nitrification/denitrification process	Excess activated sludge	0.104	0.0173	81	6.0
	Mixed sludge	0.185	0.0255	79	7.3
Anaerobic/oxic process	Excess activated sludge	0.129	0.0215	75	6.0
Chemical addition process	Excess activated sludge	0.157	0.0262	69	6.0
	Mixed sludge	0.238	0.0343	72	6.9
Oxidation ditch process	Excess activated sludge	0.138	0.0173	81	8.0

CONTROL OF PATHOGENIC MICROORGANISMS IN WATSEWATER SYSYTEM

H. Morita, S. Ochi and T. Kitamura

Sludge Management Division

Project period: 1997-2000

OBJECTIVES

Cryptosporidiosis was caused by the 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, a 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 in the upstream part of the water supply plant intake.

According to the spread of sewerage systems, WWTPs tend to be locate in upstream 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, the sanitary treatment of sewage sludge is important. This study aims to control pathogenic microorganisms in wastewater treatment systems.

In FY 1999, We examined the assay for evaluating viability or infectivity of the *Cryptosporidium* oocysts. We investigated the experimental condition, convenience and problem of the excystation assay, the animal infection assay and cell culture assay.

METHODS AND RESULTS

(1) The evaluation of the viability by the excystation assay.

The effect of incubation time and acid pretreatment on the excystation ratio was shown in Figure .1,2. It was proven that the excystation ratio of the oocysts were improved by the acid pretreatment. The optimum excystation condition was acid pretreatment for 30 minutes followed to incubate over 2 hours in the excystation liquid. The maximum excystation ratio became 95% for 4 hours during the incubating. The evaluation of the viability of the oocysts by the excystation assay was possible in a convenient and short time.

(2) The evaluation of the infectivity by the mouse.

Figure.3 shows the relationships between the progress days after oocysts administration and oocysts number discharged from the mouse. After the oocysts were administered to the mouse, it was proven that the oocysts discharged from the mouse reached the plateau over 30 days. After 30 days progress, the number of the oocysts discharged per day reached 10^6 . It was difficult to detect the oocysts under 10^4 in feces. The mouse had to be kept over 15 days in order to accurately detect the oocysts from feces. When the infectivity is evaluated by this assay, it is necessary to use 3 or more mice per 1 condition. This is necessary, because the individual specificity occurs between mice. When the inactivation of the oocysts are determined quantitatively by this assay, it is necessary to increase the number of mice used for the experiment. This assay is not a convenient and quick method.

(3) The evaluation of the infectivity by the cell culture.

After the sporozoite was inoculated in the HCT-8 cell, it was observed that the stage of growth of the *Cryptosporidium* was formed on the cell culture for 48 hours. We observed Macrogametes, microgametocyte and Meront formed in the cell.(Photo.1) It was proven that this assay could conveniently evaluate the infectivity of the sporozoite.

The convenient evaluation of the inactivation of the oocysts were possible by the excystation assay. It was possible to evaluate the infectivity of the excysted sporozoite by performing an infection test using the cell culture.

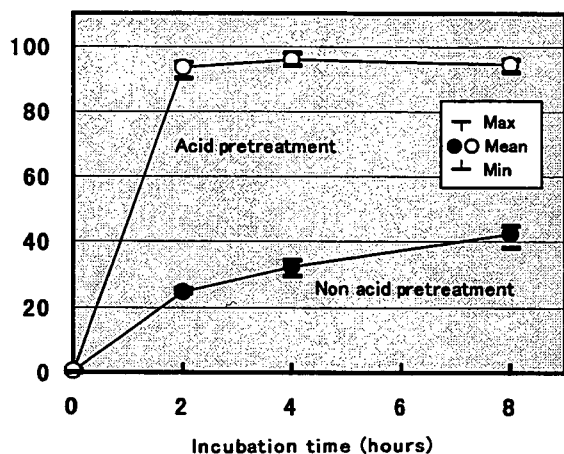


Fig.1 Effect of of incubation time and acid pretreatment on the excystation ratio of *C.parvum* oocysts using sodium deoxycholate + sodium hydrogen carbonate.

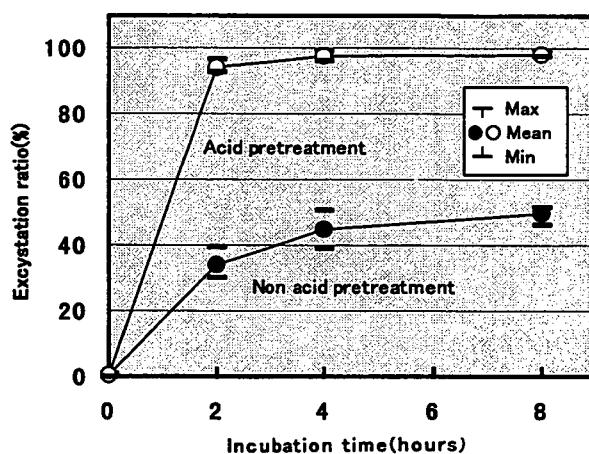


Fig.2 Effect of incubation time and acid pretreatment on the excystation ratio of *C.parvum* oocysts using trypsin + sodium taurocholate.

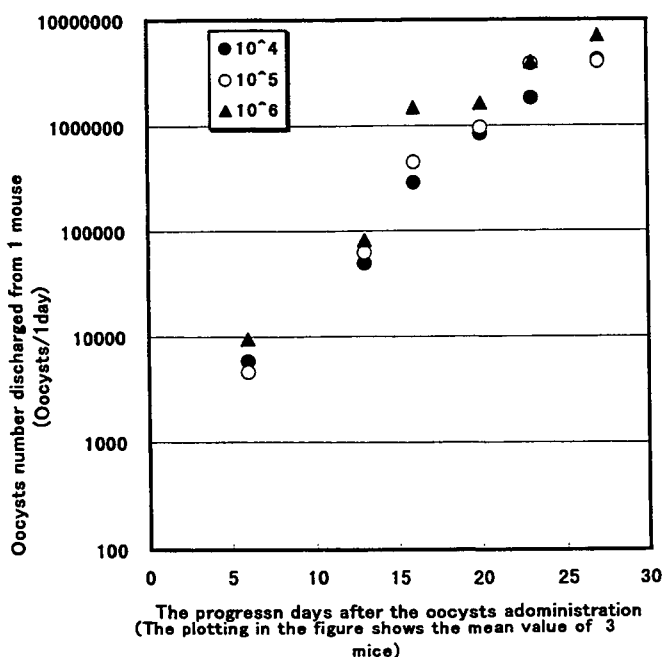


Fig.3 Relationships between the progress days after oocysts administration and oocysts number discharged from the mouse.



Photo.1 Stage of growth of the *Cryptosporidium* in HCT-8cell.

CONTROL OF HEAVY METALS IN SLUDGE TREATMENT PROCESS

Hiroaki MORITA, Yukinori KAWASHIMA, Masamichi KOBAYASHI

Project period;1998-2000

OBJECTIVES

Small quantities of hazardous substance, such as heavy metals, flow into sewage treatment plants. Some are concentrated in sludge generated in the water treatment process. When the sludge is recycled, as much of these kinds of hazardous as possible must be removed in order to reduce their environmental effects.

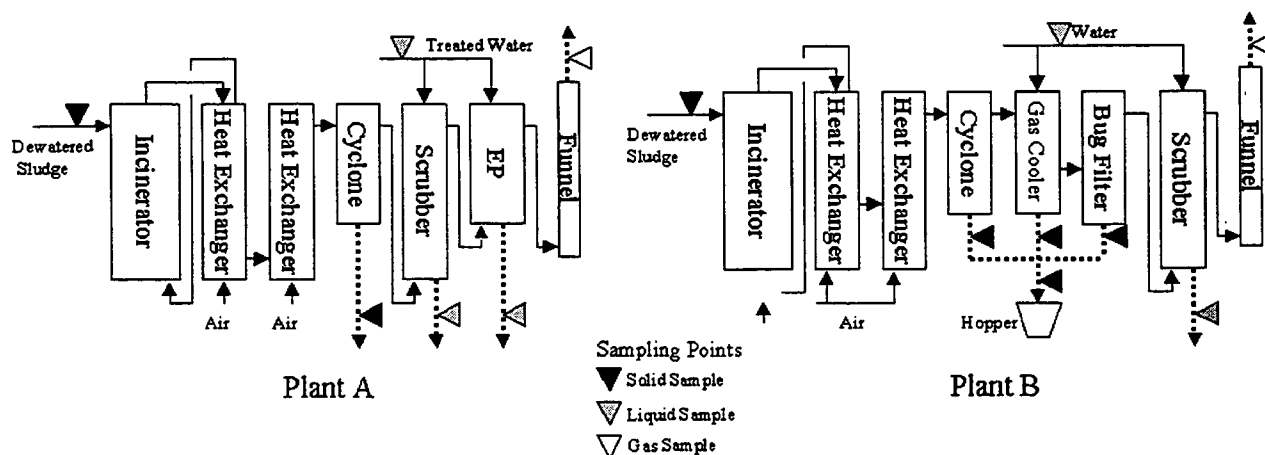
This study was performed to develop a method of decreasing heavy metals in sewage sludge. To find such a method, the behavior and chemical forms of heavy metals should be investigated. In FY 1999, research on the behavior of heavy metals in incineration and anaerobic digestion process were performed, because it was forecasted that the chemical forms of heavy metals changed in these process.

RESULTS

1. SURVEY ON THE BEHAVIOR OF HEAVY METALS IN ACTUAL INCINERATORS

The research which focused on arsenic and selenium was performed at actual incinerators, because relatively high concentration of these kinds of substances were often found in elution of leachate testing of sewage sludge. In our investigation last year, it was found that the concentration of selenium in ash collected at around 200°C was high. It was assumed that selenium in the sludge evaporated in the incinerator and discharged to the exhaust gas treatment equipment, and it was assumed that gaseous selenium condensed on the surface of ash in the ash collector where the temperature is lower than their evaporation temperature. The results of leachate test described above, were surmised to be due to selenium on the surface of ash.

This investigation was performed monthly until September 1999, and the results revealed that the behavior of selenium did not change throughout the year. It was also found that the temperature, at which selenium was concentrated into ash, was lower than 270°C (at the gage pressure of approximately -2000Pa). The effects of the diameter and the specific surface area were also examined. But, in this study, it was difficult to find a clear relationship between these factors and the concentration of selenium.



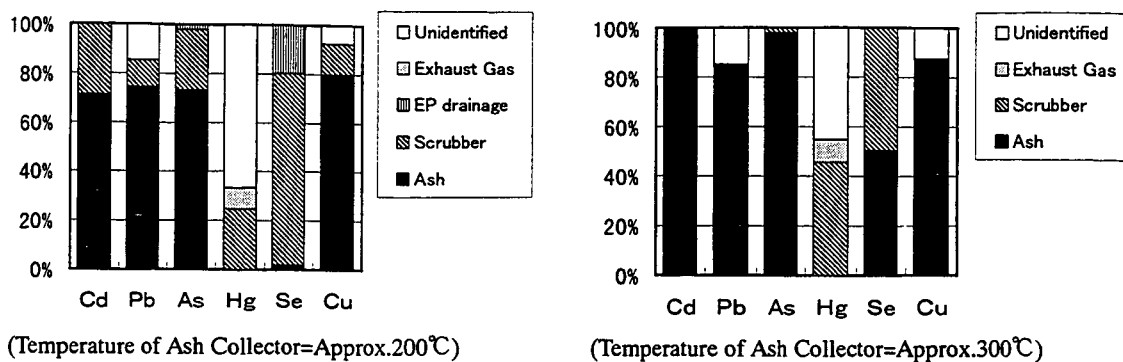


Fig.2 Distribution Ratio of Heavy Metals

2. EXPERIMENTAL RESEARCH ON THE BEHAVIOR OF HEAVY METALS IN INCINERATION

The relationship between the behavior of volatile metals (arsenic and selenium) and other constituents of dewatered sludge was examined by burning sludge of various kinds. The results of this study revealed that the behavior of selenium depended on the dehydration method. Selenium in the sludge treated with polymer evaporated, while selenium in the sludge treated with slaked lime and ferric chloride didn't evaporate. Arsenic didn't evaporate regardless of the kind of sludge.

3. EXPERIMENTAL RESEARCH ON THE THERMOCHEMICAL CHARACTERISTIC OF HEAVY METALS

This survey was performed to gain an understanding of the range of temperature where arsenic and selenium were condensed on the surface of ash. Various kinds of ash were examined at several temperature from 200°C to 900°C; the concentration of arsenic and selenium were measured before and after the experiments.

Arsenic in the ash didn't evaporate at any temperature. On the other hand, selenium in the ash treated with polymer evaporated. But the result of this experiment was different from the result of the investigation on actual incinerators. Selenium in the ash didn't evaporate at the temperature below 400°C. To understand this result, the difference between the condition of an actual incinerator and a laboratory, such as the pressure and the density of oxygen, should be examined. It is, therefore, necessary to conduct another research project to clarify this point.

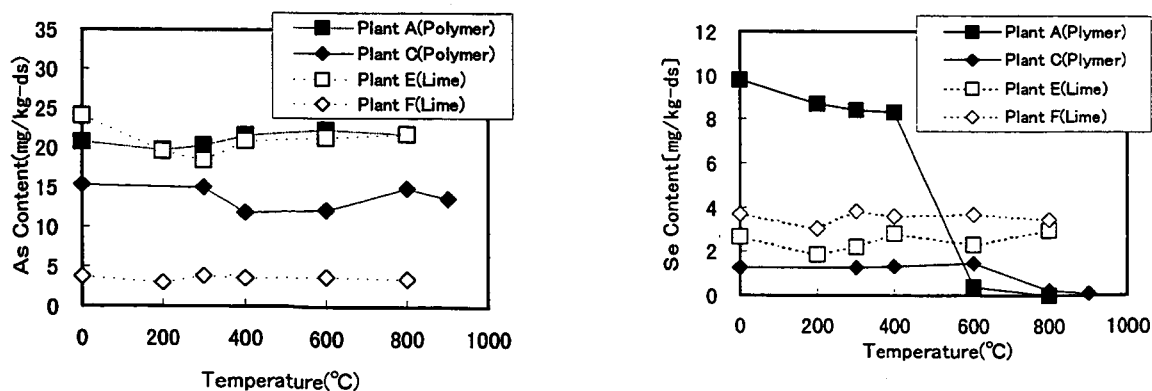


Fig.3 Arsenic and Selenium Remaining in Heated Ash

EMISSION VALUE FOR UNIT MATERIAL PRODUCTION FOR LCA OF SEWERAGE SYSTEM

H. Morita, I. Harada and H. Saino
Sludge Management Division

Project period : 1998-2000

OBJECTIVES

Sewerage systems have been constructed principally to improve our living environments, prevent inundation, and preserve water quality. But they also impact the environment. The operation and the construction of the facilities consume energy and generate carbon dioxide (CO₂). Green House Gases (GHGs) such as CO₂ and nitrous oxide (N₂O) are generated through water and sludge treatment processes. The first necessary step in reducing the environmental impact caused by any system is a quantitative and objective evaluation using a methodology such as Life Cycle Assessment (LCA). The purpose of this study is to organize the unit value for LCA, and develop the evaluation method: Life Cycle Inventory (LCI) analysis for sewerage systems.

This study was conducted as a joint research project by the Japan Sewerage Works Agency, the Association of Water and Sewage Works Consultants Japan, and the Japan Sewage Treatment Plant Constructors Association.

METHOD

Goal and scope definition should be determined carefully when LCA is performed, because the method and the required quality of data depend on them. In FY 1998, a survey of some existing databases was performed, and the goal and the scope definition of LCA for sewerage systems were organized. Then a basic model of LCI analysis, which was applied to evaluate plans and designs of sewerage systems, was proposed.

In FY 1999, we examined the LCI model through case studies of existing full-scale plants and model plants designed according to the standard. Also, the study, which was focused on differences between the water treatment processes and the capacity of plants, was conducted using the LCI model. However, our studies covered the emission of CO₂ and the energy consumption, because existing databases were limited to CO₂ and energy.

RESULTS

CASE STUDY

LC-CO₂ and LC-E of mechanical / electrical equipment were estimated using the LCI model developed in our study and the results of the survey on full-scale plants. In addition, simulation models of different capacity, which were designed according to the standard, were used to evaluate the difference caused by its capacity.

SENSITIVITY OF LCI MODEL

A fundamental examination of the sensitivity of LCI model was performed using the results of the case

studies mentioned above. It indicated that most of the LC-CO₂ of equipment came from electricity consumption in the operation phase. (Fig.1) And it also revealed that parameters such as electric load factor influenced the result of LCI. On the other hand, the LC-CO₂ from processing, transportation and installation were extremely small. So, as for processing, transportation and installation, it was considered that the result wouldn't depend on the quality of data when estimating the overall plant.

PLANT A (Conventional Activated Sludge Process)

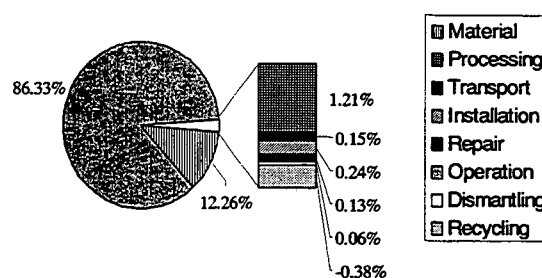


Fig.1 LC-CO₂ Classified by Life Cycle

REPRODUCIBILITY OF THE LCI MODEL

The reproducibility of the LCI model was examined regarding the LC-CO₂ which came from electricity consumption in operation phase, because it had great effect on the estimation. Electricity consumption measured in the plant and estimated using the LCI model were compared by the examination. The estimated electricity consumption was approximately 1.5 times larger than the measured consumption, but the ratio was smaller than the ratio of influent. The volume of influent used in the LCI model was obtained from design of facilities, and it was approximately 2 times larger than the actual volume. The ratio difference was considered to be caused by the equipment, whose electric load and operation time didn't depend on the volume of influent. For example, mixers in aeration tank works turn on and off when the volume of influent is much smaller than the design. Therefore, we tried to match the estimation to the actual condition using a calibration factor which corrected the operation time of equipment such as mixers. It achieved a good result of this case study. But it is considered necessary to examine this to see if it is applicable to other cases.

SIMPLIFICATION OF INPUT DATA

The composition of LC-CO₂ of sludge treatment process suggested the possibility that the input data for LCI model would be simplified; input data has to be simple when LCI model is used at planning stage, because we cannot obtain detailed data at that stage. We investigated the LC-CO₂ from the equipment in sludge treatment process of two plants, and it revealed that the top 10 items accounted for more than 80% and most of them were common in both plants. So, it might be possible to estimate the LC-CO₂ roughly if we obtain the data of major equipment.

APPLICATION OF LCI MODEL TO SEWERAGE SYSTEM

As a sample application of the LCI model, we attempted to evaluate the LC-CO₂ from equipment in plants with different capacities. The result from a full-scale conventional activated sludge process plant where the influent volume was 2,500 - 33,450m³/day, didn't indicate any scale-merit. As for the oxidation ditch, LC-CO₂ per unit influent decreased slightly as the capacity of the plant increased. (Fig.2) But the composition of LC-CO₂ was not related to the capacity of the plants.

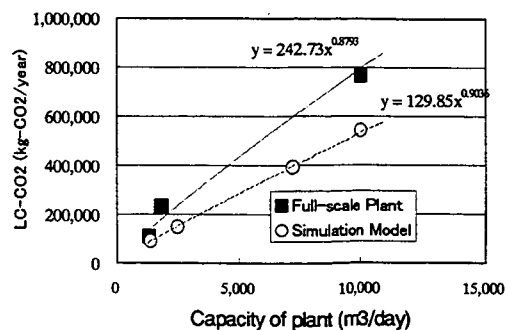


Fig.2 Relationship between LC-CO₂ and Capacity of plant (Oxidation Ditch)

BEHAVIOR OF ENDOCRINE DISRUPTORS IN SEWAGE SLUDGE

H. Morita, S. Ochi and Y. Kawashima

Sludge Management Division

Project period : 1999 _ 2001

OBJECTIVES

In recent years, there have been many reports on environmental problems caused by endocrine disruptors (EDs) discharged as trace-chemicals in the many countries and regions. The problem is that among the many kinds of manufactured chemicals necessary for our lives and activities that are used and discharged, there are some that can disrupt the endocrine of humans and living things in the wild state. Therefore thorough investigations have been done deal with this problem around the world.

The Ministry of Construction carried out a national investigation on the pollution of river waters and treated wastewater by EDs in Japan in FY1998. Some trace-chemicals suspected to be EDs were detected at almost all surveyed points by this investigation. Research and investigation are needed to study countermeasures to deal with EDs in the sewerage system. The research aims to clarify the behavior of EDs in the unit processes performed at sewage sludge treatment facilities.

RESULTS

In FY1999, we carried out experiments to develop an EDs analysis methods for sewage sludge samples, to monitor the EDs in the soil which was spread sludge compost, to survey the EDs movement in anaerobic sludge digestion and in EDs elution tests of used sludge compost to search for clues to the movement of EDs in soil. Nonylphenol(NP), nonylphenol ethoxylate($\text{NPE}_n \leq 4$, $\text{NPE}_5 \leq n$), 17 β -estradiol(17 β -E), bisphenol-A(BP-A) and di-2-ethylhexyl phthalate(DEHP) which were chosen as the target EDs because these trace-chemicals were detected in higher amounts and at many surveyed points during aforementioned national investigation.

(1) Development of Analysis Methods

There are no useful analysis methods. Firstly, because the extraction process is an important step in analyzing EDs in the sludge, the extraction experiments were carried out by mixing different concentrations of extractively solution and sludge made using excess activated sludge powder. The first result was unnaturally as in the example shown in Fig. 1, and it was assumed that it was caused by the clean-up process with solids phase extraction which needs many minuteness technics. Fig. 2 shows an example of results obtained by the analysis process without solids phase extraction as the clean-up process. It was a clearer phenomena and concentration was higher than in the first results.

(2) Monitoring for Soil and Plans

The experiment was started with six radices of lysimeters which were set for different soil conditions with soil as the only control case, EDs soil was added, EDs-spread sludge compost soil was added, and periodically the

former soils were plowed. Fig. 3 shows an outline of the setting of the lysimeter. The weather has been continually observed, and soil samples have been stored by freezing until the analysis methods of EDs are established.

(3) Behavior in Anaerobic Sludge Digestion

Anaerobic digestion experiments were performed continuously for 95 day periods with a digestion temperature of 35°C and digestion periods by 20 days. The supplied sludge was produced by the excess activated sludge under different wastewater treatment conditions with sludge retention times to 10, 15 and 20 days. In the all digestion condition, the EDs concentrations of the digested sludge were higher than the supplied sludge according to present EDs analysis methods.

(4) Elution from Sludge Compost

The elution test was carried out using samples of one dried anaerobic digested sludge and three kinds of composts with different production processes. The method is a continued mixing sample and H₂O-solvent by ratio 1 to 9, mixing periods is 24hr, pH conditions are 7, 6, 5 and 4 which pH were controlled by using pH controller and 2N-HCl solution. The EDs were analyzed by the present analysis methods for the extracted liquids which were taken by filtration with 1 μ m-fiber/grass filter and centrifugation with 3000rpm-20min. The results show a tendency EDs elution to decrease as the pH of solvents drops as in the example shown in Fig. 4.

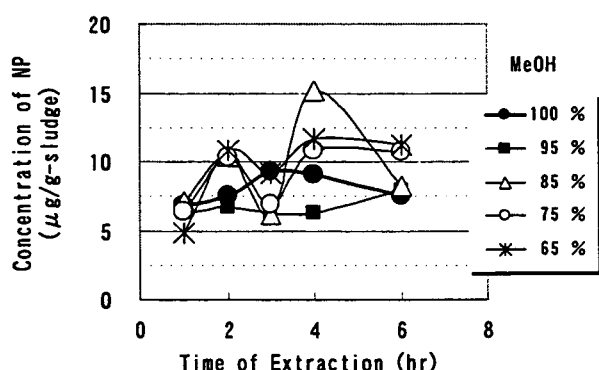


Fig. 1 Results by present analysis methods

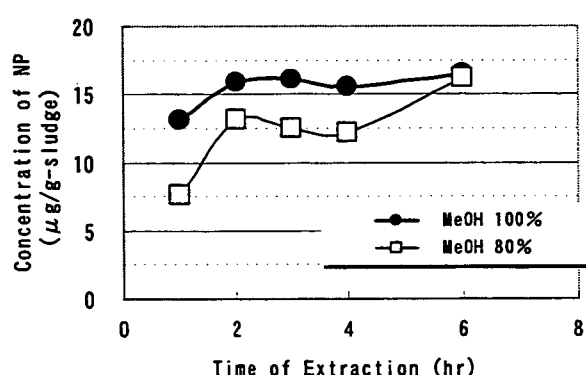


Fig. 2 Results of without solids phase extraction

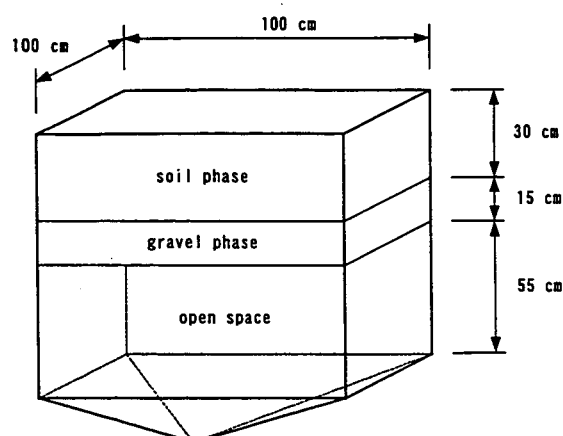


Fig. 3 An outline of setting lysimeter

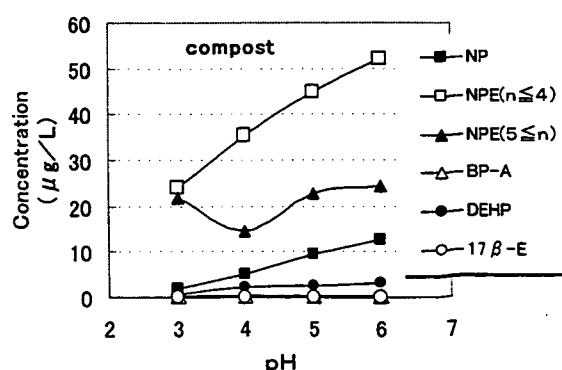


Fig. 4 An example of elution tests

IDENTIFICATION OF PATHOGENIC MICROORGANISMS IN WASTEWATER SYSTEM

H. Morita, S. Ochi and T. Kitamura

Sludge Management Division

Project period: 1999-2002

OBJECTIVES

It is important to quickly confirm existence of pathogenic microorganisms in sewage, treated sewage and sewage sludge in order to evaluate the microbiological safety of the water environment. This study aims at developing the method for quickly and conveniently detecting pathogenic microorganisms. Recently, Cryptosporidiosis of the waterborne infection disease was outbreak in Japan. The *Cryptosporidium* oocysts must be removed by a sewage treatment process, in order that the Cryptosporidiosis does not expand. It is necessary to measure the oocysts in sewage, treated sewage and sewage sludge in order to confirm whether the *Cryptosporidium* oocysts are actually removed by the sewage treatment process. But it is very difficult to detect the *Cryptosporidium* oocysts in sewage and sludge. Generally, the next step is the detection of the *Cryptosporidium* oocysts in sewage and sewage sludge. At first, the oocysts in sewage or sewage sludge are concentrated by the filter or sucrose floating technique. Next, concentrated oocysts are stained by the fluorescent antibody technique. Finally, the oocysts are detected by observation using a microscope. Microscopy is the more time-consuming way to detect this. A convenient and quick oocysts detection method should be developed.

In FY 1999, a basic examination was done to find a method of rapidly detecting oocysts with a Flow cytometry cell sorter(FCCS). The following were examined in this fiscal year.

- (1) What kind of information is obtained when the *Cryptosporidium* oocysts is analyzed in FCCS.
- (2) What kind of effect is generated, when a sample consisting mainly of a contaminant is analyzed in FCCS.
- (3) Is it possible that FCCS distinguishes the empty oocysts and intact oocysts.

RESULTS

The results obtained are as follows.

- (1) It was proven that the *Cryptosporidium* oocysts by FCCS could be easily detected by doing fluorescent antibody staining of the oocysts. It was possible to detect the signal of the oocysts by analyzing the signal from two parameters: side scatter and fluorescence intensity.
- (2) When the sample consists mainly of contaminant, it is necessary to cut the signal of the contaminant with a discriminator.
- (3) The discrimination of empty oocysts and intact oocysts by FCCS can be done by analyzing the oocysts signal from two parameters: forward scatter and side scatter.

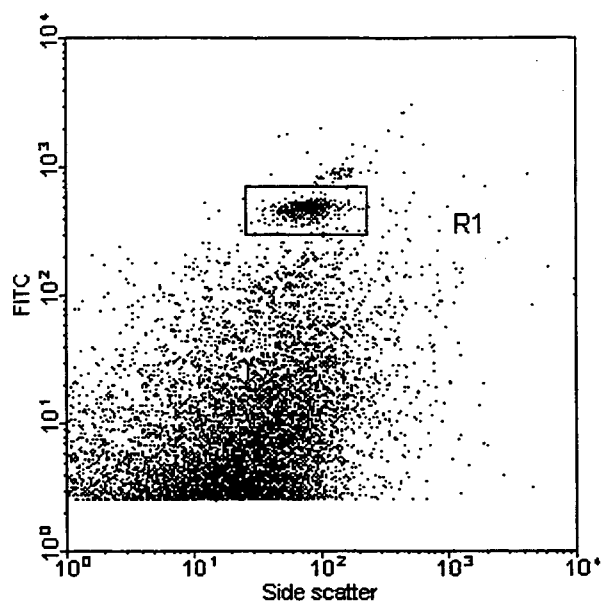


Figure.1 The histogram of the oocysts after the fluorescent antibody staining. The plotting in R1 is a signal of the oocysts.

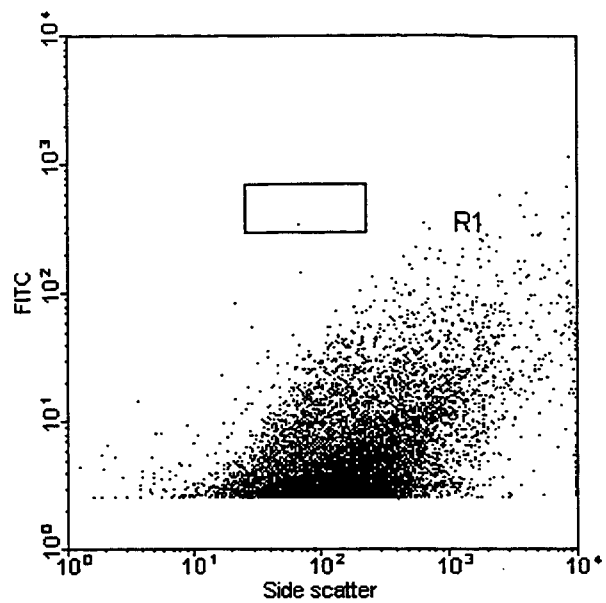


Figure.2 The histogram of the oocysts before the fluorescent antibody staining.

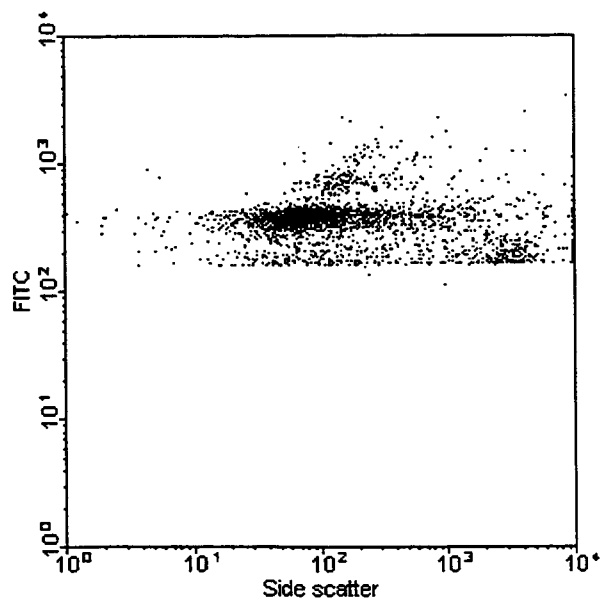


Figure.3 The histogram in cutting the signal of the contaminant by discriminator

BIOASSAYS FOR EVALUATING EFFECTS OF TREATED WASTEWATER ON ECOSYSTEMS

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

Water Quality Division

Project period : FY 1996-1999

OBJECTIVES

Due to recent development of sewerages in Japan, 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. So, it is necessary to evaluate the effect of treated wastewater on ecosystems in receiving water 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 water based on biological methods. Particularly, 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 1999, we aim to develop three methods using recombinant yeast for evaluating estrogenicity of chemicals and water samples, and apply to evaluation of sewage and treated sewage.

RESULTS

APPLICATION OF PRETREATMENT

It is important to concentrate samples for evaluation of estrogenicity. Usually, wastewater contains many chemicals and some times shows estrogenicity, but its level is too low to evaluate estrogenicity using recombinant yeast with concentration procedure. We compared solid phase extraction and solvent extraction as the concentration methods. The solid phase extraction is more useful for evaluating estrogenicity because of high percentage of recovery and low toxicity of extract.

ESTROGENICITY OF CHEMICALS

We evaluated estrogenicity of some chemicals that were considered endocrine disrupters (EDs) using three different recombinant yeast methods. Table 1 shows the result. For calculation of the chemicals estrogenic potential, the dose-response curve was used. The maximum absorbance level where 17β -estradiol (E_2) concentration in the assay medium is high enough to induce maximum production of β -galactosidase is assumed EC100 and the minimum absorbance level where the assay medium without E_2 is tested is assumed EC0. The EC50 of E_2 concentration can be estimated from the dose-response curve. As the dose-response curves of the other chemicals were also obtained, the EC50s of the chemicals were also estimated. We could evaluate the relative estrogenic strength of each chemical based on a reciprocal of its relative EC50 to E_2 .

Estron and estriol are the natural female hormones. 17α -ethynylestradiol and diethylstilbestrol are synthetic hormones. Bisphenol A (BPA) is a raw material of resin and 4-n-nonylphenol (NP) is a raw material of surfactant.

The estrogenicities of estron, 17α -ethynylestradiol and diethylstilbestrol are rather strong, while those of BPA and NP are quite weak. Three recombinant yeast assays show similar tendency in the above-mentioned substances, but there are large differences in estrogenicity of some

chemicals. For example, the estrogenicity of NP using Two-hybrid strain is more than hundred times as strong as the that of Sumpter strain. These results suggest that three different recombinant yeast methods could shows different estrogenicities when the same sewage sample that may contain many chemicals is measured.

We calculated coefficient of variation (CV) of the estrogenicities when the same chemical is measured to compare these methods. The CV of the CIIT method is smaller than the others, but is larger than that of results by GC/MS analysis method.

EVALUATION OF SEWAGE SAMPLE

We evaluated estrogenicity of sewage samples using Sumpter strain. Figure 1 shows the result. The average of estrogenicity of the influent g/L in summer and 0.058 ng/L in fall. The estrogenicity of effluent decreased by activated sludge process to 0.003 ng/L in summer and 0.015 ng/L in fall. We calculated removal ratio (Rr) as shown in the following :

$$Rr (\%) = (1 - \text{estrogenicity of effluent} / \text{estrogenicity of influent}) \times 100$$

The average Rr is 95% in summer and 76 % in fall, which suggests that Rr varies in different seasons.

Table 1 Estrogenic Potential of Endocrine Disruptors Using Three Recombinant Yeast Strain

Recombinant Yeast Strain***	Relative Estrogenic Potential*			Coefficient of Variation** %		
	S	T	C	S	T	C
17 β -estradiol	1.00	1.00	1.00	29	51	5
2-hydroxyestradiol	0.012	0.034	0.3	22	59	20
Estrone	0.61	0.14	0.1	23	59	7
Estriol	0.0034	0.0041	0.004	29	38	6
17 α -ethynylestradiol	0.93	5.7	0.7	19	58	56
Diethylstilbestrol	0.39	3.6	0.4	16	66	5
Bisphenol A	0.00009	0.00014	0.00005	9	23	45
4-n-nonylphenol	0.00003	0.0037	0.0002	94	162	19
average	—	—	—	30	65	20

* The value represents relative activity when 17 β -estradiol is set as a standard

**Coefficient of variation of each chemicals is calculated when it's estrogenic activity was measured at 50% of full absorbance.

*** S: Sumpter, T: Two-hybrid, C: CIIT

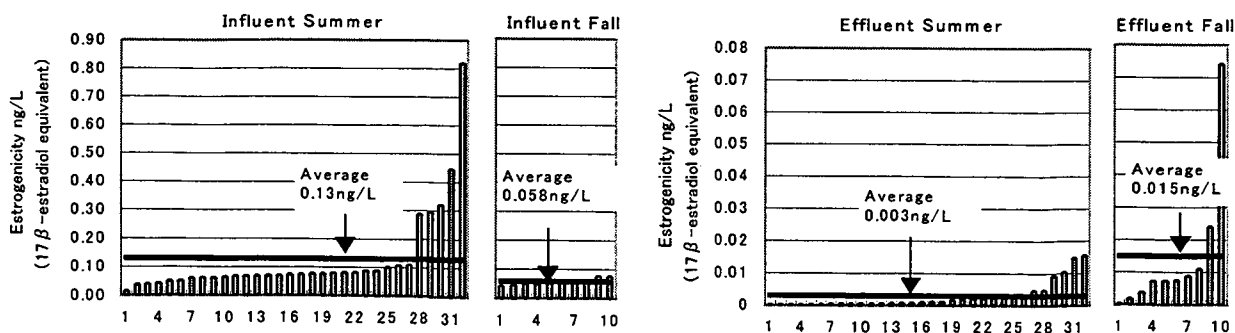


Figure 1 Estrogenicity of sewage samples using recombinant yeast (Sumpter method)

COUNTERMEASURES AGAINST ABNORMAL WATER QUALITY DUE TO SPILL ACCIDENTS

H. Tanaka, M. Shirasaki and Y. Okayasu

Water Quality Division

Project period : 1997-1999

INTRODUCTION

Many water quality accidents in rivers are caused by oil spill. River administer must forecast water quality in rivers in order to do countermeasure quickly and appropriately when oil spill accidents happen. But forecast model about oil outflow in rivers has not been established yet. So we research the forecast model about oil spill. Besides we research the application of fluorometric analyzer to measurement of oil concentration and fate of oil in rivers after outflow.

RESULTS

(1) Research on advection-diffusion equation

Horizontal two-dimension Advection-diffusion equation is as follows.

$$\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial x} = D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2}$$

C: concentration, t: time, u: flow velocity, x: longitudinal distance, y: cross distance, D: diffusion coefficient

This equation is transformed by next equation.

$$t = \tau T_0 = \tau \frac{B^2}{D_y}, \quad y = \eta B, \quad x = \chi L_r = \chi c U \frac{B^2}{D_y}, \quad u = \mu U$$

B: river width, c: constant, U: difference of flow velocity between center and side of the river

Further, by use of below relation for transformation, Advection-diffusion equation becomes next one.

$$Pe_x = \frac{BU}{D_x} \quad Pe_y = \frac{BU}{D_y}$$
$$\frac{\partial C}{\partial \tau} + \mu \frac{\partial C}{\partial \chi} = \frac{1}{Pe_x Pe_y} \frac{\partial^2 C}{\partial \chi^2} + \frac{\partial^2 C}{\partial \eta^2}$$

This Advection-diffusion equation contains non-dimension parameter, Pe. Thus, even if B, U and D is different from each other, in condition that Pe is the same number, the results of forecast must be the same on non-dimensioned coordinates (vertical line: $t/B^2/D_y$, horizontal line: $x/cUB^2/D_y$). So in order to compare the results of forecast, we did forecast calculation in condition that B, U and D were different and Pe was the same. The result of forecast was almost same if the Pe was the same. From this result, it is confirmed that Pe characterizes the oil outflow in river water.

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

By reference of analysis method of environment agency, we measured the sensitivity of each kind of oil to fluorometric analysis. The water quality of river used in the measurement is shown in Table-1. The oil used in measurement is A-heavy oil, light oil and gasoline. The collection rate is shown in Table-2, Table-3 and Table-4.

In case of heavy oil, collection rate of 0.1mg/l was smaller than that of 0.5mg/l. And in case of 0.1mg/l, the collection rate of sample D was smallest among all samples. So effect of organic matter to measurement of heavy oil is suggested. In case of light oil, the trend of result was similar to that of A-heavy oil. In case of gasoline, it was difficult to detect gasoline in river water, even if the density of it was 1mg/l. And the collection rate was generally small.

From these results, it became clear that fluorometric analysis is effected by the density of organic matter and the measurable range is different among the three kinds of the oil.

Table-1 River water quality

	A	B	C	D	E
SS(mg/l)	1	2	8	13	17
CODMn(mg/l)	2.8	0.9	3.3	6.3	-

Table-2 Result of collection experiment
(Heavy oil)

Concentration(mg/l)	1	0.5	0.1
Sample	Collection rate(%)		
A	88	113	92
B	84	82	64
C	94	76	82
D	85	72	22
E	98	78	68

Table-3 Result of collection experiment
(Light oil)

Concentration(mg/l)	1	0.5	0.1
Sample	Collection rate(%)		
A	100	110	60
B	120	121	84
C	94	132	48
D	110	92	0
E	96	108	40

Table-4 Result of collection experiment
(Gasoline)

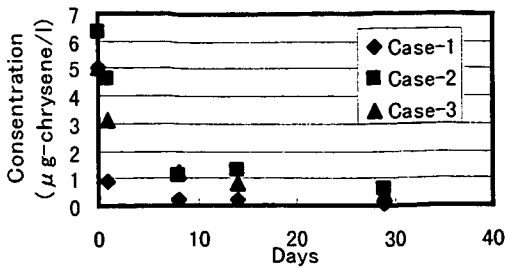
Concentration(mg/l)	1000	100	10
Sample	Collection rate(%)		
A	66	66	73
B	50	30	37
C	63	35	33
D	52	37	42
E	69	38	36

(3)Research on the fate of oil in river water

After A-heavy oil was added to the river water, the concentration of oil was measured. Experimental condition is shown in Table-5 and the result in Figure-1.

As the concentration in case-3 decreased most rapidly, the effect of water temperature on volatility and degradation of oil was recognized.

Table-5 Experimental condition		
Case	Water temperature (°C)	SS concentration (mg/l)
1	20	1~3
2	10	10~20
3	10	1~3



EFFECTS OF WATER QUALITY OF RIVERS ON AQUATIC ECOSYSTEM

H. Tanaka, A. Takahashi, T. Higasitani 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 1999, we evaluated the relationship of the water quality and aquaticbiota using diversity index (DI) and pollution index (PI) calculated from fundamental date of FY 1996-1998.

RESURTS

RELATIONSHIP OF WATER QUALITY AND AQUATIC BIOTA IN THE SMALL STREAMS

Table 1, 2 and 3 shows the summery of the study points, water quality, DI and PI of aquatic biota in rivers a to c where effluent discharge from a sewage treatment plant is only source of the river. Water quality was different at the upstream point and the downstream point of the small streams. Water temperature at the downstream point rose in summer and decreased in winter. However, the concentration of BOD, nitrogen and phosphorus hardly changed in streams. And, the concentration of the residual chlorine decreased towards to the downstream direction. It indicates that change of the water quality affected the diversity of biota. The DI of the periphytic algae rose as residual chlorine concentration decreased. Water temperature at the upstream point was stable because it was mainly affected by the sewerage effluent, but the water temperature at the downstream point widely varied because it was affected by atmospheric temperature and sunlight in addition. This difference probably resulted in more diversity of the aquatic organism at downstream point besides change of water quality.

RELATIONSHIP OF WATER QUALITY AND AQUATIC BIOTA IN THE URVANIZED RIVER

Tables 4 and 5 show water quality, DI and PI of aquatic biota in rivers d and e that make confluence with the effluent discharge from a sewage treatment plant. Water quality changed when the river received. Especially, water temperature rose by 3°C as annual mean at the downstream point when effluent discharge from sewage treatment plant was received. Because there was no seeding source of biota besides the sewage effluent and water temperature was stable at the discharge points, the DI of the periphytic algae at the discharge point tended to be lower than those of the upstream point and the downstream point. The DI and the PI of benthic invertebrates were also same at all the three locations, which suggests that sewage effluent gives less adverse effect on the benthic invertebrates than algae from the view of diversity and population.

Table 1 Summery of the study points

	distance from St.1			
	St.1	St.2	St.3	St.4
a River	0	620	1420	
b River *	0	320	640	
c River	0	750	3300	4650
d River	0	10	100	
e River	0	10	260	

St.1 is 190m below from the source of the river

Table 2 Water quality of the small streams whose source water is only effluent discharge from WWTP effluent. (Anual Average)

	a River			b River			c River			
	St.1	St.2	St.3	St.1	St.2	St.3	St.1	St.2	St.3	St.4
Water Temp.	18.3	18.2	16.9	20.4	20.6	20.6	22.2	22.2	20.5	19.1
DO	7.6	11.2	11.0	12.7	9.9	9.0	7.6	8.1	8.8	9.2
Residual Cl	0.7	0.5	0.2	—	—	—	—	—	—	—
BOD	1.4	3.2	4.3	4.2	3.6	3.4	1.9	1.5	1.4	1.4
NH ₄ -N	2.0	1.6	1.2	1.3	1.3	1.0	0.8	0.8	0.8	0.8
NO ₃ -N	7.3	7.5	7.6	11.8	12.2	12.9	4.8	4.5	5.3	5.2
T-N	10.4	10.8	11.0	15.6	16.1	16.7	6.2	5.8	7.0	7.3
T-P	0.2	0.2	0.2	1.9	1.9	2.0	0.3	0.2	0.2	0.2

Unit : mg/L (water temp. °C) , - : no date (Ozonation was used for disinfection)

Table 3 The D I and P I of aquatic biota in the small streams whose source water is only effluent discharge from WWTP effluent only. (Anual Average)

		a River			b River			c River			
		St.1	St.2	St.3	St.1	St.2	St.3	St.1	St.2	St.3	St.4
D I	Algae	0.5	0.8	1.2	1.4	2.7	1.4	1.5	1.6	2.1	2.5
	Benthos	0.8	1.5	0.9	1.9	1.8	1.7	1.7	2.0	2.4	2.4
P I	Algae	2.8	2.6	2.5	2.8	2.6	2.6	2.9	2.7	2.8	2.7
	Benthos	2.6	2.6	2.8	2.7	2.7	2.4	3.0	2.7	2.2	2.6

Table 4 Water quality of the urbanized rivers that makes confluent with effluent discharge from WWTP. (Anual Average)

	d River			e River		
	st. 1	st. 2	st. 3	st. 1	st. 2	st. 3
Water Temp.	16.2	20.1	19.2	17.6	21.5	20.3
DO	14.3	7.9	9.1	7.4	7.7	8.0
Residual Cl	—	0.1	0.1	ND	ND	ND
BOD	1.1	1.4	1.3	4.6	0.8	2.1
NH ₄ -N	0.0	0.1	0.1	1.1	0.0	0.3
NO ₃ -N	6.2	9.8	9.5	1.0	9.0	7.3
T-N	6.7	10.8	10.2	4.2	10.1	9.5
T-P	0.0	0.8	0.6	0.5	0.7	0.8

Unit : mg/L (water temp. °C) , - : no date , ND : not detect

Table 5 The D I and P I of aquatic biota in the urbanized rivers that makes confluent with effluent discharge from WWTP. (Anual Average)

		d River			e River		
		St.1	St.2	St.3	St.1	St.2	St.3
D I	Algae	3.0	2.0	2.9	2.7	1.7	2.2
	Benthos	1.4	2.1	1.6	1.4	1.5	1.9
P I	Algae	2.5	3.0	2.5	2.7	3.3	2.6
	Benthos	3.2	2.9	2.9	3.3	2.1	2.9

FATAL PREDICTION OF VOLATILE ORGANIC COMPOUNDS IN ACTIVATED SLUDGE PROCESS

H. Tanaka, K. Komori, Y. Okayasu, K. Taketoshi and T. Higashitani
Water Quality Division

Project period: FY1996-1999

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 dischargers to sewerage systems must 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 1999 can be summarized as follows:

(1) BIODEGRADATION TEST OF VOCs

We conducted biodegradation test of VOCs by coulometric BOD measuring equipment, 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. O₂ consumption curves of the chemicals are shown in Figure 1. The results of benzene, toluene, *m*-xylene and *p*-xylene, showed that they are significantly biodegradable. The results of dichloromethane, showed that it is less biodegradable. Degradation rates of VOCs for 14 days were 59%, 60%, 51%, 59%, 34% and 7% of benzene, toluene, *m*-xylene, *p*-xylene, *o*-xylene and dichloromethane, respectively.

(2) MODELING OF FATE OF VOCs IN ASP

A simulation model was newly developed for predicting the fate of VOCs in activated sludge process in combination with part of the IAWQ Activated Sludge Model. This model considers adsorption, surface volatilization, bubble volatilization, and biodegradation from the dissolved phase as removal mechanisms. And this model has the following characteristics compared with existing models: (1) some parameters can be determined from operational conditions of the ASP; (2) this model assumes that only a specific group of active heterotrophic bacteria can degrade a target compound of the VOCs; (3) mass balance about biochemical reactions obtained is considered from stoichiometric balance; (4) parameters on the specific bacteria that can degrade a target VOC can be determined from the data on a biodegradation test that was described above so as to fit its oxygen consumption curve.

Then, the model was applied to the data obtained from the pilot plant in this study, where target VOCs were benzene, dichloromethane, toluene and *m,p*-xylene. As the results, the model can fairly simulate the fate of the VOCs in activated sludge process. However, further investigation on improvement of modeling and acquisition of data for validation is necessary in the future.

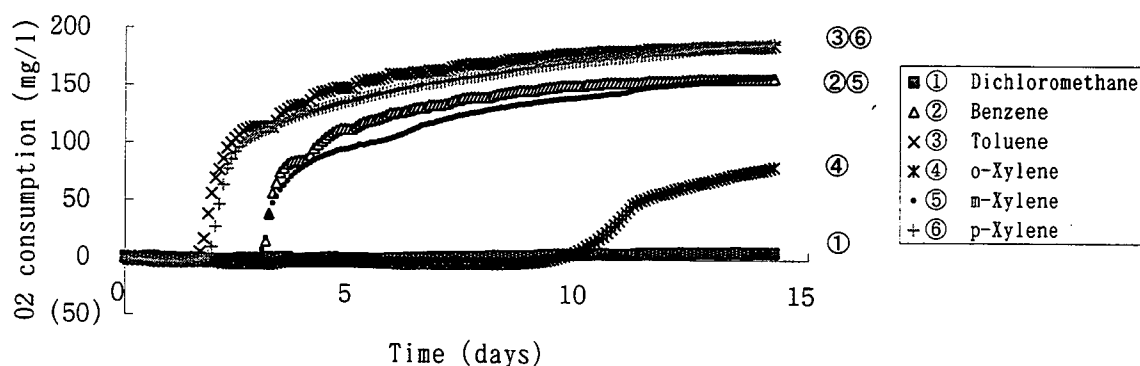


Figure 1 O₂ consumption of chemicals

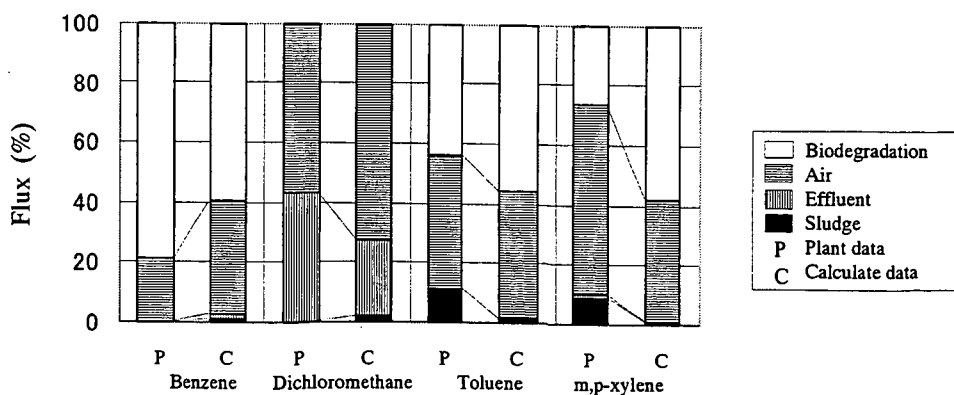


Figure 2 Comparison between plant data and calculate data

MANAGEMENT OF HAZARDOUS SUBSTANCES IN SEWERAGE

H. Tanaka, K. Komori, Y. Okayasu, K. Taketoshi, Y. Yakou and T. Higashitani
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 their risk to human and ecological health, in establishing managing hazardous chemical substances in sewerage system.

In FY 1999, we studied on endocrine disrupting chemicals (EDCs) for the reason why EDCs issues 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 is known as a typical EDs. In addition, we developed a novel analysis method of an estrogen, 17 β estradiol (E2), in wastewater.

RESULTS

(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 in 24 hours surveys where each sampling was conducted at an interval of two hours. Then, we estimated mass fluxes of NP and NPEO that entered into and emitted out of the treatment process. All the samples were concentrated with a solid phase extraction method and were measured with HPLC. NPEO was separately measured NP1-4EO group and NP $n \geq 5$ EO group. Where ethoxylates number of NP1-4EO is from 1 to 4 and that of NP $n \geq 5$ EO is greater than or equal to 5.

Mass balances of NP and NPEO are shown in Figure 1. 19 % of NP, 33 % of NP1-4EO and 19 % of NP n EO were estimated to be emitted out of the treatment process compared with their entering mass fluxes.

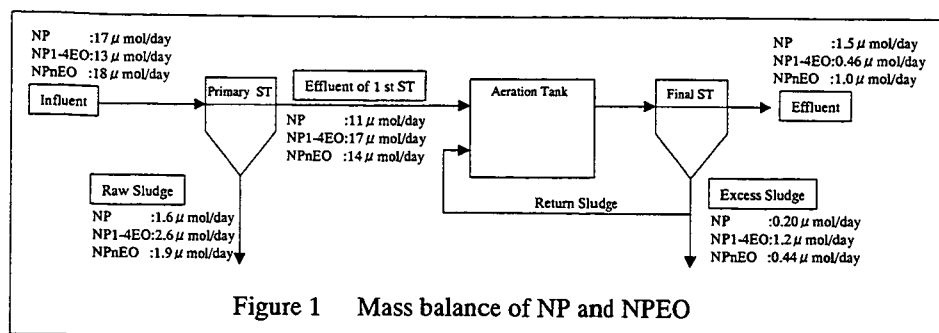


Figure 1 Mass balance of NP and NPEO

(2) DEVELOPMENT A NOVEL ANALYSIS METHOD OF AN ESTROGEN, 17 β ESTRADIOL (E2), IN WASTEWATER

Estrogens are thought to be one of key substances that may give estrogenic effects on fish in the water environment because estrogens have relatively stronger potentials than other EDCs such as NP, bisphenol A and diethyl phthalate, and are reported to exist in the water environment at not negligible level. Therefore, we developed a novel analysis method of an estrogen, E2, in wastewater. Sample preparation in this method applies solid-phase extraction with Sep-Pak Plus C18 for filtrate, supersonic extraction liquid for suspended matters and clean up with Sep-Pak Plus florisil and thin layer chromatograph (TLC) are shown in Figure 2. The prepared sample is analyzed with LC/MS/MS under the condition in Table 1. Determination limit and recovery ratio of the estrogen in this method are shown in Table 2.

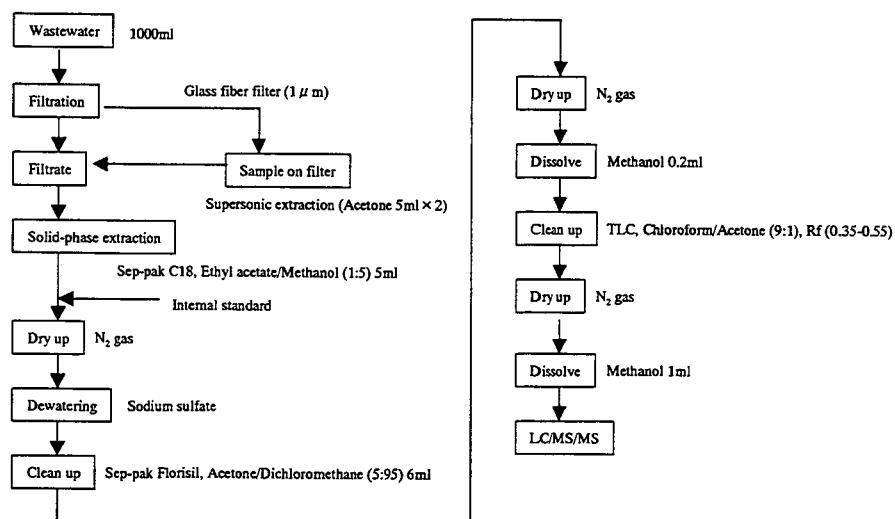


Figure 2 Procedure of E2 analysis

Table 1 Analysis condition of LC/MS/MS

LC/MS/MS	TSQ, HP1100
Sample size	10 μl
Column	HP Zorbax Eclips XDB-C18, 2.1×150mm, 40°C
Eluent	Acetonitrile/Water (60:40), 0.2ml/min
Ionization	AP-ESI Negative, Collision Energy 40eV, Argon 2.2-2.3 mTorr
Measurement ion	271(Parent), 145(Daughter)

Table 2 Determination limit and recovery ratio of E2 in water samples with LC/MS/MS

Determination limit (μg/l)	Recovery ratio (%)		
	Pure water	Effluent wastewater	Influent wastewater
0.001	100	72	74

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 including water supply and sewerage systems that is affected by human activities 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 preserve the sound water environment. Although we need to grasp how and to 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 a 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 a model of watershed that is significantly 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 water pollution runoff on rainy days besides fine days. The Ohtsu River is one of the rivers flowing into the

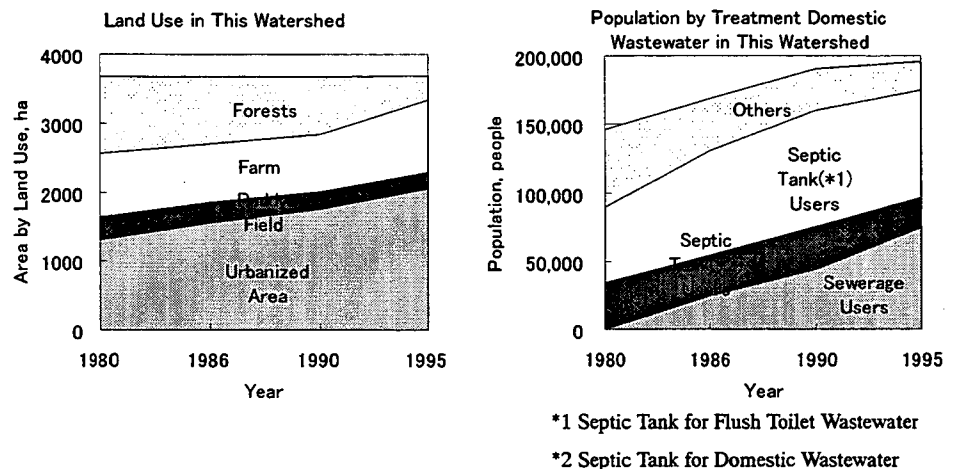


Fig.1 Background of the Observation Watershed

Lake Teganuma that is located in northwest of Chiba Prefecture and the most polluted lake in Japan due to the advance of urbanization in its watersheds. We set three observation points along the Ohtsu River. The backgrounds of this watershed are shown in Fig. 1. One was set up at the main stream, and the other points were set up at the tributaries

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 curves obtained in this stream. Regarding the fluctuation of water quality, we sampled the river water every hour and then analyzed about BOD, COD_{Mn} , NH_4-N , NO_2-N , NO_3-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

Variation of the Water Qualities and the Discharge Loads in Fine Days

We observed the discharge loads and flow rates in fine days. We compared the total runoff, weighted mean concentrations and pollutant loads between the observation in the 1980s (1986-1990) and in the 1990s (1996-1999). As Fig.2 shows the change of two periods on the total runoff, water quality and pollutant loads in fine days, the total runoff

and specific pollutant loads in the 1990s are significantly smaller than those in the 1980s. BOD, COD_{Mn} and SS concentrations slightly decrease in the 1990s than in the 1980s. However, concentrations of nutrients in the 1990s are larger than those in the 1980s, though sewerage systems are developing in this observed basin. Fig.3 shows the change of discharge loads estimated by the frame data and unit pollutant loads of this basin. This is probably caused by the increase in the percentage of the discharge from industrial facilities and septic tanks for flush toilet wastewater in basic flow rate from this watershed, with the development of sewerage systems.

Variation of the Discharge Loads per Rainfall Event

We also observed the discharge loads and flow rates in rainy days. We compared the difference of the rainy runoff and pollutant loads between the observation in the 1980s and the 1990s. From the relationships of the rainy runoff, specific pollutant loads and ratios of runoff due to individual rainfall events between the observation in the 1980s and the 1990s shown in Fig.4. We found that the specific discharge loads are not always in proportion to the rainy runoff during a rainy event. As mentioned above, we found that the pollutant runoff coefficient in fine days decreases recently. This suggests increase of the particles on the riverbed and the watershed. So we guessed that the factors influencing the specific discharge loads in rainy days were not only scouring force acted on particles but also amount of the accumulated pollutant on the riverbed and the watershed.

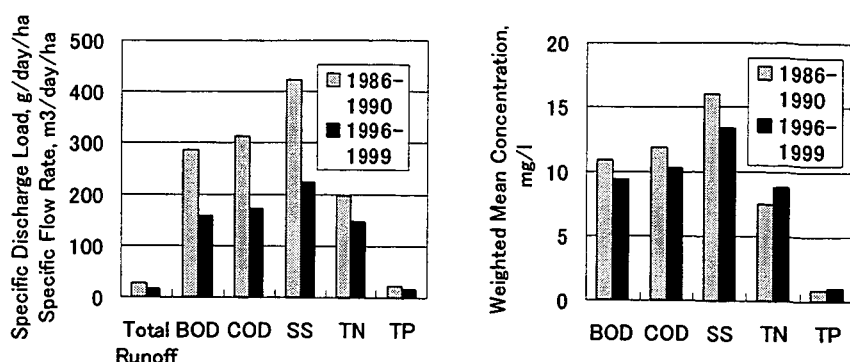


Fig.2 Comparison of the Total Runoff, Water Qualities and Pollutant Loads in Fine Days of the 1980s and the 1990s

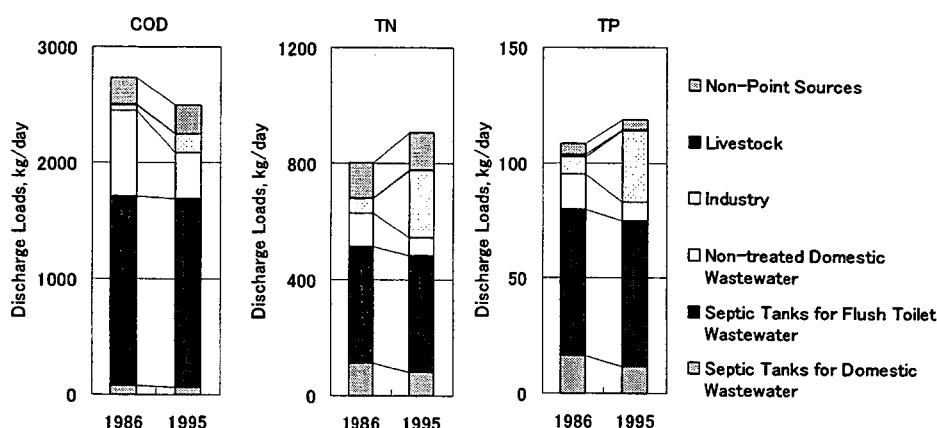


Fig.3 Comparison of discharge Loads in the 1980s and the 1990s Estimated by the Frame Data and Unit Pollutant Loads of This Basin

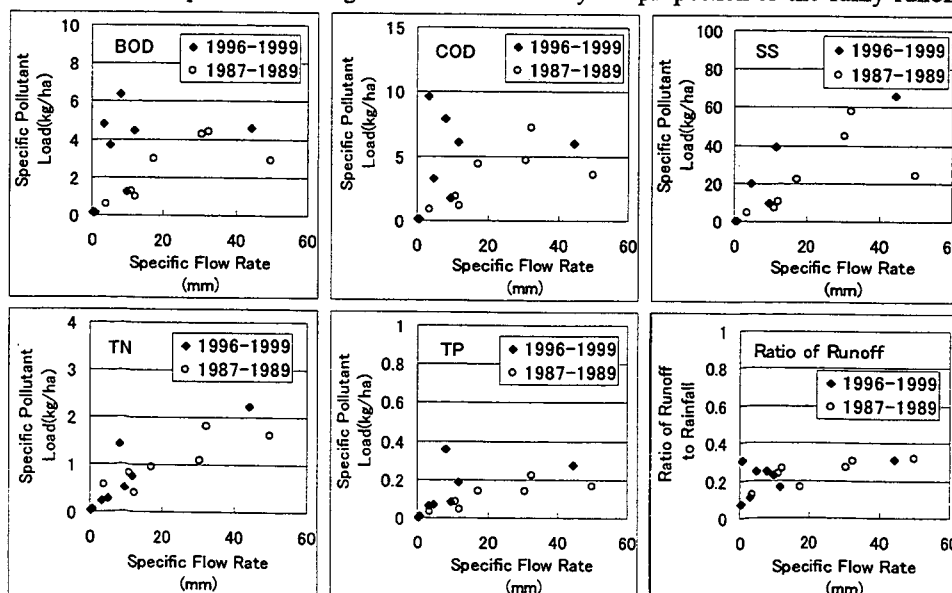


Fig.4 Relationship between the Rainy Runoff and Pollutant Loads, Ratios of Runoff in the 1980s and the 1990s

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

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Project Period: FY 1998 -2000

OBJECTIVES

Development of sewerage systems has increased the amount of urban water returning to natural waters through sewerages. 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 concern water works about the safety and that may be included in the discharge from sewerages have 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, and suspected-chronic toxicants on the basis of chemical analyses using GC-MS, etc. as well as biological assays applying mutagenicity tests, etc.

METHODS

Extraction from Sewage Samples

Untreated wastewater and secondary effluent in the experimental activated sludge process facilitated in an actual public sewage treatment plant were used for this experiment. 10 L of each sample was filtrated and then was pumped through a Sep Pak tC18 solid phase cartridge that had been previously conditioned at pH 2 and rinsed with methanol (MeOH) and pure water at the flow rate of 10 ml/min. Only 500 ml of the sample was pumped through each cartridge for avoiding breakthrough. After dewatering the cartridge, the constituents absorbed on the cartridge were eluted with 10 ml of MeOH, which was followed by the same elution process with 10 ml of dichloromethane (DCM). Mixture of the eluted DCM and MeOH was condensed with a rotary evaporator and was made perfectly dryness with nitrogen-gas blowing. The dry residual was dissolved with MeOH, which was used for the polarity separation. At the same time, the rest of the dry residual was dissolved with dimethyl sulfoxide (DMSO), which was used for a mutagenicity test.

Polarity Separation

Polarity separation was conducted using a reverse phase column chromatograph filled with ODS (Prepare C18, Waters) . First, each 10 to 15 ml of elute from the chromatograph was separately collected. Next, color and spectrum absorbance of each separated fraction was measured. Then, several fractions were combined into a new fraction based on the colors and the spectrums. The combined fractions were diluted with pure water by 1 % of solvent concentration, which were extracted with the same solid phase extraction method that was described in the above mentioned **Extraction from Sewage Samples**. The extracted dry residuals were mostly dissolved again with MeOH for the molecular separation and were partially dissolved with DMSO for the mutagenicity test.

Molecular Separation

Molecular separation was conducted with a high-performance liquid chromatograph (HPLC). First, the condition of the separation was investigated with molecular markers and standard mutagens of Trp P-1 and Trp P-2. The following separation conditions gave good results that the markers and the standard mutagens could be separated to each other at efficient recovery ratios: styragel HR-3 (ϕ 30mm $\times$ L300mm) was applied for the column and an elute consisting of tetrafran (THF)/MeOH=4/1 was used at 0.6ml/min. Among the fractions separated on the polarity basis, those that showed positively mutagenic were molecularly separated.

Mutagenicity Test

Mutagenicity was measured with *umu* test and positive of the samples was judged when β -galactosidase activity exceeded twice of that of the reference.

RESULTS

Polarity Separation

Three fractions as shown in Table-1 were obtained for the untreated sewage and the secondary effluent. Then, their mutagenicities were tested. For untreated sewage, Fraction I-II showed positive when S9mix was added, and did slightly positive although clear positive result could not be obtained when no S9 mix was added. For secondary effluent, Fraction II-I showed positive when S9mix was added, but little when no S9mix was added. Because Fractions I-II and II-I were obtained at different condition of elution, the mutagen in each fraction is thought to differ.

Table-1 Characteristics of Fractions Obtained with Polarity Separation

Fraction	Elution Condition	Color	Spectrum (200~700nm)
I - I	MeOH/10mMAMmonium	dark green	Peak at ultra violet and at 700nm
II - I	acetate=6/4, 30~50ml		
I - II	MeOH/10mMAMmonium	light brown	Absorbance at <200nm, shoulder
II - II	acetete=6/4, 120~180ml		and peak at 260nm
I - III	MeOH, 300~360ml	dark brown	Absorbance at <200nm, shoulder
II - III			and no peak at 260nm

Molecular Separation

Fractions I-II and II-I obtained in the above polarity separation were separated on the molecular size basis. Fraction I-II was further separated so that two different peaks at 29.0 min and 31.8 min identified were separated as Fractions I-II-I and I-II-II. Because a single peak was identified from Fraction II-I at retention time (RT) 31.5min, the fraction was separated into three new fractions retained around the peak. These fractions were listed in Table-2.

Table-2 Fractions Obtained with Molecular Size Separation

Fraction	Elution time	Estimated molecular weight(MW)	Characteristics of fractions
I - II - I	0~31min	1000<	Peak of OD240nm at RT29.0min
I - II - II	31~50min	1000>	Peak of OD260nm at RT31.8min
II - I - I	0~28min	8000<	No absorbance of OD240
II - I - II	28~37min	400~8000	Peak of OD240nm atRT31.5min
II - I - III	37~50min	400>	No absorbance of OD240

In the two fractions of the untreated sewage, Fraction I-II-II that deemed to be molecular weight (MW)>1000 exhibited significant mutagenicity when S9mix was added, but did not when no S9mix was added. Another Fraction I-II-I showed slight mutagenicity although it was not enough to be judged positive. Among the three fractions of the secondary effluent, no significant mutagenic samples were identified, but only Fraction II-I-I with S9mix tended to suggest slightly positive. These suggest that mutagenicity in sewage is derived from a fraction of large molecular whose MW> 1000 and that the polarity of the mutagens in untreated sewage is different from that in secondary effluent, which implies that the mutagenicity and the polarity of the mutagens in sewage are changed during sewage treatment.

FATE OF SUBSTANCES PRODUCING ENDOCRINE DISRUPTORS IN WATERS

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Project period : 1999-2002

OBJECTIVES

Nonylphenol polyethoxylates (NPnEO) are the substances that are widely used for industrial use. Biodegradation of NPnEO shortens the hydrophilic chain and forms lipophilic metabolites. And nonylphenoxy carboxylic acids are also formed by biodegradation. These metabolites finally form NP under anaerobic condition. It is said that NP may have endocrine disrupting properties and this substance is detected in many rivers and effluents from sewerage treatment plants in Japan. So we study about the fate of NPnEO, which finally produces NP by the biodegradation, to predict the concentration of NP in water and sediment.

METHODS AND RESULTS

Biodegradation test was done by use of the water of Ayase river. The test was done in two conditions and dissolved oxidation conditions were different from each other.

As shown in figure-1(line1:DO concentration was more than 5mg/l) and figure-2 (line2:DO concentration was less than 5mg/l), the concentration of NPnEO(n=1-4) and NPnEO(n $\geq$ 5) decreased in river water and the accumulation of NPnEO(n=1-4) was not found.

As shown in figure-3 (line1) and figure-4 (line2), the concentration of NP decreased in river water. On the other hand, in one case (line2), the concentration of NPEC increased and, in another case (line1), the concentration did not increased. The reason why the results were different from each other is not clear.

Next leaching test from sediment was done in two conditions by use of the bottom sediment of Ayase river. The water above sediment was water of Ayase river. In one line(line1), DO concentration was more than 2(mg/l), and in another line(line2), the concentration was less than 2(mg/l). As NP, NPEO and NPEC are not conservative substances, we calculated the leaching speed from the sediment by removal of the change of concentration in river water.

Analytical result of sediment is shown in table-1. Leaching speed from sediment is shown in table-2. This leaching speed is the average speed between the first day and 28th day. As shown in table-2, NP, NPnEO(n=1-4) and NPnEO(n $\geq$ 5) leached from the sediment. But the leaching of NPEC was not recognized. As for leaching speed, that of NPnEO(n=1-4) was largest among three substances.

By use of the concentration in sediment and river water on it before the beginning of the leaching test, the distribution ratio of concentration per organic carbon in sediment to river water was calculated. The ratio was 1,900,000, 960,000(mg/kg-TOC)/(mg/l) for NP, 240,000, 72,000(mg/kg-TOC)/(mg/l) for NPnEO(n=1-4) and 3,000,000, 620,000(mg/kg-TOC)/(mg/l) for NPnEO(n $\geq$ 5). Though the distribution ration of NPnEO(n $\geq$ 5) was

thought to be smallest as hydrophobic of NP is largest and that of NPnEO($n \geq 5$) is smallest among three substances, the ratio of NPnEO($n=1-4$) was smallest among them. Thus the concentration in the sediment might not reach the equilibrium state or the change of the concentration in the river water might influence the concentration in the sediment.

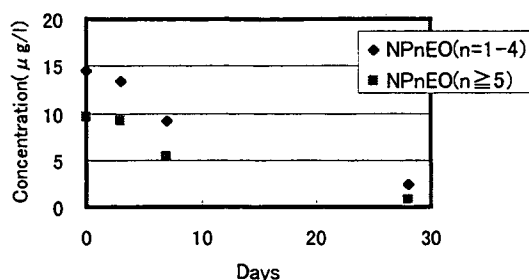


Figure-1 Change of concentration of NPEO(line1)

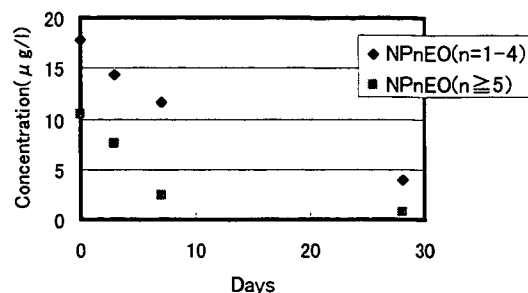


Figure-2 Change of concentration of NPEO(line2)

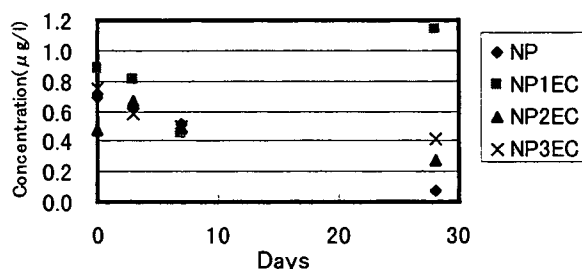


Figure-3 Change of concentration of NP and NPEC(line1)

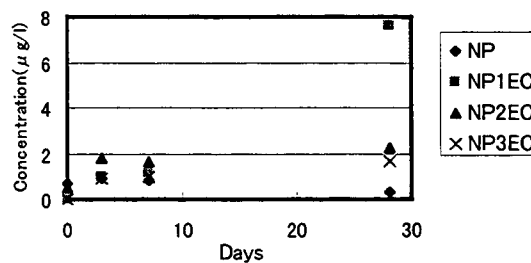


Figure-4 Change of concentration of NP and NPEC(line2)

Table-1 Analytical Result of Sediment

	TOC	Water Content	Ignition Residue	NP	NPnEO (n=1~4)	NPnEO (n≥5)
	(mg/g-dry)	(%)	(%)	(µg/kg-dry)	(µg/kg-dry)	(µg/kg-dry)
line1	2.2	38.0	6.18	2,940	7,540	63,800
line2	5.4	37.4	-	3,620	6,890	34,800

Table-2 Leaching Speed

	(µg/m ² ·day)		
	NP	NPnEO (n=1~4)	NPnEO (n≥5)
line1	23.8	46.4	10.5
line2	15.6	69.6	16.9

NOVEL TECHNOLOGY FOR DETECTION OF MICROPOLLUTANTS IN WASTEWATER

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Project period: FY1999-2001

OBJECTIVES

It is very important that performance of activated sludge is kept stable in wastewater treatment process. But activated sludge is possibly damaged by continuous or sudden spill of harmful chemical substances dumped into sewerage. Recently, it was reported that an accidental spill of huge amount of sulfuric acid upset activated sludge process. Now the following three techniques to manage such chemicals need to be established in sewerage works. The first is assessment techniques of damage, which harmful chemical substances give on activated sludge. The second is continuous monitoring techniques of detecting such chemicals in wastewater. The third is techniques controlling wastewater treatment process using the information of the continuous monitoring. Nitrifying bacteria in activated sludge plays an important role of biological nitrogen removal process. The activity of nitrifying bacteria is known to be easily inhibited by harmful chemical substances. In this research, it is examined whether toxicity tests by nitrifying bacteria can be applied to assessment technique.

On the other hand, recently it have been pointed out that there are many chemical substances that disrupt endocrine system of human beings and aquatic organisms in municipal wastewater. The concentrations of these substances in water are usually measured by the method using high performance analytical instruments. That are very expensive and complex, and need well-trained operators. In this research, the ELISA (Enzyme-Linked Immunosorbent Assay) method was also examined to measure the concentration of estrogen in wastewater. This method has potential to proceed to an automated monitor for laboratory or on-site use.

Finally, these results contribute to wider monitoring and more proper managing of water quality in wastewater treatment process.

METHOD & RESULT

Sensing of Nitrifying Bacteria to Selected Chemicals

The following three methods (Table 1) using nitrifying bacteria assay were examined.

Table 1 Nitrifying Bacteria Assays

1) Batch testing method	Exposure period	Detection produced
① Toxicity test by pure culture nitrifying bacteria (<i>Nitrosomonas europaea</i>)	24hr	NO ₂ ⁻ -N concentration
② Toxicity test by mixed culture nitrifying bacteria	24hr	NO ₂ ⁻ -N concentration
2) Microbial-probe testing method		
③ Toxicity Biosensor with immobilized nitrifying bacteria (<i>Nitrosomonas europaea</i>) and DO probe	10min	Oxygen concentration

Table 2 Toxicity of phenols on nitrification

Target substances	Pure culture EC ₅₀ [mg /L]	Mixed culture EC ₅₀ [mg /L]	Sensor EC ₁₀ [mg /L]
Phenol	7.01×10^{-1}	2.80×10^0	2.20×10^0
2-chlorophenol	1.10×10^{-1}	6.80×10^{-2}	1.30×10^0
3-chlorophenol	4.60×10^{-2}	9.00×10^{-2}	1.40×10^0
3-chlorophenol	9.40×10^{-3}	2.30×10^{-1}	4.10×10^0
2,3-dichlorophenol	5.40×10^{-2}	8.80×10^{-2}	1.50×10^1
2,4-dichlorophenol	1.50×10^{-1}	3.70×10^{-2}	4.00×10^1
2,5-dichlorophenol	4.10×10^{-2}	5.80×10^{-1}	7.60×10^0
2,6-dichlorophenol	1.10×10^0	1.30×10^0	5.90×10^1

The toxicity of phenol and chlorophenols was examined with each bioassay methods (Table 2).

As the results, it was found that the bioassay test by the pure culture nitrifying bacteria is most sensitive in toxicity. On the other hand, it was found that sensitivity of the toxicity test by the sensor with the immobilized nitrifying bacteria is from 10 to 100 times lower than the other tests. The batch testing methods need intensive and skillful man power and more than a day until we get the results. The microbial-probe testing method needs less man power and skill, and needs only twenty minutes until we get the results. Therefore, combination of both the batch and the microbial-probe testing methods seem to be effective in management of harmful chemical substances in sewerage works in considering their characteristics.

ELISA

ELISA (Enzyme-Linked Immunosorbent Assay) is an assay that uses an enzyme which is colored and linked to an antigen or antibody. First, antibody against target substances is got. In measurement of water quality, antibodies are reacted with mixed liquid of sample water and the enzyme at certain rate. In this reaction, the smaller enzymes react with antibody, the much a concentration of target substances in sample water is. On the other hand, ELISA method has some problems. A positive result may occur if un-targeted substances react with the antibody nonspecifically and some substances in water sample inhibit activity of enzyme, antigen and antibody. In this research, ELISA method was applied to detection of EE2 (Ethinylestradiol) in wastewater. EE2 is main component of the pill, which is an oral contraceptive. As the result, it was estimated that EE2 was contained in the raw wastewater and secondary effluent and it is possible that EE2 is detected by the ELISA method.

Table 3 EE2 Concentration in raw wastewater and secondary effluent

WWTP	Raw wastewater [ng/L]				Secondary effluent [ng/L]			
	Jul.	Aug.	Sep.	Avg.	Jul.	Aug.	Sep.	Avg.
A	4.9	4.3	6.8	5.3	1.5	1.7	2.3	1.8
B	3.9	4.4	5.2	4.5	2.0	2.0	1.8	1.9
C	6.8	7.3	14.3	9.5	1.0	1.0	0.8	0.9
D	9.7	8.7	11.8	10.0	1.4	1.1	1.2	1.2
Avg.	6.3	6.2	9.5	7.3	1.5	1.5	1.5	1.5