FY2002 RESEARCH SUMMARY OF WASTEWATER MANAGEMENT AND WATER QUALITY CONTROL

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Synopsis

This Research Summary briefly introduces researches on wastewater management and water quality control carried out in Fiscal 2002 by National Institute Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport, Japan and Incorporated Administrative Agency Public Works Research Institute.

Key words: wastewater system, wastewater treatment, advanced wastewater treatment,
            wastewater sludge, water quality control, recycling

PREFACE

This Research Summary briefly introduces researches on wastewater management and water quality control that were carried out in fiscal 2002 by National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport and Incorporated Administrative Agency Public Works Research Institute. While the full content of each research is presented in Japanese in the Annual Report of Wastewater Management and Water Quality Control (Technical Note of NILIM No.138, Technical Memorandum of PWRI No. 3917), the abstract of each research is being published in both Japanese and English. Since we have several tens of foreign visitors to NILIM and PWRI each year to exchange views on water quality control engineering each other, English version, though abstract, is considered useful for that.

NILIM's researches introduced in this Research Summary were funded through Research Funds for Sewerage & Sewage Purification Programs, Construction Technology R&D Expenses, Research & Study Expenses for ODA, Research & Study Expenses, Global Environment Research Fund and Environment Research Program Budget, while PWRI's through Grants for operating expenses and Income from entrusted research inclusive of Research Funds for Sewerage & Sewage Purification Programs. 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 wastewater management and water quality control. Hopefully, more intensive exchange of views in water quality control engineering is to be promoted through this Research Summary.

Shigeru Miyahara, Director
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CONTENTS

STANDARD FOR DISCHARGE OF DOMESTIC WASTEWATER WITH HIGH CONCENTRATION

M. Takahashi, H. Morita, K. Mori, K. Taketoshi, A. Yoshida and T. Hamada

Water Quality Control Department

Project period: 2000-2003

Objective

As part of our overall research on the introduction of disposers, we examined the influence that a disposer has on a wastewater system. Our final objective is to propose technological standards to be used when a disposer is introduced.

Experiment City

This research was conducted in Utanobori, Hokkaido Prefecture. Disposers have been set up for a number of general homes in the treatment area since 1999. We have evaluated their influence on the wastewater and garbage disposal systems and have conducted overall evaluations using LCA and cost-effectiveness analysis. Disposers are presently set up in approximately 35% of the homes in the treatment area.

Experimental Outline

Soil and sand accumulate in sewer pipes due to various reasons. Garbage might accumulate and increase sediment in sewer pipes when a disposer is introduced. We started our investigation of the amount of sediment in sewer pipes in 1999 when we first set up the disposers. We conducted internal inspections using a TV camera and observed garbage such as eggshell and seashell that were thought to have been exhausted from disposers in the lower reaches of sewer pipes of houses that had research disposers set up since last year.

In the current year's research, we investigated the amount of sediment in sewer pipes since last year. We also conducted sewer pipe inclination investigations, inorganic matter analysis of sediment to obtain mass balance, and fixed-point observation using a video camera.

We estimated the amount of sediment for each unit length of sewer pipe in which we observed sediment as a result of our previous investigation. We attempted to establish a relationship between the unclean sewer period and amount of sediment in sewer pipes to examine the possibility of sewer pipe clogging due to increased sediment, and we examined whether or not sediment increased with time. In addition, we analyzed the substances adhering to the sides of the sewer pipes in both the disposer installation area and non-disposer area.

In the process of investigating the amount of sediment in the sewer pipe, we conclude that increased sediment was not necessarily constant time wise, and there was a possibility that traction of sediment occurred. Fixed-point observation was executed to observe the generation of sediment.

Conclusion

1) Sediment, other than soil and sand, originating from garbage was generated in the lower reaches of the main line that was estimated to have fast flow velocity. The reason for this was assumed to be that flow velocity decreased when rainwater invaded the sewer pipe.

2) We observed substances adhering to the sides of the sewer pipes in the non-disposer area that closely resembled the substances in the disposer installation area.

3) A positive correlation was not necessarily seen between the amount of sediment and the unclean sewer period.

4) About 76% of the sediment was generated in reverse-inclination sewer pipes, determined from the results of establishing a relationship between sewer pipe inclination and amount of sediment.

5) A large amount of calcium content was present in the sediment of the disposer installation area, determined from the results of inorganic matter analysis of the sediment. This was assumed to be from eggshell derived from the garbage.

6) Sediment in the sewer pipe was determined to be the result of traction and movement along with the sewage. The possibility that infiltration took part in the traction of sediment was suggested, because at the maximum there is double or more the amount of flow from the treatment plant when rainfall is heavy.

STUDY OF CONDUIT MAINTENANCE LEVELS

H. Morita, and K. Mori

Wastewater System Division

Project period: 2001-2003

OBJECTIVES

The force main, which is one of the systems of sewer transportation, may produce sulfide in sewerage, which causes concrete pipe corrosion. A sewer structure that may become corroded with sulfide could be changed to a structure protected against sulfide by controlling the generation of sulfide or by using material that is resistant to corrosion by hydrogen sulfide.

It is very important to predict the amount of generation and influence of sulfide, when presuming the sulfide corrosion range and selecting the required countermeasure to it. Some prediction techniques have been proposed regarding sulfide generation in the force main. However, few research reports are available regarding the action of a sulfide in the gravity main. Therefore, it is difficult to predict the action of a sulfide with practical accuracy in the design stage for sewer pipe.

Therefore, in order to predict the action of the sulfide in sewer pipe, a WATS model, which expresses the water quality change, was arranged. We made our evaluation based on previous research results on applicability.

RESULTS

It is necessary to experiment with some reactions when attempting to reproduce the actions of sulfide in sewer pipe using the WATS model. The contents required to reproduce the actions using the model are shown in Table 1.

Table 1   Contents required to reproduce actions when using the WATS model

	Reaction	Research situation
Reaction in the wastewater	The reaction that decomposes the organic matter	There are some research reports. However, it is necessary that the parameter of each model formula be improved in accuracy through the experiments.
	The reaction that generates sulfide in the biofilm	There are many research reports. The accuracy of predictions using the model can be increased by a theoretical approach related to the reaction of the organic matter.
	The reaction by which sulfide oxidizes in the wastewater	There are some research reports. However, that alone is inadequate for determining the coefficient of the equations.
	The reaction by which sulfide oxidizes in the biofilm	There is almost no research reported. Verification by experiments is required.
	The reaction by which oxygen dissolves in the wastewater	It is possible to quantify a reaction from examples in previous research, and to incorporate in a WATS model.
	The reaction by which hydrogen sulfide is emitted from the wastewater	It is possible to quantify the reactions from previous research results, and to incorporate in the WATS model.
Reaction in the air in the sewer pipe	The reaction by which hydrogen sulfide is emitted from the wastewater	It is possible to be able to quantify the reactions from the past research results, and to take in to the WATS model.
	The reaction by which hydrogen sulfide adsorbs and oxidizes on the surface in the sewer pipe	There are few research reports and theoretical considerations based on field survey, which is required.
Reaction in the fall in the sewer (Substance movement between air-water)	The reaction by which oxygen dissolves in the wastewater	There are some research reports. However, that alone is inadequate for determining the coefficient of the equations.
	The reaction by which hydrogen sulfide is emitted from the wastewater	There are few research reports and theoretical consideration based on field survey, which is required.

STUDY ON IMPROVEMENT OF URBAN RAINWATER MEASUREMENT SYSTEM

H. Morita, M. Matsubara, M. Nasu, and H. Mori

Wastewater System Division

Project period: 2001-2003

INTRODUCTION

In recent years, the problems of city rainwater in Japan have focused on both quantity and quality, such as city-type flood damage and combined sewer overflow. Therefore, development of a pollution load outflow model in wet weather for combined sewer was studied, and a technique for safely checking the blow-out phenomenon of manhole covers installed in the storage pipe of an inverted siphon form was developed using a numerical model of the multiphase flow of air and water formed by high head falling inflow based on the results of hydraulic model experiments.

I. DEVELOPMENT OF A LOAD OUTFLOW MODEL OF COMBINED SEWER

Objectives

This study aims to improve the Yamaguchi-Nakamura Model, which is a lumped type model, into a distributed type model and to simultaneously apply this model to many points. The study also aims at establishing the calculation method of total nitrogen, total phosphorus, and the total number of coliform groups (TC).

Improvement of the Yamaguchi-Nakamura Model

The Yamaguchi-Nakamura model was improved to the distributed type model. As a basic composition element of a distributed type model, we decided to combine two models, a basin model and a pipeline model. The results of calculation in rainy weather are shown in Fig. 1. Here, in addition to the observed value, comparison with the calculation results using the concentrated type model is also conducted.

As a result of calculation, in the distributed type model, reappearance of the same grade as a lumped type model is possible regarding the amount of loads, and, in addition, it was shown that reproducibility is higher than in a concentrated type model on the whole. However, regarding TC, a future subject remains in respect of the behavior in pipes, and it is necessary to add examination and improvement of these points from now on.

No. A—1   No. B—1
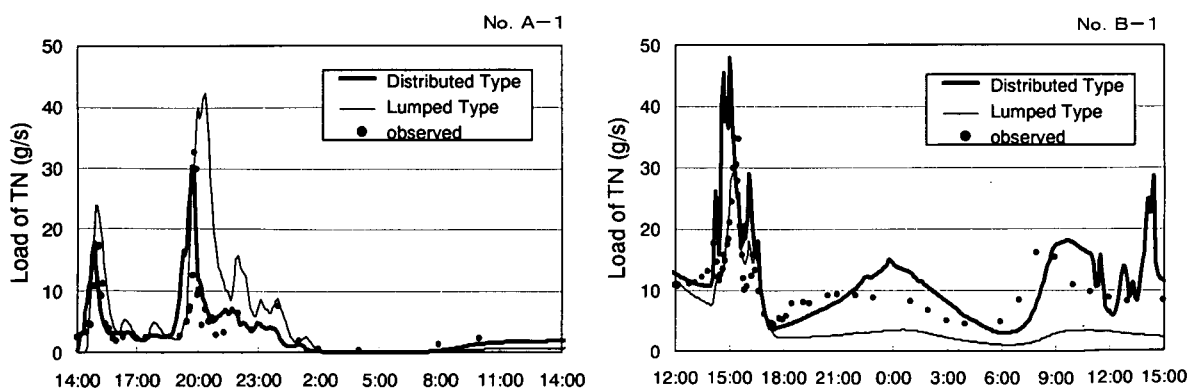
Fig. 1 Results of comparison with calculation

II. STUDY OF AIR MIXING AND DISCHARGE IN RAINWATER SEWERS

Objectives

In this study, we examined the phenomenon of air mixing and discharge in a storage pipe, in order to clarify the mechanism and develop a design method that considers the blowing-out of manhole covers. The behavior of water and air is quantitatively grasped by hydraulic model experiments of a storage pipe of the inverted siphon form, and then a numerical model of the multiphase flow of air and water is derived.

Development of numerical model

The storage pipe was divided into two manhole blocks and 48 pipe blocks, and the analysis factors were defined in each block and each section. These analysis factors correspond to variables of a fundamental equation and to physical quantities calculated by numerical analysis. The main analysis factors of the multiphase flow model, which were defined based on the results of hydraulic model experiments, are shown in Fig. 2. Among these, seven factors (water density, air density, bubble density, flow rate of water, flow rate of air, water depth and air pressure) should be modeled, as other analysis factors can be calculated from these seven factors.
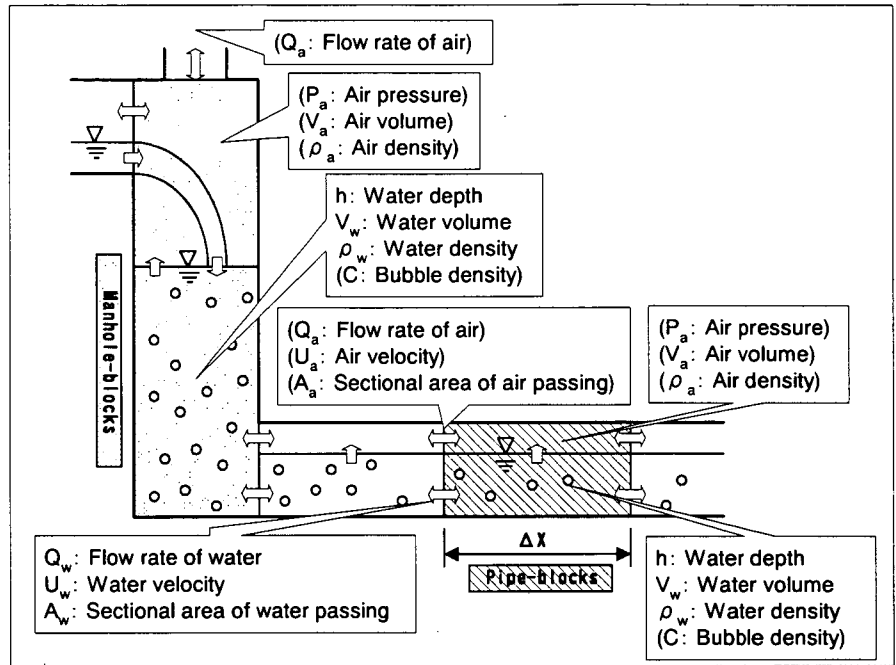
Fig. 2   Analysis factors of numerical model

Verification

The results of hydraulic model experiments and those of numerical analysis were compared to examine the accuracy and validity of the numerical model. However, it is difficult to perfectly match the wave shapes (the changes with time) of both, so the peak air pressure, which was a criterion for checking the safety of blowing-out of manhole covers, was examined in the verification. The verification was done at two water flow rates in three cases, that is, in Model 1, in Model 2 and in Model 3. (Model 1: Q1 = 150 liter/s, Q3 = 100 liter/s, Model 2: Q1 = 27 liter/s, Q3 = 18 liter/s, Model 3: Q1 = 5 liter/s, Q3 = 3 liter/s.)

As a result, the difference between the two (= |(Result of hydraulic model experiment) – (Result of numerical analysis)| ÷ (Result of hydraulic model experiment) ×100) ranged from 9% to 66% for Q1 and 2% to 209% for Q3. The difference was large in the case of small water flow rate (Q3), but the accuracy for a large water flow rate (Q1), in which the peak air pressure was big, was found to be relatively good.

STRATEGIC INVESTMENT IN SEWAGE WORKS

H. Morita, T. Yoshida, and H. Yamagata
Wastewater System Division

Project period: 2002-2005

OBJECTIVES

Cost benefit analysis can be effective in setting the target for water quality improvement in public water areas. The effect of water quality improvement by sewage works is categorized into two items: use value such as recreation, and non-use value such as ecosystem conservation. The Contingent Valuation Method (CVM) can be used to measure the benefits including non-use value, but there are not many researches involving the benefit measurement technique in our country, and thus general application methodologies should be established.

On the other hand, the United States, which has actively adopted CVM in environmental assessment, evaluated the nationwide benefit of water quality improvement due to the Clean Water Act, based on CVM surveys conducted at 61 sites. In Japan, the establishment of benefit transfer must be researched further, and various conditions such as assumptions of function forms must be examined for possible cases. Therefore, this research considers the applicability of benefit transfer and presents a general methodology of benefit measurement for water quality improvement.

The framework of this multi-year research is shown in the following, among which (1) and (2) were conducted in FY 2002.

       (1) Literature review on benefit transfer

       (2) Examination of the relation between preferred water quality level and attributes of individuals

       (3) Examination of nationwide research

       (4) Implementation of pre-survey

       (5) Implementation of nationwide survey

       (6) Examination of methodology of benefit transfer

RESULTS

(1) Literature review on benefit transfer

The practice of benefit transfer by USEPA (United States Environmental Protection Agency) was found to be a leading and relevant case that should be carefully reviewed. Its methodology is to measure the Willingness To Pay (WTP) per household for all major rivers and lakes to be improved into either a swimmable, fishable or boatable condition, and to implement a benefit transfer by adopting WTP as a unit value. One of the major weaknesses of the methodology is that features other than water quality level, for example, largeness of water bodies and attributes of individuals, were neglected. Another is that there is a lack of theoretical ground in terms of distribution method among local/in-place benefits and non-local/existence benefits. In order to address the former weakness, application of benefit transfer is appropriate, and then the validity of benefit transfer must be examined statistically. For the latter, conjoint analysis can assure theoretical validity.

(2) Examination of the relation between preferred water quality level and attributes of individuals

In measuring the benefit of ambient water quality improvement, regions incurring benefits and water quality level

preferred by beneficiaries must be grasped. Desirable water quality level from a standpoint of efficiency or equity presumably differs among regions and/or individuals. The relation between preferred water quality level and attributes of individuals was therefore examined by using the results of the questionnaire "Towards Sewage Works Reflecting Your Voices" conducted by Sewerage and Wastewater Management Department, Ministry of Land, Infrastructure and Transport. This examination also considers how to set study sites of a nationwide CVM research, which is expected to be conducted in the subsequent year.

As a result, the following attributes of individuals are suggested to have significant influence on preferred water quality level: availability of sewerage services, awareness of sewerage fees, and recognition of riparian life and surrounding landscape. It is also suggested that preferred water quality level differs between prefectures. Therefore, an applicable benefit transfer function on a national level must take into consideration attributes of individuals and regions. We intend to examine a methodology for CVM for benefit transfer in subsequent fiscal years.

# LOW-COST SEWERAGE SYSTEM FOR DEVELOPING COUNTRIES

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Wastewater System Division, and Wastewater and Sludge Management Division

Project period: 2001-2004

OBJECTIVES

As hygiene deteriorates with the remarkable progression of urbanization, improving the water environment and securing water resources become important in developing countries. Especially in rural areas, people live in poor hygienic conditions caused by the spread of epidemics and the shortage of water resources, because they have less understanding of the importance of

Fig. 1 Concept of low-cost sewerage system
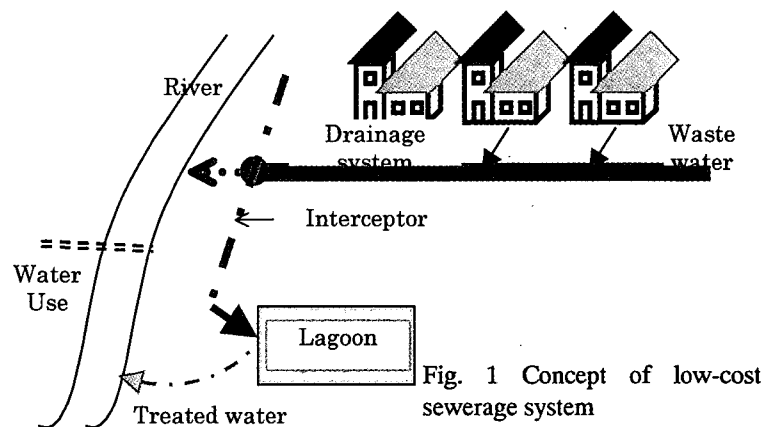
wastewater treatment than those who live in urban areas. To solve these problems, the quality of these water resources should be improved by establishing low-cost sewerage systems through improving existing drainage facilities such as septic tanks, wetland and soil filtration. Therefore, the objective of this research is to develop low-cost sewerage systems suitable to the characteristics of developing countries, such as high temperature and low cost for labor and land, including citizen participation and efficient management of sewerage systems.

RESULT

FIELD SURVEY OF DRAINAGE SYSTEMS AND WASTEWATER TREATMENT PLANTS IN THAILAND

The combination of interceptor and lagoon create low-cost sewerage systems that are suitable for improving water quality and hygiene in the rural areas of developing countries. But the present interceptor and lagoon systems are not functioning. We carried out field surveys to determine the problems of the present interceptor and lagoon systems in Thailand and Indonesia in October 2002.

Our survey revealed two results. First, although sedimentation and biodegradation in interceptor pipes was not confirmed, the concentration of BOD in wastewater was lower than that in Japan because river water ran into the interceptor. Second, the concentration of suspended solid in the effluent of lagoon systems was higher that that of wastewater treatment plants in Japan because algae grew in the lagoon and was contained in the effluent.

EXPERIMENT TO IMPROVE THE TREATMENT OF LAGOON SYSTEMS IN THE TROPICS OR SUBTROPICS

Wastewater influent with low BOD in lagoons of the tropics or subtropics is a problem. The first step is to change the method used for operation and maintenance, which are inadequate. In addition, there is the problem of algae and the sanitary condition of the treated wastewater from the lagoon. We researched these matters and conducted experiments in

Okinawa Prefecture, the sole subtropics area in Japan.

The lagoon has a water depth of 2 m and a capacity of 100 m³. BOD of the wastewater influent was changed to 50, 100, and 200 mg/L. The hydraulic retention time (HRT) of the lagoon was changed to 2, 5, 10, and 20 days. The processing condition of the lagoon was confirmed. This fiscal year, the BOD was set at 50,100 mg/L (except HRT at 20 days) and we conducted experiments using hygrophyte purification to advance the lagoon treated wastewater. We waited for the HRT set to 20 days and for the hygrophyte to grow.

For the lagoon results, in the case of wastewater influent BOD 50 mg/L, the necessary HRT was 5 days. In the case of wastewater influent BOD 100 mg/L, the necessary HRT was 10 days. When sanitary conditions are considered, in the case of wastewater influent BOD 50 mg/L, proper HRT was 10 days. In the case of wastewater influent BOD 100 mg/L, proper HRT was 30 days. However, HRT of 20 days was not set for the wastewater influent BOD 100 mg/L period. When we evaluated the treated wastewater of the lagoon, it was not possible in only the evaluation of the total samples (T-BOD, SS etc) because it does not check wastewater that was not treated or algae that appeared with treatment. Therefore, we must evaluate it taking into consideration the dissolved solids and lagoon conditions.

In the results of the hygrophyte purification, T-BOD and T-COD, SS of the treated water was low because the sunlight does not reach the water. In this way, algae growth is restrained and the density of algae in the treated water was reduced.
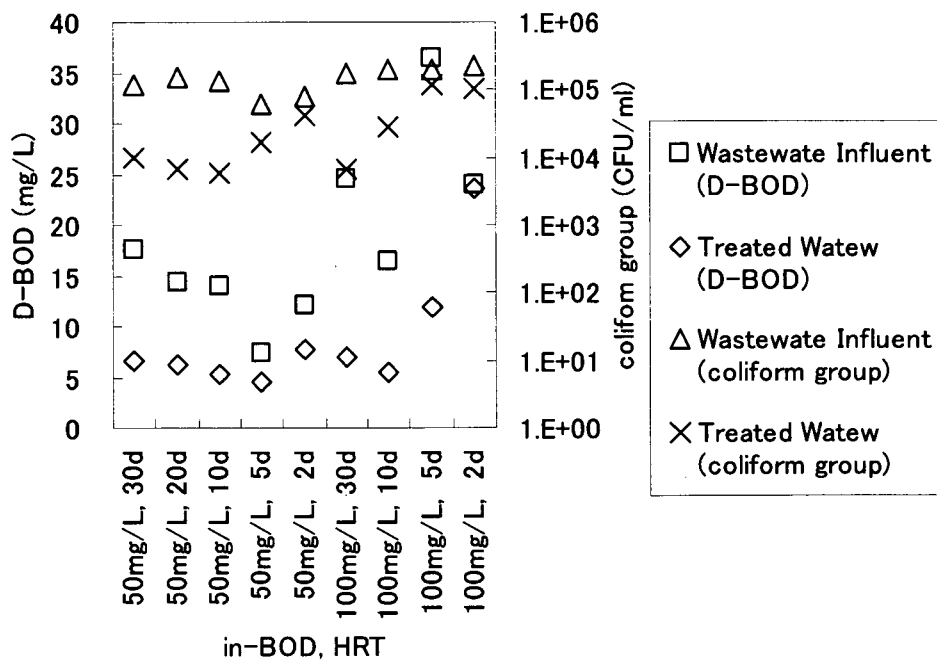
Fig. 2 Water quality of the lagoon

STUDY ON CHARACTERISTICS OF TRACTION OF SEDIMENT FROM GARBAGE IN SEWER PIPE

H. Morita, K. Mori, A. Yoshida and T. Hamada

Wastewater System Division

Project period: 2002-2004

OBJECTIVES

In the town of Utanobori, which has installed garbage disposers, sediment such as eggshell and seashell were observed at the bottom of sewer pipes. The objective of this study is to clarify the traction flow velocity of eggshell and seashell (thereafter, sediment). Therefore, we examined sediment shapes after they were crushed in the garbage disposer, and measured the traction flow velocity of the sediment by sewer pipe model experiment.

EXPERIMENTAL OUTLINE

(1) Test sediment properties

After crushing the sediment in the garbage disposer, we measured specific gravity, average grain size and shell thickness. Specific gravity was measured using the Test Method for Density of Soil Particles (JIS A 1202). Average grain size was measured using the Test Method for Particle Size Distribution of Soils (JSF T131-1990). Sediment has an indefinite shape and cannot be assumed to be spherical. Therefore, we measured the shell thickness by taking the average thickness of five pieces of shell using vernier calipers.

(2) Specification of sewer pipe model

Vinyl chloride pipe of f 200 is generally used in Utanobori. Therefore, we used transparent acrylic pipe of f 200 for this experiment, because the coefficient of roughness of acrylic pipe is almost the same as the vinyl chloride pipe, and observation is easy. Pipe length was 15 m (pumping area of 2 m, experimental area of 10 m, and drop-down area of 3 m). A flow meter was set up in the feed water pipe. Flowing quantity was adjusted with a flowing quantity adjustment valve.

(3) Traction experiment on existing sediment

Flowing quantity was increased one by one after setting up sediment, and we measured the flow velocity and depth at which the sediment began to move. We used fixed sediment from a weir made of clay, and the sediment was set up at a length of 2 m and a depth of 2 cm. Three kinds (1/478, 1/202, 1/103) of sewer pipe model of inclinations were set. The traction condition was classified into three stages, and we measured the flow velocity and depth at each stage.

(4) Experiment on sedimentation and traction of pumped sediment

We observed the flow velocity of sedimentation generation and traction according to increase in amount of flow to examine the relationship between change of sediment (sedimentation and traction) and flow velocity in the sewer pipe.

CONCLUSION

(1) Test sediment properties

The specific gravity of eggshell was 2.6 and that of seashell was 2.8. Average grain size was 1.9–2.5 mm. Eggshell thickness was 0.5 mm and seashell thickness was 1.0 mm.

(2) Traction experiment on existing sediment

The traction flow velocity of eggshell was 42.9 cm/s at the beginning of movement, 47.5 cm/s in the middle of movement, and 55.9 cm/s during overall movement. The traction flow velocity of seashell was 44.9 cm/s at the beginning of movement, 52.4 cm/s in the middle of movement, and 60.1 cm/s during overall movement.

(3) Experiment on sedimentation and traction of pumped sediment

Sediment is not generated if the amount of flow is 2.0L/s (flow velocity 54 cm/s) or more in sewer pipes of inclination 1/200.

OPTIMUM MANAGEMENT OF FOOD WASTE THROUGH SEWERAGE SYSTEMS FOR ABATEMENT OF ENVIRONMENTAL IMPACT

H. Morita, A. Yoshida and H. Yamagata

Wastewater System Division

Project period: 2002 - 2004

OBJECTIVES

The efficient collection and reuse of residential food waste is expected through the introduction of a food waste disposer (FWD) to discharge it to sewerage systems and digestion and composting of sludge waste. In addition, the introduction of FWD should improve the situation in an aging society. However, FWD increases sedimentation in sewer pipes, pollution load to wastewater treatment facilities and pollution discharge through combined sewer overflows, so FWDs are not allowed in Japanese sewerage systems. The objective of this research is to comprehensively evaluate the effects of FWD on sewerage systems, waste disposal systems and society by applying Life Cycle Analysis (LCA) and Cost Benefit Analysis (CBA), and to propose the optimum management of food waste through sewerage systems.

The research topics in FY2002 are as follows:

1) Overseas research on the effect of FWD

We investigated reports on the current status of introduction of FWD overseas, and conducted field surveys on the effect of diffusion of FWD to frequency of cleaning of sewer pipes (separate systems) in the United States where diffusion of FWD is high.

2) LCA and CBA of the introduction of FWD

We conducted LCA of the effect of diffusion of FWD on the frequency of cleaning of sewer pipes in the town of Utanobori where FWD was first introduced in sewered areas in Japan in 1999. We also conducted an economic evaluation of the benefit of users of FWD through application of the contingent valuation method (CVM) at Utanobori.

RESULTS

1) Overseas research on the effect of FWD

The coverage of sewer pipes in the United States is higher than that in Japan. However, there is no particular relation between diffusion of FWD and frequency of sewer pipes (**Fig. 1**). According to interviews with managers of sewerage systems at Denver, CO, where both diffusion of FWD and frequency of sewer pipes are very high, stoppage of sewer pipes are mainly caused by kitchen grease from such places as restaurants, high frequency of sewer pipes is the result of preventive maintenance, and the effect of diffusion of FWD to frequency of sewer pipes is not affirmed.
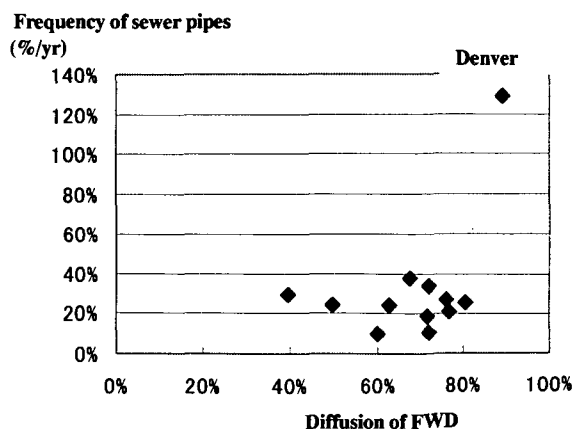
Fig. 1 Frequency of sewer pipes compared to diffusion of FWD (12 cities in USA)

2) LCA and CBA of the introduction of FWD

(1) LCA of the effect of diffusion of FWD to frequency of cleaning of sewer pipes

We conducted a questionnaire on the cleaning of sewer pipes to municipalities in Hokkaido prefecture to establish a basic unit of the environmental effect per distance of drive and time to run high-pressure cleaning cars, sludge vacuum cars and water wagons. We set the sedimentation depth and cleaning distance of sewer pipes and calculated the environmental effect of cleaning sewer pipes if diffusion of FWD is 100% in Utanobori. According to the calculation, LC-CO_2 of cleaning sewer pipes is increased by 182 kg CO_2/yr, and LCE is increased by 2,596 MJ/yr (Fig. 2).

(1) Without FWD (frequency : 8.7%/yr)   (2) With FWD (frequency : 11.7%/yr)
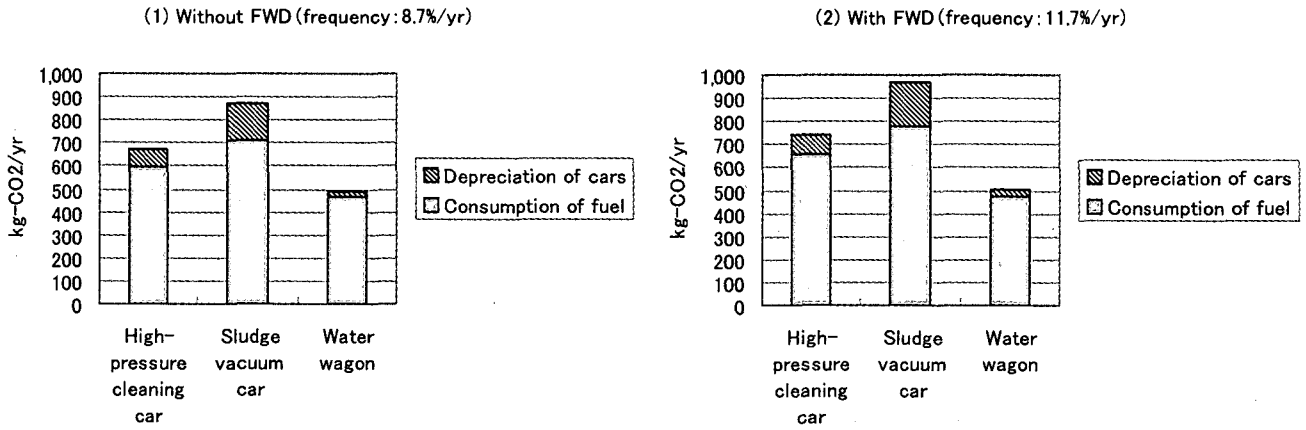
Fig. 2   LC-CO_2 of cleaning of sewer pipes with/without FWD in the town of Utanobori

(2) Economic evaluation of the benefits to users of FWD.

We conducted a questionnaire on the benefits of FWD to 272 users in the town of Utanobori. The distribution of Willingness to Pay (WTP) is shown in **Fig. 3**. According to the questionnaire, the average WTP of public houses where FWD was introduced whether or not installation was wanted is 550 yen/month/household, and the average WTP of private houses where FWD was installed only where installation was wanted is 957 yen/month/household.

WTP (yen/month/household)   WTP (yen/month/household)
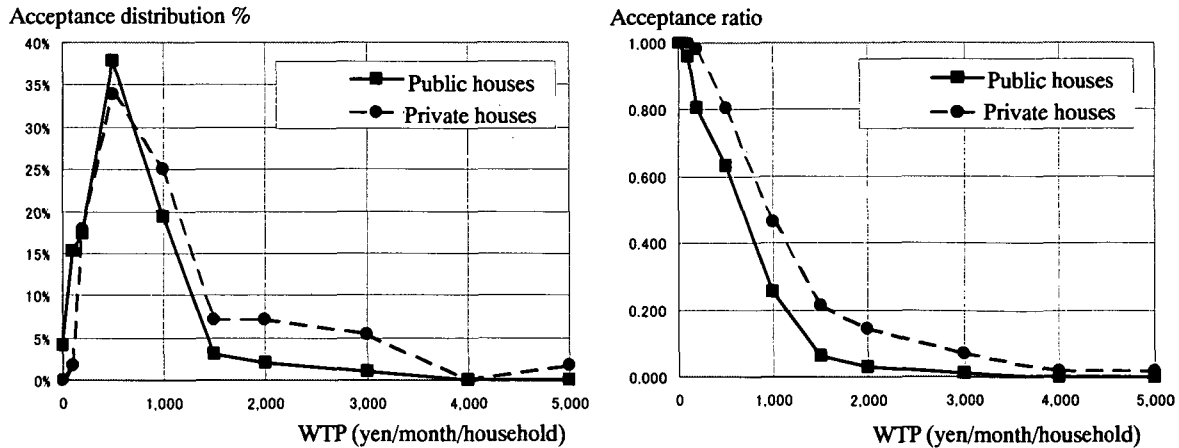
Fig. 3   Distribution of WTP to use of FWD in the town of Utanobori

STUDY ON DEVELOPMENT OF THE EVALUATION TECHNOLOGY OF INFLUENCE ON WATER CYCLE AND SUBSTANCE CIRCULATION CHANGE

H. Morita, M. Matsubara, M. Nasu, and H. Mori

Wastewater System Division

Project period: 2002-2004

INTRODUCTION

The objective of this study was to estimate the influence of combined sewer overflow on the river basin and city and to promote effective improvement of combined sewer system. The actual survey at the model basin including the sea was carried out in this fiscal year.

METHODS

The Hirasaku river basin in Yokosuka city, Kanagawa prefecture was selected as the model basin. The characteristics of this basin are as follows:

1) The main rainwater inflow course from the city to Tokyo bay is only Hirasaku River.

2) Most of the area of this basin is urbanized with a high rate of population-served sewers, including a combined sewer system.

Surveys were carried out in both fine weather and wet weather. The survey conducted during fine weather collected two water samples at two survey points. The survey conducted during wet weather collected water samples for five days after rain at the two survey points. The water samples were collected in accordance with the ebb and flow of the tide at six times in two days, which is the

Area : 28km²
Population : 19,000
River length : 10.2km.
Rate of served sewer : 94%
Area of served CSS* : 14km²
*Combined Sewer System

Fig. 1 Study area and survey stations

survey starting day and the next day. After those days, the water samples were collected at the time of ebb tide in the daytime once a day.

Water quality analysis items were COD, SS, T-N, T-P, the total number of coliform groups (TC), and the total number of fecal coliform groups (FC). TC was analyzed by BGLB culture medium – MPN method, and FC was analyzed by M-FC agar culture medium method. In addition, the water temperature, DO, and electrical conductivity were measured.

RESULTS AND DISCUSSION

The rate of the peak water quality in wet weather and the average water quality in fine weather is arranged as shown in Fig. 2. It was found that COD, T-N and T-P have a comparatively small difference at the time of rainy weather and fine weather, but TC and FC have a large difference, which has the value of a ratio as large as 10^2 to about 10^4. The figure also shows that water quality differs greatly between fine weather and rainy weather.
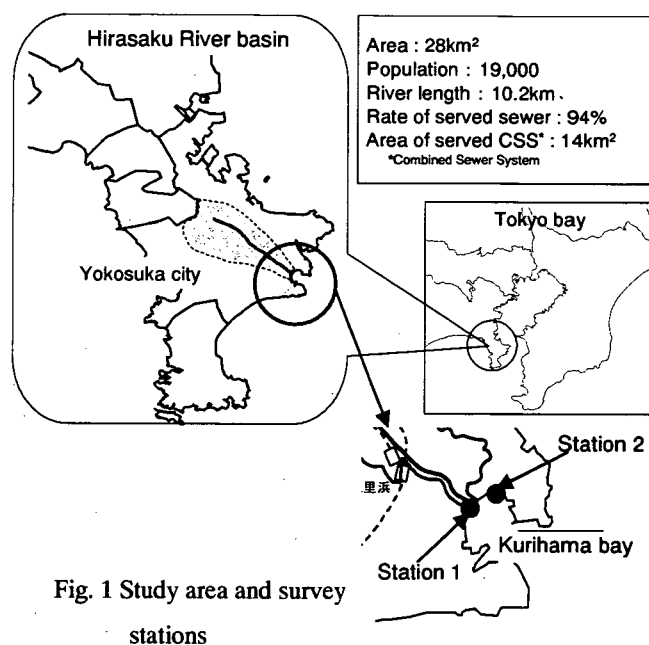
The arrangement of the days taken to recover the water quality that had deteriorated by rainwater to the average water quality at the time of fine weather for each water quality item was studied. The result shows that COD, T-N, and T-P were recovered one day after the rain ended, but SS, TC and FC required about three days. It is considered to be

Fig. 2 Rate of water quality in wet weather and in fine weather

one of the reasons why the water quality differs greatly between fine weather and rainy weather as mentioned above.

The ratio of the value at Station 1 to the value at Station 2 for the water quality items is shown in Fig. 2. Their tendencies can be roughly classified into three.

i)   The ratio of COD, T-N and T-P is almost entirely fixed.
ii) The ratio of SS may be less than 1.
iii) The ratio of TC and FC is large in the early stages of an outflow.

Regarding ii), it is assumed that SS increased due to the influence of floating sediment and drifting. Regarding iii), it is assumed that the inflow water quality in rainy weather is markedly worse compared with that in fine weather, and that the ratio becomes large due to extinction of the coliform in the sea.

Fig. 3 The rate of water quality at two survey stations

CONCLUSION

The water quality survey was conducted on rainy weather in the sea into which CSO flowed. The conclusion is as follows:

i)   SS, TC and FC differ greatly in fine weather and rainy weather. Especially for TC and FC, the peak of water quality in rainy weather was about 10^2 to 10^4 times the average in fine weather.

ii) COD, T-N and T-P took one day to recover, but SS, TC and FC needed about three days to recover to the average water quality in fine weather after the rain stopped.

iii) The feature of the water quality change in the sea was classified into three groups: COD, T-N, T-P; SS; TC and FC.

The behavior of pollution that flowed into the sea will be clarified by more detailed survey, and it will be necessary to study the relation between the amount of inflow loads and the water quality of the sea by conducting both a water quality investigation of CSO flying into the sea and rainwater of separated sewers.
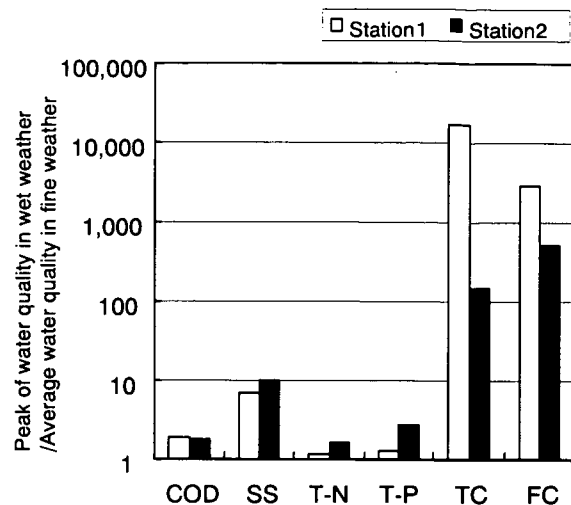
RESEARCH ON THE TECHNICAL STANDARD OF THE TREATED WASTEWATER REUSE SYSTEM

A. Tajima and H. Nakajima

Wastewater and Sludge Management Division, Water Quality Control Department

Project period: 2001-2004

OBJECTIVES

In Japan, treated wastewater is reused for many uses in the cities as low quality water resources. But there happened some serious problems such as facilities troubles caused by treated wastewater. It is very important to adopt the appropriate materials or constructions and maintain the facilities adequately in order to make use of the treated wastewater as water resources. The objectives of this research is to show the measures to construct the safe, comfortable and sustainable re-use system of treated wastewater to the many uses of treated wastewater by studying the measures to protect the troubles in the re-use of treated wastewater.

RESULTS

In 2004, we researched the below three things.

(1) The study on the factors which influence the generation of the biofilm, which is easily found in the re-use system of treated wastewater.

(2) The annual study on the water quality changes in the tank, because the large decrease of the residual chlorine in the tank may cause the generation of the biofilm in the customer's facilities.

(3) The study on the propriety of using the Langerier Index as the corrosion index of treated wastewater

As a result of the research of (1), we could find out the below things.

① The coloring of the surface of the tank is caused by Mn , and the surface is colored definitely on the condition that more than 3mg/m2 of Mn is attached to it.

② The higher Mn concentration in the treated wastewater is, the more Mn is attached to the surface of the tank. This shows that it is very important to decrease Mn concentration in the treated wastewater in order to protect coloring of the surface.

③ The higher water temperature is, the more Mn is attached to the surface of the tank. Treated wastewater by sand filtration does not color the surface so much on the case of 15℃, but Treated wastewater by flocculation and ozonation colors the surface so much on the case of 25℃.

As a result of the research of (2), we could find out the below thing.

① Nitrification proceeded and residual chlorination decreased so much in the tank, and there was little residual chlorination in the effluent from the tank.

As a result of the research of (3), we could find out the below things.

① The higher the temperature, residual chlorination, and electricity conduction in the treated wastewater is, the more the corrosion of iron proceeds. The temperature has a greatest influence on the corrosion of these factors.

② It may not be appropriate to estimate the corrosion by treated wastewater on the basis of only the Langerier Index.

RESEARCH OF LCA TO SEWERAGE SYSTEM

H. Nakajima, H. Yamashita and S. Nakajima

Wastewater and Sludge Management Division

Project period: FY2001-2004

OBJECTIVES

Recently, to solve global environmental problems including global warming, environmental load is analyzed quantitatively in each field, and various techniques to decrease the load are studied now. Moreover, to decrease the environmental load from public infrastructure facilities to public waters, it is important to evaluate the relationship between their effect on the water quality improvement and the environmental load derived from their construction and running. This research aims to apply LCA method to wastewater system at the design stage, and we are at work on making life-cycle inventory (LCI) model to standardize the method and improve its efficiency. In FY 2002, we executed the case study of the LCI model for the wastewater system, analyzed the environmental impact of different types of wastewater system and examined the applicability of the model. In addition, we examined the method in which we integrated and evaluated each of environmental elements in LCA analysis.

RESULTS

1. Calculation of amount of environmental load to different types of wastewater system

We practiced the case study of different types of wastewater system to evaluate the applicability of the LCI model. We selected three different types of wastewater system, namely advanced wastewater treatment process, conventional activated sludge process and oxidation ditch (OD) process. As a result we found that most of the environmental load from each of the processes was derived from the electricity consumption of their running and that the amount of the environmental load from OD process was the largest, that from advanced wastewater treatment process was the second largest and that from conventional activated sludge process was the least. We supposed that this result came from the characteristic of the running of OD process, the short length of its operation period and the ratio of the quantity of treated water to the ability of the treatment plant.

2. Analysis of consumption of electric power for each of the equipments of a wastewater treatment plant in the running stage

We analyzed consumption of electric power for each of the equipments in three different types of wastewater system to evaluate environmental load in the running stage of a wastewater treatment plant. As a result, we found that the blower discharged the most amounts of environmental load and the environmental load from the blower and the pump occupied the 90 % of the total environmental load. Moreover, we found that there were some features in the result of the calculation in each of the wastewater processes. As a result we suggested the possibility of the LCI

model's simplification by extracting major equipment in the wastewater process and by calculating its environmental load with assuming its ability to treat and its time to operate to be a parameter.

3. Analysis of the LCI model through the operating period of a wastewater treatment plant

To study the influence of the time after operating start on the LCI model, we compared the result from the LCI model and the result from the actual data and analyzed the change of the amount of the consumption of the electric power through the operating period of a wastewater treatment plant. As a result, we suggested that the rate of the volume of wastewater influent to the facilities ability to treat had a great influence on the result of the environmental load calculated by the LCI model. It is important that we consider an evaluation point on the axis of time to evaluate different type of wastewater systems; wastewater process, facilities ability or the rate of the volume of wastewater influent to the facilities ability.

4. Overall evaluation on environmental elements in the LCA analysis

There are some environmental elements in the LCA analysis. Global warming, consumption of energy, water quality improvement, acid rain and reclaimed wastes are the examples of some environmental elements in the LCA analysis. In the next study it will be necessary to establish how to unify these environmental elements and estimate the unification. In this time, we practiced the case study for an advanced wastewater treatment process and a conventional activated sludge process to analyze the evaluation method. In this research, we suggested the method to evaluate the relationship between nitrogen and phosphorus in eutrophication item and carbon dioxide in global warming item. We suggested the method to evaluate the unification of some environmental elements in the LCA analysis and showed the effect of an advanced wastewater treatment to reduce environmental load in the LCA analysis.

Evaluation method for advanced wastewater treatment system

H. Nakajima, H. Yamashita, S. Nakajima

Wastewater and Sludge Management Division

Project period: 2002-2004

OBJECTIVES

Advanced wastewater treatment is indispensable to improve the water quality in closed water bodies and the safety of treated wastewater, which are highly demanded in these days. This study aims to make suggestions for policy making to progress implementation of advanced wastewater treatment through the development of evaluation method for advanced wastewater treatment, the presentation of clear alternative scenarios based on the sound science and the proposal of the consensus-based decision making method. The feasibility of the suggestions were examined thorough the case study of the Lake Biwa watershed.

RESULTS

The research results in fiscal 2002 are as follows.

1. Development of a benefit evaluation method for advanced wastewater treatment

We developed a benefit evaluation method (so-called "alternative implementation cost method") in which we consider the minimum implementation cost for the water environment conservation efforts for the Lake Biwa as the benefit of the water environment of the lake because the implementation cost should be less than social Willingness-To-Pay of citizens when those efforts are implemented in the most efficient manner (Figure 1).

As the results, the unit benefit of water quality conservation is estimated to be 3,130 yen per Total CODs kg.
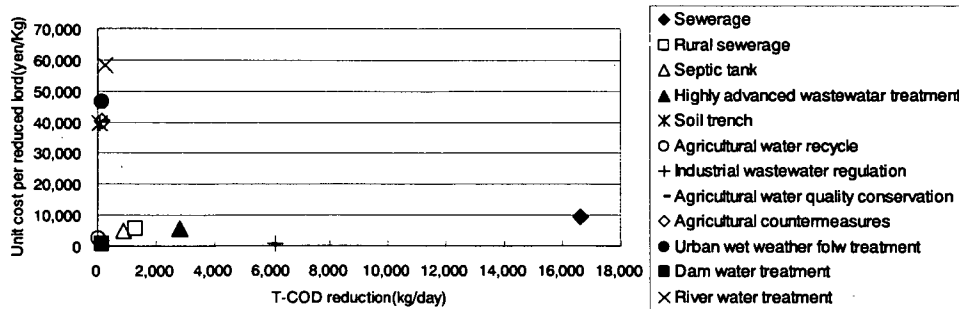
Figure 1   Relationship between T-COD reduction and unit cost per reduced lord

2. Evaluation of a nation wide benefit of water quality conservation through the implementation of sewerage

Total amount of investment for the construction, operation and maintenance of sewerage summed up to around 35 trillions yen while total reduction of pollution lord was calculated to be approximately 21 million Total CODs ton. Accordingly, the benefit of water quality conservation was estimated to be around 66 trillion yen through the calculation using the unit benefit 3,130 yen per Total CODs kg. Consequently, we obtained CBA results of B/C >1.9, which means that sufficient water quality conservation benefit has been produced compared to the investment needed. Considering other benefits of sewerage implementation such as convenience of flush toilet use and improvement of living environment, B/C would be much larger.

On the other hand, the cost and benefit of the advanced wastewater treatment was estimated to be 70 and 140 billion yen respectively. This suggested that the nation wide advanced wastewater treatment implementation strategy has given enough economical efficiency so far.

Technically based risk standard for wastewater treatment

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Wastewater and Sludge Management Division

Project period: 2002-2004

OBJECTIVES

In Japan, as elsewhere, the water related health risk posed by pathogenic microorganisms such as outbreaks of Cryptosporidium and food poisonings caused by Noro viruses has become an increasing problem. This study aims to present a necessary technically based standard for the reliable safety of treated wastewater.

RESULTS

The research results in fiscal 2002 are as follows.

1. Proposal of safety guideline for Cryptosporidium

   A general procedure for countermeasures in the event of a mass outbreak and annual average risk control was obtained as shown in Table 1. Annual infection risk 10-2 was set as a tentative control goal. Where observed values deviate significantly from the lognormal distribution based on measurement data taken after secondary treatment and after sand filtration, this indicates an abnormal situation with the potential to cause a mass outbreak and emergency procedures should be instituted. L1, the threshold for increased monitoring, may be defined as the upper limit of the 95% confidence range for the distribution obtained from the geometric mean of certain number of samples (i.e., several consecutive separate measurements). L2, the threshold for emergency procedures, may also be defined in the same way. When the threshold value is exceeded, the relevant countermeasures are instituted. Ideally, the geometric mean of the measurements would be used for comparison with the threshold values; however, in cases where the latter of the consecutive measurements is higher and the concentration level appears to be on the increase, this situation may satisfy the prerequisites for the geometric mean. For this reason, in order to allow for a margin of safety, all of the consecutive measurement values are required to be below the geometric mean.

Table 1   Threshold values for mass outbreak countermeasures

Form of contact/reuse	L1 (threshold for increased	L2 (threshold for emergency procedures)	Upper Limit	Category	Annual Risk
Bathing	2.8	4.1	6.0	Secondary treatment	$10^{-2.2}$
Source water for	2.8	4.1	6.6		$10^{-2.2}$
Recreational water (parks)	0.39	0.49	2.4	Sand filtration	$10^{-2.7}$
Landscape water (parks)	0.39	0.49	23.1		$10^{-3.7}$
Flush toilet water (office)	0.39	0.49	91.9		$10^{-4.3}$
Sprinkling water (parks)	0.39	0.49	40.0		$10^{-3.9}$

Upper Limit: Standards cannot be changed above these value
Concentration (Cryptosporidium per L)

2. Risk benefit analysis by QALYs (Quality Adjusted Life Years)

   The benefit of countermeasures against cryptosporidium was estimated as the avoidance of both personal and social excessive cost caused by the microorganism. The personal benefit included protection of health (measured by QALYs) and avoidance of economical loss (health care expenses and decrease of income caused by the absence from job). The social loss was the cost of public health care support for the infected individuals. The efficiency of the countermeasures were estimated to be more than 10 million yen / QALYs. Most countermeasures turned to more costly, mainly because average risk was as low as 10-2 to 10-5 and additional risk reduction gave little benefit compared the cost needed.

REDUCING CH_4 AND N_2O GAS EMISSION FROM WASTEWATER TREATMENT FACILITIES BY IMPROVING APPLICABILITY OF CORE CONTROLLING TECHNOLOGIES

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Wastewater and Sludge Management Division

OBJECTIVES

Global warming is one of the most serious environmental problems, and we have to control emission of the green-house effect gas(GHG) such as carbon dioxide(CO_2), methane(CH_4) and nitrous oxide (N_2O). In wastewater treatment plants, these GHGs are emitted according to the biological wastewater treatment, the incineration of sludge and the use of electricity, fuels and chemicals. The CH_4 and N_2O gases are more problematic because these gases have higher green-house effect than the CO_2 gas. The CH_4 gas is emitted from biological wastewater treatment process and the N_2O gas is emitted from biological nitrogen removal process and sludge incineration. The CO_2 gas emitted from the treatment process is not the target because the CO_2 gas is globally recycling in the gas-vegetable life.

It was already cleared that the CH_4 gas emission is able to be suppressed by introducing anaerobic or anoxic zones to wastewater treatment process, and that the N_2O gas emission from sludge incineration process decreases according to the temperature increase in furnace. The purpose of this research is to improve applicability of core technologies controlling emission of GHG, and also to make the GHG emission inventory more accurate.

RESULT

We did the research of the Green House Gas (CH_4, N_2O) from the wastewater treatment plant. Research divided into 2 of the wastewater treatment process and sludge treatment process and did it.

The wastewater treatment process examined the Green House Gas that is discharged from an aeration tank to the object. The examination of CH_4 did the contrast experiment of anaerobic-oxic activated sludge process, recycled nitrification/denitrification process and conventional activated sludge process. As for the result, the recycled nitrification/denitrification process was high with effect of decrease, anaerobic-oxic activated sludge process and conventional activated sludge process were the same control effect almost. The examination of N_2O did experiment of the N_2O that occurs from the nitrification process. As for the result, there was much emission quantity when imperfect nitrification process in the time when treatment to bad time and nitrification promotion.

The sludge treatment process did the N_2O emission quantity survey of the fluidized bed furnace. As for the result N_2O density was fluctuating largely every progress time. Therefore, it became clear that it does not

become a representative value in a short term survey, in the case that I decide the fluidized bed furnace. Furthermore, as for N_2O density the influence of the free board temperature is biggest, the estimation of the N_2O density is possible from free board temperature. From the result, the N_2O gross weight from the fluidized bed furnace of Japan was $3.6Gg-N_2O/year$.

Table 1 Results of CH_4 balance in the wastewater treatment process

	recycled nitrification/denitrification process	anaerobic-oxic activated sludge process	conventional activated sludge process
The concentration of CH_4 in the wastewater influent (mg/m^3)	617.5	431.3	550.9
The concentration of CH_4 in the treated wastewater (mg/m^3)	5.0	0.5	0.0
CH_4 emission volume (mg/m^3)	195.0	335.2	424.6
CH_4 balance ((emission+outflow)/inflow)	0.32	0.78	0.77

Table 2 Results of N_2O emission from sludge incineration

| Incinerator		A	B			C			D		E	F		
Measurment		A	B1	B2	B3	C1	C2	C3	D1	D2	E	F		Capacity
Measuring period		Jan-01	May-00	Dec-01	Sep-02	Dec-00	Aug-01	Oct-02	Sep-01	Feb-03	Mar-01	Nov-01	Mean	weighted mean
Mean N_2O emission, O_2=6%		64	119	270	153	325	311	275	392	319	181	338		
Conversion of N in sludge to N_2O, %		1.62	2.25	4.55	3.33	5.42	5.95	4.11	7.36	6.74	3.35	7.31		
Emision factor, g-N_2O/t-WS	Mea	307	359	792	470	1,007	1,087	636	1,213	1,033	726	1,080	792	866
	Min.	150	207	401	272	239	632	191	600	380	257	522	350	363
	Max.	971	554	1,558	748	1,592	1,440	1,637	1,955	1,456	2,260	1,405	1,416	1,555
Emision factor, g-N_2O/t-DS	Mea	1,520	1,830	3,770	2,188	4,700	4,400	2,848	6,400	4,863	2,880	5,910	3,755	4,024
	Min.	750	1,040	1,910	1,265	1,190	2,560	855	3,160	1,790	1,020	2,850	1,672	1,697
	Max.	4,900	2,780	7,410	3,482	7,520	5,830	7,333	10,300	6,853	8,970	7,690	6,643	7,134
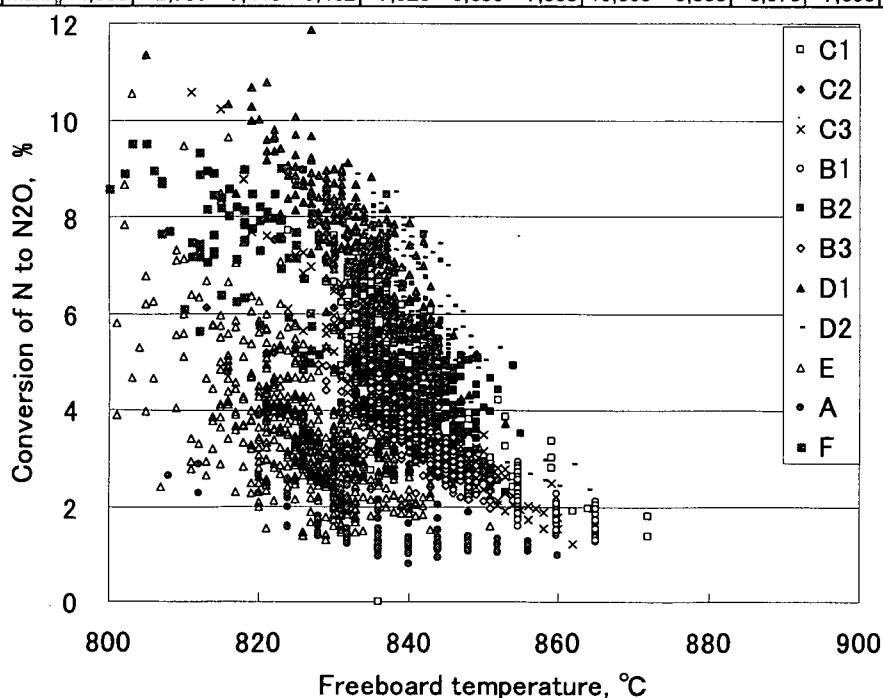
Figure 1 Connection between conversion of N in sludge to N_2O and freeboard temperature

DECOMPOSITION OF ENDOCRINE DISRUPTERS
UTILISING MICROORGANISM GROUPS

H. Nakajima, H. Saino
Wastewater and Sludge Treatment Division

Project period: FY2001-2003

OBJECTIVES

It is necessary to efficiently reduce endocrine disrupters (EDs) through sewage treatment processes because EDs generated by urban activities are discharged to sewerage systems. Although the majority of EDs are removed, some cannot be removed. On the other hand, microorganisms which effectively decompose EDs have been found (Ogoshi, et al. 2001) , and have the potential to be used in existing wastewater treatment facilities.

This research examined how such microorganisms act, and how wastewater treatment processes could be controlled to utilize such microorganisms. Finally, wastewater treatment technologies which reduce the risk of EDs were developed.

METHOD

The performance of EDs which decompose microorganisms was investigated by using a wastewater treatment pilot plant. In FY 2002, before the performance investigation, the relationship between MLSS, which is one of the main indicators for controlling microorganisms in activated sludge, and removal of EDs were surveyed.

This investigation was conducted using pilot plants of the conventional activated sludge process at 20℃. The influent was the primary effluent of an actual wastewater treatment plant. 17 β estradiol (E2) was added to the influent, to give a concentration of 1μg/L or 10μg/L.

RESULTS

Fundamental data concerning the removal of EDs and MLSS were obtained. The results of the studies in FY2002 are summarized as follows.

1) In the case of higher E2 concentration in influent, the higher the MLSS, the lower the concentrations of E2 and Estrone (E1) in effluent. However, in the case of lower E2 concentration, both E2 and E1 were effectively removed, and no correlation between EDs and MLSS was observed (Fig. 1, 2).

2) The removal conditions of E2 and E1 in each tank were studied. E2 was decomposed rapidly, whereas the decomposition of E1 was delayed. The reason was thought to be that E2 was decomposed to E1, and the decomposition velocity of E1 was slower than that of E2 (Tanaka, et al. 2002). However, the amount of E1 generated did not correspond to the amount of E2 decomposed, so most of the E1 may have been decomposed, too (Fig. 3).

In FY 2003, the reduction of EDs using a carrier with ED decomposing microorganisms will be investigated using the same pilot plant.

REFERENCE

Ogoshi M, et al. (2001) Result of the search for Estradiol or Nonylphenol degrading microorganisms, the proceedings of 35th annual meeting of Japan Society on Water Environment, Vol. 35, p. 301

Tanaka M, et al. (2002) Studies on degradation of estradiol and related compounds by activated sludge, the proceedings of 36th annual meeting of Japan Society on Water Environment, Vol. 36, p. 160
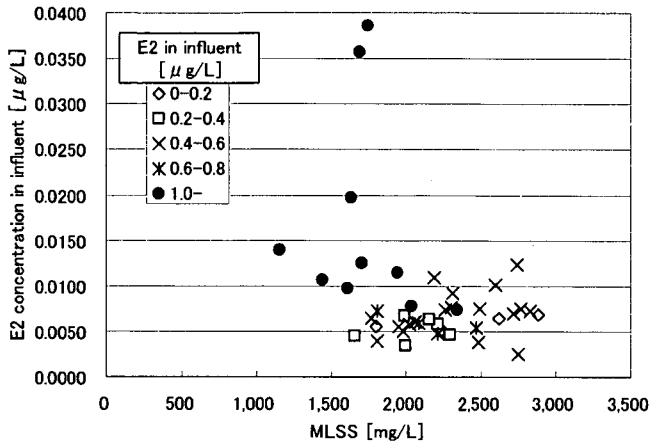
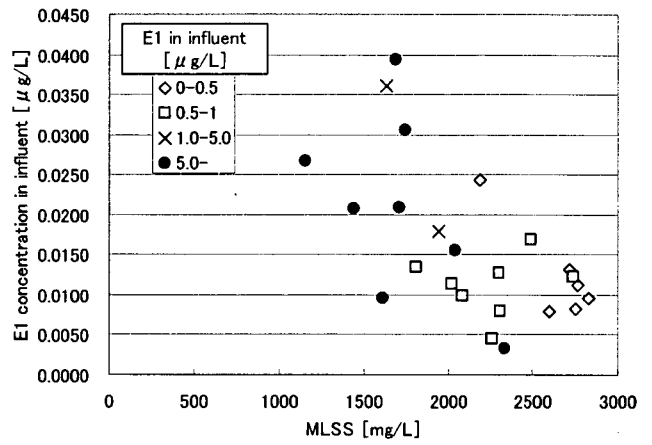Fig. 1 The relationship between MLSS and E2 in effluent

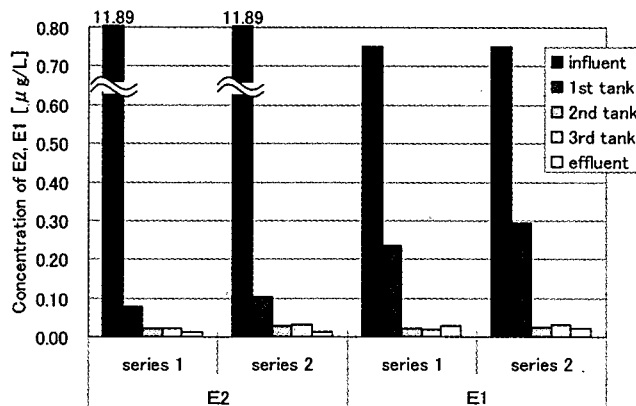Fig. 2 The relationship between MLSS and E1 in effluent

Fig. 3 E2 and E1 in each tank

STUDY ON WASTEWATER RECLAMATION SYSTEM FOR RIVER ECOSYSTEMS

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Wastewater and Sludge Management Division

Project period: FY 2001-2005

INTRODUCTION

As the sewerage system diffuses, the amount of wastewater to be treated increases proportionally. When treated wastewater is discharged to public water bodies, it has a serious impact on the ecosystem of the receiving water body that cannot be ignored. Treated wastewater is increasingly being re-used as landscaping water in urban areas in an attempt to restore the waterside environment lost by urbanization. Such places provide oases in cities for the growth of aquatic life.

Aquatic biota, including algae, aquatic insects, and fish that live in these artificially restored waterside areas are mainly species known to survive in somewhat polluted waters. This means that a genuinely good living environment has yet to be restored, as the objectives of the wastewater reclamation system are limited, with primary emphasis on BOD, hygienic safety, and appearance (coliform count, SS, chromaticity, etc.). In fact, when treated wastewater is discharged to rivers and channels, wastewater is simply given advanced treatment using sand filtration or other similar processes. There have been few cases where more advanced treatment is employed to remove nitrogen or phosphorus or apply disinfection by ozone or ultraviolet light. Also, it has not been fully clarified yet what impact or effect such highly advanced treatment processes have on aquatic life.

Further knowledge is needed on wastewater treatment methods and treatment levels necessary to create good habitats for aquatic life at artificial watersides to which treated wastewater is discharged.

Aiming to restore and create genuinely good habitats for aquatic life at receiving waters, we studied the relationship between aquatic biota, including algae, benthos, and fish, and environmental factors, including the quality of treated wastewater and hydraulic conditions at wastewater receiving waters, and propose an ideal form of wastewater reclamation system acceptable for the ecosystem in terms of effectiveness and economy.

Method

The research this year includes implementation of a control experiment of discharging wastewater treated by different processes and of varying water quality, in order to identify differences in aquatic biota created in the test channel under different conditions. We discussed the relationship between the quality of treated wastewater and aquatic biota.

The test channel was constructed inside an experiment building to eliminate the influences of natural conditions and keep the experiment conditions almost constant. Two types of stainless steel channel were used: one measured 2 m long and 5 cm wide and the other 2 m long and 9.5 cm wide. Six of each, totaling 12 channels, were installed for various conditions, such as supply water volume or flow rate. A plate for algae to grow on was installed in the upstream part of each channel, while gravel was laid on the downstream part for the benthic life experiment.

Experiments conducted this year were based on the following conditions, focusing on the relationship between concentration of nutrient salts or chlorination and periphytic algae or benthic life.

In the first experiment, dilute wastewater treated by an actual treatment plant using the anaerobic-anoxic-oxic process and sand filtration discharged

Channel 1: dilute wastewater treated by an actual treatment plant using the anaerobic-anoxic-oxic process and sand filtration

Channel 2: wastewater used for Channel 1 with nutrient salts added (set concentration: 5 mg/l for NO3-N and 0.05 mg/l for PO4-P)

Channel 3: wastewater used for Channel 1 with nutrient salts added (set concentration: 5 mg/l for NO3-N and 0.1 mg/l for PO4-P)

Channel 4: wastewater used for Channel 1 with nutrient salts added (set concentration: 5 mg/l for NO3-N and 0.5 mg/l for PO4-P)

Channel 5: wastewater used for Channel 1 with nutrient salts added (set concentration: 2 mg/l for NO3-N and 0.5 mg/l for PO4-P)

Channel 6: wastewater used for Channel 1 with nutrient salts added (set concentration: 1 mg/l for NO3-N and 0.5 mg/l for PO4-P)

- In the second experiment, wastewater treated by an actual treatment plant using the anaerobic-anoxic-oxic process and sand filtration discharged with chlorination

Channel 1: wastewater treated by an actual treatment plant using the anaerobic-anoxic-oxic process and sand filtration without chlorination

Channel 2: wastewater used for Channel 1 with chlorination (set concentration: 5 mg/l for residual chlorine)

Channel 3: wastewater used for Channel 1 with chlorination (set concentration: 3 mg/l for residual chlorine)

Channel 4: wastewater used for Channel 1 with chlorination (set concentration: 1 mg/l for residual chlorine)

Channel 5: wastewater used for Channel 3 with chlorination (set concentration: 0.3 mg/l for residual chlorine)

Channel 6: wastewater used for Channel 3 with chlorination (set concentration: 0.1 mg/l for residual chlorine)

Results

In the first experiment, it was found that Chl-a (alga biomass (mg/cm2)) and the growth rate of periphytic algae tended to increase with increase in phosphorus concentration. But algae appeared with a smaller number of species, which is inversely proportional to phosphorus concentration.

In the second experiment, the total cell count of algae (cells/cm2) is not proportional to increase in concentration of residual chlorine. And algae appeared with a smaller number of species under the influence of chlorination. But it was not fixed concentration of residual chlorine that influences algae growth. The authors consider it necessary to test cases with lower nutrient concentration according to the same procedure used this time in order to clarify the relationship between nutrients and periphytic alga.

Benthic life also appeared during both experiment, but with a smaller number of species. Leeches was the dominant types. The observed fact may be attributed to the amount of benthic life contained in untreated water. When analyzing the amount of benthic life that may exist or grow in the receiving water body, it is necessary to consider the amount of benthic life supplied by treated wastewater in addition to nutrient concentration and chlorination.

FATE OF SANITARY INDICATORS IN TREATED WASTEWATER

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Wastewater and Sludge Management Division

Project period: 2002-2004

OBJECTIVES

As a sanitary indicator of water, coliform bacteria are used for effluent standards, and fecal coliforms are used for bathing water at present. However, their fate in natural water is not known, for example, it is well known that coliform group often increases after disinfection, so these sanitary indicators may be unsuitable.

The Ministry of Health, Labour and Welfare therefore revised the water quality standards for drinking water, in which the use of coliform bacteria as a sanitary indicator was changed to E. coli. These standards will be enforced from April 1, 2004.

This study examined the propriety of sanitary indicators, the actual conditions in natural water and fates of sanitary indicators including conventional indicators such as coliform bacteria and new indicators such as E. coli, fecal streptococci, and enterococci.

METHODS

In FY2002, data on sanitary indicators in treated wastewater was gathered, and the tendency of whether these indicates are increasing or decreasing in water to which treated wastewater is discharged, was investigated. Therefore, in FY2002, an investigation using an experimental channel and a field study were conducted.

In the investigation using the experimental channel, the fates of sanitary indicators were studied by flowing treated wastewater disinfected by chlorine through the channel. The concentration of chlorine was set as 2.0 mg/L, and contact time was set as 15 min. The water was passed through the experimental channel cyclically. The experiment was continued for 6 months and samples were taken every week.

In the field study, the fates of sanitary indicators were studied at various actual sites to which treated wastewater was discharged from an actual wastewater treatment plant. Samples were taken from Lake Kasumigaura, Kokai River, landscaped spaces utilizing reclaimed wastewater in Yokohama city, and modified effluent in Hachioji city.

Coliform bacteria, fecal coliform, standard plate count, E. coli, and fecal streptococci in every sample were measured.

RESULTS

Some fundamental data concerning sanitary indicators were obtained through these studies. The results of the studies in FY2002 were as follows.

(1) From the investigation using the experimental channel, E. coli and fecal streptococci were thought to be more suitable as sanitary indicator because the other indicators increased greatly. However, the causes of the increase of indicators could not be determined, so other investigations should be conducted (Fig. 1).

(2) Concerning the field study, sanitary indicators except for E. coli increased at the landscaped spaces utilizing

reclaimed wastewater, and the modified effluent. On the other hand, only E. coli did not increase and remained almost constant.

(3) Concerning the field study, the difference between river or lake water and treated wastewater was clear, but the increase or decrease of sanitary indicators in the process of mixing or flowing was not observed (Table 1).
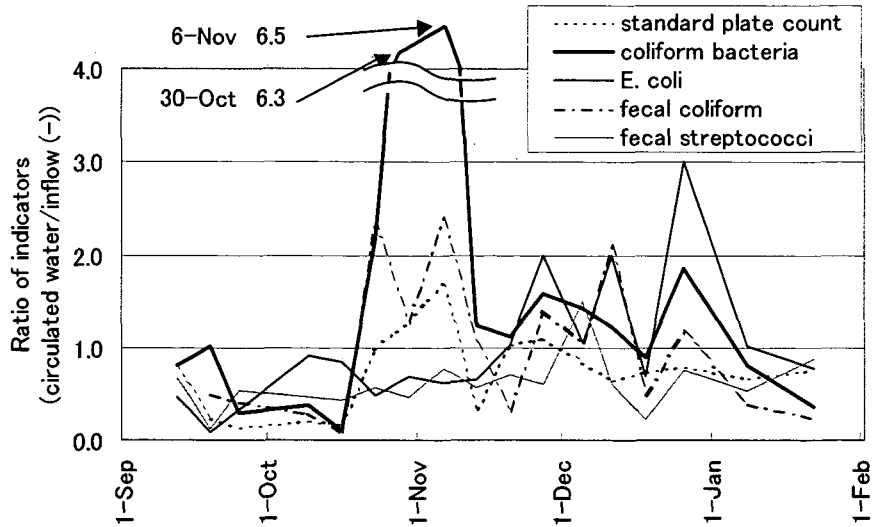

Fig. 1 The fates of indicators in the experimental channel

Table 1 Sanitary indicators of field study

Lake Kasumigaura

Oct. 8, 2002	water temp. [°C]	pH	DO [mg/L]	EC [mS/cm]	chlorine [mg/L] total	chlorine [mg/L] free	SS [mg/L]	COD [mg/L]	standard plate count	coliform group MPN	E. coli plate	fecal streptococci MPN
50 m upstream	23.6	6.71	5.50	0.49	0.07	0.03	6.5	5.5	3,680	>1,600	10	23
outlet of WTP	25.2	7.40	7.40	0.61	0.10	0.02	0.5	4.8	100	33	0	3
5 m downstream	24.5	6.39	6.70	0.60	0.11	0.05	2.0	5.3	85	79	0	3
10 m downstream	25.0	6.42	6.20	0.58	0.09	0.04	10.5	5.5	65	130	0	3
50 m downstream	23.8	6.50	5.95	0.50	0.08	0.06	14.5	5.9	1,710	>1,600	5	13

WTP: wastewater treatment plant

Kokai River

Mar. 10, 2003	water temp. [°C]	pH	DO [mg/L]	EC [mS/cm]	chlorine [mg/L] total	chlorine [mg/L] free	SS [mg/L]	COD [mg/L]	standard plate count	coliform group MPN	fecal coliform plate	E. coli plate	fecal streptococci MPN
50 m upstream	8.3	7.22	13.02	0.21	0.03	0.02	8.6	4.3	2,700	290	14	2	1
outlet of WTP	15.1	6.43	8.10	0.45	0.08	0.04	7.2	11.6	44,900	6,340	2,825	135	500
around the confluence	9.0	7.11	12.64	0.21	0.09	0.04	10.6	4.3	2,840	377	38	2	12
0.3 km downstream	8.7	7.17	12.96	0.21	0.06	0.04	8.8	4.3	3,180	377	29	3	3
1 km downstream	8.8	7.19	12.67	0.21	0.07	0.05	8.8	4.3	3,635	321	36	2	2

EFFICIENT REMOVAL OF SLIGHT HAZARDOUS MATERIALS BY OZONATION

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Project period: 2002-2004

OBJECTIVES

The problems of the slight hazardous materials represented by the endocrine disruptors are getting more serious year by year. These materials may have a bad influence on natural environment, ecosystem and human health even if these are slightly contained. Endocrine disruptor is said to decrease sharply in process of wastewater treatment by some researches, but the influence which endocrine disruptor have on ecosystem is unknown and it may be needed to decrease more on the basis of the influence. The objectives of this research is to establish the way of efficient removal of slight hazardous materials by ozonation.

RESULTS

We decided organic materials, endocrine disruptors(E2, NP, BPA, BZP), TOX and bacteria(E.coli, fecal coliform) as the target materials, and researched the influence which the factor of ozonation have on the amount of decrease of the target materials. As a result of this research, we could find out the below things.

(1) E2, NP, BPA decrease up to less than detected level by 5mg/l~20mg/l of ozone injection. On the other hand, BZP decreases up to less than detected level by more than 10mg/l of ozone injection.

(2) The removal percentage of TOX increases according to the increase of amount of ozone injection, and 60% of TOX is cut by 20mg/l of ozone injection.

(3) The removal percentage of E.coli and fecal coliform is about 1.5log ~2.5log, and the percentage is almost the same by 5mg/l~20mg/l of ozone injection.

(4) The removal percentage of all kinds of the target materials is almost the same by 7~20min of ozone contact time.

(5) 50~70% of E260 is cut by ozonation. On the other hand, the removal percentage of COD is 20~30% and TOC isn't cut almost at all. As a result of this, organic materials which have unsaturated combination are easily oxidized by ozonation, but are not inorganized.

(6) The higher the ozone gas concentration is, the higher ozone adsorption efficiency is on the condition of the constant rate of ozone injection.

(7) The rate of ozone injection is in proportion to the sum of electricity consumption of ozonizer. As a result of this, it is important to ozonize by the minimum rate of ozone injection in order to cut down the expense.

Advanced Systems for Effective Use of Sewage Sludge Energy

Y. Suzuki and S. Ochi

Recycling Research Team, Material and Geotechnical Engineering Research Group,

Public Works Research Institute

Project period: FY2000–2003

OBJECTIVES

Although the energy contained in sewage sludge is approximately 19 kJ/g-solids, no more than around 30% of this energy is used, even though considerable power and fossil fuels are consumed for sewage treatment. The aim of this study is to design an advanced system for the development and utilization of sewage sludge energy, by changing the current sludge treatment process into an energy production process. This can be achieved by converting the current incineration process into a power generation process and reforming the anaerobic digestion process into a power generating and heat recovering system based on methane gas recycling.

METHODS AND RESULTS

In FY2002, to clarify the fluctuation of power consumption levels of the main equipment and machinery installations in an existing wastewater treatment plant, continuous measurements were carried out and the data were analyzed in order to develop an effective system. Experiments on a pressurized fluidized incinerator were conducted using actual dewatered sludge to develop the new generation system. An adsorption gas storage system for advanced and consistent utilization of digestion gas was developed and implemented in practice, and life cycle assessment (LCA) and life cycle cost (LCC) analyses were performed. **Table 1** and **Table 2** show the results of these analyses, respectively.

Table 1   Results of LCA on adsorption gas storage system with gas storage capacity of 600 Nm³.

		adsorption gas storage system (developed system)	atmospheric pressured gas storage tank (conventional system)
LCA	**(t-CO₂)**	835	699
(formation)	construction	250	609
	operation	610	4.78
	evacuation	−24.9	84.9
LCA	**(10¹² J)**	16.29	8.58
(formation)	construction	3.22	7.80
	operation	13.35	0.08
	evacuation	−0.28	0.71

Table 2 Results of LCC on adsorption gas storage system with gas storage capacity of 600 Nm³.

		adsorption gas storage system (developed system)	atmospheric pressured gas storage tank (conventional system)
LCC	(10³ ¥)	182,128	232,697
(formation)	construction	112,130	189,800
	operation	66,211	32,006
	evacuation	3,787	10,891

Fate of Endocrine Disruptors in Sewage Sludge

Y. Suzuki, S. Ochi, and M. Minamiyama

Recycling Research Team, Material and Geotechnical Engineering Research Group

Public Works Research Institute

Project period: 2002 - 2005

OBJECTIVES

In recent years, there have been many reports on environmental problems caused by endocrine disruptors (EDs) discharged as trace chemicals in many countries and regions. Among the many manufactured chemicals necessary for daily lives and activities that are used and discharged, some can disrupt the endocrine system of humans and wildlife. Detailed investigations on this problem have been done 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. Research and investigation are needed to study countermeasures to deal with EDs in the sewerage system. This research aims to clarify the fate of EDs in the unit processes performed at sewage sludge treatment facilities and in the soil that includes sewage sludge compost.

RESULTS

In fiscal 2002, we carried out experiments to clarify the fate of EDs in composted sludge after land application.

The schematic diagram of a lysimeter is shown in Figure 1. Four lysimeters were set outside, which differed in soil layer conditions such as addition of sewage sludge compost or chemicals (Table 1). Samples were taken from leachate and soil, and nonylphenol (NP) and 17ß-estradiol (E2) were measured because these trace compounds were detected in higher amounts at many surveyed points during the national survey.

The JSWA analytical methods for wastewater and sewage sludge (JSWA, 2001) were applied, in which NP and E2 in soil were extracted with a reflux method and an ultrasonic extraction method and those in the pretreated samples were detected with GC/MS and ELISA, respectively.

The total amount of leachate during the two-year eight-month experiment was 6.3 − 8.2 times the volume of the soil layer.

High concentrations of NP and E2 were detected in the leachate at the early stage of the experiment, but decreased rapidly with time (Figure 2). The total amounts of NP and E2 which leaked out during the experiment for Cases 3 and 4 were 0.34 − 0.69% and 1.6 − 5.3% of the initial content in the soil layer, respectively. Very small amounts of NP and E2 leaked out from the soil layers which showed a lower leakage ratio for NP.

The NP and E2 contents in the soil layer of each lysimeter are shown in Figure 3. High contents were observed for the cases with compost, but decreased significantly to the almost the same level as that of the control after 300 days.

Because the size of the decrease of NP and E2 in the soil layer was much larger than the amount of NP and E2 that leaked out with rainfall, there must be a physicochemical or biological decomposition mechanism in the soil layer.
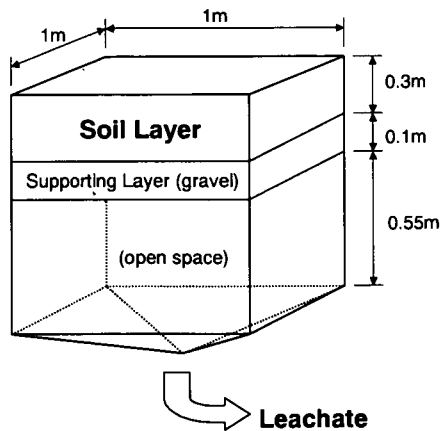
Figure 1   Schematic Diagram of a Lysimeter

Table 1   Experimental Conditions of Soil Layer in Each Lysimeter

	Condition of Soil Layer		Legend for Fig.2,3
Case 1	Soil	(control)	■
Case 2	Soil	+ Chemicals (NP, E2)	◆
Case 3	Soil + Compost		□
Case 4	Soil + Compost + Chemicals (NP, E2)		◇

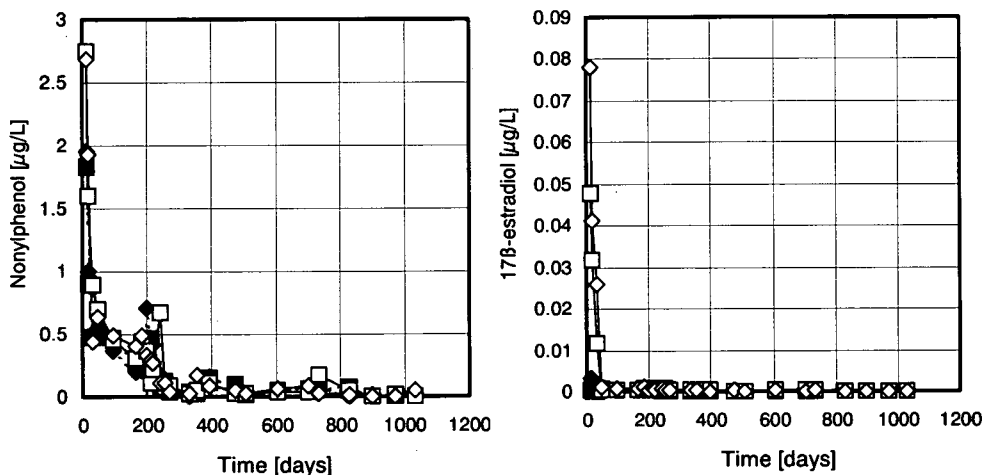Added chemicals: NP=500mg/lysimeter, E2=17mg/lysimeter

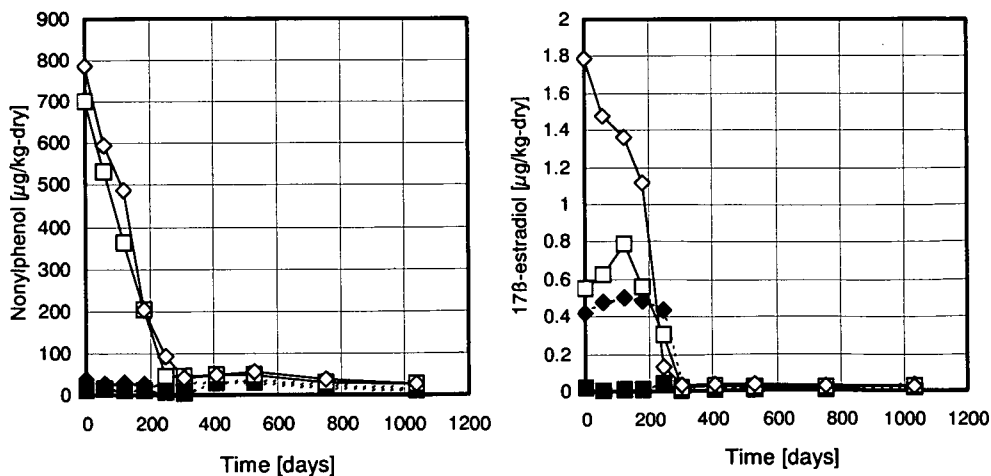Figure 2   NP and E2 Concentration in the Leachate from Lysimeter

Figure 3   NP and E2 Content in the Soil Layer of Lysimeter

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Recycling of Organic Wastes by Utilizing Bio-Solids Treatment System

Y. Suzuki and S. Ochi

Recycling Research Team, Material and Geotechnical Engineering Research Group,

Public Works Research Institute

Project period: FY2002–2005

OBJECTIVES

Large quantities of waste woods and grasses are produced during civil engineering works and maintenance of green sites such as road slopes, levees, airports and parks, and yet such wastes is scarcely used because of lack of effective means. On the other hand, wastewater treatment plants consume large amounts of energy and organic substances, therefore organic wastes have great potential as a substitute for such energy and organic substances. Moreover, bio-solids are a valuable microbiological resource containing many kinds of minerals and microorganisms.

This study aims to develop a method of co-fermentation of organic wastes and bio-solids in the existing anaerobic digester of a wastewater treatment plant, to contribute to the recycling of organic wastes.

METHODS AND RESULTS

In FY2002, we carried out experiments on the methane fermentation process of a mixture of bio-solids and waste woods which were steam-exploded. The addition of steam-exploded woods to the existing process of bio-solids methane fermentation increased the production of methane gas and fixation of isolated ammonia nitrogen. The dewaterability of fermented slurry was tested using ferric salt and polymer as coagulants, and it was revealed that the water content of the dewatered slurry was lower than that of the common fermented bio-solids, and that the filtered water was of good quality. Figures 1 and 2 show the results of dewaterability tests of fermented bio-solids of the fermented mixture of bio-solids and steam-exploded hardwoods.
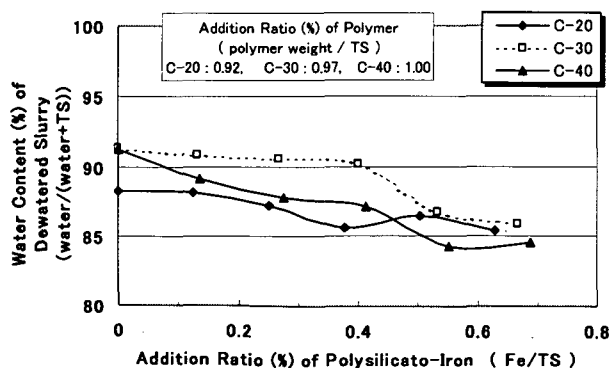

Fig. 1   Results of dewaterability tests of fermented bio-solids

where, C-20: Hydraulic Retention Time (HRT) = 20 days, C-30: HRT = 30 days and C-40: HRT = 40 days
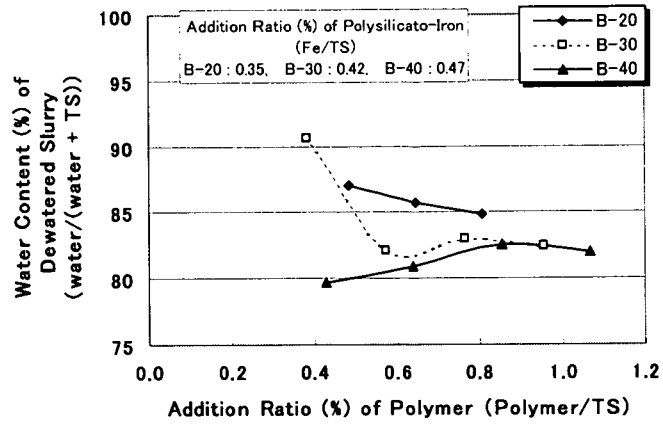
Fig. 2　Results of dewaterability tests of fermented mixture of bio-solids

and steam-exploded hardwoods

where, B-20: Hydraulic Retention Time (HRT) = 20 days, B-30: HRT = 30 days and B-40: HRT = 40 days

Development of Simplified Analysis Method for Dioxins
in Sediment Samples

Y. Suzuki, S. Ochi, and M. Minamiyama

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Public Works Research Institute

Project period: 2000 - 2002

OBJECTIVES

In recent years, the pollution by dioxins including tetra- through octa-chlorodibenzo-*p*-dioxins (PCDDs), tetra- through octa-chlorodibenzofurans (PCDFs), and coplanar polychlorobiphenyls (Co-PCBs) has become a major nationwide problem, as dioxins have high toxicity even in trace concentrations.

The amount of dioxins in bottom sediment may greatly change with sampling points. In order to carry out appropriate construction management and countermeasure evaluation, it is necessary to estimate the distribution of dioxins quickly and simply. On the other hand, the official method of measuring dioxins in bottom sediment, from sampling to acquiring analysis results, is time consuming. Thus, it is necessary to develop a quicker analysis method.

RESULTS

Water content is high for bottom sediment samples. In many cases, bottom sediment samples also contain large quantities of organic substances. Thus, the drying, extraction, and clean-up processes of the official method of analyzing dioxins in bottom sediment require complicated, time-consuming techniques. The analysis could be speeded up by innovating quicker drying and extraction techniques, therefore various drying and extraction techniques should be compared and examined.

We collected a bottom sediment sample of a river. Using this sample, we examined the effect of differences of drying techniques and extraction techniques on the analysis results. The methods used are shown in Table 1. Method A, which involves air-drying and soxhlet extraction, is the official method. Methods E, E1 - E7 are modified methods of pressurized fluid extraction (PFE).

Regarding the sampling and analysis method without drying and extraction processes, the official method was applied. The target substances were PCDDs,

Table 1. Main procedures and required time

	Drying Process	Extraction Process
Method A	Air-drying (a few days)	Soxhlet extraction using toluene (more than 16 hrs)
Method B	Percolation with acetone, followed by one day air-drying	Soxhlet extraction using toluene (more than 16 hrs)
Method C	Freeze-drying	Soxhlet extraction using toluene (more than 16 hrs)
Method D	Heat-drying (50°C)	Soxhlet extraction using toluene (more than 16 hrs)
Method E	Air-drying (a few days)	PFE using toluene (20 min, 2 times)
Method F	(not performed)	Potassium hydroxide ethanol solution is put in and left for one evening at room temperature, followed by shaking extraction using n-hexane (10 min, 3 times)
Method G	(not performed)	Ultasonic extraction using acetone (30 min), toluene (10 min), and n-hexane (10 min)
Method E1	(not performed)	PFE using toluene (20 min, 2 times)
Method E2	(not performed)	PFE using toluene with 20% acetone (20 min. 2 times)
Method E3	(not performed)	PFE using acetone (20 min) and toluene (20 min)
Method E4	(not performed)	PFE using acetone (20 min, 120°C) and toluene (20 min)
Method E5	(not performed)	PFE using acetone (10 min) and toluene (10 min)
Method E6	(not performed)	PFE using acetone (10 min), toluene (10 min). and n-hexane (10 min)
Method E7	(not performed)	PFE using ethanol (20 min) and toluene (20 min)

PCDFs, and Co-PCBs.

The obtained toxicity equivalency quantity (TEQ) values using the methods are compared in Figure 1. The TEQ values obtained by Methods C, E, E3, E4, and E7 were higher than that obtained by Method A. This means that the analysis results obtained using these methods can be considered to give safer values that those obtained using the official method. Compared with Method A in many isomers, Methods E, E3, E4, and E7 gave higher or almost the same values, as shown in Figure 2. Methods E3, E4, and E7 are expected to be quick, since the air-drying process is unnecessary. Especially, the variation coefficient obtained by Method E4 was lower than that obtained by the other two methods. Thus, Method E4 may be a useful alternative to the official method.

Methods A and E4 were compared using three sediment samples of different qualities. As a result, the TEQ values obtained by Method E4 were higher than or almost the same as that obtained by Method A.

Further verification using sediment samples of various qualities is necessary in order to use Method E4 instead of the official method. When Method E4 is used for actual polluted site investigations, its applicability must be examined beforehand. However, Method E4 is expected to be quicker for the analysis of dioxins in sediment samples.

Figure 1   Comparison of TEQ Obtained by Each Method

Figure 2   Comparison of Concentration Obtained by Each Method

Study on Techniques for Identifying Pathogenic Microorganisms and Analyzing Their Behavior

Y. Suzuki, T. Kitamura, and M. Nakamura
Recycling Team

Project period: 1999-2005

OBJECTIVES

In order to prevent outbreaks of infection caused by pathogenic microorganisms contained in treated wastewater, reclaimed water and sludge, it is important to ensure that those treated materials are safe with respect to pathogenic microorganisms. The ultimate aim of this study is to adapt techniques of molecular biology (particularly the Polymerase Chain Reaction method) to pathogen detection methods in order to develop a rapid and highly sensitive method for detecting trace levels of pathogenic microorganisms (such as viruses and protozoans) in natural water, treated wastewater and sludge. The study also aims to clarify the behavior of pathogenic microorganisms during the wastewater treatment process and in the environment.

The main areas of the work performed during FY2003 are described below.

The study focuses on the pathogen *Cryptosporidium*. The method currently used to detect *Cryptosporidium* oocysts is microscope observation of samples stained with fluorescent antibodies; however, this approach is unsuitable for wastewater samples, which have high levels of contaminants. We investigated a quick and simple quantitative detection technique based on the real-time PCR method.

RESULTS

Real-time PCR detection of the *Cryptosporidium* was possible from one oocyst by targeting the 18S ribosomal RNA gene.

The *Cryptosporidium* in wastewater was detected by recovering the oocyst with an immuno-magnetism bead and then carrying out DNA extraction and purification.
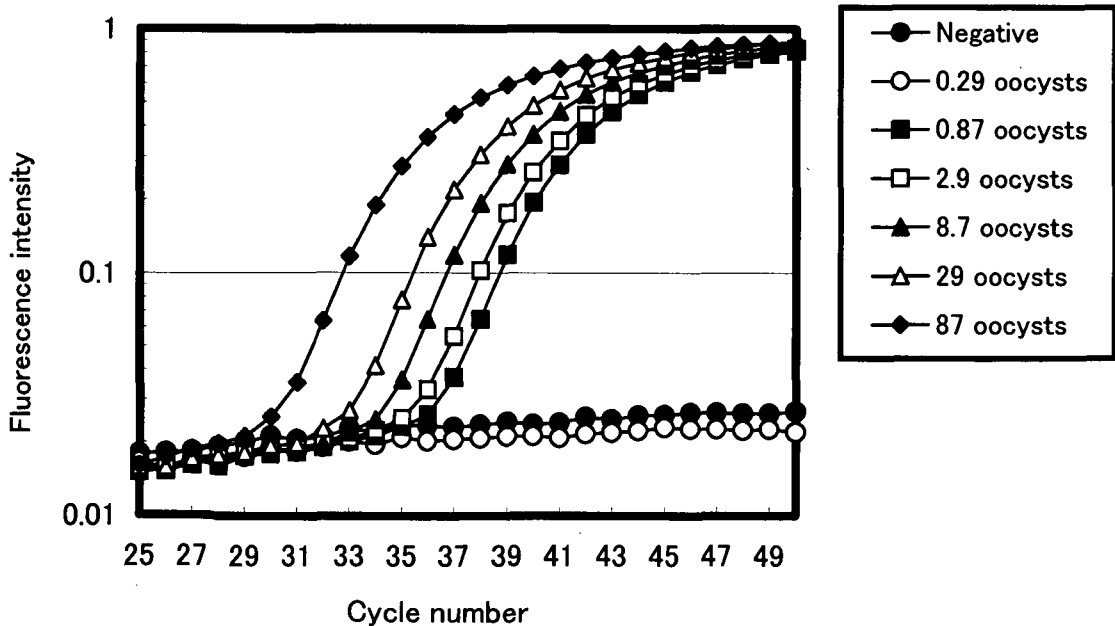

Fig. 1 Real-time PCR result of the *Cryptosporidium* oocysts

Study of Risk Assessment for Reuse of Sewage Sludge

Y. Suzuki, T. Kitamura and A. Minematsu
Recycling Research Team

INTRODUCTION

It is necessary to promote the reuse of sewage sludge while ensuring its safety in order to form a recycling-based society. At present, sewage sludge is recycled as a construction material and fertilizer.

The PRTR (Pollutant Release and Transfer Register) law was enforced in 2001, requiring sewerage managers to measure and report the status of heavy metals in the sewage treatment process. This study set out to clarify the behavior of heavy metals in the sewage treatment process and the amounts of heavy metals eluted from products made using sludge.

OBJECTIVES

The material balance of the heavy metals (Zn, Sb, Cd, Ag, Cr, V, Co, Se, Cu, Ni, Pb, Ba, As, Be, Sn, B, Mn, Mo, In, Tl, Te) that are included in the PRTR law, in the sewage treatment process was clarified in fiscal 2002.

METHOD AND RESULT

One-day composite samples of influent, primary effluent, secondary effluent and sidestream water were collected once a month for 5 months in a sewage treatment plant with an incineration facility. At the same time, samples of dewatered sludge and incineration ash were collected, but by spot sampling. Based on the survey results, the material balance in the sewage treatment process was clarified.

The fluctuation of influent load of Ba, B, Zn, Ni, Cu was large, but that of other elements was small. The behaviors of inflow load fluctuation of Ba, B, Zn, Ni, Cu were similar to each other. The removal ratios of heavy metals were different, but those of V, Cr, Mn, Co, Ni, Cu, Zn, As, Ag, Sb, Ba, and Pb showed the same behavior.

The remaining ratios in the ash of B, V, Cr, Mn, Co, Ni, Cu, Zn, As, Se, Mo, Ag, Cd, Sn, Sb, Ba and Pb were 1.2%, 65.3%, 49.2%, 23.1%, 26.3%, 16.6%, 75.1%, 48.4%, 36.0%, 20.7%, 17.8%, 80.7%, 66.2%, 88.8%, 69.0%, 79.3% and 75.8%, respectively.

The sidestream loads of heavy metals except for Se were in the range of 9 – 28% of the influent loads, but that of Se was almost the same as the influent load.
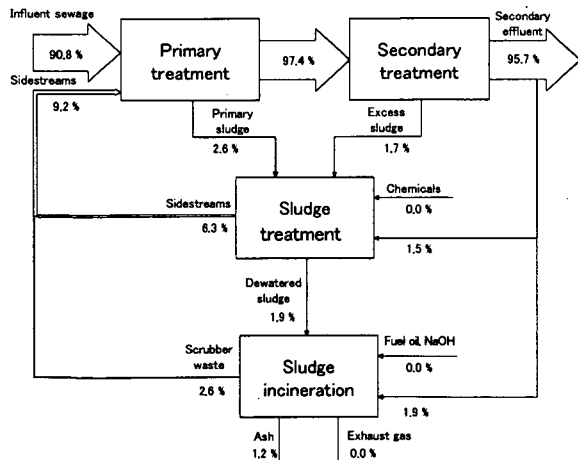
Fig. 1 Material balance of B in sewage treatment process
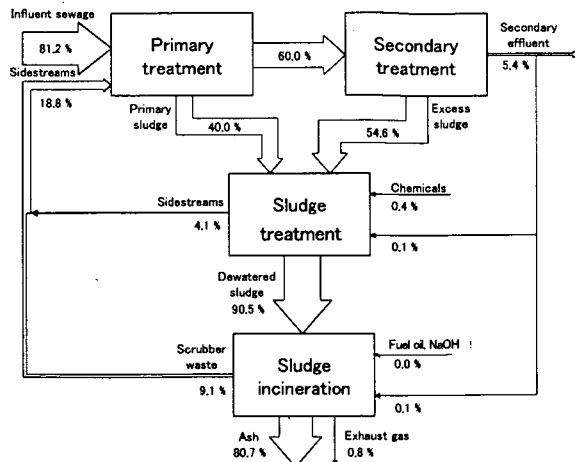

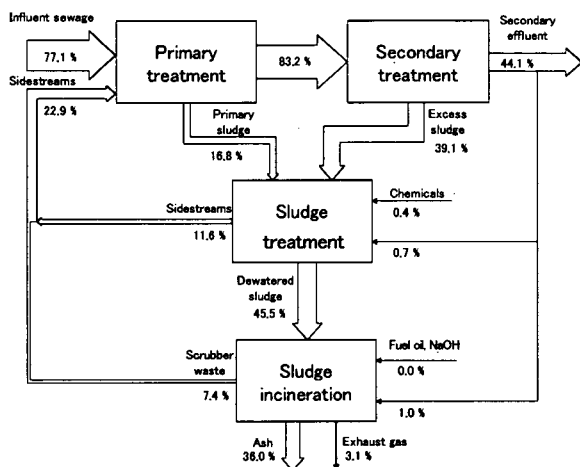
Fig. 2 Material balance of Ag in sewage treatment process

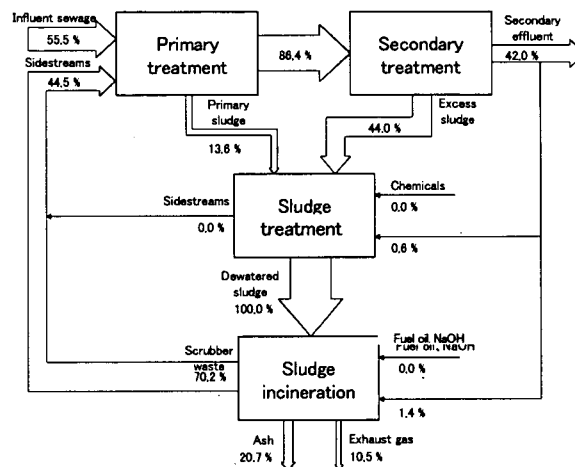Fig. 3 Material balance of As in sewage treatment process

Fig. 4 Material balance of Se in sewage treatment process

Residual organic matter removal for municipal sewage effluent reuse using advanced biological treatments

Kim Shijun and Suzuki Yutaka

Recycling Research Team, Public Works Research Institute

Project Period: 2002 - 2005

Objective

Municipal sewage effluent that usually maintains good water quality is discharged into public water areas such as rivers or estuaries. As part of water environment restoration, reuse of abundant municipal sewage effluent is gradually being regarded as a valuable method for obtaining new water resources in the near future. However, an obstacle to wastewater reuse is the existence of potentially residual organic matter (OM). Although residual OM has a low concentration, it can be a source substance for apparent bacterial regrowth by providing energy sources for biomass production. As a result, a biofilm accumulation or blockade in the distribution systems occurs as a result of the multiplication of viable bacteria. Lastly, the existence of residual OM can lead to deterioration of water quality, jeopardizing the feasibility of wastewater reuse.

Therefore, with the increasingly stringent requirements for effluent water quality, an effective treatment process for wastewater reuse is required. Reverse osmosis (RO) technology is gradually being applied in the field of water reuse, but because the cost remains high and it is strongly affected by energy consumption, an economical and efficient technology for eliminating residual OM is needed.

The objective of this study was to eliminate residual OM, thereby enhancing the value of sewage effluent as a water resource. This paper presents the results obtained from batch laboratory-scale experiments using advanced biological processes: an immobilization process and a membrane bioreactor process. Furthermore, NF membrane treatment was applied to effluents of both advanced biological processes.

Results

The MW distribution of the secondary sewage effluent of a conventional activated sludge process was separated into four peaks using the GPC method. The peaks were mostly small fractions less than MW 1000. Also, relatively large amounts of TOC of the residual OM were identified as small MW fractions, occupying 50% by UF fractionation.

The immobilization process removed large MW fractions >5000 in spite of short HRT, since immobilized microorganisms had sufficiently acclimated. The NF membrane was more effective in rejecting large MW fractions in the effluents of the immobilization and the MBR processes. It was difficult to reject small MW fractions <1000 by NF; thus the total TOC portion had a low rate of removal efficiency (Figure 1).

The immobilization and the MBR processes exhibited a significant removal rate of MW fractions >10,000 during the batch long-term aeration phase. However, MW composition following the long-term aeration phase was significantly converted to small MW fractions <1000 that might be hardly biodegradable (Figure 3).

The TOC difference in the treated water of the sequential immobilization reactor was quite little, and a very small quantity of microorganisms accumulated in the second reactor. It suggests that apparent bacterial regrowth potential is strictly controlled by the accumulation of effective microorganisms in the first reactor (Figure 3).
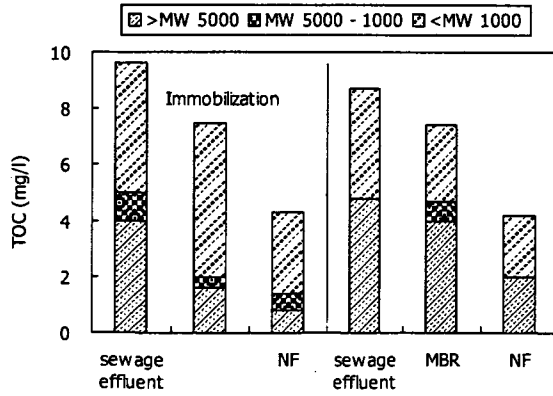
Fig. 1 Removal of MW fractions in advanced biological treatments (HRT; 3hrs) and NF
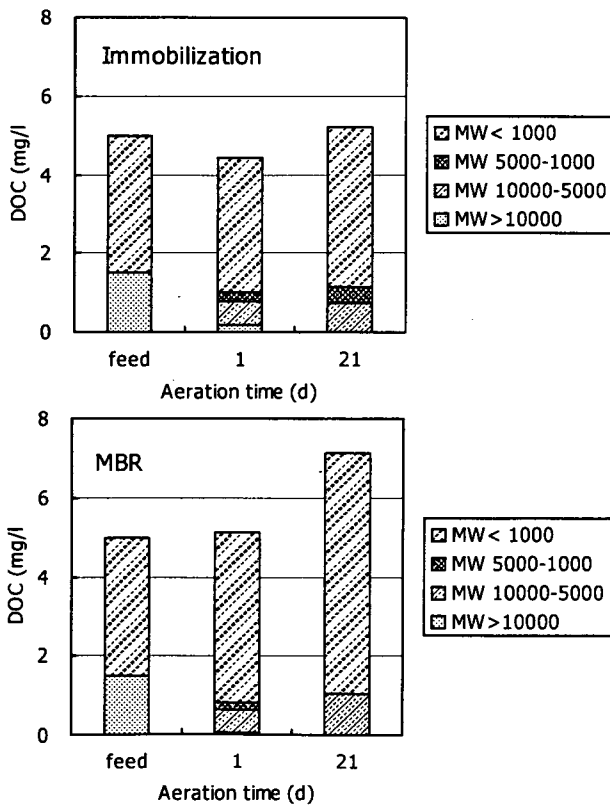treatment of both advanced biological effluents

Fig. 2 Removal of MW fractions in the advanced biological
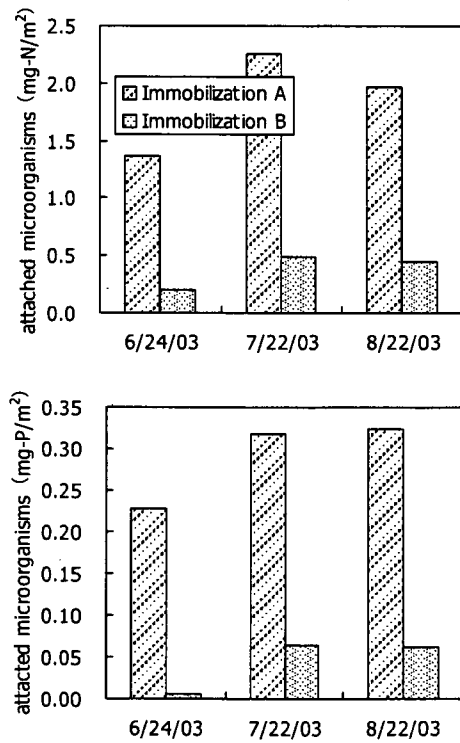treatments by long-term aeration

Fig. 3 Quantities of immobilized microorganisms of both
immobilization carriers

Status of Pollution and Fate of Polycyclic Aromatic Hydrocarbons in Lake Sediment

Y. Suzuki and M. Minamiyama

Recycling Research Team, Material and Geotechnical Engineering Research Group

Public Works Research Institute

Project period: 2002 - 2005

OBJECTIVES

In recent years, environmental pollution caused by hazardous organic substances has become a problem. It is thought that hazardous organic compounds that are generated or used in the watershed concentrate in closed water bodies via rivers. In particular, several papers have reported on the pollution of bottom sediment of closed water bodies with polycyclic aromatic hydrocarbons (PAHs). Figure 1 shows examples of the structural formulae of PAHs. Some PAHs such as benzo[a]pyrene (BaP) are reported as probable human carcinogens. Therefore, it is necessary to clarify the status of pollution of sediment with PAHs.

RESULTS

In fiscal 2002, literature investigation and analysis of PAHs in sediment samples collected from the surface layer of bottom sediment of a lake were carried out.

The literature investigation revealed that PAHs were not detected in large quantities from water samples that had been sampled from some closed water bodies in Japan. On the other hand, PAHs were frequently detected in the bottom sediment samples. It was also reported that the amount of PAHs in the sediment samples became high in the closed area of river mouths. Therefore, it is necessary to investigate not only the pollution situation of various closed water bodies but also the pollution distribution in closed water bodies.

The surface samples were collected from three sets of core samples of bottom sediment that had been collected at almost the same sampling point in a lake. A schematic diagram of the lake and the sampling point is shown in Figure 2. This lake is in a state of eutrophication. The sampling point is far from pollution sources such as roads and river mouths. The amounts of sixteen kinds of PAHs shown in Figure 1 were measured using GC/MS. Table 1 shows the results. The amounts of PAHs in the surface samples of the bottom sediments were within the ranges that had already been reported.

In the following years, we will investigate the pollution distribution of PAHs in some closed water bodies and examine the relationship between pollution situation and land use in the watershed of closed water bodies.

naphthalene

acenaphthene　　acenaphthylene　　anthracene　　fluorene　　phenanthrene

fluoranthene　　pyrene　　benz[a]anthracene　　chrysene

benzo[a]pyrene　　benzo[b]fluoranthene　　benzo[k]fluoranthene　　dibenz[a,h]anthracene

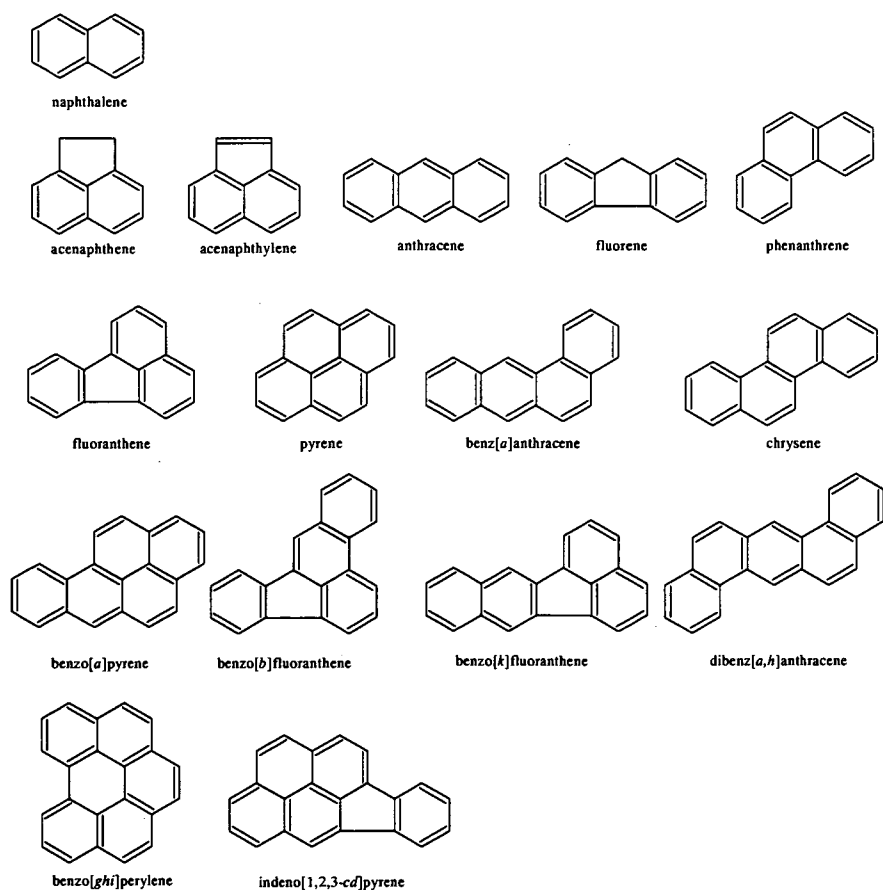benzo[ghi]perylene　　indeno[1,2,3-cd]pyrene

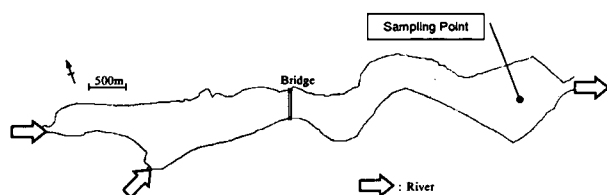Figure 1　Examples of Structural Formulae of Polycyclic Aromatic Hydrocarbons

Figure 2　Schematic Diagram of the Lake and the Sampling Point

Table 1　Amount of PAHs in the Sediment

[ng/g-dry]

	No.1	No.2	No.3
Naphthalene	83.8	61.5	80.5
Acenaphthylene	22.4	19.3	26.3
Acenaphthene	6.0	4.7	6.2
Fluorene	34.2	25.1	41.3
Phenanthrene	108.7	81.2	75.5
Anthracene	12.0	10.1	12.1
Fluoranthene	80.4	61.9	94.9
Pyrene	70.0	54.2	79.8
Benz[a]anthracene	14.2	10.7	16.5
Chrysene	24.3	18.4	29.1
Benzo[b]fluoranthene	17.4	13.3	19.7
Benzo[k]fluoranthene	7.5	5.6	8.0
Benzo[a]pyrene	12.1	9.0	13.5
Indeno[1,2,3-cd]pyrene	24.1	18.1	27.4
Dibenz[a,h]anthracene	0.7	0.4	0.8
Benzo[ghi]perylene	6.9	4.4	7.1

RESEARCH ON EVALUATION OF TRACE CHEMICALS
AT WASTEWATER TREATMENT PLANTS

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

Project period: FY2001 – 2005

OBJECTIVES

Sewage works accept domestic and industrial wastewater, treat them and discharge treated water into the receiving water. Wastewater contains various chemicals and it has been pointed out that a very small amount of chemicals (trace chemicals) still remain in final effluent from wastewater treatment plant. Therefore, at present, it is required to reduce trace chemicals from wastewater treatment plant and to ensure safety of final effluent. In this survey, endocrine disrupting chemicals were mainly focused on out of various trace chemicals. Objective of this survey is to develop methods for estimating suspected endocrine disrupting chemicals in wastewater. In FY 2002, we conducted 1) development of ELISA method for roughly and rapidly measuring free estrogens in wastewater and 2) development of analytical methods for correctly measuring free/conjugated estrogens, nonylphenol (NP) and its related substances and understanding of behavior of these trace chemicals in wastewater treatment process.

RESULT .

1. Development of ELISA method for measuring estrogens in wastewater

Pretreatment procedures of ELISA kit for measuring estrone (E1) were studied. Following two procedures were compared about influent and secondary effluent of 20 WWTPs.

Procedure-I (P-I) :Sampled, Refrigerated, Solid Phase Extraction with C18, Eluted with dichloromethane

Procedure-II (P-II):Sampled, Added ascorbic acid, Refrigerated, Solid Phase Extraction with C18, florisil
and aminopropyl.

In both procedures, almost all estrone added to water samples was recovered in final extraction. About P-I influent, values measured by ELISA were much overestimated compared with those by LC/MS/MS. But about P-II influent, P-I secondary effluent and P-II secondary effluent, values measured by ELISA were within 1.5 times as much as those by LC/MS/MS. Therefore, using florisil and/or aminopropyl were effective for reducing overestimation.

2. Understanding of behavior of trace chemicals in wastewater treatment process

A bench-scale conventional activated sludge treatment process accepting actual municipal wastewater was studied. Concentrations of 17β-estradiol (E2) and estrone (E1) of the influent were the same as those of the

primary effluent, and so it is thought that degradation of E2 and E1 did not occur in primary sedimentation process. Concentrations of E2 were gradually decreased in the aerobic process and finally became lower than the detection limit (0.5ng/L) in the middle of the aerobic process. On the other hand, concentrations of E1 in the aerobic process temporarily increased and reached to 1.8 times as much as those of the primary effluent and then gradually decreased. E2 seemed to be easily decomposed by activated sludge and changes to E1 as some previous surveys reported. Degradation rate of E1 was smaller than that of E2, so that E1 remained in the aeration tank.

Concentrations of NP, nonlyphnol ethoxylates (NPnEOs) and nonylphenoxy acetic acids (NPnECs) drastically changed in the aerobic process. NP and NPnEOs decreased and became from one tenth to one hundredth as much as those of the influent, while NPnECs became more than twice as much as those of the influent. In the influent and the primary effluent, various NPnEOs (n=1-12) existed almost equally, while NPnEOs (n=5-15) disappeared and there remained from NP1EO to NP4EO in the final effluent. On the other hand, in terms of NPnEC, there existed a little high NP2EC and NP3EC and almost equal NP1EC and NP4EC∼NP10EC in the influent and the primary effluent. In the aeration tank, NPnECs (n=5-15) declined and NPnECs (n=1-4) increased. About 96% of NPnECs in the final effluent were NPnECs (n=1-4). These results indicated that NPnEOs were drastically decomposed in aerobic process. And it is considered that there are two major degradation pathways. One degradation pathway is that NPnEO changes to shorter EO-chain NPnEO. The other degradation pathway is that NPnEO changes to NPnEC and further to shorter EO-chain NPnEC. In the aerobic process, NPnECs accumulated because of difference between degradation rate of NPnEOs and that of NPnECs. Moreover, it is likely that NPnEOs (n=1-4) changed to NPnECs because obvious increase of NPnECs (n=5-15) were not observed. The result indicated that NPnEOs are decomposed to not NP but NPnEO (n=1-4) and NPnEC(n=1-4) in aerobic wastewater treatment process.

Finally, a method for measuring estrogen conjugates in wastewater with LC/MS/MS was developed and applied to actual wastewater. Target substances were followings; estrone-3-sulfate (E1-S), β-estradiol 3-sulfate (E2-S), estriol 3-sulfate (E3-S), estrone β-D-glucuronide (E1-G), β-estradiol 17-(β-D)-glucuronide (E2-G), estriol 3-(β-D-glucuronide) (E3-G), β-estradiol 3-sulfate 17-glucuronide (E2-S&G) and estradiol 3,17-disulfate (E2-diS). Further improvement of pretreatment procedure were needed because only less than 50 per cent of sulfates and glucuronides added to water sample were recovered after pretreatment. We applied the method and found that removal efficiency of free estrogens (E2 and E1) in wastewater treatment was 89-99%, while removal efficiency of a conjugated estrogen (E2-G), which is said to be easily decomposed by activated sludge and changes to E2, was 58-93%. And it was observed that concentrations of estrogen conjugates in the influent and the final effluent were 2-100 times as much as those of free estrogens. Observed concentrations of E1-S and E2-S in the influent were as much as values, E1-S (6.4ng/l), E2-S (2.7-62.9ng/l), which is previously reported. But, observed concentrations of E3-S and E2-G in the influent were about 30 times as much as previously reported values, E3-S (4.5ng/l), E2-G (<0.8-12.7ng/l).

EFFECTS ON WATER ENVIRONMENT AFFECTED BY SEWERAGE SYSTEMS

H. Tanaka, M. Sasaki, H. Tamamoto, N. Miyamoto
Water Quality Team

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 watershed, partially in urban areas. A previous report has shown that in certain river areas, the reuse ratios for wastewater after treatment have exceeded 90%.

The major objective of the present research was to examine the impacts of consolidation of sewerage works upon the river water quality and aquatic organism ecosystems. Besides this, the influences of chemical compounds in sewage effluent, especially endocrine disrupting chemicals performing like feminine hormones, on aquatic organisms such as fishes were also studied.

RESULTS

In 2002, an observatory study on the pollution discharges of the Ohtsu River, an urban river flows into the Lake Teganuma, was performed. Then, the impacts of associated river basin variances on the stream conditions and the discharged pollution loads were examined. Moreover, to evaluate the estrogenic effects of sewage discharges on aquatic organisms, a risk assessment experiment was conducted by exposing a fish species to the wastewater using an experimental unit installed in a wastewater treatment plant.

The research of this year led to the following results. The changes in the mechanisms of water circulation were assessed. The needs for further investigations of the accumulation and decomposition of organic substances and nutrient salts in river channel were clearly demonstrated in order to better understand the sewage impacts on natural water environment systems.

To investigate the sewage impacts on fishes, two series of exposure tests using male carp and mixed male and female carp, respectively, were performed. No matter which test series was concerned, the VTG formation was not recognized for the male carp used. Similarly, for the parallel control test conducted using tap water after the removal of residual chlorine, the VTG formation for the male carp was not found either. The reason for the observed result that VTG was not induced in the male carp was probably because the male carp's physiological activities depressed in the period of April when the test was conducted, taking into account the understanding that

male carp is physiologically most active in early spring.

By introducing the measurement of EROD activity, tests related to the P4501A1 formation of carp became feasible. An increasing tendency of EROD activity was observed in the test series of exposure to treated wastewater samples. It was thus conceived that drug-metabolic enzyme was probably induced with the treated wastewater.
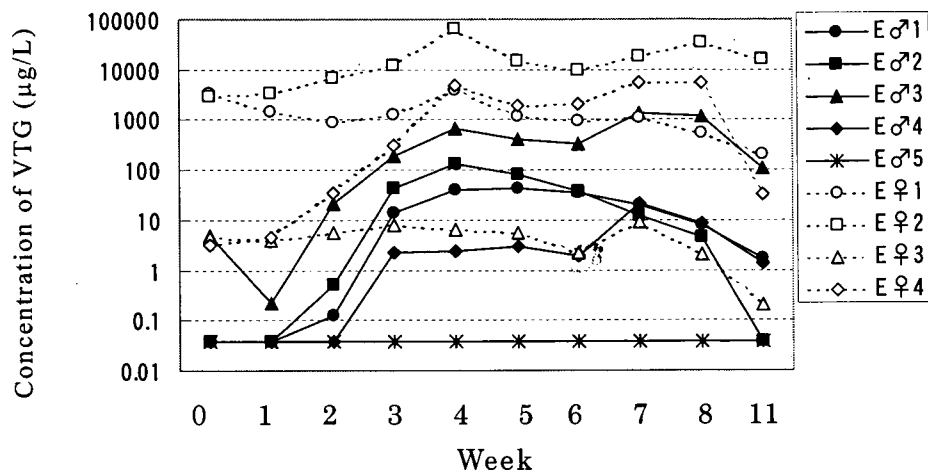

Fig.1 Concentration of VTG (μg/L)

SYSTEMATIC WAY FOR SURVEYING WATER QUALITY OF RIVERS

H. Tanaka, K Komori and M Sasaki
Water Quality Team

Project period: 2000 - 2002

OBJECTIVES

Water quality surveys are now performed in conformity with the River Erosion Control Technical Standard, however, individual river administrative officials are allowed to independently decide the needed survey locations and survey frequencies. It is necessary to clarify the significance of the measurements and set rational survey conditions for implementation of more efficient water surveys. The present situation is that river water quality surveys are not necessarily systematized.

This study, has been therefore, carried out in cooperation with a couple of technical offices in order to systematize water quality surveys and finalize related regulations. The Public Works Research Institute will study the basic theory of water quality surveys performed by river administrative officials and in particular, the bottom sediment survey method that is one specific category of survey method that has not been sufficiently systematized.

RESULTS

In 2002, an analysis based on existent manuals and the data of executed questionnaire investigations towards regional bureaus of the Ministry of Land, Infrastructure and Transport was conducted. Then, present situations in regard of the sediment release tests and the oxygen consumption rate tests were evaluated. Based on these, the sediment release tests and the oxygen consumption rate tests were proposed in consideration of the present technological levels.

And, future subjects and work needed for systematic sediment investigations were put in order as follows.

Major Subjects and Measures for Standardization of Sediment Releasing Experiments

1. Sampling Method

The representative capability of supplied samples to targeted water bodies is examined based on case studies and statistical analyses.

2. Comparison of Experimental Methods

The results obtained by employing different methods for an identical sample should be compared.

3. Cautions to Be Paid

1) The run time needed for indoor batch experiments was analyzed based on observed results. A run time of about 10 days, which is shorter than 15-20 days practiced so far, was confirmed suitable for the releasing trend to be stable.

2) The volumetric ratio of water to the sedimented mud played an important role when the releasing of nutrients from disturbed sedimentate mud was assessed. Also, from the viewpoint of the phenomenon evaluation, analytical results for nutrients in both dissolved and particulate forms were confirmed necessary.

3) Cautions that had to be noticed for manipulation of the experiments were summarized. An examination of each individual item is found indispensable from now on.

4. The Releasing and Oxygen Consumption Mechanisms of Sediments

By characterizing the phosphorus species in sedimented particulates, these mechanisms should be elucidated by examining the phenomena involved in respective processes.

5. Assessment of Experimental Results:

1) Considerations relate to the calculation of nutrients' releasing rates were presented based on the results obtained from batch and sequential indoor experiments.

2) Examinations were needed as related to the assessment of results obtained using in-situ experimental facilities.

Besides this, an action draft of "River Water Quality Investigation Outlines (draft)" was summarized. The subject which became clear is as the following.

1. Basic considerations related to monitoring indices, locations and frequencies were summarized when an investigation plan was to be prepared. All these were systematically summarized as a draft version of 'River Water Quality Investigation Outlines (draft)'.

2) Existent experimental methods and releasing data obtained through experiments performed by the Ministry of Land, Infrastructure and Transport were analyzed and assessed, for releasing experimental methods with few descriptions on detailed technical criteria. As a result, the test methodology for monitoring river sediments was summarized in details.

3) As a future topic relates to sediment investigations, furthered evaluations and modifications are considered necessary for test methods that have not been thoroughly compared.

Investigations should also be made on such aspects as the subjects of the outlines, the technological development information of foreign countries. Based on the results, efforts that could lead to furthered improvement of practical technologies, involving planning, monitoring, and method modification and development, are expected.

DEVELOPMENT OF TECHNOLOGY FOR DIOXIN CONTAMINATED SOIL COUNTERMEASURES

H. Tanaka, K. Komori, Y. Okayasu and M. Yasojima

Water Quality Division

Project period: 2000 - 2002

OBJECTIVES

In recent years, the pollution by dioxines (DXNs) including tetra- through octa-chlorodibenzo-p-dioxins (PCDDs), tetra- through octa-chlorodibenzofurans (PCDFs), and coplanar polychlorobiphenyls (Co-PCBs) has become a major nationwide problem, as dioxins have high toxicity even in trace concentrations.

The content of dioxins in the bottom sediment may greatly change with collection position. In order to carry out appropriate construction management and countermeasure evaluation, it is necessary to estimate the distribution of dioxins quickly and simply. The official method which is high resolution GC/high resolution MS (HRGC/HRMS) method of measuring dioxins in bottom sediment and in water samples, from sampling to getting analysis results, is time consuming, so it is necessary to develop a quicker analysis method.

In this research, it aims at development of the simple detection technology which used the enzyme-linked immunosorbent assay (ELISA$_{ECO}$ and ELISA$_{DT2}$) method, Ah receptor binding assay (Ah-IA) and high resolution GC/low resolution MS (HRGC/LRMS) method. Moreover, a judgment is difficult if the accuracy management technique of the official method is complicated like analysis and it is not a specialist. Technique which can be easily judged also by whom is proposed.

RESULTS

In this research, the following results were obtained about the simple analysis method and the accuracy management technique.

1) We carried out joint research with private sector about ELISA$_{ECO}$, ELISA$_{DT2}$ and Ah-IA. We investigated the feature of ELISA$_{ECO}$, ELISA$_{DT2}$ and Ah-IA, and it were compared with the actual sample. The value of ELISA$_{ECO}$ and Ah-IA showed the larger value than the concentration of DXNs. The value of ELISA$_{DT2}$ showed the large value or the small value than the concentration of DXNs.

2) Comparison examination was carried out using the sample which performed the pretreatment of the same dryness, extraction, and refining about the simple detection technique by ELISA$_{ECO}$, ELISA$_{DT2}$, Ah-IA and HRGC/LRMS. Though there were few samples (20 samples), comparatively good correlation was obtained (Figure 1).

3) We patternized and systematized the check work of measurement data and the reported measured value created the software which checks whether it is obtained in the state of satisfying the quality control specification defined by the official method.
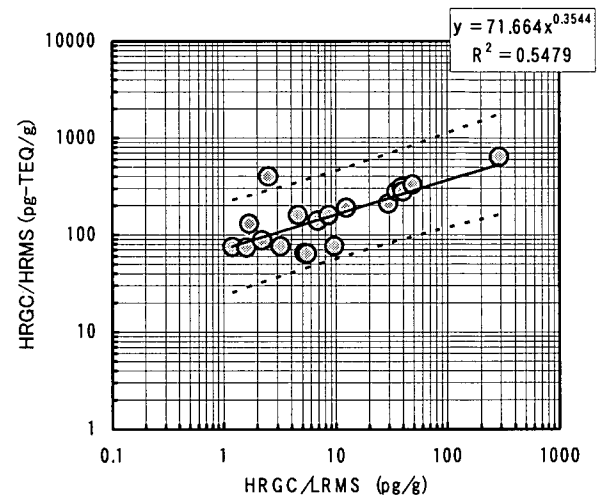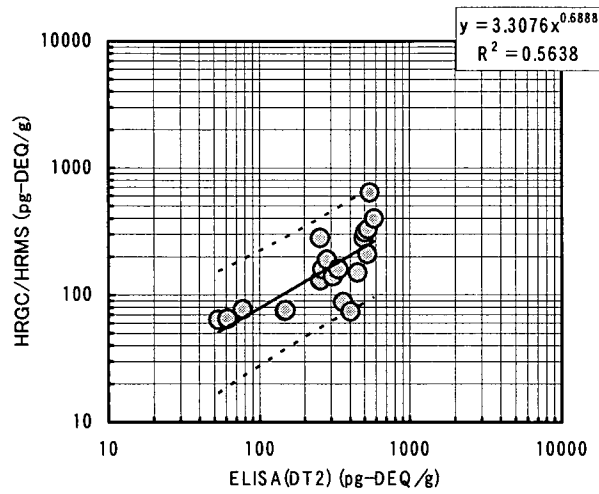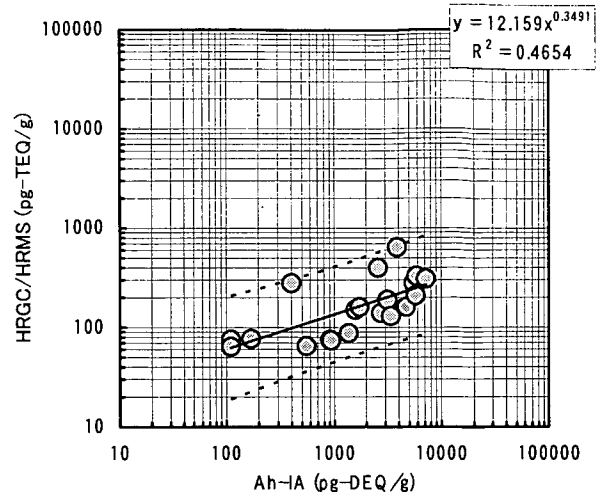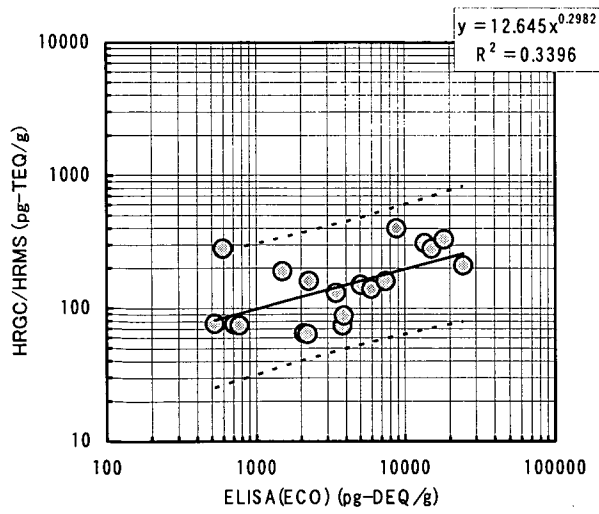
Figure 1 Relationship between the simple detection technique and the official method

(----: 95% confidence interval)

Evaluation of River Water Quality from the Viewpoint of Aquatic Ecosystem

H. Tanaka, K. Komori, H. Tamamoto, and N. Miyamoto

Water Quality Team

Project period : FY 2000-2005

OBJECTIVES

In recent years, sewerage systems have widely spread in urban areas. At the same time, the volumetric percentage of water in river water sources quantity derived from sewage treatment plants (STPs) has been increasing. As a result, the quality of river water is greatly influenced by the quality and the quantity of treated wastewater. It is, therefore, assumed that the treated wastewater may exert positive or negative impacts on natural ecosystems. However, studies on STP discharge's impacts upon organisms and receiving rivers are very limited.

The final objective of this study is investigated the relationship between water quality and living organisms. Tama River was selected as the research site.

In FY 2002, we investigated the mixing characteristics of treated wastewater and river water. Furthermore, we investigated the diversities and the quantities of benthos.

RESULTS

The summary of the study conducted in FY 2002 is as follows.

(1)The treated wastewater was not mixed to river water at 100m downstream from the discharge outlet (St.2). Figure-1 shows the changes of the electric conductivity changed in the cross direction of the stream at St.2. Treated wastewater was nearly blended at downstream position 1400m away from the discharge outlet (St.3). The blended behavior in summer differed greatly from that in winter. This difference was considered to be attributed to temperature differences between the river water and the treated wastewater.

(2) The quantity of benthos differed in the cross direction at the St.2 where treated wastewater was not mixed sufficiently with the river water as shown figure-2. There were declining tendencies for the amounts of benthos and also for the diversity index towards the left bank of the river where the rate of treated wastewater was high.
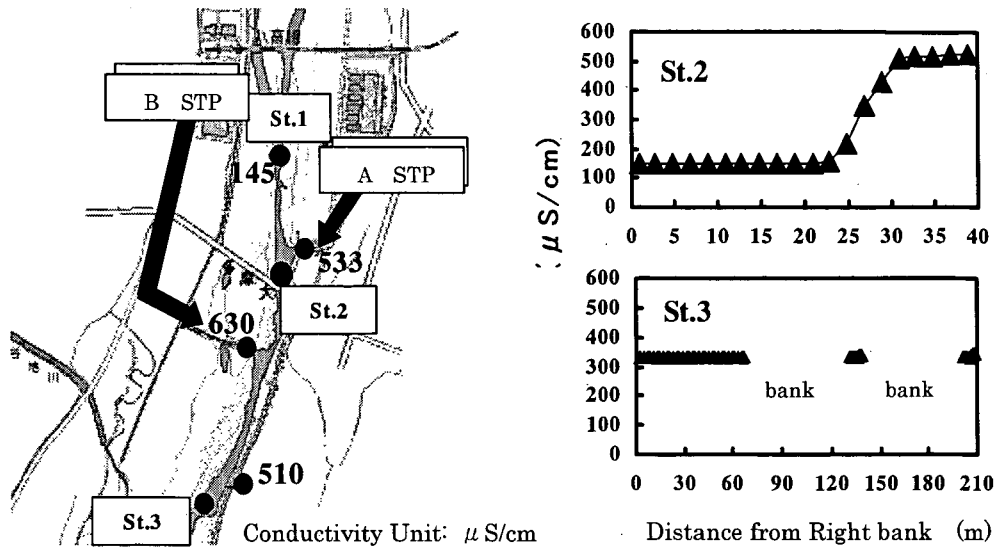
< This study is done as a part of the research of River Ecology Research Group.>
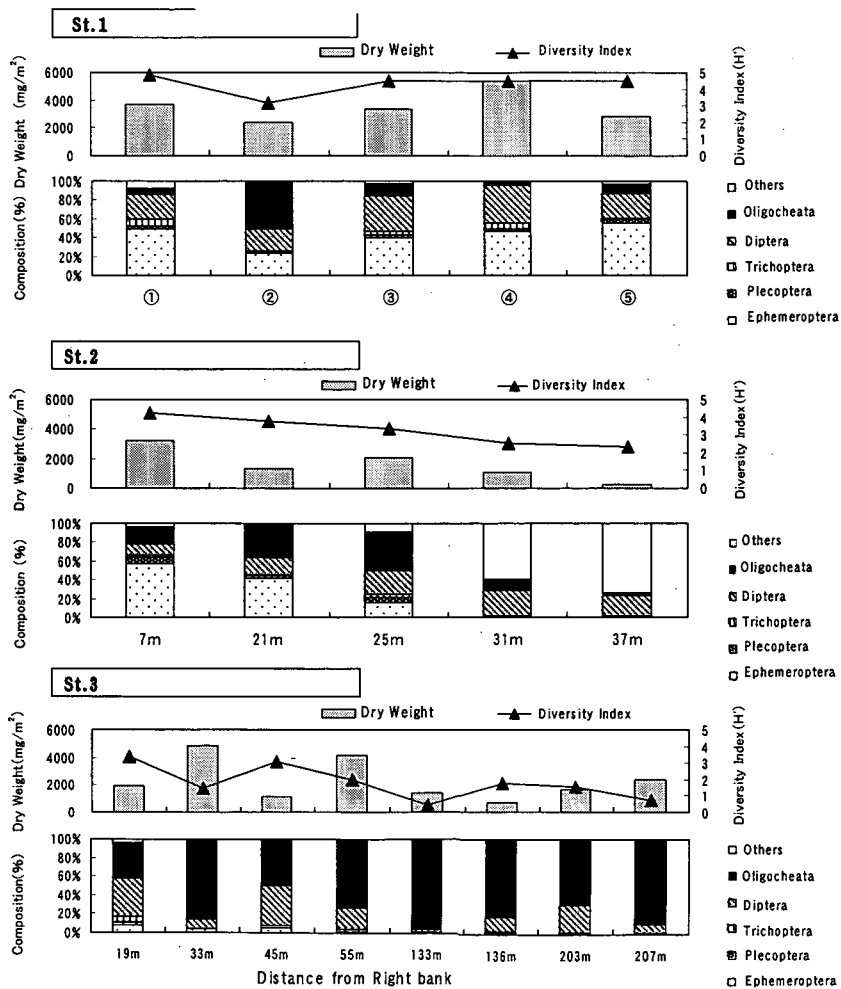
Fig.·1　Conductivities of river water in Tama Ohashi area

Figure-2　Dry weight, Diversity Index and Composition of Benthos

TRANSPORT OF CONTAMINANTS AT SEDIMENT-WATER INTERFACE

H. Tanaka, M. Sasaki, J. Li, J. Wada

Water Quality Team

Project period: FY2001-2005

OBJECTIVES

The release of pollutants from the sediment mud in water systems is a reason that causes delays for the water quality improvement. Besides their impacts on water quality, the delays may also influence the environment of aquatic organisms. It is thus necessary to establish some effective countermeasures relate to the bottom mud and to predict the future water quality. For such purposes, the changing mechanisms of pollutants (including nutrient salts) in sediments should be clarified, and effective approaches for assessment of the sediment impacts upon water quality are urgently needed.

The aims of this investigation were to elucidate the releasing mechanisms of nutrients form sediments, and to propose a test methodology for quantification of the released nutrients, and an estimation method for assessing the impacts of sediments on water qualities.

RESULTS

An indoor experiment was performed in 2002 for investigating the exchanges of nutrients between sediment particulates and water, accompanied by such processes as settlement, sorption and releasing. And, investigations were also made for the purpose of building an *in-situ* monitoring system for water column and surface layers of the sedimented mud in the spot of lake and dam reservoirs.

The relations of the released amounts of nutrients with such continuous *in-situ* monitoring results as water temperature, DO (Dissolved oxygen) and ORP (Oxidation reduction potential) were examined. The *in-situ* experiment was conducted in the Ushikubiri Reservoir, a pre-reservoir of the Miharu Dam, from July to September of 2003. This experiment involved supplying oxygen water with a higher oxygen concentration in the reservoir. During the experimental period, water temperatures, DO and ORP were consistently monitored, and data relate to these indices were also collected both before and after the experiment.

Water quality results collected nine days after the introduction of the oxygen water were compared with those collected one day prior to the oxygen introduction. A decrease in the NH4-N concentration was observed as a result of the rise in the DO concentration of the water at the depth of 5-6m. And, a rise in the NO3-N concentration was also confirmed. The result implied that nitrification in the deep part of the water column was promoted. On the other hand, the remarkable decrease in the NO3-N concentration observed in the water depth of 3-4m was conceived to be a result of enhanced denitrification. The decreases in the content of TN, DTN and DOC observed at the same water depth could be also explained with the hypothesis raised above. Nitrification and denitrification were also confirmed in the water column of the Point B. It was conceivable that the quantity of ammonia released from the sedimented mud was efficiently removed.

Besides all these, field investigations and indoor experiments were also conducted for quantification of nutrients

released from sediments and for assessment of related releasing mechanisms.

From now on, an ORP sensor will be used in spot observations, and the oxidation-reduction conditions in deep water layer and bottom mud will be confirmed. Based on this approach, efficient *in-situ* observatory methodologies needed for monitoring and estimation of water quality and released quantities of nutrients will be developed. In regard of indoor experiments, a turbidity monitoring system is decided to be combined in addition to DO and ORP. An experimental approach for estimating the released quantities of nutrients from sediments, based on indoor static and suspended releasing experimental modes, will be established. All finding obtained will benefit the systematization of nutrient releasing test approaches.
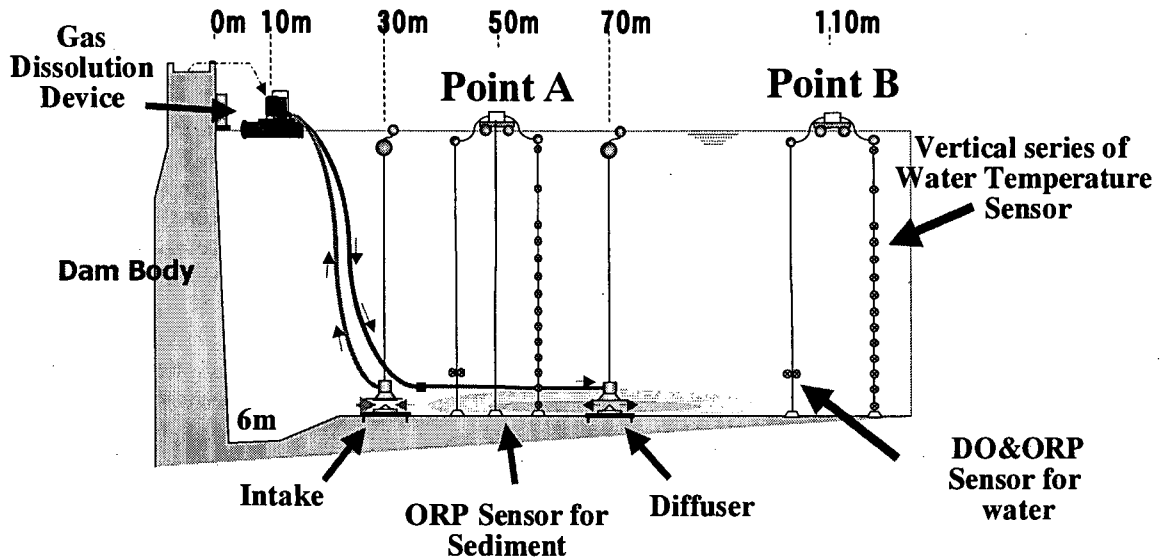
Fig.1 High Oxygen Supply System to the Deep Layers in Reservoir and Water Quality Monitoring System
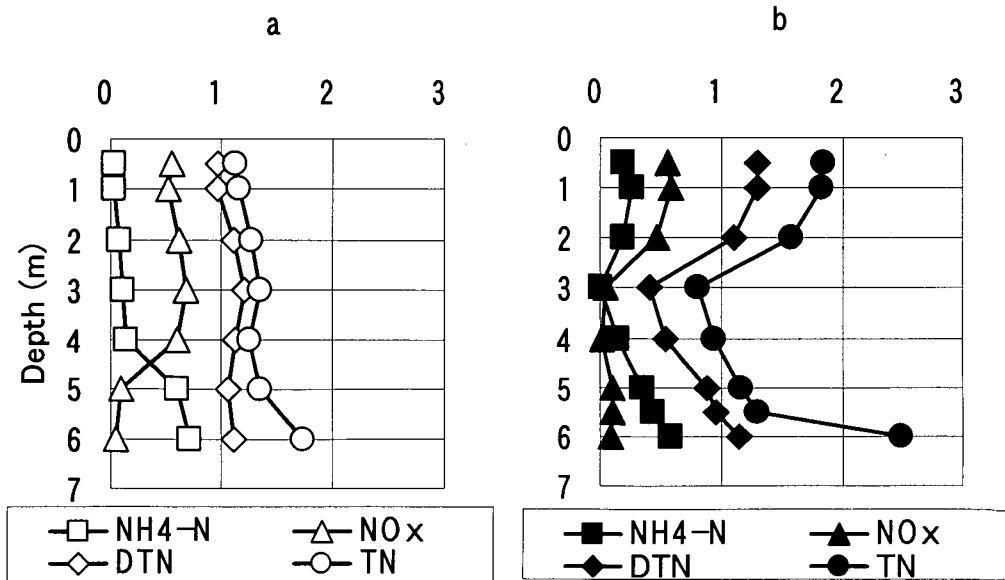
Fig.2 Concentration of Nitrogen compounds in water column at Point A (a: one day before and b: nine days after the supply of oxygen water)

BEHAVIOR OF CHEMICALS FROM URBAN DISCHARGE IN WATER ENVIRONMENT

H. Tanaka, K. Komori, M. Sasaki, Y. Okayasu, M. Yasojima, and K. Mibu

Water Quality Team

Project period: FY 2001-2005

OBJECTIVES

Recently, it is reported that the internal secretion disturbance of the wild creature may occur due to decomposition by products of surface active chemicals medicine in water environment, and humans and animals related hormones, and so on. Efficient risk reduction countermeasures are thus required by eliminating there sources and presence levels in discharges. To achieve such purposes, the behaviors of the risky chemicals should be grasped, and the influences of such chemicals exerted onto water systems should be examined.

This project aims at the development of efficient investigation and analytical techniques in urban discharge in water and sediments of river water systems for endocrine disrupting chemicals. The changing behaviors relate to decomposition and formation in the water environment are investigated.

RESULTS

In 2002, an examination on analytical approaches for nonylphenoxyacetic acid in sedimented mud samples was made. By modifying conventional GC/MS based analytical techniques, the recovery ratios ware enhanced. Using the modified method, the behaviors of endocrine disrupting chemicals in water environment were studied.

Observatory studies on lakes and rivers were performed, and the inflow conditions of city drainages, changes along the river channel and accumulation characteristics in the bottom mud were clarified.

1) The possibility relates to estrogens and NPs' sorption onto the bottom mud, and their changes and decomposition within the pathway of rivers was demonstrated.
2) The accumulative conditions of estrogens (NP, BPA, and E2) onto attached algae and benthos were investigated. It was found that E2 and NP were concentrated at higher levels in attached algae and benthos than in the water phase. As illustrated in figure 1, the contents of estrogens and NPs in the bottom mud of the lake polluted by the city drainage is comparatively high. And, it was also found that these compounds existed in higher concentrations in the bottom mud for a long time, even if certain proportions of them were consistently decomposed under aerobic conditions.
3) The changes of estrogens and NPs in the basin greatly affect the vertical distributions of E1 and NPs in the bottom mud. The mole-based NP concentrations resembled those of NPEO.
4) The quantity of NPEC was one-order lower, and the existence ratios of these compounds (NP, NPEO, NPEC) were comparatively stable. The NP ratio was higher in the sediments than in the river water, and NPEC showed a tendency of being smaller. It was found that the bottom mud and the bottom organisms contained higher contents of estrogens and NPs than the water phase did.
5) The results suggest that the food-chains of organisms in water are probably an important pathway for water pollution by endocrine disrupting chemicals oriented from city drainages.

In coming studies, the transform of estrogens into organisms is to be investigated, in addition to their decomposition and changing behaviors in rivers and, pretreatment approaches that could further enhance the recovery

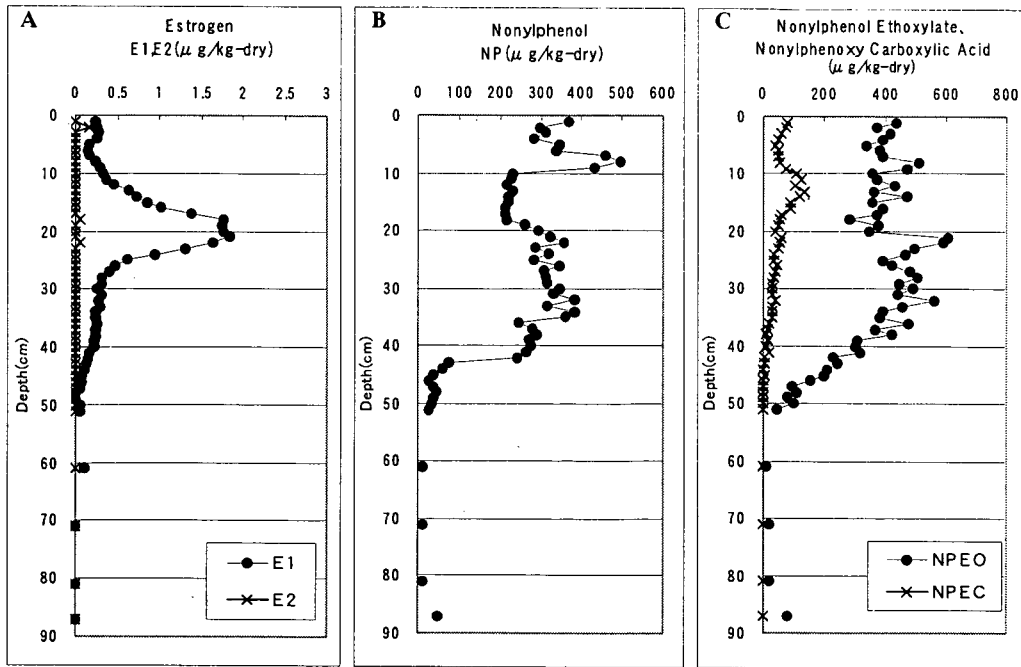ratios of NPEC for quantitative analysis of their presence in sediment samples are expected.

Fig.1 Vertical concentration profiles for E1, E2, NP, NPnEO and NPnEC in sediments of Lake Teganuma

Evaluation of Estrogen-like Substances using Bioassay

H. Tanaka, K. Komori, H. Tamamoto, and N. Miyamoto
Water Quality Team
Project period : FY 2001-2005

OBJECTIVES

In recent years, a new environmental issue has emerged, namely the appearance of endocrine disruptors (EDs), in our water environment. In this study, in order to evaluate the multiple effects of the EDs, the estrogen-like activities in water samples were measured using DNA recombinant yeasts involving human estrogen receptor gene. Besides this, using fractionation techniques and recombinant yeast assay, the water samples to characterize and estimate major origins of the estrogenicity were fractionated.

RESULTS

The summary of this study conducted in FY2002 is as follows.

(1) As shown in Figure 1, the estrogen-like activity in sewage could be effectively removed in a sewage treatment plant. The reduction ratio relative to the median values of estrogen-like activity measurements was about 76%.

(2) We compared the observed estrogen-like activity to the estimated estrogen-like activity of estrogen-like substances measured by the instrumental analysis. The results shown in Figure 2 indicated that E1 was the primary contributor to the theoretical estrogen-like activity in the treated wastewater, and both E1 and E2 are contributors in the untreated wastewater. However, the estrogen-like activity was not perfectly explained by estrogen and estrogen-like substances.

(3) We fractionated water samples with a solid phase extraction column and several different polarized solvents. The estrogen-like activities of the treated wastewater samples were mainly found in a single fraction, and those of the untreated wastewater were in a couple of fractions.
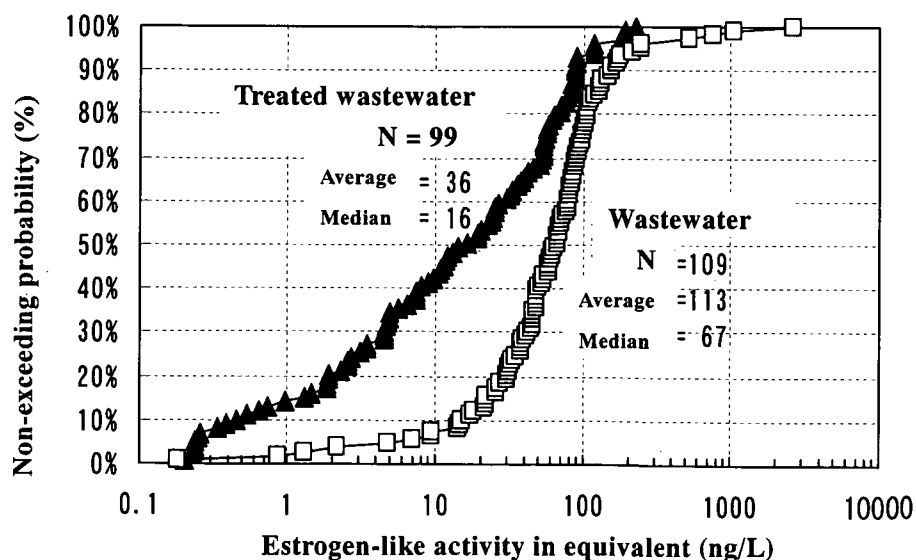

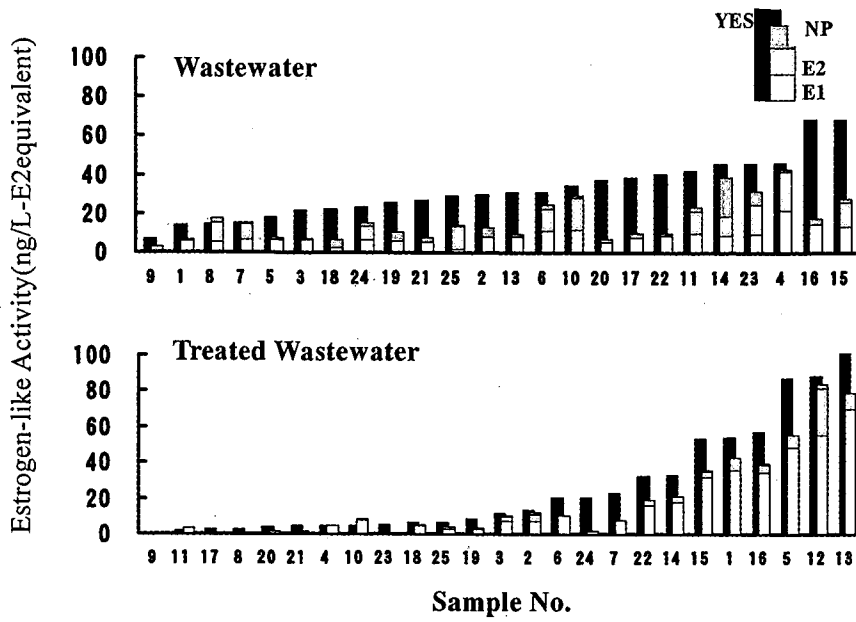Fig.1 Estrogen-like activities of wastewater before and after treatment

Fig.2 Comparison between the observed estrogen-like activity and the theoretical estrogen-like activity estimated the results of chemical analysis

Detection of Environmental Stresses on Aquatic Organisms Using Gene Analysis Technology

H. Tanaka, K. Komori, H. Tamamoto, and T. Higashitani

Water Quality Team

Project period : FY 2002-2006

OBJECTIVES

Human genome research has been progressed on worldwide levels in recent years. It is expected that medical chemicals, which are effective on individual gene levels, will be manufactured and used in the near future. These kinds of medicines taken by people will move into sewers. If probably not treated enough in sewage treatment plants, they will merge into rivers through the effluent from the plants, which may bring about stresses onto aquatic organisms stress and may also affect human health.

Some stresses caused by such new chemicals may not be detected with traditional bioassay methods. Nowadays, a method that can be used to analyze and evaluate the influences of such chemicals from gene levels has been developed. However, this method is mainly used in the medical field. In this study, we attempted to apply this method to the environmental field for evaluation of the chemical impacts on aquatic organisms present in rivers or treated wastewater.

RESULTS

In FY2002, our major attention was paid to the gene diagnosis using DNA chips and studies on whether this method could be actually applied to the evaluation method of chemicals influence in the environmental field were performed.

A lot of genes can be treated with DNA chips at a time. DNA chips were spotted with genes like cDNA fragments. Then, mRNA extracted from a given species of organism was labeled with fluorescence. And then, the labeled mRNA was hybridized with genes spotted on the chip. If the difference in gene expressions is clear between the sample given a sort of stress and the control sample, this means that it is possible to utilize a method for the evaluation of water environment.

The summary of the study is as follows.
1. When the DNA chip is used to evaluate water environment, it is necessary to make an exclusive DNA chip having hundreds of spots. Each spot is used to derive a single gene. If we are to study all genes in a given organism, we need a lot of time to analyze data about the genes and a lot of money to make the DNA chip. So, we considered that it was effective to select genes obtained through screening. We concluded that, for practical use, the screening procedure was necessary.

2. We selected a screening method using microbeads. This method was advantageous because it did not require the DNA sequence data. In this screening process, only mRNA derived from the tissues was used. Microbeads were constructed using the mRNA derived from the tissues being treated and not with a stress substance. Fluorescence labeled probes were then prepared using the mRNA derived from the tissues treated with a stress substance. Using the mRNA derived from the control tissues, colored fluorescence labeled probes were also prepared. Microbeads and probes were hybridized, and genes confirmed to have expression changes were selected.

It was clear that the extract and preservation conditions of the pre-treatment process should be controlled more strictly than those of the general electrophoresis method and the PCR method. This pre-treatment process was applied to Japanese medaka, and its suitability was confirmed by a microchip-type electrophoresis test.

THE INVESTIGATION OF SYSTEMATIZATION FOR PERFORMING MORE EFFICIENT DESIGN AND COST ESTIMATION IN SEWER CONSTRUCTIONS

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Construction System Development Division

Project period: 2002-2004

OBJECTIVES

The civil engineering project estimation system has been formulated for systematizing the method, and the volumes on contract and cost estimation, in order to enhance the accountability and define the contents of the contract conditions of public works, and to perform more efficient estimation. In sewer projects, the parts which compose a construction structure has been systematized, which forms the core of the civil engineering project system, and the standard of cost estimation, the commom specification, and the definiens of the terms etc. have been formulated. But the standard of construction supervision, and the manual and the format for quantity survey are not formulated yet.

In order efficiently to reduce construction cost, it is necessary to keep promoting cost reduction of component parts that the ratio which construction expense occupies is large, preponderantly, and therfore it is effective to analyze the cost constitution ratio of each component parts and machines, labors, and materials, etc.

This investigation is, as a part of these systematizations for sewer public works, to formulate the standard of construction supervision, and the manual and the format for quantity survey, and to analyze cost constitution on the basis of the data of cost estimation results.

RESULTS

(1)The way to formulate the standard of construction supervision for sewer public works

As the common specificaton formulated previously, the composition of this standard is based on the standard for civil engineering, Minstry of Land, Infrastructure and Transport(MLIT standard), and formulated as an addition to MLIT standard. In addition, this standard concerning sewer public works is published in a separate volume to be able to be used independently. This content consists of the description on supervision of process, measure of figure and quality of constructions, and supervision by photo.

(2) The way to formulate the manual and the format for quantity survey for sewer public works

As the standard of construction supervision, the composition etc. is based on the standard for civil engineering of Minstry of Land, Infrastructure and Transport.

Pipe works are generally divided into 4 work units, excavation, small-diameter hole drilling, hole drilling, and shielding, that are located at level 4 at the systematized parts. Each unit consists of standard manhole, special manhole, fitting pipe, drainage pit, soil improvement, and vertical holing etc. Therefore, we will make the 4 files in this standard.

(3)The way to analyze cost consutitution of sewer public works

It is necessary, for analyzing construction cost of sewer public works, to divide the cost of each construction structure into the cost of some composed parts, machines, labors, and materials, and to define systematically what kind of cost each part's

cost for estimating is composed of. The standard of cost estimation for sewer public works was systematized at 2001. Therefore, it is the fist step to analyze the data of cost estimation results at 2001, to investigate how the cost ratio of the each component at level 4 is, and how the cost ratio of the machine, labor, and materials of the each component is.

SURVEY OF THE DEVELOPMENT OF RUNOFF AND INUNDATION MODELS FOR URBAN REGIONS

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Project period: 2002–2005

OBJECTIVES

It is becoming increasingly important to implement countermeasures that link rivers and sewerage systems in drainage basins to promote effective inundation protection measures in urban regions. Inundation simulation models that account for sewerage systems and other inner waters are needed in order to provide more realistic predictions of inundation phenomena in drainage basins.

This survey is a study of an inner water simulation model of a sewerage system that should be incorporated in existing inundation simulation models in order to simulate inundation throughout drainage basins , and at the same time, to develop a model (NILIM: New Integrated Low-land Inundation Model) that can more precisely represent the effectiveness of urban rain countermeasures by improving the prototype urban runoff and inundation model (PWRI model) that has already been developed so that it will more accurately clarify the effectiveness of facilities built to control rainfall, drainage, and runoff.

RESULTS

Analysis results were compared with the water level in trunk pipelines measured in 2001 and with past inundations in the actual city shown in the left of Figure 1 where urbanization has advanced and where a natural flow type combined wastewater system has been provided. Figure 2 shows a hydrograph and height graph and analysis results for a point at almost the center of the drainage basin. Unusually good results were obtained for the start-up and peak values, verifying the model's ability to reliably track the water level inside sewerage pipes.
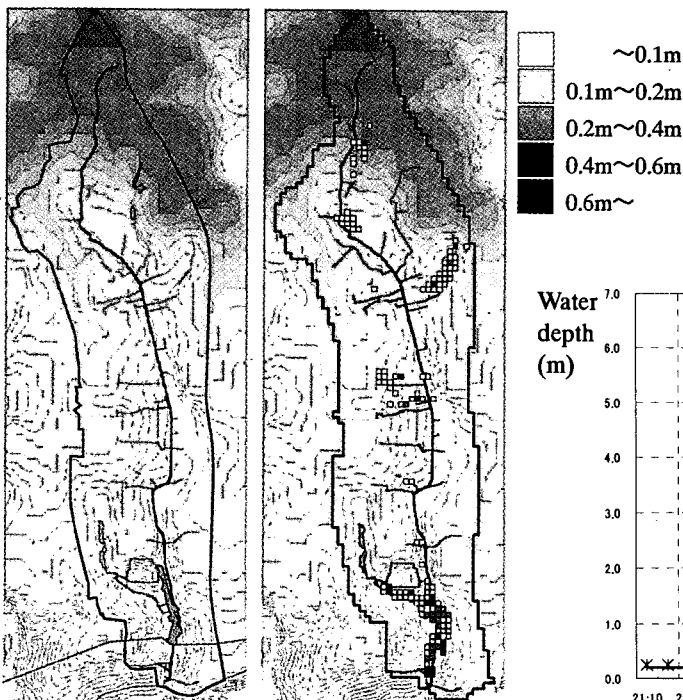

~0.1m
0.1m~0.2m
0.2m~0.4m
0.4m~0.6m
0.6m~

Figure 1. Actual drainage basin analyzed
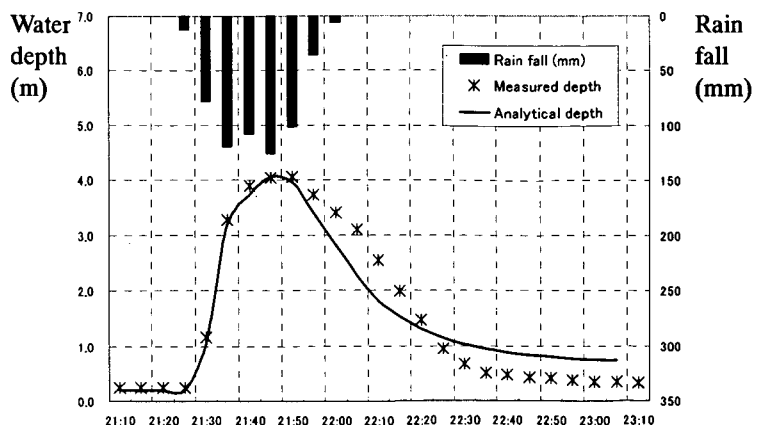Left: Actual inundation Areas
Right: Analytical results

Figure 2. Hydrograph and Height Graph at the Center Point of the Basin

The right side of Figure 1 shows the results of an analysis accounting for surface inundation. The inundation of the land near the downstream end shown in the bottom of the figure covers an area that is a little larger than the actual inundation. Considering that it is possible that this occurred because inundation of approximately 0.2m to 0.3m is not recorded, it can be concluded that relatively good results were obtained. In the upper and middle parts of the basin, inundation areas that differ from actual inundation appear. It is suspected that this occurred because the analysis was done uniformly using data obtained by rain gauges installed on the downstream side, and this data are larger than actual rainfall in the upstream area.

In the future, models for more drainage basins must be verified to study the impact of input, geographical features, and other conditions on the effectiveness of the models and differences in their characteristics to improve their reliability.

STUDY ON RATIONAL METHODS OF EVALUATING AND SELECTING SEWAGE PIPE CONSTRUCTION METHODS

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Construction Technology Research Team

Project period: 2000-2002

OBJECTIVES

Methods of constructing sewerage pipes can be broadly categorized as cut and cover methods, drilling methods, and shield methods, but recent technological development has provided new technologies that contribute to cost reduction and environmental conservation. These include drilling methods that can perform long distance drilling and can be applied under various ground conditions, and fast and safe cut and cover methods featuring lightweight temporary structure materials and pipe material and backfill using fluidized soil, and so forth. And it is now important to consider the noise, vibration, traffic congestion caused by work on street, disposing of by-products of construction, and other impacts of pipeline work on the surrounding environment. And in addition to laying new pipes etc., pipe maintenance and replacement technologies have become important issues as the existing stock has deteriorated. For these reasons, when sewerage pipe construction methods are selected in the future, the candidate methods must be comprehensively evaluated by accounting not only for the construction cost and other initial costs, but also for external costs such as the impact of the work on the surrounding environment and maintenance costs that account for future repair and reconstruction of the pipe.

This study was carried out to propose a rational method of selecting a sewerage pipe construction method that encompasses the external cost and the life cycle cost of each method.

RESULTS

This year, a case study of external cost items and their impacts was carried out focusing on sewerage work on an existing road. The impacts of maintenance and repair work on life cycle costs were studied by performing an analysis of the present state of pipe maintenance accompanied by a trial calculation of life cycle costs.

(1) Study of external costs of sewerage pipe work

The impact on the external environment of sewerage pipe work on an existing road was trial calculated by selecting traffic congestion caused by the work—a factor that has a high degree of impact when converted to cost and which is relatively easy to measure and predict—as the external cost factor.

The trial calculation assumed that the work was done on a two-lane road with traffic closed on one lane as automobiles traveled on the other lane alternately in two directions. The trial calculation obtained the following results.

• As the traffic volume increases, the external cost of traffic congestion rises sharply.

• The external cost varies widely according to the length of road that is closed and the closure method (signal light pattern alternating traffic flow direction etc.).

• The impact on traffic congestion also increases under the effects of the width of the road's traffic lanes and its shoulders and of roadside conditions.

• It is possible to greatly lower external cost by simple improvements such as narrowing the width of the road closed,

delaying the start of closure, etc.

(2) Life cycle cost study

Trial calculations were performed to study differences in the life cycle cost resulting from differences in the pipe selected at the design stage and in the maintenance and repair planning. The design working life was set as 100 years with reference to the state of existing sewerage pipes and design standards for various kinds of structures. The maintenance cost was set according to the age of pipes based on the results of a survey of the way that maintenance is done. The following are four trial calculation cases.

Case 1: The design working life is satisfied by repeatedly carrying out minor repairs before the strength properties of the pipe begin to decline.

Case 2: The design working life is satisfied by performing a major repair when the strength properties of the pipe have declined over a period of years and have approached the lower limit values of its required performance.

Case 3: The design working life is satisfied by reconstructing the pipe to improve its durability when the strength properties of the pipe have declined over a period of years and have approached the lower limit values of its required performance.

Case 4: Case where the frequency of repair work was reduced by laying pipe with improved durability.

There are only small differences between the results of the trial calculations for all cases 50 years after construction, but a comparison of life cycle costs over a period of 100 years revealed that results were more economical in two cases: repeated small repairs before maintenance costs rise (case 1) and laying high performance pipe despite its higher initial cost (case 4).

In the future, we must set rational repair standards for sewerage pipes, establish degree of damage evaluation methods, and clarify changes in the performance of pipes under varying conditions to establish rational and economical construction method selection method.

DEVELOPMENT OF PRACTICAL TECHNOLOGY RELATED TO NEW MATERIALS FOR SEWERAGE TREATMENT FACILITIES

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Advanced Material Team

Project period: 2001–2003

OBJECTIVES

In order to efficiently construct sewerage systems, their corrosion resistance performance must be enhanced by improving the reinforced concrete that has been used in the past. It is expected that technologies that permit the use of new materials with superior corrosion resistance in sewerage systems will be developed. This paper describes the search for new materials of this kind and a survey of their corrosion resistance and applicability in sewerage systems and reports on improvements and new technology development performed to permit their use as corrosion proof materials in sewerage systems. In recent years, the corrosion resistance of newly constructed structures has been improved by the provision of corrosion resistance guidelines for sewerage system structures. And because the sewerage system penetration rate reached 62% by 2000, the importance of maintenance of existing structures is growing. The object of the research is materials used to repair concrete in sewerage systems.

A joint research project with 12 private companies capable of developing materials and repair technologies that satisfy the required performance levels began in 2002 in order to conduct research in this area more efficiently. In 2002, the following three technological items related to sewerage treatment system repair materials were studied to establish the required performance and methods of evaluating their performance. Preliminary tests related to part of this research have been done.

(1) Applicability of acid resistant mortar

(2) Improving the reliability of coating type lining materials

(3) Developing new sheet lining materials

RESULTS

(1) Applicability of acid resistant mortar

The use of acid resistant mortar as section repair material can control deterioration of coating type lining materials caused by pin holes. And in relatively gentle corrosion environments, it can be used without a coating. This means that the acid resistance of acid-resistant mortar must be appropriately evaluated, but a problem with testing by soaking it in a sulfuric acid solution as has been done in the past was that environmental conditions were actually far different. A sulfuric acid dripping method has been proposed as a test method that mimics the sulfuric acid formed on walls by microorganisms. The results of the preliminary test have revealed that this test method can be applied as an acid resistance evaluation method: for example, it can measure the depth of corrosion by sulfuric acid.

(2) Improving the reliability of coating type lining materials

A conventional coating type lining material is susceptible to swelling caused by inadequate bonding with the concrete, but this can be mitigated by improving the primer, etc. Because it was difficult to evaluate such bonding with the BRI (Building Research Institute) bonding test used in the past, the applicability of the peeling method as a new evaluation

method will be studied to improve its correlation with its swelling control performance.

(3) Developing new sheet lining materials

There are two problems with conventional sheet lining materials: they are relatively expensive and difficult to install. Therefore, these materials will be improved to develop new sheet lining materials. Work began on the development of [1] sheet lining material made of FRP drawn formed material and [2] sheet lining materials made of titanium plates (film) and detailed studies of execution methods and connection methods etc. were carried out.

EVALUATION OF EARTH PRESSURE ACTING ON A BURIED PIPE
IN RENEWING SEWERAGE FACILITIES

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Soil Mechanics Team

Project period: 2001-2004

OBJECTIVES

In considering the renewal of sewerage pipes after several tens years from the construction, it is questioned that the earth pressure originally calculated based on Marston-Spangler theory may be over-estimated due to the time-dependent behaviour of ground such as earth pressure stabilisation or ground ageing etc. In this study, the long term behaviour of ground around a buried pipe are investigated and the evaluation of time-dependent earth pressure, if any, is aimed at to propose.

RESULTS

The possible causes for time-dependent behaviour of earth pressure acting on underground structures can be categorised mainly into the following three patterns; a) the ground is subjected to external force, b) due to the deformation of underground structure, the surrounding ground deforms as a result, c) the mechanical properties of the surrounding ground change with time. From 2001, the mechanism of the interaction between underground structure and the surrounding ground (pattern b) has been investigated by a long-term monitoring of earth pressure around buried pipes and a series of trap-door tests. In 2002, those experiments were performed in more precise and detailed manner. In addition, patterns a) and c) were also considered in the monitoring and the trap door testing.

[1. Long-term monitoring of earth pressures acting on buried pipes] The strain-gauged pipes were laid in the model sand ground in a soil chamber. The earth pressures in the surrounding ground and the deformation of the pipes were measured during and after laying. The measured earth pressure on the flexible pipe was significantly smaller (nearly equal zero) than the overburden pressure due to the small deformation of the pipe. Noticeable change was not observed both in the earth pressures and pipe deformation for one year. Lightly cemented sand was then used for the model ground and the similar monitoring is currently being continued to evaluate the effects of ageing (cementation) of the ground on the earth pressure changes.

[2. The observation of ground arching by trap-door testing] A series of trap-door tests was carried out on Toyoura sand to investigate the rate effects of moving pedestal. The pressure acting on the moving pedestal dropped rapidly with displacement and stabilised at about 20% of the initial value. It was found that the pressure-displacement relationship was not strongly affected by the displacement rate but when the displacement rate was temporarily changed by up to 100 times the pressure changed by several percent. Test results on clayey sand showed that the drop of pressure in the overall pressure-displacement curve was less steep but the temporal change of pressure was more sensitive to the rate change.

[3. Disturbance of ground arching] Small ups and downs of the moving pedestal were given after stable ground arching was developed in the model ground in trap door testing. The pressure increased and decreased depending on the movement of pedestal. The degree of disturbance was less significant in the case of clayey sand.