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FY2003 RESEARCH SUMMARY OF WASTEWATER MANAGEMENT AND WATER QUALITY CONTROL

National Institute for Land and Infrastructure Management,
Ministry of Land, Infrastructure and Transport, Japan

Incorporated Administrative Agency
Public Works Research Institute

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FY2003 RESEARCH SUMMARY OF WASTEWATER MANAGEMENT AND WATER QUALITY CONTROL

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WASTEWATER AND SLUDGE MANAGEMENT DIVISION
of WATER QUALITY CONTROL DEPARTMENT

CONSTRUCTION SYSTEM DEVELOPMENT DIVISION
of RESEARCH CENTER FOR LAND AND CONSTRUCTION MANAGEMENT

FLOOD DISASTER PREVENTION DIVISION
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NATIONAL INSTITUTE FOR LAND AND INFRASTRUCTURE MANAGEMENT,
MINISTRY OF LAND, INFRASTRUCTURE AND TRANSPORT, JAPAN

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of MATERIAL AND GEOTECHNICAL ENGINEERING RESEARCH GROUP

WATER QUALITY RESEARCH TEAM
of WATER ENVIRONMENT RESEARCH GROUP

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SOIL MECHANICS RESEARCH TEAM
of MATERIAL AND GEOTECHNICAL ENGINEERING RESEARCH GROUP

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Synopsis

This Research Summary briefly introduces researches on wastewater management and water quality control carried out in Fiscal 2003 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 2003 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. 228, Technical Note of PWRI No. 3952), 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 and Global Environment Research Fund, 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.

高橋正宏

Masahiro Takahashi, Director
Water Quality Control Department,
National Institute for Land and Infrastructure Management,
Ministry of Land, Infrastructure and Transport

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STANDARD FOR DISCHARGE OF DOMESTIC WASTEWATER WITH HIGH CONCENTRATION

M.Takahashi, K.Fujiu, A.Yoshida, R.Hiraide and T.Hamada
Water Quality Control Department

Project period: 2000-2003

Objectives

The purpose of this research is to clarify the impacts of the introduction of garbage disposers on sewage systems in regions where they are introduced.

Experimental Outline

In the town of Utanobori in Hokkaido, a trial installation of garbage disposers was done in and around a housing estate managed by the town from August 1999 to March 2002. At this time, garbage disposers are installed in 301 households (639 people) that is a garbage disposer penetration rate of 36% (/person).

Conditions in sewer mains, pumping stations and sewage treatment plants before and after the introduction of the garbage disposers in Utanobori in Hokkaido were surveyed. TV cameras were used to examine the inside of sewer mains to clarify conditions inside them, and materials deposited inside the mains were sampled and their composition surveyed. At pumping stations, the state of maintenance was surveyed by interviewing sewage system managers, and materials deposited in the pumping stations were sampled and their oil etc. content was analyzed. At treatment plants, the qualities of the influent and treated water were analyzed. Spot samples taken twice a month at 9:00 a.m. were used to analyze the influent and the treated water.

Conclusion

- 1) It was confirmed that regardless of whether garbage disposers are installed or not, materials adhere to the inside surfaces of sewer mains.
- 2) After installation of garbage disposers, the frequency that pumping stations were cleaned and the quantities of materials deposited in them did not change.
- 3) Materials deposited in pumping stations were 86.5% soil and 8.0% garbage, n-Hex content was 3.83%, and the volatile solids content was 34.8%.
- 4) The results suggest that during the peak garbage disposer operation period, water discharged from garbage disposers in households has an impact on the quality of the influent to treatment plants.
- 5) It is assumed that at garbage disposer penetration of 100%, good processing will be possible, because the ASRT necessary for nitrification inside treatment tanks can be guaranteed.

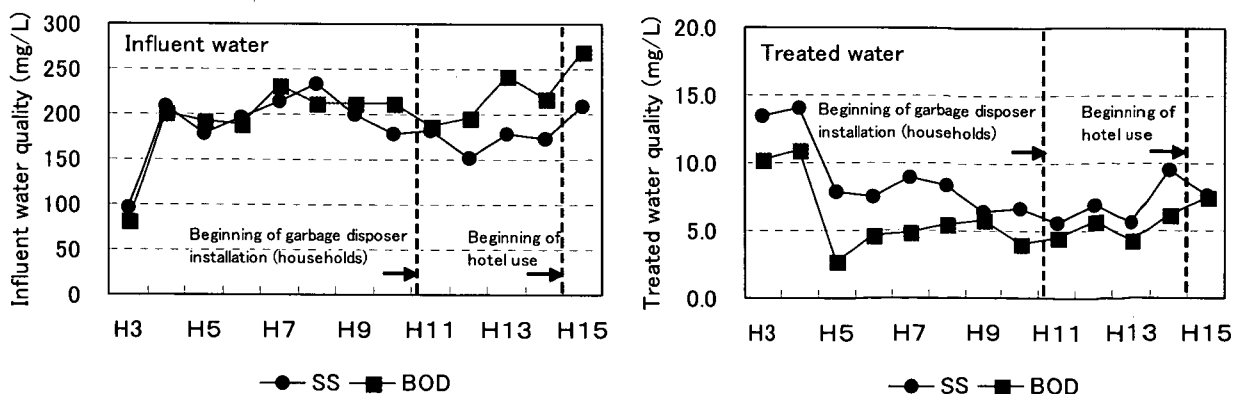


Figure 1. Change Over Years of Influent Water Quality and Treated Water Quality (Spot Samples taken at 9:00 a.m.)

STUDY OF CONDUIT MAINTENANCE LEVELS

K. Fujii, and K. Namekata
Wastewater System Division

Project period: 2001-2003

OBJECTIVES

Some metropolises began to construct the sewer, there are few sewers used for above 50 years. But most of the sewers were constructed after 1960's in Japan. Therefore, the sewer rehabilitation will increase suddenly in the near future, because the lifetime of sewer may be 50 years. When the sewers will become superannuated, the sewers will lose the function for cracking, corroding, and shifting the seams. The sharp loss of the function of the sewer will cause the collapse of the important lifelines, and it is important theme should be avoided.

For the maintaining the sewer functions, it is necessary to establish the method of investigating of the condition of the sewers, and the efficient method to rehabilitation of the sewers. But it is difficult to find the function losing sewers, because the sewers have been constructed under the ground. It is not fully solved that the lifetime and the conditions of the superannuated sewers, and it is also difficult to plan the rehabilitation of sewers.

Therefore, in order to rehabilitation of the superannuated sewers intentionally, it is necessary to investigate the actual condition of the sewers constructed in the past, and the actual condition of the superannuated sewers. This study arranged the construction conditions of sewer classification by the statistics of sewers, and it analyzed the reply by the questionnaire about the actual condition of the repair works in Japan.

RESULTS

This study was classified sewers into four kinds, concrete pipes, polyvinyl chloride pipes, vitrified clay pipes, and others. The construction conditions of sewer classification arranged by the statistics of sewers, and it analyzed the reply by the questionnaire about the actual condition of the repair works that were rehabilitated in 2000 in Japan. It is shown follow the result matters.

- 1) The rate of concrete pipes was as high as 92% in the sewers that diameter is 1,000mm or more. The rate of polyvinyl chloride pipes was as the highest as 48% in the sewer that diameter is 500mm or less.
- 2) In rehabilitated sewers, the rate of sewers that diameter is 500mm or less was as high as 81% in concrete pipes, polyvinyl chloride pipes and vitrified clay pipes.
- 3) About the age of rehabilitated sewers, about 30 years was the highest in concrete pipes and vitrified clay pipes, and those rehabilitation extensions per a year were about 5.7km/year and about 1.0km/year. In polyvinyl chloride pipes, the rehabilitation extension was always about 0.2km/year.
- 4) About the condition of the superannuated sewers, it saw with the tendency much that concrete pipes lost the function for corroding and cracking, polyvinyl chloride pipes lost it for meandering and shifting the seams, vitrified clay pipes lost it for cracking, shifting the seams and breaking of the wall.
- 5) About caving in the surface above sewers, it had generated mostly in concrete pipes and vitrified clay pipes, and there were few cases in polyvinyl chloride pipes.
- 6) About corroding, it had only in concrete pipes, and the rate of force main and industrial wastewater were high with the factors for corroding.

A STUDY OF IMPROVEMENT OF URBAN RAINWATER MEASUREMENT SYSTEM

K. Fujiu, M. Nasu, H. Mori, K. Yamada

Wastewater System Division

Project period: 2001-2003

INTRODUCTION

In recent years, the problems of city rain water are focused from both sides of quantity and quality, such as city type flood damage and combined sewer overflow in Japan. Then, development of a pollution load outflow model in wet weather of combined sewer is studied, and a technique for safely checking the blow-out phenomenon of manhole covers installed in a storage pipe of an inverted siphon form is 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 apply this model to simultaneous many points, and 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 result of calculation in rainy weather is shown in Fig.1. Here, in addition to the observed value, comparison with the calculation result by 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 about the amount of loads, and, in addition, it was shown that reproducibility is higher than a concentrated type model on the whole. As for the TC, it was found that the distributed type model is highly applicable when the coefficient is the same as BOD ($m=1, n=0$). However, in respect of the agreement of the peaks, the model may not be applicable enough. The model must be improved further by examining other river basins and sub-models of the increase and decrease of the number of TC in the sewer tunnels.

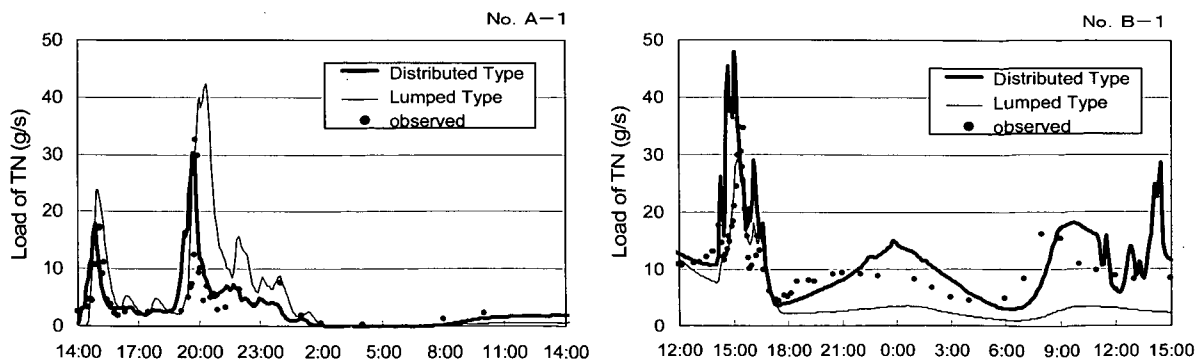


Fig.1 Results of comparison with calculation

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 Figure 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.

Checking Method of Safety of Facilities

To take measures from the design phase for the phenomenon in which a manhole cover rises up and flies upward, we analyzed air entrainment and blowout behavior numerically. Then, using graphs and other information, we examined a simple method to compare the maximum pressure that may occur in the designed facility and the withstanding inner pressure below the manhole cover. As a result, when the opening area of the upper part of the manhole is 2.0m^2 or larger, the peak air pressure of the upstream manhole and the downstream manhole is almost equal. On the other hand, when the opening area is smaller than 2.0m^2 , the peak air pressure of the downstream manhole becomes larger than that of the upstream one. This trend becomes more apparent when the diameter of the main pipe increases. Moreover, when the opening area of the upper part of the manhole is less than 0.5m^2 , the peak air pressure rises drastically. When the diameter of the main pipe is $\phi 3000\text{mm}$ or less and the opening area is 2.0m^2 or larger, the peak air pressure will not exceed the withstanding inner pressure of the flat-type iron cover. However, in designing a storage pipe with the diameter of $\phi 5000\text{mm}$ or more, a detailed examination is required. The effect of the difference of conduit extension on the peak air pressure was not confirmed.

Table 1 Preparation of Simple Determination Chart

Item	Unit	Range
Flow volume	--	Flow volume equivalent to full bobbin flow rate of 1.0, 2.0, 3.0, 4.0, and 5.0m/s to each diameter of main pipe is set.
Diameter of main pipe	mm	$\phi 1350$, $\phi 2000$, $\phi 3000$, $\phi 5000$, $\phi 6000$
Extension of main pipe	m	250, 1000, 3000
Depth of manhole	m	25
Diameter of manhole	of	1.5 times of main pipe diameter
Opening area of vent hole	m^2	0.125, 0.25, 0.50, 1.00, 2.00, 4.00

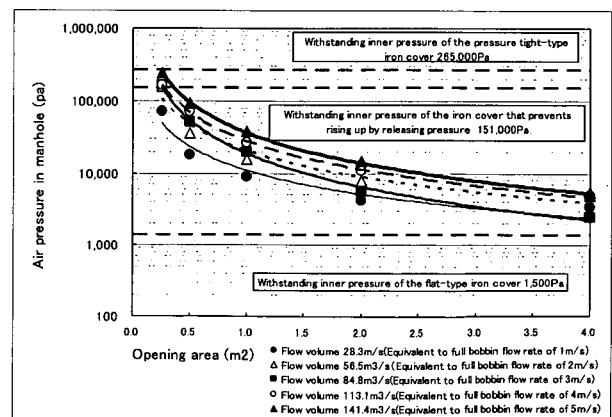


Fig.13 Example of Simple Determination Chart
(Peak Air Pressure at Downstream Manhole)

(Diameter of main pipe: $\phi 6000\text{mm}$, Extension: 1000m,
Diameter of manhole: $\phi 9000\text{mm}$, Depth of manhole: 25m)

STRATEGIC INVESTMENT IN SEWAGE WORKS

K. Fujiu, T. Yoshida, and H. Yamagata
Wastewater System Division

Project period: 2002-2005

OBJECTIVES

Cost benefit analysis can be effective in setting 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 environment 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.

In addition to the benefit transfer research, the methodology of asset management was investigated in light of strategic investment in sewage works. This concept provides a basis to sustain the function of existing facilities and to efficiently manage sewage facilities in response to the surroundings.

RESULTS

A case study of benefit transfer was conducted targeting the watershed of Arakawa, where the relevant data were obtained in a CVM survey conducted by Wastewater System Division. The benefit transfer function was estimated with its validity verified. The function's explanatory variables were resident attributes, such as income and water environment awareness, and local characteristics. In analysis, data was categorized into three regional locations in the watershed, i.e. the upper, middle, and down areas. Random utility model, assuming application of logit model, was selected among several possible function models. Equation (1) is an example of the estimated function.

$$\Pr(\text{yes}) = \frac{1}{1 + \exp[-C - \gamma \cdot \text{PAY} - \alpha_1 \cdot \text{UN} - \alpha_2 \cdot \text{INC}]} \quad \text{----- (1)}$$

where $\Pr(\text{yes})$: probability that respondents reply yes to a bid amount; C, γ, α_i : parameters;
 PAY : a bid amount (yen); UN : use of Arakawa (no use: 1, use: 0); and INC : rank of income (the larger means the higher income.).

"n-1 model" was a model constructed by using data excluding one regional location. In case of n-1 model of down area, for example, the function was constructed using middle and upper area data, and the estimation of down area was obtained through the function and the down area data. In this fashion, the comparison between the estimation and the local model verified the validity of the benefit transfer. These results are shown in Table 1.

Table 1. Verification of Benefit Transfer Function by n-1 model

Target	Down area				Middle area				Upper area			
	Local model		n-1 model		Local model		n-1 model		Local model		n-1 model	
Variable	Coefficient	(t value)	Coefficient	(t value)	Coefficient	(t value)	Coefficient	(t value)	Coefficient	(t value)	Coefficient	(t value)
PAY	6.5963E-04	(6.11104)	5.8291E-04	(7.74839)	6.3613E-04	(5.75226)	5.9057E-04	(7.98467)	5.3239E-04	(5.15393)	6.3009E-04	(8.33520)
UN	1.09282	(3.85622)	0.684733	(2.91002)	0.617945	(2.00491)	0.89731	(4.05389)	0.769022	(2.06878)	0.844536	(4.10994)
INC	-0.18893	(-2.43770)	-0.141994	(-2.95286)	-0.159087	(-2.54231)	-0.139236	(-2.55064)	-0.10358	(-1.31410)	-0.153689	(-3.24685)
C	-0.322982	(-0.99171)	9.22E-03	(-0.03845)	-0.026343	(-0.81166)	-0.18182	(-0.75232)	-9.83E-03	(-0.02696)	-2.12E-01	(-0.93415)
Sample number	350		661		353		658		308		703	
Log likelihood	-194.588		-367.191		-197.85		-366.206		-168.718		-394.294	
Goodness of fit	0.702857		0.698941		0.705382		0.697568		0.688312		0.699858	

LOW-COST SEWERAGE SYSTEM FOR DEVELOPING COUNTRIES

K. Fujiu, H. Nakajima, H. Yamagata, R. Hiraide and K. Sakurai
Wastewater System Division, and Wastewater and Sludge Management Division

Project period: 2001-2004

OBJECTIVES

As hygiene deteriorates with the remarkable progress of urbanization, it is becoming important to improve the water environment and secure water resources in developing countries; especially in rural areas where 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 wastewater treatment than

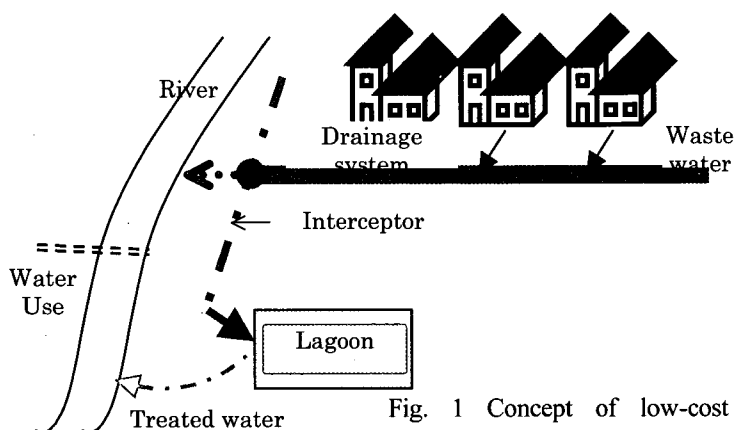


Fig. 1 Concept of low-cost sewerage system

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 temperatures and low labor and land costs, including citizen participation and efficient management of sewerage systems.

RESULT

1. Survey of the present state of interceptor sewerage systems

Interceptor sewerage systems are counted on to be suited to suburbs in developing countries where there is a demand for future improvements. In order to clarify the state of the introduction and maintenance of interceptor sewerage systems and gain an understanding of problem points, an interview survey of sewage system managers was conducted and documents were collected in March 2004 in Khon Kaen City in the northern part of the Kingdom of Thailand where an interceptor sewerage system has been introduced. The results revealed a number of problems. (1) No progress has been achieved in linking the sewage system to homes, and individual treatment methods such as septic tanks or soil penetration pits do not function adequately. (2) There is fear that the flow capacity will be reduced by deposition inside interceptors, but appropriate maintenance is not done because there are no guidebooks to pipeline maintenance methods and because of a shortage of personnel and funds necessary for maintenance. (3) Regarding the planned treatment capacity of treatment plants, it is necessary to study maintenance methods suited to the inflow load, because although it is assumed that sewage system connection has advanced, the present inflow load of BOD is only a little less than 20% of the planned level and the facility capacity is excessive.

2. Experiment to improve treatment by lagoon systems in the tropics or subtropics

Wastewater influent with low BOD is a problem in lagoons in the tropics or subtropics. The first step is to replace inadequate operation and maintenance methods. Other problems are algae and the sanitary condition of the treated wastewater from lagoons. We researched these matters and conducted experiments in Okinawa Prefecture: the sole subtropical area in Japan.

The lagoon has a water depth of 2 m and a capacity of 100 m³. BOD of the wastewater influent was varied between 50, 100, and 200 mg/L. The hydraulic retention time (HRT) of the lagoon was varied between 2, 5, 10, and 20 days. The processing condition of the lagoon was confirmed. (except BOD 200 mg/L, HRT 20 d)

According to the lagoon results, the necessary HRT was 5 days in a case of wastewater influent BOD of 50 mg/L. The necessary HRT was 10 days in the case of wastewater influent BOD of 100 mg/L. The necessary HRT was 10 days in the case of wastewater influent BOD of 200 mg/L. When sanitary conditions are considered, the proper HRT was 10 days in the case of wastewater influent BOD of 50 mg/L. The proper HRT was 20 days in the case of wastewater influent BOD of 100 mg/L. The proper HRT was 30 days in the case of wastewater influent BOD of 200 mg/L. The treated wastewater from the lagoon could not be evaluated based on the evaluation of the total samples (T-BOD, SS etc) because it does not check untreated wastewater or algae caused by the treatment. Therefore, we must evaluate it considering the dissolved solids and lagoon conditions.

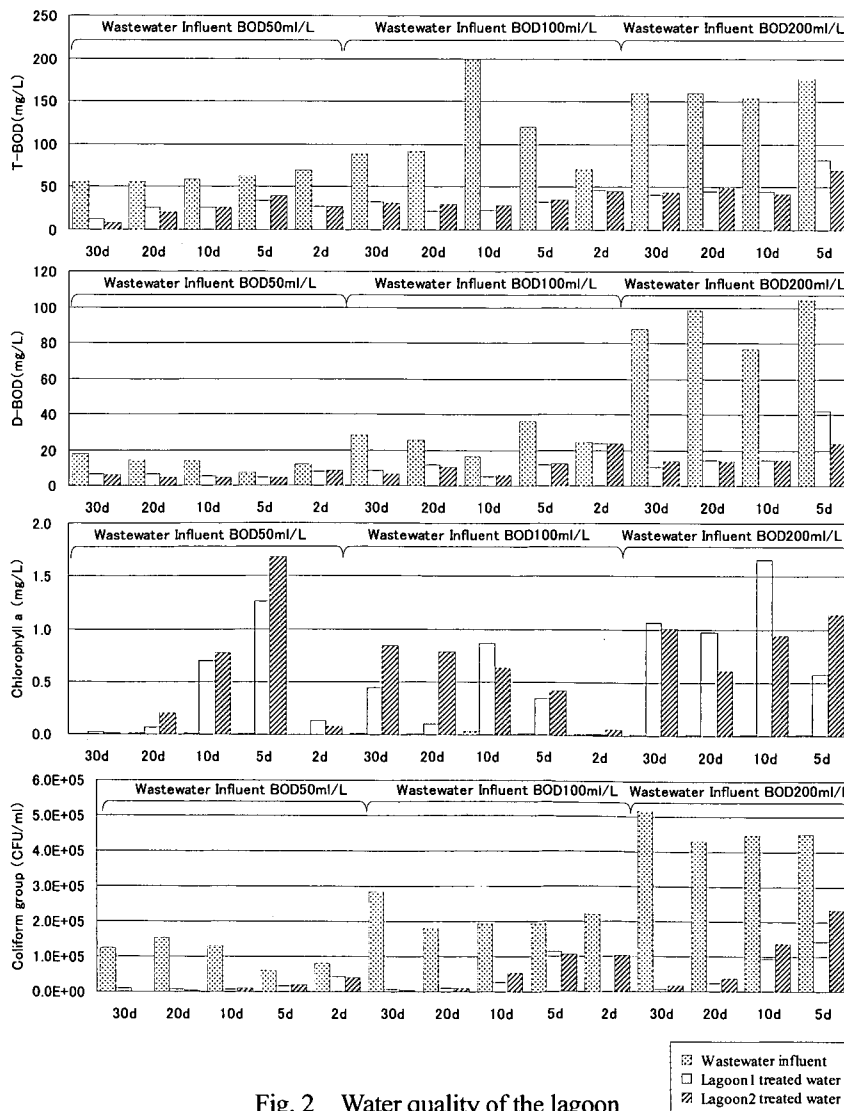


Fig. 2 Water quality of the lagoon

A STUDY ON DEVELOPMENT OF THE INFLUENCE EVALUATION TECHNOLOGY OF WATER CYCLE AND MATTER CYCLE CHANGE

K. Fujiu, H. Morita, M. Nasu, K. Yamada

Wastewater System Division

Project period: 2002-2004

INTRODUCTION

This study aims to examine a method to estimate the influence of combined sewer overflow on receiving water body, as well as to promote an effective combined sewer overflow controls.

We investigated in the combined sewer drainage district where the most a lot of loads were discharged in the receiving water body in wet weather and examined the pollutant load runoff model for the calculation of pollutant loads for the combined sewer drainage districts.

METHODS

The Hirasaku River basin in Yokosuka City, Kanagawa Prefecture was selected as the study area. The reasons for the selection are as follows:

- 1) The combined sewer overflows and storm wastewater from the area flow in Hirasaku River and flow from the Hirasaku River to the Kurihama Bay. And, the river that flows into this bay is only Hirasaku River.
- 2) Most areas of this drainage basin are urbanized and the percentage of sewerage population is high. And the combined sewer system is served in this area.
- 3) In the Kurihama Bay, there are some water amenity spaces.

Two investigation points were set up in the combined sewer drainage district located upstream of the study area and investigations were done in dry weather and wet weather. The interval of the investigation time was one or two hours in dry weather. In wet weather, the first stage of rainfall was investigated in five minutes, and then the interval of the investigation time was extended with the changes in the rainfall. Water quality analysis indexes are BOD, COD, SS, nitrogen (T-TN), phosphorus (T-TP), and the coliform group (TC).

RESULTS AND DISCUSSION

The runoff situation pertaining of the water quality (T-TN, T-TP, and TC) as examples of the investigation results in dry and wet weather is shown in Figs. 2 and 3. In dry weather, the peak runoff was observed once in the morning. The tendency of the peak runoff was observed to other investigation results. In wet weather, high concentration runoff was observed in the first stage of the rainfall, and then the water quality fell below one of dry weather. This high

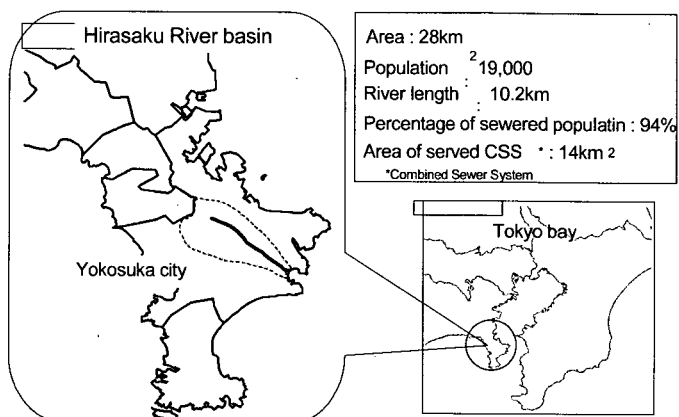


Fig.1 Study area

concentration runoff called first flush.

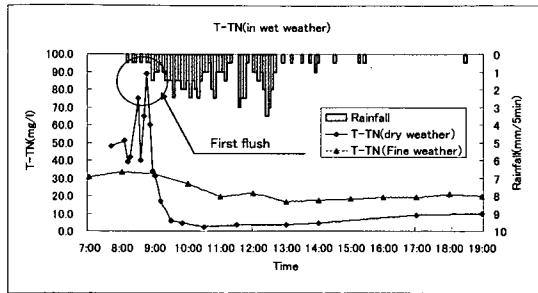


Fig.2 Water quality observation result in wet weather (Point A, T-TN)

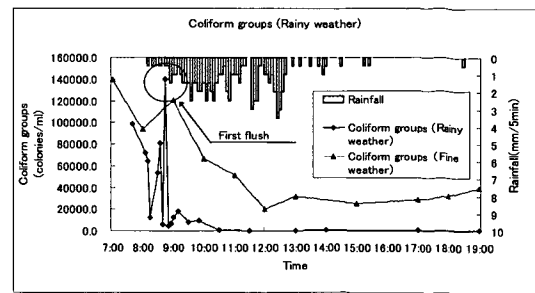


Fig.3 Water quality observation result in wet weather (Point A, Coli groups)

Fig. 4 shows the comparison of the total runoff loads in wet weather versus ones in dry weather. The values of T-TN and T-TP showed a tendency to grow smaller than the values of SS and larger than those of BOD and COD. The values of TC showed a tendency to become small compared with other water quality analysis indexes. Therefore, it can be assumed that T-TN and T-TP have the runoff characteristics similar to those of BOD and COD, the pollution load of TC is lower than other indexes, and TC pollution load supplied from roads, etc. by the rainfall is small.

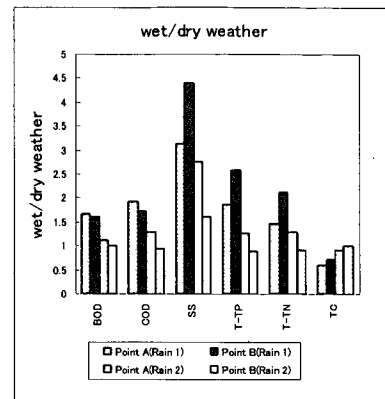


Fig.4 Comparison (wet/dry weather)

CONCLUSIONS

The following points have been discovered as the runoff characteristics of nitrogen, phosphorus, and the coliform group:

- i) As for the runoff situation in dry weather, there is a peak runoff in the morning.
- ii) In wet weather, all water quality indexes showed the first flush as in the case of BOD etc. The concentration of runoff in the first stage of rainfall was high, and then the level fell below the value in dry weather. The water quality takes time to recover compared to BOD etc.
- iii) It can be assumed that T-TN and T-TP have runoff characteristics similar to BOD and COD, as well as investigation results in other drainage districts. Most of loads of TC are assumed to run out at the first flush unlike other pollutant loads.
- iv) Because T-TN and T-TP have the runoff characteristics similar to BOD and COD, it may be reasonable to presume that the formulae similar to BOD and COD can be used in the model construction. It is thought that the TC should be examined as a model that is little affected by the amount of loads from road, etc.

In our future study, we will construct pollutant load runoff model from the combined sewer system and develop a model for the runoff to the sea area and behavior there. Furthermore, as to the TC, the amount of loads from roads, growth and death depending on the temperature, etc. should be examined to construct a model.

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

K.Fujiu, A.Yoshida and T.Hamada
Wastewater System Division

Project period: 2002-2004

Objectives

The purpose of this research is to obtain the flow speed and limit traction necessary for sewage water to remove egg and shellfish shells deposited in sewer mains after the introduction of garbage disposers. Model sewer main experiments verified the physical properties of egg and shellfish shells crushed in garbage disposers, their deposition in sewer mains, and traction conditions.

Experimental Outline

- 1) Experiment to investigate the state of traction of egg and shellfish shells deposited in sewer mains

Water was supplied to a pipeline with a gentle gradient in which egg and shellfish shells have been deposited to study the hydraulic quantities that start moving egg and shellfish shells. Differences between the results and the traction properties of particles of sand deposited in ordinary pipelines were studied.

- 2) Experiment to investigate the state of deposition and traction of egg and shellfish shells that flow continuously into a sewer main

It is assumed that egg and shellfish shells flow semicontinuously when garbage disposers are used. Hypothesizing the state of inflow of egg and shellfish shells when garbage disposers are used, the relationship of hydraulic quantities with change of the state of deposition of egg and shellfish shells (deposition height and length) flowing continuously into a sewer main was studied.

- 3) Experiment to investigate the state of deposition and traction of egg and shellfish shells flowing continuously into a sewer main using a pipeline model with a reverse gradient.

Because in sewer mains in the region where the garbage disposers were introduced, egg and shellfish shells are deposited where pipeline settlement has created reverse gradients, the state of deposition and traction of egg and shellfish shells on a reverse gradient were studied.

Results

- 1) In a sewer pipe designed so that flow velocity of 0.60m/s might be guaranteed, it is possible to guarantee flow velocity between 0.35 and 0.50m/s and deposit will not exceed a height of 3cm at the design flow rate.
- 2) The traction movement properties discovered by the hydraulic model tests performed with the downstream end of a block of deposited material fixed by clay are represented accurately by an existing equation proposed for sand grain, when analyses are performed by using the average grain diameter of the material.
- 3) The hydraulic model tests revealed that if a flow of 0.001 m³/s or more was guaranteed in the sewer pipe of uniform gradient of 2‰ or more, the deposited material was moved by traction without exceeding 3cm in height, then flow velocity was between 0.35 and 0.50m/s.
- 4) In a sewer pipe bent by unequal settlement, the part below an imaginary line drawn between the bottom of the pipe at opposite ends of the bend is filled with deposits as the time passes and finally surface of the deposits become a uniform gradient and flow is identical to that in a pipe installed at a uniform gradient.

Life Cycle Analysis on Disposal and Reuse of Food Wastes in Sewerage Systems

K.Fujiu, A.Yoshida and H.Yamagata

Wastewater System Division

Project period: 2002-2004

Objectives

1. Study of technologies to collect and treat organic waste material in sewer systems

Documents have been studied and a field survey conducted in cities in the United States where the garbage disposer penetration rate is already high to obtain information about efficient sewer main maintenance technologies for use after the introduction of garbage disposers. In order to estimate the increase of the load of influent wastewater caused by the introduction of garbage disposers, the quality of garbage disposer wastewater prepared based on the quantity of kitchen garbage placed in the garbage disposers and the kitchen garbage collected from households using garbage disposers was analyzed in Utanobori Town in Hokkaido, Japan where a public garbage disposer introduction trial has already been carried out. The impact on water overflowing from a combined sewer system was studied by setting a model district and simulating the load increase.

2. Research on the overall evaluation of the environmental impacts of the introduction of garbage disposers

The impacts on sewer systems (sewer mains and treatment plants), waste treatment systems (collection and incineration facilities, final disposal sites), and on homes of the introduction of garbage disposers (household waste material only, not waste material from business offices) were studied by performing an overall evaluation based on LC-CO₂ and LCE (life cycle assessment).

Results

1. Study of technologies to collect and treat organic waste material in sewer systems

- 1) The sewer main cleaning rate in the United States is 29%, that is higher than the combined sewer main cleaning rate in Japan, but the correlation of the garbage disposer penetration rate – sewer main cleaning rate was low.
- 2) In Denver where both the garbage disposer penetration rate and the sewer main cleaning rate are both high, the main cause of sewer main plugging is the inflow of grease from kitchens and of tree roots, so it was impossible to confirm the direct impacts of garbage disposer waste water on sewer main cleaning.
- 3) It is assumed that the introduction of garbage disposers will increase the discharged load from combined sewer systems during rainfall.

2. Research on the overall evaluation of the environmental impacts of the introduction of garbage disposers

- 1) Because the introduction of garbage disposers increased the electric power consumed by sewage treatment plants and the quantity of nitrous oxide discharged during sludge incineration and reduced the quantity of electrical power produced by waste material in a waste material treatment system, the environmental load increased in terms of CO₂.
- 2) The introduction of garbage disposers reduced the environmental load in terms of CO₂, because it increases the quantity of energy recovered by anaerobic digestion.
- 3) A relatively small reduction of environmental load accompanied the rise in electrical power and water consumption by household use of garbage disposers, the increase of sewage sludge polymer coagulant, reduced traveling distance of garbage trucks, and the extension of the lifetime of final disposal sites.

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 maintain the beauty of the treated wastewater and protect the troubles of the function in the treated wastewater reuse system.

RESULTS

In 2003, we researched the below two things.

- (1) The study on the technical standard to maintain the beauty of the treated wastewater and protect the troubles of the function in the treated wastewater reuse system.
- (2) The fundamental study on the evaluation of the amount of the aerosols that may be produced in the reuse of treated wastewater.

We have studied about the technical standard of the treated wastewater reuse in the committee about the criteria of the treated wastewater in the treated wastewater reuse system(chairman; Prof. Kaneko, The Univ. of Setsunan).The main results of the discussion in the committee are the below things.

- ① The criteria will be applied to the water for toilet flushing, recreational impoundments, aesthetic impoundments, and sprinkling to trees, roads, fields and so on. Recreational impoundments and landscape impoundments may be ponds, rivers, fountains and water falls.
- ② The targets about the beauty of the treated wastewater and the troubles of the function were decided in consideration of the actual conditions of the troubles in treated wastewater reuse in Japan.
- ③ Chromaticity may be the important index in consideration of the results of questionnaire about the color, the clouds and the smell of the treated wastewater.

The committee will study about the technical standard of the treated wastewater reuse in 2004, too.

At the research of(2), we measured the coliform group and the heterotrophes in airs by the air filtration, using the experimental aeration tank as the source of aerosols. As a result of this research, we could find out the below thing.

- ① We should consider evaluating the amount of the aerosols by measuring the heterotrophes because the heterotrophes from the aeration tank were detected though the coliform group weren't detected.
- ② We may not have to consider the death of the heterotrophes under dry condition because the detected number of the heterotrophes is in proportion to the vacuuming time. But we should consider the way except the air filtration because the amount of the vacuuming air is little by air filtraion.

APPLICATION OF LCA TO WASTEWATER SYSTEM

H. Nakajima, Y. Aratani and R. Hiraide
Wastewater and Sludge Management Division

Project period: FY 2001 – 2004

OBJECTIVES

Recently, it has become necessary to evaluate the effect and influence of not only sewerage projects but also other public works from the viewpoint of global environmental protection. To evaluate the global environmental impact of projects, Life Cycle Assessment (LCA) is an effective technique. The life-cycle of social infrastructure includes the construction stage, operation and maintenance stage, and disposal stage; LCA studies the environmental aspects and impacts throughout this life-cycle. This research aims to establish and apply LCA to wastewater projects. We started this research in FY 2001, and in FY 2003 we calculated and analyzed the emissions of CO₂ and consumption of energy from a centralized wastewater treatment system and private (decentralized) wastewater treatment system.

METHOD

First, we selected an area for the case study and then calculated the present and future populations of the area. Next, we assumed that either a centralized wastewater system or private (decentralized) wastewater system would be installed in the area and defined four cases (Table 1). Finally, we calculated the emission of CO₂ and consumption of energy (environmental load) for each case.

Table 1 Classification in case study

Classification	Private (decentralized) wastewater treatment system (Case ①)		Centralized wastewater treatment system (Case ②)	
	General septic tank	Advanced septic tank	Building a new plant in the area	Treating wastewater at the existing plant outside the area
Sludge treatment	Treating at the sludge treatment facility outside the area	Treating at the sludge treatment facility outside the area	Treating at the sludge treatment facility outside the area	Treating at the existing incineration facility outside the area
Case No.	Case ①-1	Case ①-2	Case ②-1	Case ②-2

RESULTS

The results were as follows (Fig. 1):

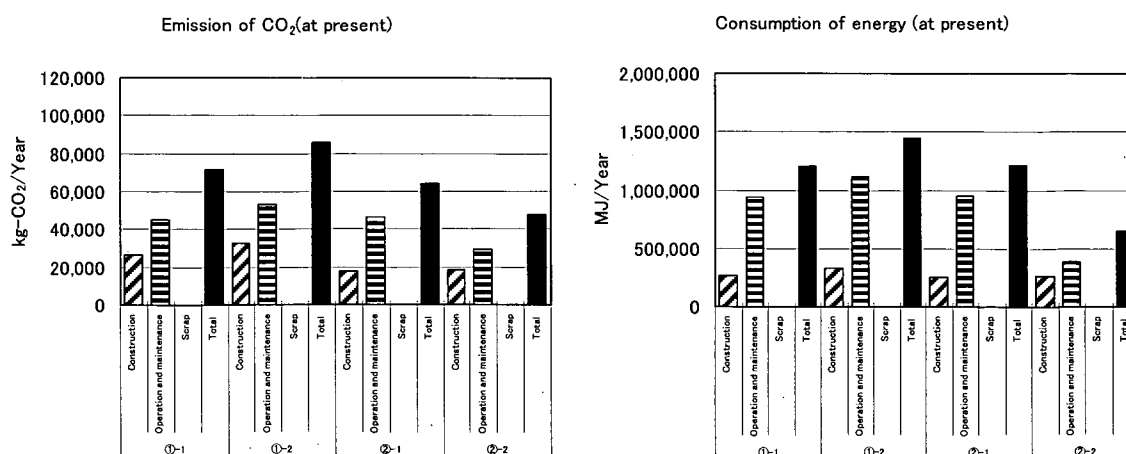


Fig. 1 Emission of CO₂ and consumption of energy (at present)

- (1) The environmental load from the centralized wastewater treatment system was smaller than that from the private (decentralized) wastewater treatment system.
- (2) Case ②-2 had the least environmental load of the four cases; case ①-2 had the highest load.
- (3) In every case, the environmental load from the operation and maintenance cycle was more than that from the construction cycle, typically accounting for 60% to 79% of the total environmental load. The trend of the total load in the four cases can thus be inferred by analyzing the load of the operation and maintenance cycle.

Evaluation method for advanced wastewater treatment systems

H. Nakajima, H. Yamashita, Y. Aratani
Wastewater and Sludge Management Division

Project period: 2002-2004

OBJECTIVES

Advanced wastewater treatment is essential for improving the water quality in closed water bodies and the safety of treated wastewater, which are now strongly demanded. This study makes suggestions for policy-making concerning advanced wastewater treatment by developing a method for evaluating such treatment, presents clear alternative scenarios based on scientific principles, and proposes a consensus-based decision-making method. The feasibility of the suggestions was examined through a case study of the Lake Biwa watershed.

RESULTS

In FY2003, we studied a consensus-based method for evaluating advanced wastewater treatment: the study was conducted in cooperation with a non-profit organization (NPO), 'Biwako Mizu Net', which focuses on the sewage and water quality conservation of Lake Biwa as well as Shiga Prefecture.

Various stakeholders such as local residents, NPOs, specialists, and so on are involved in this social experiment. The framework of the study and the role of participants are shown in Fig. 1.

The research results were as follows.

1. Questionnaire of NPOs' opinions regarding public works for conserving the water quality of Lake Biwa

A questionnaire study revealed that NPOs consider society should concentrate its efforts on the following: environmental education, measures against pollution from household wastewater and agricultural run-off, and implementation of sewage. Measures against familiar problems and reducing the large amount of pollutants were considered important. On the other hand, each NPO was interested

in participating in the following measures: environmental education, measures against pollution from household wastewater, preservation of water-resource forests, and measures against agricultural run-off. Measures against familiar problems, as mentioned above, were considered important. Activities that are familiar and easy to participate in, such as planting trees and preserving mountain villages, attracted great interest, while less familiar or more difficult activities for NPOs, such as sewage, attracted little attentions, even though the necessity of the measures was recognized.

2. Methods for evaluating the effects of public involvement in the process by questionnaire of local citizens

According to the results of a questionnaire of local citizens, the citizens' group with a high level of knowledge about the water environment of Lake Biwa tended to state a higher willingness-to-pay (WTP) compared to the middle- and low-level knowledge groups (the average WTP was 789, 564 and 593 yen per house monthly, respectively). The higher the knowledge about the water environment of Lake Biwa, the more interested the respondent was about environmental issues including sewage. Therefore, a correct knowledge about these issues is essential to stimulate interest and awareness. It is also important to continuously supply information.

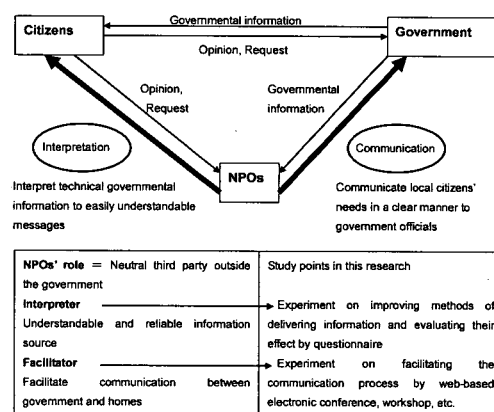


Fig. 1 Study framework and the role of the participants

Technology-based risk standard for wastewater treatment

H. Nakajima, H. Yamashita, H. Saino, K. Sakurai
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 noroviruses has become an increasing problem. This study presents a technology-based standard for ensuring the safety and reliability of treated wastewater.

RESULTS

In FY 2003, we studied the occurrence and evaluated the risk of several bacteria and viruses in raw sewage, treated wastewater and reclaimed wastewater of eight wastewater treatment plants. We also continued the detection of Protozoan (*Cryptosporidium* and *Giardia*) in these samples as in FY2002. In addition, we conducted a risk communication study by analyzing the results of FY 2002's questionnaire for pathogen risk with reuse of reclaimed wastewater.

The main results of research in fiscal 2003 were as follows.

1. Study for bacteria

Total and fecal coliform groups, *Escherichia Coli*, fecal streptococcus group, enterococcus group, and *Clostridium perfringens* were examined as indicator organisms; and *Salmonella* spp., *Legionella* spp., *Campylobacter jejuni* and *E. Coli* O-157 were tested as pathogens. All measurements were conducted by culture methods. Rare detection of these pathogens suggested that the annual risk of infection by them was far below 10^{-2} , yet it was difficult to estimate the statistical probabilities of their occurrence. *Salmonella*, *C. jejuni* and *E. Coli* O-157 are thought to be inactivated by proper disinfection (chlorination etc.) at the point of effluent discharge, so no special treatment is required. *Legionella*, on the other hand, is thought to re-grow in bio-film (slime) in pipes and so further research on this risk should be conducted.

2. Study for viruses

Enteroviruses and noroviruses (genotype G1 and G2), RNA virus, and adenoviruses, DNA virus, were detected by a real-time PCR (polymerase chain reaction) method and enumerated by the MPN method. Frequent occurrence of viruses was observed in raw sewage and secondary treated wastewater; noroviruses were detected in advanced treated wastewater sporadically. There were several difficulties in assessing the risk of noroviruses and so a tentative risk assessment had to be adopted: PCR positive results (gene detection) did not directly mean the occurrence of infectious viruses and cell-culture methods for noroviruses have not yet been developed. A dose-response model of noroviruses is not available, so the risk should be calculated by a model of the surrogate viruses. The use of advanced disinfection techniques such as ozonation and ultraviolet radiation (UV) should be considered if the risk of infection is considered to be high, such as reused recreational water

3. Study for protozoa

Cryptosporidium parvum oocyst and *Giardia lamblia* cyst were examined by microscopy as in FY 2002. The occurrence of *Cryptosporidium* decreased significantly compared to FY 2002; modification of collection step (changed to collect both oocyst and cyst simultaneously) might have affected the recovery rate of oocyst. The occurrence of *Giardia* was high in raw sewage, but the internal structure was difficult to confirm in treated/advanced treated wastewater; thus, their infectivity should be considered for risk assessment because they were not so robust to chlorination as *Cryptosporidium*,

DECOMPOSITION OF ENDOCRINE DISRUPTERS UTILIZING 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.

RESULTS

The performance of EDs which decompose microorganisms was investigated by using a wastewater treatment pilot plant. In FY 2003, a batch investigation and a pilot plant investigation were conducted. The results of the investigations in FY2003 are summarized as follows.

- 1) In the batch investigation, E2 was added to the activated sludge to the amount of $100 \mu\text{g/L}$, and the state of decomposed EDs was observed. In one case, the carriers, that immobilized the EDs that decompose microorganisms, were mixed with activated sludge, and in another case, the carriers were not mixed. As a result, most of the E2 were decomposed quickly in both cases. The amount of decomposed E2 was higher in the case where the carriers were mixed. The difference was observed especially just after E2 was added to activated sludge. (Fig. 1)
- 2) In the pilot plant investigation, two pilot plants were prepared. The carriers were mixed in one pilot plant, and not in the other. 10mg of E2 were added to each pilot plant at time 0, and the state of decomposed EDs was observed. As a result, E2 concentration in treated water was always lower in cases where the carriers were mixed. The decomposition rate was thought to be larger in the cases where the carriers were mixed because not only E2 was lower, but also E1.(Fig. 2) that was investigated using the same pilot plant.

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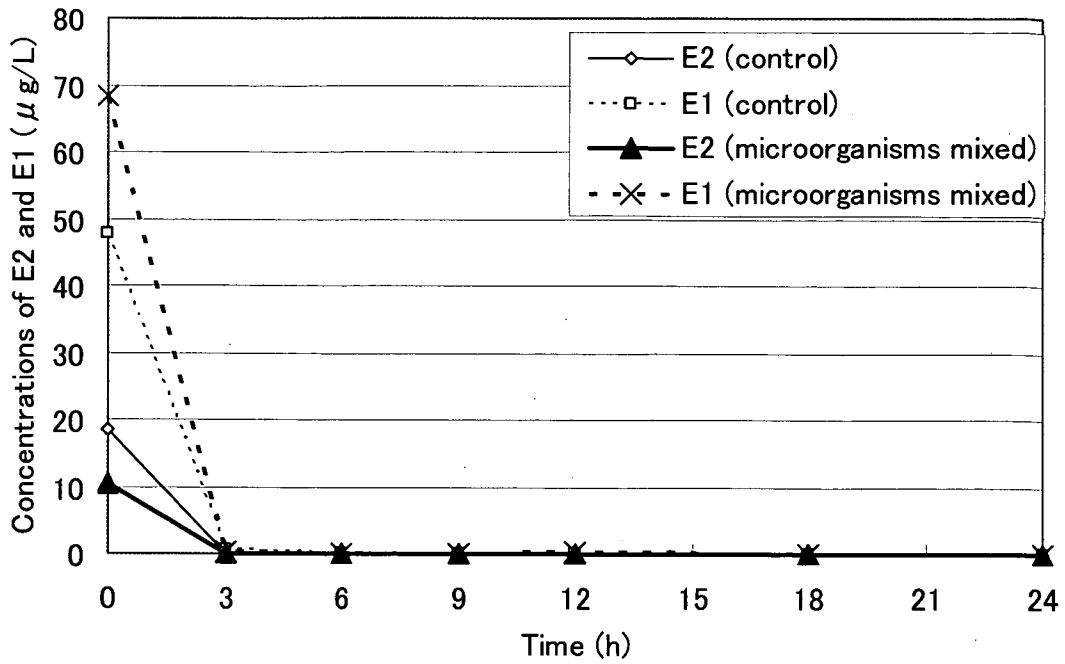


Fig. 1 E2 and E1 in batch investigations

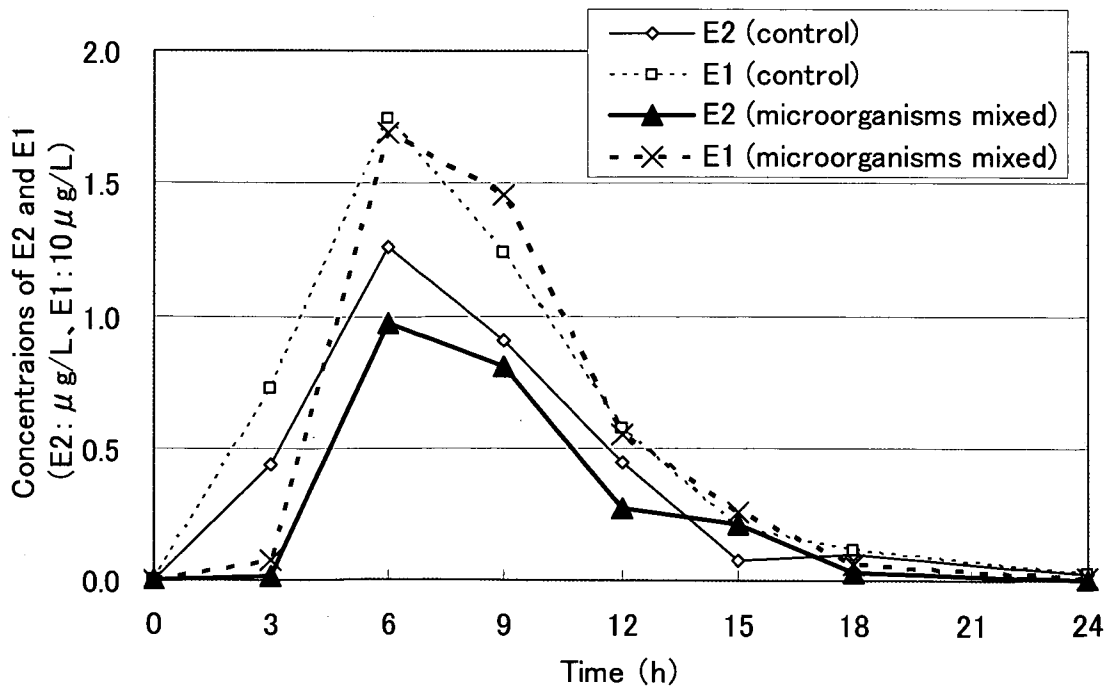


Fig. 2 E2 and E1 in pilot plant investigations

Study on Wastewater Reclamation System for River Ecosystems

(FY2001–2005)

Hideichiro Nakajima, Yusuke Aratani and Atsushi Tajima
Wastewater and Sludge Management Division, Water Quality Control Department
National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure and Transport

Introduction

As the sewerage system diffuses, the amount of treated wastewater 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. The amount of treated wastewater reused as landscaping water in urban areas is being increased to restore the waterside environment that had been lost by urbanization. Such places provide oases in cities for aquatic life.

However, 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 is because 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, wastewater treated with sand filtration or other similar processes after biological treatment is often reused for landscaping water, but there have been few cases in which more advanced treatment for removal of nitrogen or phosphorus or disinfection by ozone or ultraviolet irradiation has been applied. Also, it is not yet fully understood what impact or effect such highly advanced treatment processes have on aquatic life.

Therefore, further research 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 better habitats for aquatic life at receiving waters, we are studying 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. We will propose an ideal form of wastewater reclamation system which is acceptable for the ecosystem in terms of effectiveness and economy.

Method

1) Fieldwork in Yokohama city

The purpose of this fieldwork was to identify the differences of aquatic biota caused by different types of wastewater treatment method and treatment level, especially concentration of nutrients. The Kohoku wastewater treatment plant in Yokohama city uses two different treatment processes: the conventional activated sludge process and the anaerobic-Wuhrmann process. Each process has its own effluent point. We observed aquatic biota at each effluent point and analyzed the features of the biota which had formed there. We observed attached algae, benthic animals and phytoplankton; analyzed the biomass, dominant species, occupancy rate and biological diversity for the organisms; and examined the transformation of species composition.

2) Fieldwork in Tadotsu town

Tadotsu town in Kagawa prefecture plans to reuse treated wastewater effectively in the town and has some facilities for this purpose. These facilities began to be operated at the beginning of FY 2004. This fieldwork is analyzing the transformation of species composition before and after the facilities began to be operated.

This year, we observed the species composition before the facilities began to be operated. We examined aquatic biota at three effluent points: Sakaemachi artificial channel, Higashisakura River and Sakura River.

3) Laboratory test

This test included implementing a control experiment of discharging wastewater treated by an actual treatment plant using the anaerobic-anoxic-oxic process and sand filtration without chlorination in order to identify differences in aquatic biota growing at the test channel under different conditions of disinfection. We discussed the relationship between the quality of treated wastewater and aquatic biota. Experiments conducted this year were based on the following two stages: the first stage focusing on the relationship between chlorine dosage and attached algae, and the second stage focusing on the relationship between different types of disinfection method (chlorination, ozonation and ultraviolet irradiation) and attached algae. As the second stage was continuously conducted after the first stage, we could observe the transformation of aquatic biota caused by changing the disinfection method from chlorination to ozonation or ultraviolet irradiation (see Table 1).

Table 1 Disinfection Method and Concentration

channel No.	the 1st stage			the 2nd stage		
	disinfection method	concentration	unit	disinfection method	concentration	unit
A	chlorination	0.01	mg/L	chlorination	0.01	mg/L
B	chlorination	0.1	mg/L	chlorination	0.1	mg/L
C	chlorination	1.0	mg/L	chlorination	1.0	mg/L
D	chlorination	1.0	mg/L	ozonation	5.0	mg/L
E	chlorination	1.0	mg/L	ultraviolet	200	J/m ²
F	not disinfection	-		not disinfection	-	

Results

1) Fieldwork in Yokohama city

In this fieldwork, we obtained the following results:

- There was no difference of biomass caused by different types of wastewater treatment method or treatment level, especially the concentration of nutrients at each effluent point.
- The higher the concentration of nutrients is, the higher the occupancy rate of green algae is.

2) Fieldwork in Tadotsu town

This year, we observed the species composition before the reclamation facility began to be operated at three different effluent points. Next year, we will observe the species composition after the facilities began to be operated at the same points; analyze the biomass, dominant species, occupancy rate and biological diversity for the organisms; and examine the transformation of species composition.

3) Laboratory test

We are continuing to carry out this experiment in the test channel and analyze the results. In the first stage, we observed visible differences between the biomass growing at channels A, B and F and that growing at channels C, D and E. The amount of biomass growing at channels A, B and F is more than that growing at channels C, D and E, and we consider that this phenomenon was caused by differences of chlorine dosage.

FATE OF SANITARY INDICATORS IN TREATED WASTEWATER

Hideichiro Nakajima, Hideyuki Saino, Kensuke Sakurai

Wastewater and Sludge Management Division

Project period: 2002-2004

OBJECTIVES

With the ongoing development and expansion of sewage systems, treatment plants are discharging treated sewerage water in considerable volumes into rivers and waterways, steadily increasing the proportion of treated water in natural water resources. Meanwhile, recycling of sewerage water is being introduced in urban areas to help conserve finite water resources. Treated sewerage water from treatment plants is used for a range of applications such as flushing toilet, using landscape, watering of vegetation and industrial processes. In this way, members of the general public are increasingly likely to come into contact with treated sewerage water in the course of normal everyday life.

Sewerage contains a variety of pathogenic microbes generated by human activity. Total coliforms, the microbe indicator traditionally used to identify pathogenic microbes, are not considered a sufficiently reliable indicator. In order to maintain proper hygienic standards in treated sewerage water and environmental water, we need to assess to all indicator microbes, not just total coliforms, and select the most suitable indicator for the task at hand. In this study, we compared the behavior of total coliforms with that of E.Coli, Faecal streptococcus and C.perfringens spores in discharged sewerage and analyzed the characteristics of indicator microbes in water resources such as rivers, coastal areas and discharge streams.

METHODS

The study involved a combination of a model watercourse experiment and a field survey. The model watercourse shown in Fig.1 was constructed for the purpose of the experiment. Disinfected treated sewerage water was circulated along the watercourse with a pump and indicator microbes were measured periodically over time. For the field survey, river water was sampled in five to six locations prior to treated sewerage discharge, then directly following discharge, then further downstream. Indicator microbes and water quality indicators were analyzed on the day of sampling.

RESULTS

(1)Watercourse experiment

The watercourse experiment was designed to provide information about chronological changes in indicator microbes in discharge areas. The results are shown in Fig.2.

The test measurements indicated a change in the total coliforms count, as measured using desoxycholate base agar medium, over the period following chlorine disinfection. These results suggest that microbe populations in sewerage discharge can vary depending on the time of measurement. Note that the E.coli count from the medium used in this experiment did not increase after chlorine disinfection.

- Faecal streptococcus had lower survival rates than total coliforms, both with and without chlorine disinfection. As with E.coli, the number of Faecal streptococcus colonies did not increase after disinfection.

- Chlorine disinfection did not have any effect on C.perfringens spores. With no disinfection, the concentration fell directly after discharge. In this way, the behavior of C.perfringens spores clearly differs from that of the other indicator microbes (total coliforms, E. Coli and faecal streptococcus).

(2)Field survey

The field survey was conducted in order to corroborate the results from the watercourse experiment.

- In the field survey, the treated water is diluted by the river water and reduced levels of indicator microbes were recorded. However, the increase in total coliforms observed in the watercourse experiment was not detected in the field survey.

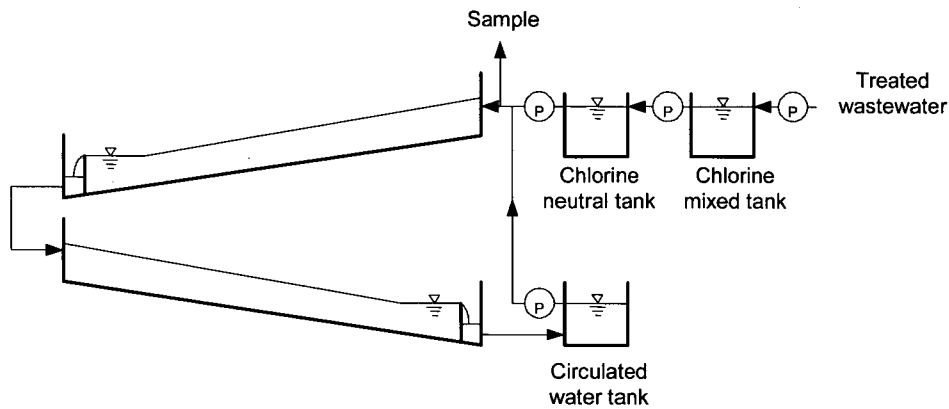


Fig.1 Schematic of model watercourse

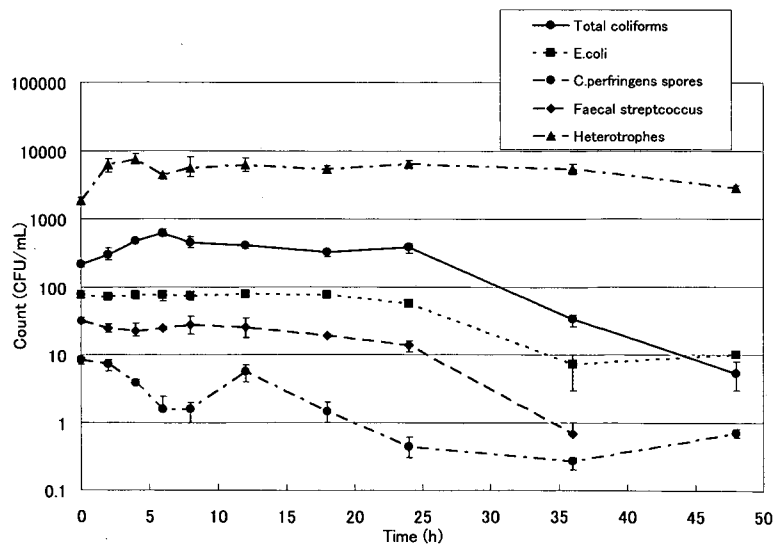


Fig.2 Microbe behavior when chlorine added at 0.5mg/L

EFFICIENT REMOVAL OF SLIGHT HAZARDOUS MATERIALS BY OZONATION

A. Tajima and H. Nakajima

Wastewater and Sludge Management Division, Water Quality Control Department

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 considered the details of the experiments as below on a basis of the last-year results and set up the systems for the experiment.

(1) decision of the target materials

We will choose NP and BPA which may be the endocrine disruptors to the fishes and E1 and E2 which may be the endocrine disruptors included in the urine of human and animals as the target materials.

(2) decision of the property of the treated wastewater used in the experiments

We will choose the treated wastewater by the conventional activated sludge process and the A2O process in the pilot plant and by the sand filtration in the real treatment plant in order to grasp the influence of the property of the treated wastewater on the removal efficiency of the endocrine disruptors.

(3) decision of the concentration of the target materials in the treated wastewater before ozonizing

We will add the standard liquid of the target materials into the storage tank and adjusted the concentration in the tank to the maximum concentration in the effluent from the sewerage treatment plant in 2000. (NP=1.0 μ g/L, BPA=0.5 μ g/L, E1=0.06 μ g/L, E2=0.003 μ g/L)

(4) decision of the ratio of the amount of ozone to the flow of the treated wastewater, the reaction time, and height of the reactor

We found that it is important to reduce the amount of ozone and reaction time as much as possible in order to reduce the maintenance cost and the construction cost of the ozone treatment facilities from the last-year experiment. And also, we found that E2, NP, and BPA were reduced down to the level of N.D. under the condition that the ration of ozone is more than 5mg/L and the reaction time is more than 7min from the last-year experiment.

So, we will consider the removal efficiency of the target materials under the condition that the ration of ozone is less than 5mg/L and the reaction time is less than 7min. And also we will consider the influence of the reactor height on the removal efficiency of the target materials and ozone dissolution efficiency by setting the reactor height in the four stages of 1.6m, 2.4m, 3.1m and 4.1m.

RESEARCH ON THE RISK ASSESSMENT OF CHEMICAL SUBSTANCES IN A WATER ENVIRONMENT

M. Takahashi, H. Saino
Wastewater and Sludge Management Division

Project period: 2003-2005

OBJECTIVES

Recently, there has been growing concern about the effects of chemical substances like dioxin or endocrine disrupters on human health and the ecosystem. For example, companies have been required to register the release or transfer of 354 chemical substances under the PRTR law (Pollutant Release and Transfer Register) since 1999. The environmental standards were examined in view of aquatic life protection, and total zinc was added to the environmental standards list on Nov. 5 2003.

The Ministry of Land, Infrastructure and Transport, that manages rivers, sewerage systems, roads, and so on, is obligated to perform risk management of chemical substances in the environment cooperatively with stakeholders. But, the actual state of chemical substances in the environment is not clear. So this research was case studies of water environment like rivers, and the collection and classification of information necessary for risk management such as the amount of chemical substances or chemical change of these substances in the environment.

METHODS

The actual state of chemical substances in the environment of rivers for example is not clear, so in FY2003, appropriate rivers were chosen, and the actual states of the main chemical substances were studied.

As appropriate rivers, Kurokawa river (in Tochigi Pref.) and Yatagawa river (in Gunma Pref.) were chosen because many chemical substances referred to in the PRTR flowed into them in 2001. We surveyed chemical substances such as those often detected in environmental standards and PRTR in 2001, and endocrine disrupters such as Nonylphenol and estrogen which is discharged from wastewater treatment plants.

RESULTS

The results of the studies in FY2002 were as follows.

- (1) On the Kurokawa river, which was not affected very much by industrial wastewater, the effects on wastewater treatment plant of organic substances and heavy metals were severe, and these substances were reduced as the river flowed. On the other hand, organic substances produced by the chemical industry were detected but completely unaffected by wastewater treatment plant. (Fig. 1)
- (2) On the Yatagawa river that was affected severely by industrial wastewater, the effects of the wastewater treatment plant were not observed. On the other hand, discharged chemical substances were thought to differ between industries, because the concentrations of chemical substances produced by the chemical industry were very different at each sampling point. (Fig. 2)

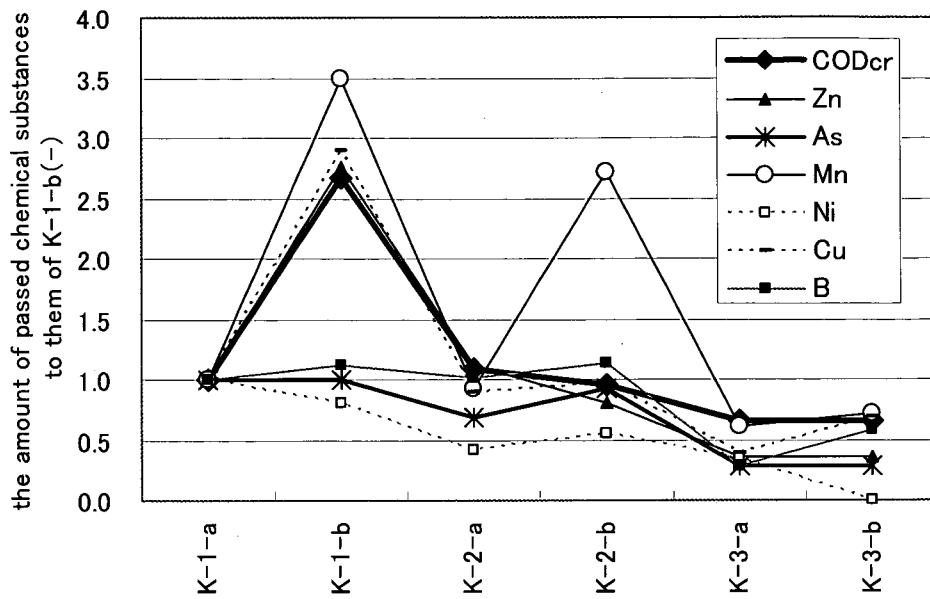


Fig. 1 The amount of heavy metals in Kurokawa river

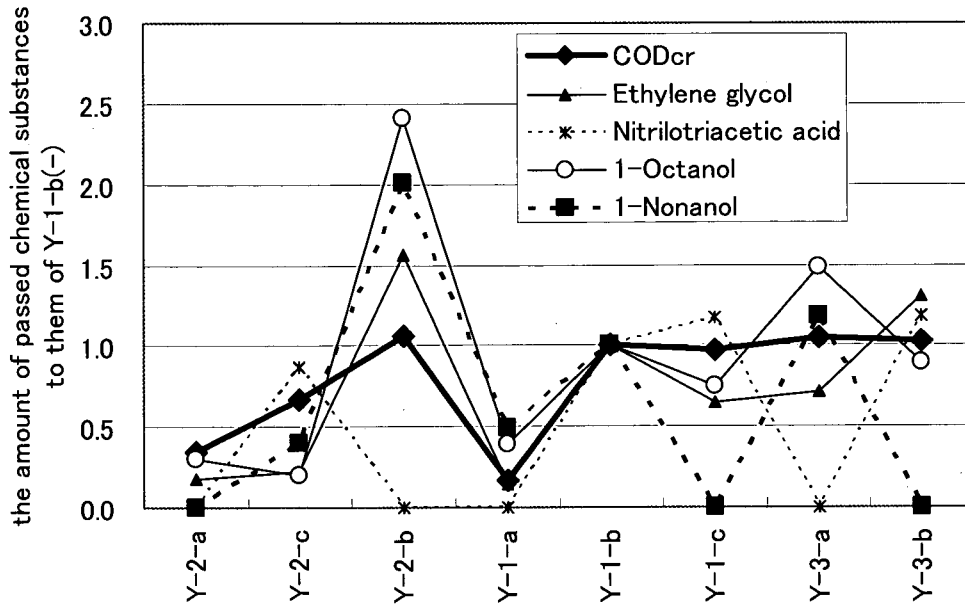


Fig. 2 The amount of organic substances in Yatagawa river

EVALUATION OF WATER QUALITY SECURITY MEASURES IN THE GANGES RIVER BASIN

H. Nakajima, S. Nakajima, R. Hiraide
Wastewater and Sludge Management Division

Project period: FY2003-2008

OBJECTIVES

In Asia and other regions, rapid population growth, urban development, and industrialization have exacerbated water problems, and human activities have caused fluctuation of water cycles and other problems. The goal of this research is to help resolve these problems by presenting policy scenarios for nine typical Asian river systems. This research is done as team research (CREST type) led by research representative Professor Sunada of the University of Yamanashi, because the area studied is vast and faces many challenges. The Wastewater and Sludge Management Division of the NILIM is in charge of the presentation of policy scenarios with priority on water problems in the Ganges river basin.

OBJECT AREA

The Ganges river is the most heavily populated river basin in Asia, and here, population growth and urbanization have been accompanied by water quality pollution and the consequent shortage of sanitary water, flooding, and other serious problems. Asian rivers typified by the Ganges River are irreplaceable for the daily life of the people, many of whom use them for bathing and washing clothes, and who discharge their human waste in their waters. This results in rampant infectious diseases originating in the river water, and in regions where urbanization is particularly advanced, water pollution accompanied by health problems caused by pathogenic microorganisms are serious public issues. Therefore, water quality preservation measures have been proposed as ways to prevent health problems caused by pathogenic microorganisms, taking the Ganges River Basin as the major example.

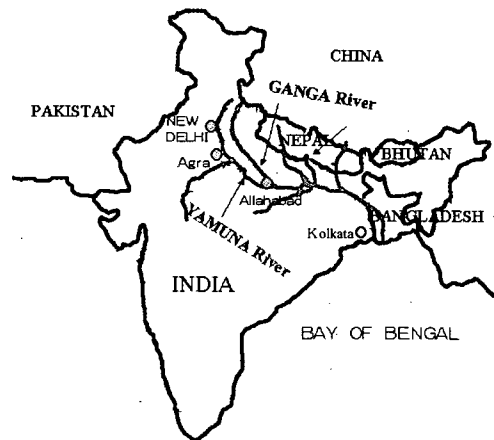


Figure 1 Ganges river area

METHOD

This research is carried out by first conducting a field survey to collect adequate basic documents concerning the life style of the local people, state of pollution of the river, pollution sources and basic units, then based on these findings, organizing step-by-step sewerage system provision methods that hypothesize future developments to present scenarios with the priority on water quality problems. The field survey is a

survey centered on the Indian capital city of New Delhi where water pollution is particularly severe. In New Delhi, the Yamuna river that is a tributary of the Ganges river is used as a source of water for daily use by the local people.

In 2003 that was the first year of the surveys, a field survey was performed in India to complete basic documents. The survey included observations of the region and measurements of water quality in New Delhi and its surroundings.

RESULT

The results have shown that the water quality is high in the upstream section, but its water quality is severely harmed as it passes through cities (Table 1). The causes are insufficient sewerage treatment plants and the excessively dense population, but in New Delhi in particular, the quantity of water flowing into the city is too low, because upstream, water is used for irrigation and is taken for treatment by water treatment plants.

Table 1 Water quality of Yamuna river

		Up Stream	Down Stream	Down Stream
		Palla	Okhla	Mahatpur
pH		7.2	7.5	7.1
DO	(mg/L)	5.7	2	0
T-BOD	(mg/L)	<1	30	35
T-COD _{cr}	(mg/L)	3	96	122
T-N	(mg/L)	1.6	32.4	45.53
K-N	(mg/L)	1.4	20	37
NH ₄ -N	(mg/L)	1	17	32
NO ₂ -N	(mg/L)	0.2	0.7	0.03
NO ₃ -N	(mg/L)	<1	11.7	8.5
PO ₄ -P	(mg/L)	1.3	3.1	9.1
SS	(mg/L)	5	61	27
Coliform Group	MPN (MPN/100mL)	2.4E+05	1.5E+07	9.4E+08
	Plate Culture (CFU/mL)	4.0E+02	1.1E+05	8.0E+05
Fecal Coliform Group	MPN (MPN/100mL)	2.4E+05	1.5E+07	9.4E+08
	Plate Culture (CFU/mL)	2.1E+03	8.5E+04	7.1E+06
E. coli	MPN (MPN/100mL)	2.4E+05	1.1E+07	9.4E+08
	Plate Culture (CFU/mL)	2.7E+03	7.8E+04	6.1E+05
Enterococcus	MPN (MPN/100mL)	2.3E+03	9.4E+05	9.4E+06
Salmonella		detect	detect	detect

Support: JAPAN SCIENCE AND TECHNOLOGY AGENCY (JST) CREST

Advanced Systems for Effective Use of Sewage Sludge Energy

Y. Suzuki, S. Ochi, T. Ochi and H. Nagasawa

Recycling Research Team, Material and Geotechnical Engineering Research Group,
Public Works Research Institute

Project period: FY2000–2003

OBJECTIVES

Sewage sludge is the only energy resource derived from sewerage systems that can contribute to the energy and cost saving of the sewage works; therefore, the construction of a highly developed system utilizing such energy is needed. The aim of this study is to convert the current incineration process to a power generation process and reform the anaerobic digestion process into a power generating and heat recovering system based on effective use of methane gas.

METHODS AND RESULTS

We developed a new combustion system of dewatered sludge, composed of a 0.3-MPa pressured fluidized bed furnace, a ceramic filter and an air turbo-charger, which does not require external energy supply for combustion and can supply pressured air to the aeration tank of wastewater treatment. Figure 1 shows the flowchart of the developed combustion system. The pressured-adsorption gas storage tank was also developed for storing large amounts of digestion gas, with a capacity 20 times larger than the conventional atmospheric pressure storage tank of. The developed process and system are analyzed through case studies and the effects were evaluated.

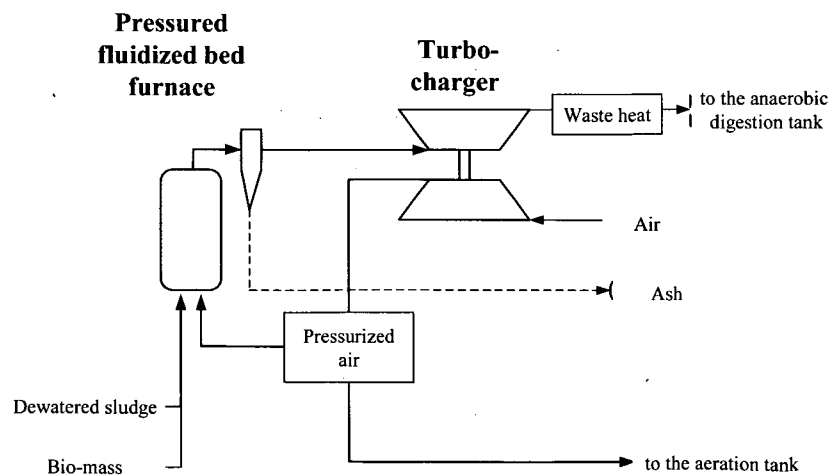


Figure 1 Flowchart of developed combustion system

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, numerous reports have been published on the environmental problems caused by endocrine disruptors (EDs) discharged as trace chemicals in many countries and regions. Among the manufactured chemicals necessary for daily life and activities, some of those that are used and discharged can disrupt the endocrine system of humans and wildlife. Detailed investigations on this problem have been conducted around the world. The Ministry of Construction carried out a national investigation on the pollution of river water and treated wastewater by EDs 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 soil that includes sewage sludge compost.

RESULTS

In FY2003, we carried out experiments to clarify the fate of nonylphenol (NP) and its related compounds such as nonylphenol polyethoxylates (NPnEOs) and nonylphenol polyethoxy carboxylic acids (NPnECs) in the anaerobic digestion process. NP is believed to be one of the EDs.

NP1EO, NP1EC, and NP2EC were spiked respectively to anaerobic digesters supplied with thickened sludge and the response was observed. NP1EO and NP1EC are considered as precursors of NP. NP2EC is considered as a precursor of NP1EC.

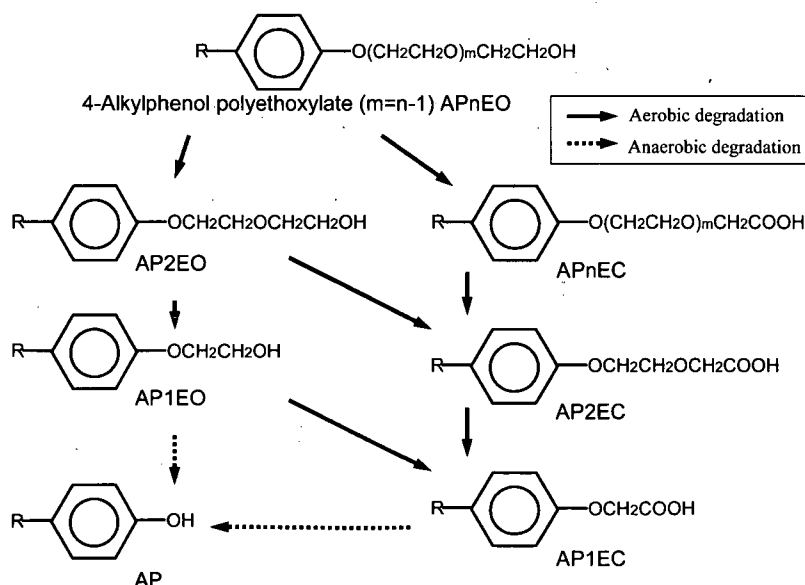


Figure 1 Decomposition of nonylphenol polyethoxylates (based on Ahel *et al.*)
AP: Nonylphenol, R: C₉H₁₉

Figure 2 shows the outline of a test apparatus. The volume of injected thickened sludge was 200 mL and the same volume of digested sludge was taken out, every day excluding holidays. The volume of digested sludge in each glass vessel was 4 L. Average retention time was approximately 28 days. The test was performed at a temperature of 35°C to simulate the mesophilic digestion.

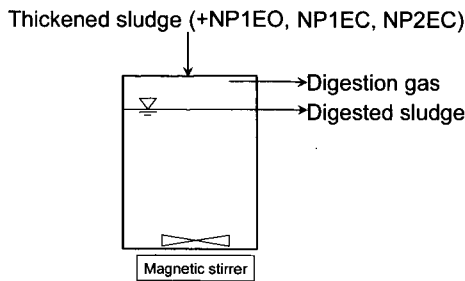


Figure 2 Outline of an anaerobic digestion test apparatus

Figure 3 shows the test results in which NP1EO was spiked. Approximately 40% of the spiked NP1EO was converted to NP.

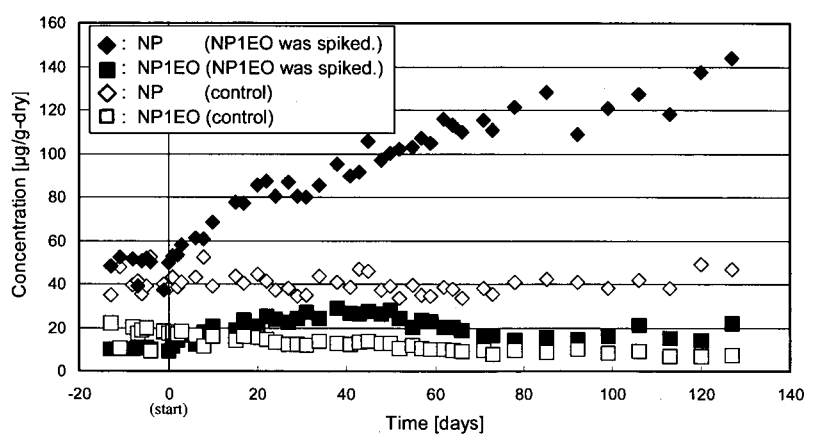


Figure 3 Decomposition of NP1EO and generation of NP in anaerobic digestion process

Almost all of the spiked NP1EC was converted to NP when injected to an anaerobic digestion testing apparatus with thickened sludge. When NP2EC was injected, conversion to NP did not occur until the 20th day.

In the coming years, it will be necessary to develop analysis techniques for the NPnECs in the sewage sludge sample to clarify the fate of NPs in more detail. It is also necessary to develop a technique for controlling NPs in the sewage sludge treatment process.

Reference

Ahel, M., Giger, W. and Koch, M. (1994). Behavior of alkylphenol polyethoxylate surfactants in the aquatic environment - I. Occurrence and transformation in sewage treatment. *Water Research*, **28**, 1131-1142.

Recycling of Organic Wastes by Utilizing Bio-Solids Treatment System

Y. Suzuki, S. Ochi and H. Nagasawa

Recycling Research Team, Material and Geotechnical Engineering Research Group,
Public Works Research Institute

Project period: FY2002–2005

OBJECTIVES

Large quantities of waste wood and grass are produced during civil engineering works and maintenance of green spaces such as road slopes, levees, airports and parks, and yet such wastes are scarcely used because of the 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 at the development of a method for 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 FY2003, we carried out experiments in anaerobic digestion of a mixture of bio-solids and steam-exploded wood to determine the fluidity and dewaterability of the digested slurry for the development of a co-fermentation process. We also carried out basic experiments in acid fermentation of waste wood using cellulose powder for the production of volatile fatty acids (VFA) that can be used as the electron donor in the denitrification process. It was clarified that the risk of increasing the load of digester mixer is low if the mixing ratio of steam-exploded wood to bio-solids is kept below 1, and that the water content of the dewatered slurry was lower than that of common digested bio-solids. The acid fermentation activity was high under the condition of pH ranging from 6.5 to 8, and the main product in such pH range was acetic acid, which reached the concentration of 10,000 mg/L (Figure 1).

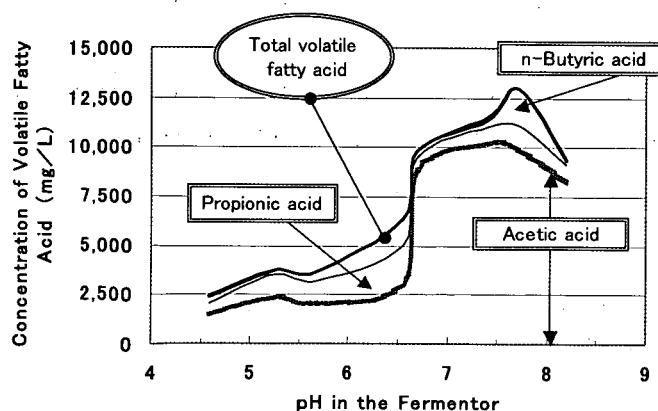


Figure 1 Relationship between pH in the fermentor and concentration of volatile fatty acid

Study on Risk Assessment for Reuse of Sewage Sludge

Yutaka Suzuki, Mamoru Suwa, Isao Igarashi

Recycling Research Team

Project period: 2001–2003

OBJECTIVES

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

The PRTR (Pollutant Release and Transfer Register) Law, which was enforced in 2001, stipulates that the sewerage manager must measure and report the behavior of heavy metal in the sewage treatment process. The goal of this study is to clarify the behavior of the heavy metal in the sewage treatment process and the elution amount of heavy metals from the sludge reuse products.

METHOD AND RESULT

Research results of FY2003 are as follows:

Elution amounts of heavy metals were examined using two elution test methods that differed mainly in the pH condition of the elution water. Elution characteristics differed among burnt construction materials, non-burnt construction materials and compost. From the elution results, health risks associated with heavy metal elution were calculated, revealing that almost all hazard ratios of reusing sludge for construction materials and compost were very low, but that those of As and Pb exceeded the value of 1 in sludge reused for fertilizer. Tables 1–3 show the results.

Further research is needed to clarify the fate of eluted heavy metals in the environment and the amount of human exposure to the heavy metals.

Table 1 Hazard ratio of burnt construction

Heavy metals	Burnt construction materials		
	max	min	average
B	1.7E-02	7.3E-04	7.6E-03
Mn	2.8E-01	2.1E-03	4.9E-02
Ni	6.6E-05	4.5E-06	3.0E-05
As	6.9E-02	1.1E-03	3.4E-02
Se	3.1E-02	5.0E-04	1.2E-02
Ag	1.5E-09	2.0E-10	3.9E-10
Cd	1.3E-02	2.0E-03	5.8E-03
Sn	8.0E-04	8.0E-04	8.0E-04
Sb	1.4E-02	3.3E-04	3.0E-03
Pb	5.2E-02	5.7E-04	6.8E-03

Table 2 Hazard ratio of non-burnt construction materials

Heavy metals	Non-burnt construction materials		
	max	min	average
B	1.2E-02	9.3E-04	4.7E-03
Mn	7.3E-03	4.2E-05	1.9E-03
Ni	1.2E-05	2.9E-06	6.3E-06
As	2.0E-01	1.0E-03	6.2E-02
Se	1.2E-03	5.0E-04	6.8E-04
Ag	2.0E-10	2.0E-10	2.0E-10
Cd	2.0E-03	2.0E-03	2.0E-03
Sn	1.8E-03	8.0E-04	1.1E-03
Sb	9.9E-04	3.3E-04	5.6E-04
Pb	3.8E-03	5.7E-04	1.4E-03

Table 3 Hazard ratio of compost

Heavy metals	Compost		
	max	min	average
B	3.0E-01	5.8E-02	1.5E-01
Mn	2.2E+00	5.4E-02	6.4E-01
Ni	2.9E-03	2.3E-04	1.3E-03
As	5.8E+00	6.0E-01	3.3E+00
Se	2.6E-01	1.4E-02	1.3E-01
Ag	1.2E-06	1.7E-08	4.6E-07
Cd	4.0E-01	2.5E-02	1.7E-01
Sn	1.9E+00	2.4E-02	4.0E-01
Sb	1.7E-01	3.3E-03	5.6E-02
Pb	5.5E+00	3.3E-02	1.1E+00

Study on Techniques for Identifying Pathogenic Microorganisms and Analyzing Their Behavior

Yutaka Suzuki, Mamoru Suwa and Akiko Suyama
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 necessary to ensure that the 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 due to the importance of developing 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 work performed during FY2003 are described below.

The study focused on the *Cryptosporidium* pathogen and virus. The method currently used to detect *Cryptosporidium* oocysts is microscopic 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

In FY2003, we carried out experiments to evaluate the adaptability of the real-time PCR method to detecting *Cryptosporidium* oocysts, and it was found that the PCR method could be used as an alternative to the microscopic observation method.

For virus detection, concentration and elution methods were investigated and suitable methods for influent, effluent and tertiary effluent were proposed. Tables 1–2 show the results.

Table 1 Recovery ratio of phage by cellulose adsorbed and coagulation

	Treated eff		Advanced eff	
	Phage add	Phage non-add	Phage add	Phage non-add
Recovery ratio (%)	5.9	56	4.3	98

Table 2 Recovery ratio of phage by various collection methods

Collection method	Recovery ratio (%)		
	Influent	Treated eff	Advanced eff
Positively charged membrane	0.68	2.3	13
Negatively charged membrane	5.5	1.7	0.6
Ultracentrifugation	59	30	20
Polyethylene Glycol	58	36	38

Advanced removal of residual organic matter in secondary effluent for wastewater reuse

Y. Suzuki and S. Kim

Recycling Research Team, Material and Geotechnical Engineering Research Group,
Public Works Research Institute

Project period: FY2002–2005

OBJECTIVES

Treated wastewater is regarded as an alternative water resource in urban areas; however, residual organic matter may cause problems such as regrowth of microorganisms in distribution facilities and change of biota in water environments. This research aims at developing advanced removal methods of residual organic matter in an efficient and cost-effective way.

METHODS AND RESULTS

In FY2003, a binding immobilization process and a membrane bioreactor were applied to the advanced treatment of secondary effluent, and three kinds of fractionation methods using gel permeation chromatograph (GPC), ultrafiltration membrane and resins were employed for characterizing the organic matter in the influent and effluent samples.

The results of the research are as follows:

- 1) Microorganism regrowth potential evaluated as attached biomass was reduced to about half after the advanced treatment, which shows the effectiveness of the advanced treatment in controlling the regrowth potential.
- 2) Neutral hydrophilic fraction (NHIF) was reduced by the advanced treatment (Figure 1), suggesting that NHIF is related to the regrowth of microorganisms.

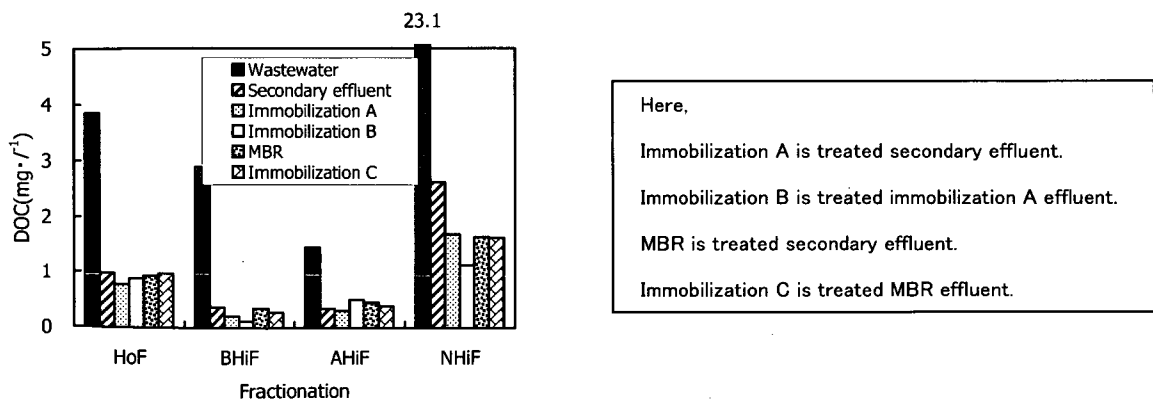


Figure 1 Results of fractionation of dissolved organic carbon in wastewater, secondary effluent, immobilization effluent and membrane bioreactor effluent

HoF: Fraction of Hydrophobic Acid, BHIF: Fraction of Hydrophilic Base, AHIF: Fraction of Hydrophilic Acid
and NHIF: Fraction of Hydrophilic Neutral Organics

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 severe problem. Organic compounds that are generated or used in the watershed are believed to 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). Some PAHs such as benzo[*a*]pyrene are reported as probable human carcinogens. Therefore, it is necessary to clarify the status of pollution of sediment with PAHs and the fate of PAHs in lakes.

RESULTS

In FY2003, sampling of sediment from three lakes and analysis of PAHs in these samples were carried out.

Schematic diagrams of these lakes and sampling points are shown in Figures 1, 2, and 3. The surface and core sediment samples were collected from the bottom sediment of the lakes. Lake A, located in an urban area (Figure 1), was in a state of eutrophication. Lake B was located in a forest area (Figure 2), and there was no residence in the lake basin. These two lakes were selected to compare the effect of human activity on the occurrence of PAHs in the sediment. An artificial lagoon, C, was located in an agricultural area. Approximately 42% of the basin of the artificial lagoon was covered by agricultural area including a lotus field.

The amounts of PAHs were measured using GC/MS.

1. At the eutrophicated lake (Lake A), the contents of PAHs with more than four rings were high in the sediment. It was also revealed that the contents of PAHs in the sediment samples taken near the river mouth were high.
2. At the lake in the forest area (Lake B), the contents of PAHs with more than four rings were high in the sediment. The order of content of PAHs was almost equal to that in Lake A. It was also revealed that the PAHs load via atmosphere may have risen after the 1960s (Figure 4).
3. It was revealed that we could control the PAHs from the river using the artificial lagoon.

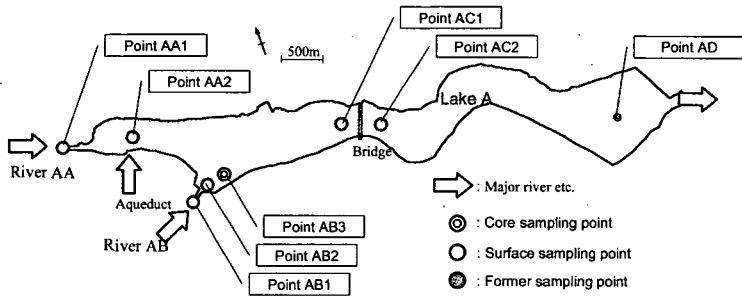


Figure 1 Sampling points in Lake A

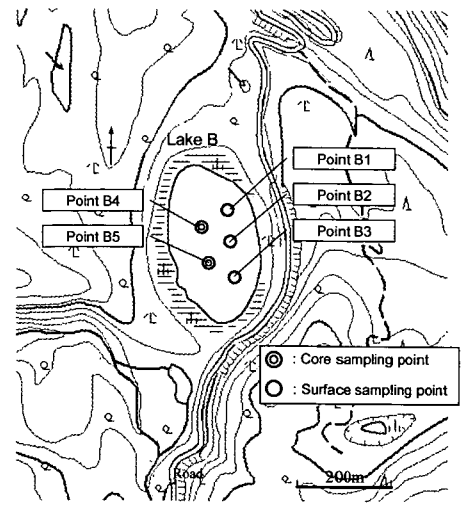


Figure 2 Sampling points in Lake B

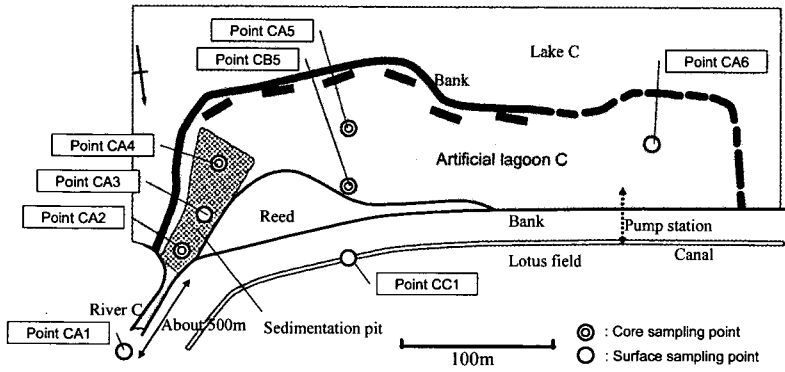


Figure 3 Sampling points in artificial lagoon C

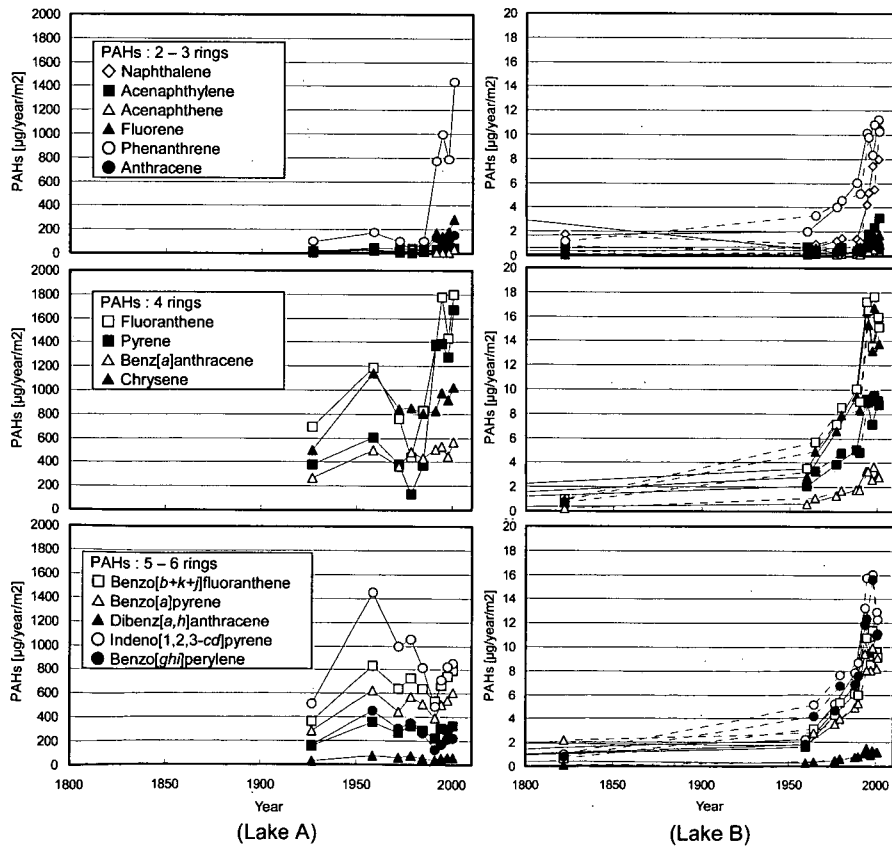


Figure 4 Sedimentation rate of PAHs

Study on technology utilizing waste wood and grass for revegetation

Y. Suzuki, S. Ochi, M. Minamiyama, A. Miyamoto and H. Nagasawa
Recycling Research Team, Material and Geotechnical Engineering Research Group,
Public Works Research Institute

Project period: FY2002–2005

OBJECTIVES

Large amounts of waste wood and grass are produced from public works. This study aims to develop technologies that effectively utilize such wastes to produce materials for planting at green spaces, and to propose a system of recycling such wastes in a closed area.

METHODS AND RESULTS

In FY2003, we carried out investigations to clarify the amount of waste wood and grass produced in specific areas. For example, the results of the investigation on generated driftwood is shown in Figure 1. Also, experiments were initiated to develop technologies utilizing waste wood as spraying materials for creating green spaces on slopes, and the results showed that the technologies using steam explosion for modification of wood structure reached a certain level for actual use.

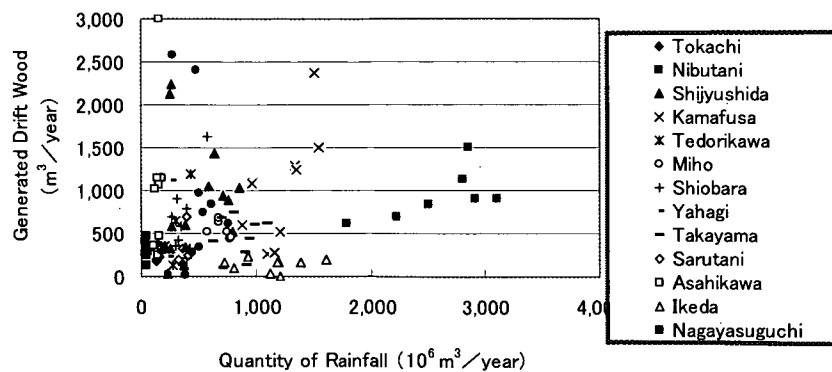


Figure 1 Relationship between the quantity of rainfall and generated drift wood in the 13 dam sites

(Here, the quantity of rainfall is calculated using the product of rainfall and drainage area.)

Fate of Pathogens in Sewage Treatment Plant in Monsoon Asia

Yutaka Suzuki, Hiroaki Tanaka, Mamoru Suwa and Akiko Suyama

Recycling Research Team

Project period: 2003–2006

OBJECTIVES

Rapid population growth, urbanization, delayed sewerage system construction and intensive rainfall in Monsoon Asia have polluted urban water environments with pathogens originating from human feces. To evaluate the associated risks to people living in Monsoon Asia, the sources, routes and fate of pathogens in the water environment must be investigated. Most sewage treatment in Monsoon Asia is performed by lagoons, and the characteristics of the removal or inactivation of pathogens by these lagoons must be evaluated in terms of the effects of temperature, sunlight intensity and amount of rainfall. Lagoons are sometimes backed up by wetlands, and this supplemental process must also be performed efficiently.

This first aim of this research is to develop indicator microorganisms representative of the three pathogen groups: bacteria, protozoa and viruses. Then, these indicators will be applied to evaluate the effects of the type of lagoon, the wetland and the climate conditions on the fate of pathogens.

RESULTS

In the first year of the research, the following surveys were conducted using an experimental lagoon installed in a sewage treatment plant in Okinawa, Japan:

- 1) Effect of climate conditions and turbidity on the fate of pathogens in the lagoon.
- 2) Evaluation of the wetland to upgrade the efficiency of its pathogen removal following lagoon treatment.

Table 1 shows the results. The removal ratio was about 60 to 90% by the lagoon process; and about 10 to 20% improvement was obtained after wetland. As a result, total removal ratio was 70 to 99%.

Table 1 Concentration and removal ratio of pathogens

		Total coliform (cfu/mL)	Norovirus (copies/100ml)	Phage (Pfu/mL)	Giardia (cyst/L)	SS (mg/L)
Rainfall (removal %)	Influent	4.9E+5	1.8E+2	5.8E+3	1.0E+2	73
	Lagoon	1.0E+5 (79%)	1.9E+1 (90%)	1.9E+3 (68%)	2.0E+1 (80%)	67 (8%)
	Wetland	3.6E+4 (93%)	(—)	1.5E+3 (74%)	1.0E+0 (99%)	52 (29%)
Fine weather (removal %)	Influent	4.6E+5	5.7E+1	4.1E+3	5.6E+2	98
	Lagoon	1.1E+5 (77%)	2.2E+1 (61%)	1.2E+3 (71%)	2.4E+1 (96%)	108 (—)
	Wetland	2.1E+4 (95%)	(—)	1.0E+3 (76%)	1.5E+0 (98%)	63 (36%)

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 2003, 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

Many previous studies have pointed out the occurrence of many trace chemicals such as endocrine disrupting chemicals in sewage. Therefore, the way to estimate their fate and risk should be established. Application of ELISA method to measurement of trace chemicals and behavior of estrogen and nonylphenol in sewage treatment were studied in FY 2003,

Main results are as follows

- 1) Two pretreatment procedures for removing cross-reacting and/or disturbing substances in measuring 17β -estradiol in sewage samples with the ELISA method were compared, but there were no obvious difference between the procedures.
- 2) The occurrence of free and conjugated estrogens in influent and secondary effluent in 20 municipal wastewater treatment plants was surveyed. Result shows that 17β -estradiol (E2) and estriol (E3) were effectively removed in wastewater treatment, while removal efficiency of estrone (E1) was about 50%. Moreover, significant levels of conjugated estrogens exist even in treated sewage as well as sewage, which has not been reported so far. Further, increase in conjugated estrogens during wastewater treatment suggests the possibility of transformation of conjugated estrogens from unidentified form of estrogens in this study although analytical method requires further improvement because of their low recovery ratio.

3) Activated sludge treatment apparatus was operated fed with nonylphenol ethoxylates (NPnEOs) as a sole organic substance. In aerobic process ($DO \approx 1.0\text{mg/L}$), nonylphenol (NP) was produced in activated sludge, which indicates that formation of NP was strongly affected by dissolved oxygen concentration in aerobic process.

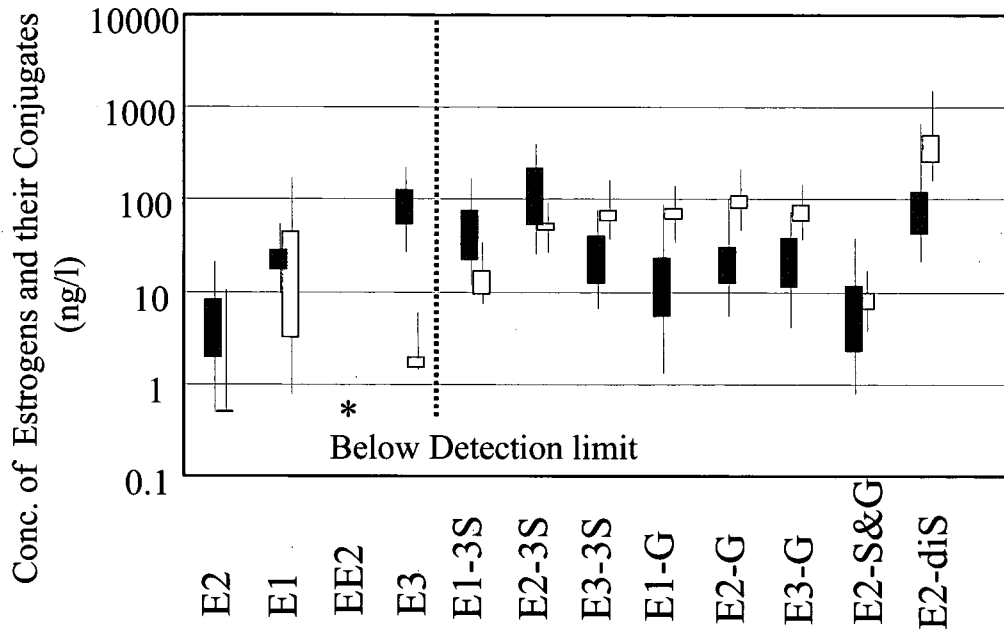


Figure 1 Concentrations of Selected Estrogens and their Conjugates in Influent / Secondary Effluent from 20 WWTPs

REFERENCES

1. K. Komori, *et al* : Analysis and Occurrence of Estrogen in Wastewater in Japan, Proceedings of IWA ECOHAZARD 2003 Conference, 45/1-45/8, 2003.9.
2. Y. Okayasu, *et al* : Degradation of nonylphenol ethoxylate in aerobic wastewater treatment process, Proceedings of IWA ECOHAZARD 2003 Conference, 13/1-13/7, 2003.9.

Effects on Water Environment Affected by Sewerage Systems

Hiroaki Tanaka, Jun Tsumori, Katsuhiko Mibu
Kiyoshi Miyajima, Tadashi Higashitani,, Naoyuki Yamashita
Water Quality Research Team

Project period: 2001 - 2005

Limited studies have been conducted so far for quantitative evaluation on change in water and water-related material cycles due to change in the watershed, particularly development of sewerage system. Furthermore quite few studies are available on its influence on aquatic ecosystem. The aims of this study are therefore to clarify the influence of the change in watersheds, especially the development of sewerage system, on the change in water flows and pollutant loads of the rivers, and to examine its impacts of sewerage works upon river water quality and aquatic ecosystems.

In FY 2003, the following results were obtained:

- 1) To develop an analytical model for Teganuma Lake and Ohtsugawa River system , we selected suitable one among several candidates and collected frame data on the watershed, which are necessary to operate the model.
- 2) We conducted an exposure examination using Medaka fish (*Oryzias latipes*) in a tank installed in a sewage treatment plant to examine the influence of estrogen-like substances in treated wastewater (Fig.1).
- 3) We applied the Algal Growth Potential Test using a micro-plate to evaluate the influence of water quality of the river receiving treated wastewater on the aquatic ecosystem.

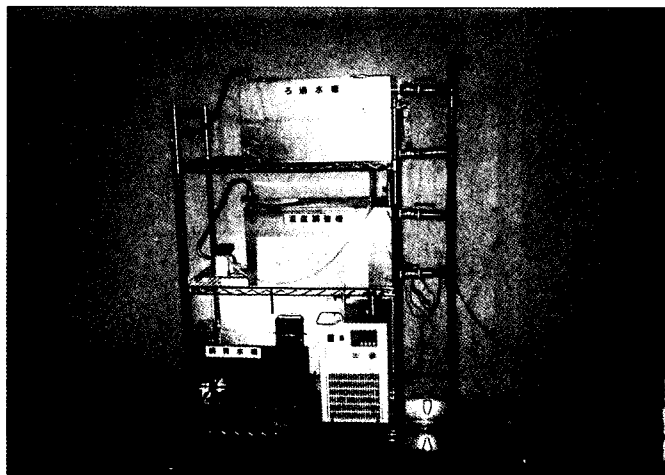


Fig.1 Medaka Fish Exposure System

Evaluation of River Water Quality from the Viewpoint of Aquatic Ecosystem

Hiroaki Tanaka, Kiyoshi Miyajima, Norihide Nakada, Tadashi Higashitani and Naoyuki Yamashita

Water Quality Team

Project period : FY 2001-2005

OBJECTIVES

In recent years, sewerage systems have widely spread in urban areas. At the same time, the volumetric percentage of water derived from sewage treatment plants (STPs) to the receiving river water has been increasing. As the 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, STP discharge's impacts upon organisms and receiving rivers are very limitedly studied.

RESULTS

The final objective of this study is investigation of the relationship between water quality and living organisms. In FY 2003, we investigated the fate of organic and inorganic compounds originated from sewerage effluent in the Tama River. Furthermore, we evaluated the bioaccumulation of estrogen and estrogen-like substances in periphytons and benthos in a river.

The summary of this study conducted in FY2003 is as follows:

- 1) The fate of compounds discharged from STPs in river water was investigated. As the results, inorganic nitrogen and phosphorus were not decreased in the section of 1000m to 3000m down stream from the STP. On the other hand, estrogenic organic compounds were slightly decreased in the section, especially in summer.
- 2) River waters, STP effluents, periphytons and benthic invertebrates were collected around STP discharge point in the Tama River, and estrogen and estrogen-like substances in these samples were analyzed. As the results, the bioaccumulation was not significantly high in higher ones. Additionally, the biomagnifications of estrogen and estrogen-like substances via periphytons to benthic invertebrates contributed little to the overall bioaccumulation of these substances.

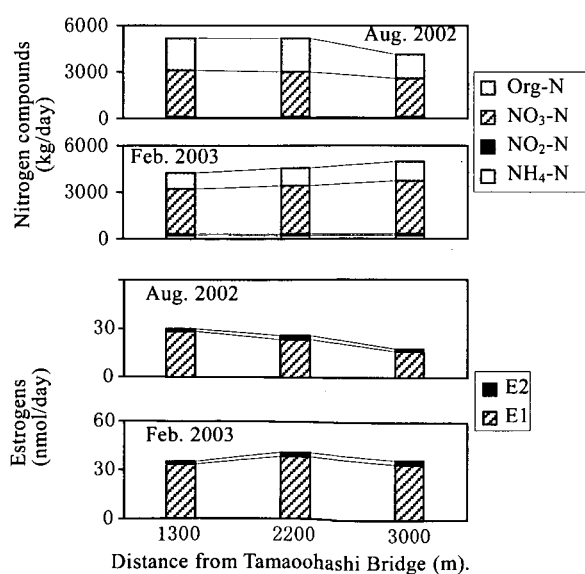


Figure 1. Flux of nitrogen compounds and estrogens

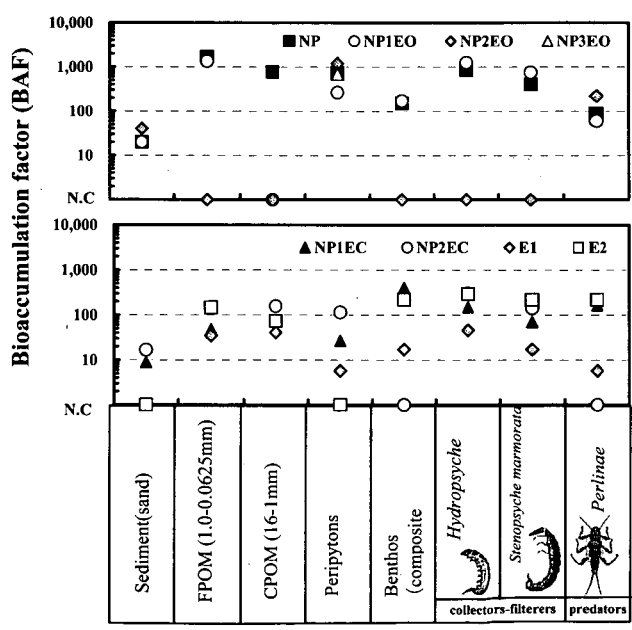


Figure 2. Bioaccumulation factor of estrogens and nonylphenol-related compounds

TRANSPORT OF CONTAMINANTS AT SEDIMENT-WATER INTERFACE

H. Tanaka, J. Tsumori, J. Li, F. Li and J. Wada

Water Quality Team

Project period : FY 2000-2005

OBJECTIVES

The aim of this study is to clarify release mechanisms of nutrients from lake and reservoir sediments from the viewpoint of eutrophication countermeasure. 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.

In FY 2003, we conducted a field investigation in Ushikubiri reservoir, an experiment of oxygen supply in bottom layer, and a laboratory experiment using sediment samples.

RESULTS

The following results were obtained.

- 1) Oxygen supply experiment in the reservoir has been conducted since FY 2002. Temperature, DO and ORP in water column were continuously monitored by the sensor during experimental period. Then, we observed the continuous change of oxidation-reduction potential and nutrients concentrations in water column with or without oxygen supply. As a result, increase of phosphorus concentrations in water column that were not found in aerobic conditions was observed after the stop of oxygen supply. However, the phenomena was not as clear as that of last year.
- 2) Batch stirring experiments were conducted using the surface, middle and bottom layers of a core sediment samples, and the rates and potentials of nutrient release from sediment mud under varied temperatures, aerobic and anoxic conditions were quantitatively assessed. From the experiments, following results were obtained; the difference of dissolution amount of phosphorus among sediment samples was small under aerobic conditions; both release concentrations and rates were promoted under anoxic conditions and high temperature (20 degree C) compared with those under aerobic conditions and low temperature (5 degree C). (Fig. 1)

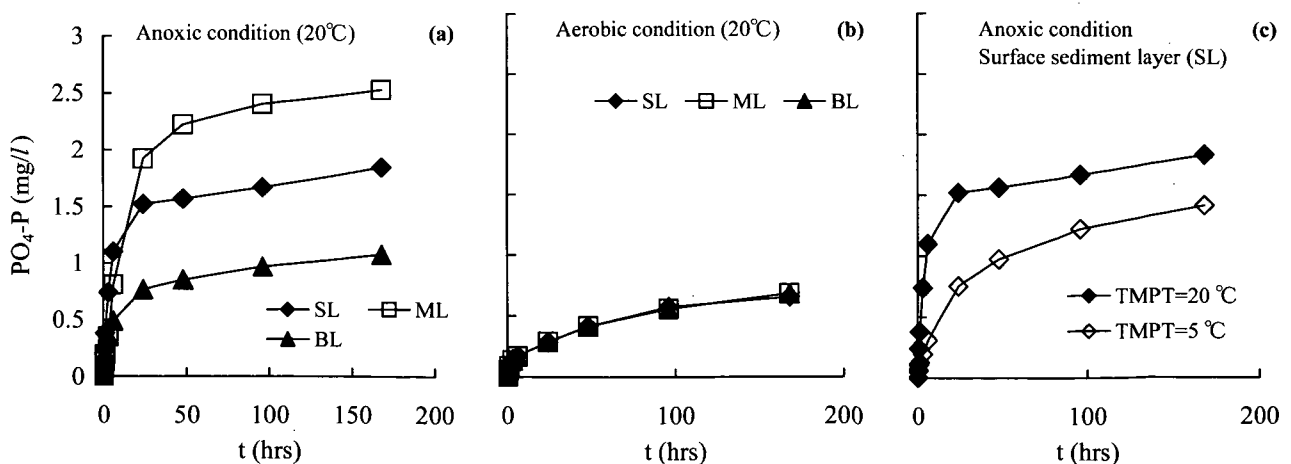


Fig. 1 Concentration profiles of PO_4-P under aerobic and anaerobic conditions

BEHAVIOR OF CHEMICALS FROM URBAN DISCHARGE IN WATER ENVIRONMENT

H. Tanaka, K. Komori, J. Tsumori, F. Li and K. Mibu
Water Quality Team

Project period : FY 2001-2005

OBJECTIVE

The target substances of this study are endocrine disruptors (EDs) such as decomposition by-product of surface active chemicals and human and animal related hormones originating from urban wastewater, and the aims of this study are the development of efficient investigation and analytical techniques of EDs in river water and sediment samples and the clarification of fate of EDs in water environment.

In FY 2003, we conducted the development of analytical techniques of the conjugated forms of natural estrogens in the sewerage treatment plant, the surveys of concentrations of estrogens, nonylphenol and its derivatives in water and sediment samples in river and lake, and laboratory experiment of estrogens' fate in sediment samples.

RESULTS

The following results were obtained.

- 1) We developed the analytical method of the conjugated forms of estrogens by using LC/MS/MS. Though a good recovery rate of 94-120% could be obtained for free estrogens, the recovery rate of the conjugated forms of estrogens were low, which were obtained from the addition and recovery examination for wastewater and treated wastewater.
- 2) To determine horizontal distribution of EDs in water and surface sediments in Lake Teganuma, field investigation was conducted. Nonylphenol (NP) concentrations showed a tendency of increase towards the downstream. On the other hand, the longitudinal distributions of estrone (E1), nonylphenol ethoxylates (NPnEO) and nonylphenoxy acetic acids (NPnEC) in the surface sediments showed that the concentrations are the highest at the inlet, and are fairly constant at lower levels towards the downstream. The obtained results indicate that mechanisms of adsorption and sedimentation associated with suspended solids such as algae of internal product. (Fig. 1)
- 3) Batch biodegradation experiments of 17β -Estradiol (E2) were conducted using the surface, middle and bottom layers of a core sediment sample from a drinking water reservoir; the impacts of temperatures, sediment mud position, aerobic and anoxic conditions upon the degradability of spiked E2 were assessed. The coefficient of decomposition rate of surface position sediment was significantly higher than middle and bottom position one. (Fig. 2)

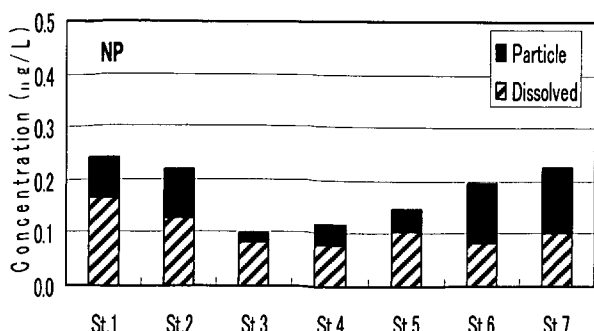


Fig. 1 Concentrations of NP in the longitudinal direction with the flow path in Lake Teganuma.

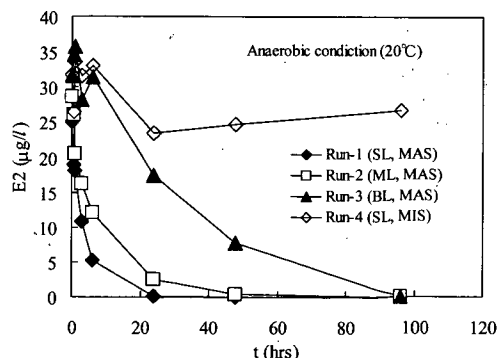


Fig. 2 Concentration profiles of spiked E2.

Evaluation of Estrogen-like Substances using Bioassay

H. Tanaka, K. Miyajima, T. Higashitani and N. Nakada
Water Quality Team

Project period : FY 2001-2005

OBJECTIVES

In recent years, a new environmental issue has occurred, 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 by *in vivo* bioassay using Japanese Medaka and by *in vitro* bioassay using DNA recombinant yeasts involving human estrogen receptor gene. Besides this, fractionation techniques combined with each bioassay were used to characterize and estimate major origins of the estrogenicity. Furthermore, the estrogenicity detected in river samples were compared with population and development of wastewater treatment facilities in the watershed where each river sample was collected.

RESULTS

The summary of this study conducted in FY2003 is as follows:

- (1) Environmental sample was fractionated not into aggregated estrogens but into each estrogen using high performance liquid chromatography. As a result of the fractionation technique combined with the yeast estrogen screen assay, the contribution of estrone was larger than that of 17β -estradiol in treated wastewater in sewage treatment plants.
- (2) A comparison between the estrogen-like activity of major river waters in Japan and the population density in the river basins indicates that the population density was a large contributing factor to the estrogen-like activity in major rivers in Japan. No clear relationship between wastewater treatment facilities provision ratio and estrogen-like activity of the river water was found.

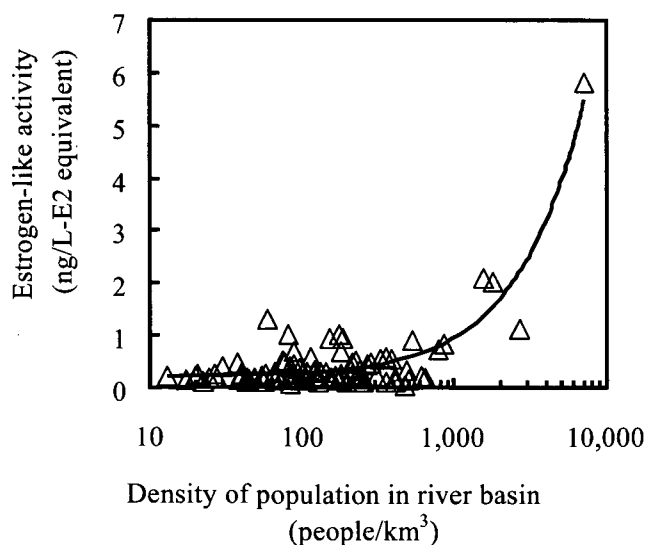


Fig. 1 Relationship of estrogen-like activity and density of population in river basin

Effects of Estrogen-Like Substances in Urban Wastewater on Fish And Their Indication

Hiroaki Tanaka, Koya Komori, Kiyoshi Miyajima, Tadashi Higashitani,
Norihide Nakada, Makoto Yasojima
Water Quality Research Team

Project period: 2002 - 2005

The purpose of this study is to evaluate the influence of estrogen-like substances contained in river water receiving effluent of urban wastewater treatment plant on the feminization of male fish by keeping the fish in the river water; to develop a simple indicator of fish feminization by combining estrogenic activity measured by DNA recombinant yeast and water fractionation method; to clarify the source of the estrogen-like substances in urban wastewater for the control of the fish feminization. Research results of FY2003 are as follows; 1) When adult male medaka were exposed for 14 day to 17 β -estradiol (E2) solution, Lowest-observed adverse effect level (LOAEL) was 5ng/L, which concentration could be termed high level among those in urban wastewater. On the other hand, when exposure periods were 2 or 7 days, no observed adverse effect level (NOAEL) of E2 was 5ng/L. Therefore, when male fish is exposed to low estrogen concentration, longer period is effective to detect the estrogenic activity. 2) The potential of estrogenic activity of estrone (E1) to produce vitellogenin in male medaka was 0.18-0.26 times of that of E2. 3) Adult male medaka were exposed to river water receiving treated urban wastewater at the site of automatic water quality monitoring stations, and if the estrogenic activity exceeded the LOAEL, hepatic vitellogenin was detected from 10% as hepatic vitellogenin induction for endpoint. 4) As a result of optimizing the fractionation of the estrogen-like substances in the effluents of wastewater treatment plants, estrogens and their conjugates were effectively separated, and it was shown that E1 greatly contributed to the estrogenic activity of the effluents.

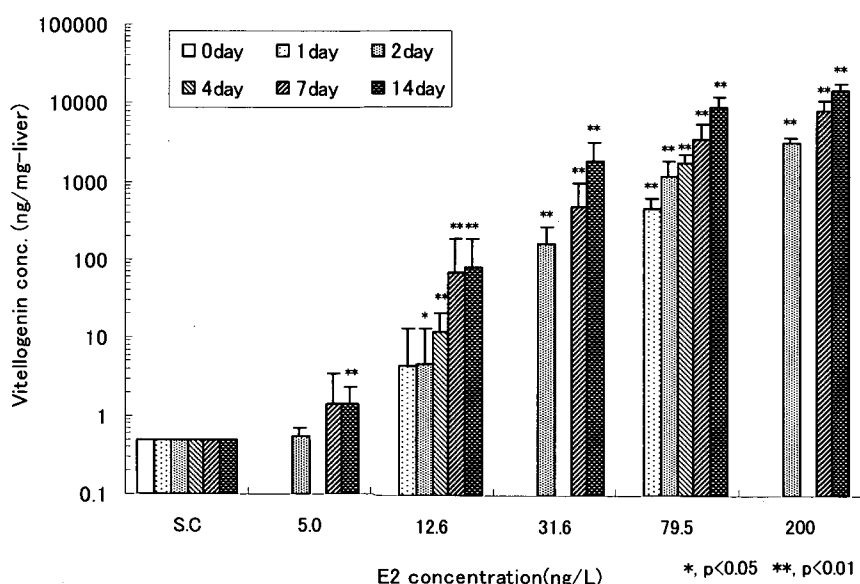


Fig.1 Hepatic vitellogenin concentration of male medaka exposed to 5 class E2 solutions.

Detection of Environmental Stresses on Aquatic Organisms Using Gene Analysis Technology

Hiroaki Tanaka, Kiyoshi Miyajima, Tadashi Higashitani and Naoyuki Yamashita
Water Quality Team

Project period : FY 2002-2006

OBJECTIVES

Some stresses, which are caused by chemicals like medicines, 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. More specifically, we are aiming at development of a DNA chip to identify the cause of fish-kill.

RESULTS

The major results obtained in FY 2003 are as follow:

- (1) After some medaka were exposed to cyanide solution, their genes were extracted. As a control, the genes of medaka that were not exposed to cyanide were also extracted.
- (2) The difference in gene expression between the above two medaka groups was investigated (Figure 1), which resulted in that expression of 889 genes was promoted but 2859 genes was suppressed by cyanide.
- (3) 189 genes were finally determined based on the above selected known genes and were put on our prototype medaka DNA chip that aims at identification of the cause of fish-kill due to spill accident of cyanide in rivers.

Further study may include applicability of the prototype to identification of cyanide and other environmental stresses and improvement of the prototype chip that can detect more environmental stresses.

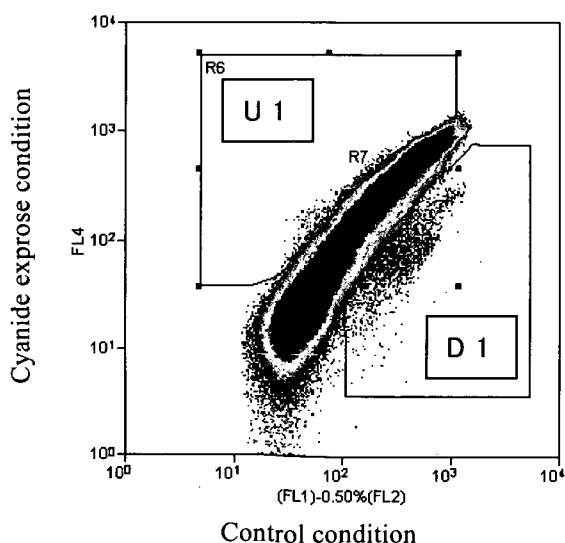


Figure 1. Gene expression under the control and cyanide expose conditions

Evaluation of the effects and improvement of performance of river purification works

H. Tanaka, K. Komori and Y. Okayasu

Water Quality Division

Project period: 2003 - 2005

OBJECTIVES

River purification works including many river water purification facilities(RWPPs) have been carried out in order to improve water quality of many rivers. The information is quite limited on what effects are expected in improvement of river water quality by the works and on whether expected performance of RWPPs is actually maintained. The governments and agencies relevant to the RWPPs hope researchers to clarify the above information.

Therefore, PWRI leads the collaborative research on evaluation of the effects and improvement of performance of river purification works among regional bureaus in Ministry of Land, Infrastructure and Transport. This study conducted by PWRI focuses on the removal performance of the RWPPs from the viewpoint of micro pollutant, particularly estrogen-like substances and ammonia, tries to understand their removal mechanisms, and will finally find the ways to improve their performance in design and operation.

RESULTS

In FY 2003, the following results were obtained.

1) The aerated gravel contact oxidation process (AGCOP) was selected because the process is one the most commonly applied to Japanese rivers. The removal efficiency of estrogen-like activity measured by DNA recombinant yeast assay (67%) is equal or greater than those of SS (66%) and BOD (40%). Therefore, the RWPP aiming at removal of BOD and ammonia is expected to reduce estrogen-like activity of river water to some extent.

2) The experiment model of the AGCOP was created in bench scale that can change hydraulic retention time. The diffusion property of the reactor in the AGCOP process was obtained by tracer test.

Research Paper

1) KOMORI, K., MIYAMOTO, N., TANAKA, H., SATO, C., HAYASHI, K. and HORIUCHI, S.: Reduction of the Estrogen-like Substances and Estrogen-like Activity in the River Water Treatment Facilities, ABSTRACTS -International Association for Great Lakes Research 46th Annual Conference & International Lake Environment Committee 10th World Lakes Conference-, p.81, 2003.6

Table-1 Concentrations of Estrogen-like activity, SS and BOD

	Estrogen-like activity (ng/l)		SS (mg/l)		BOD (mg/l)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
1	1.3	0.3	5	0.5	3.9	2.8
2	1.4	0.6	1	0.5	3.1	2.7
3	2.1	0.1	3	0.5	3.6	2.7
4	2.2	0.8	19	2.6	7.5	2.1
5	3.1	0.8	7	3	5.7	2.8
6	2.3	1.4	8	7	4.4	3.7
Max.	3.1	1.4	19	7	7.5	3.7
Min.	1.3	0.1	1	0.5	3.1	2.1
Av.	2.1	0.7	7	2.4	4.7	2.8

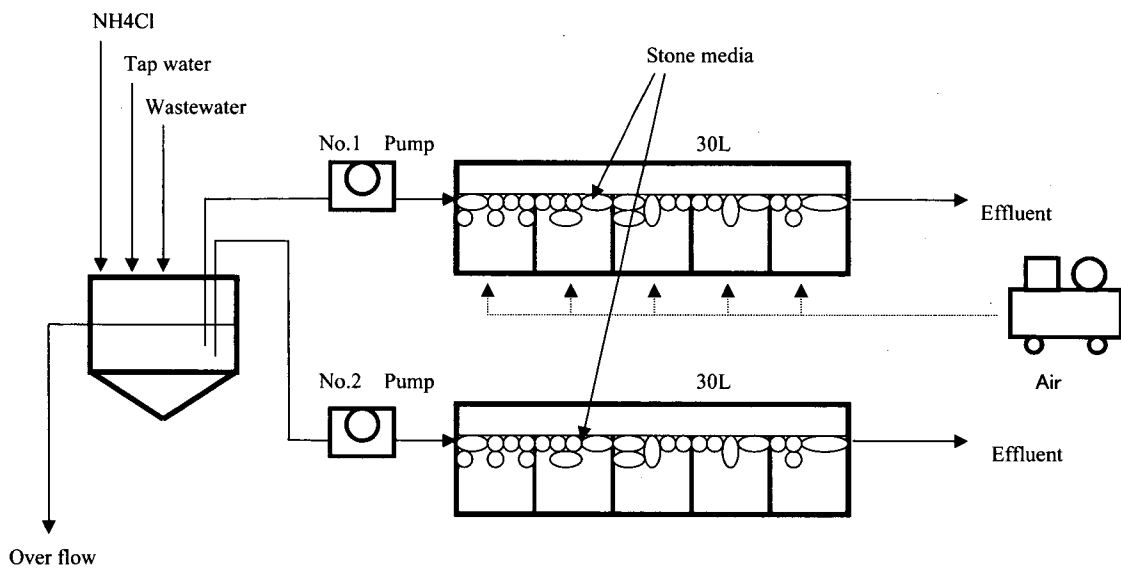


Figure 1 Experimental apparatus

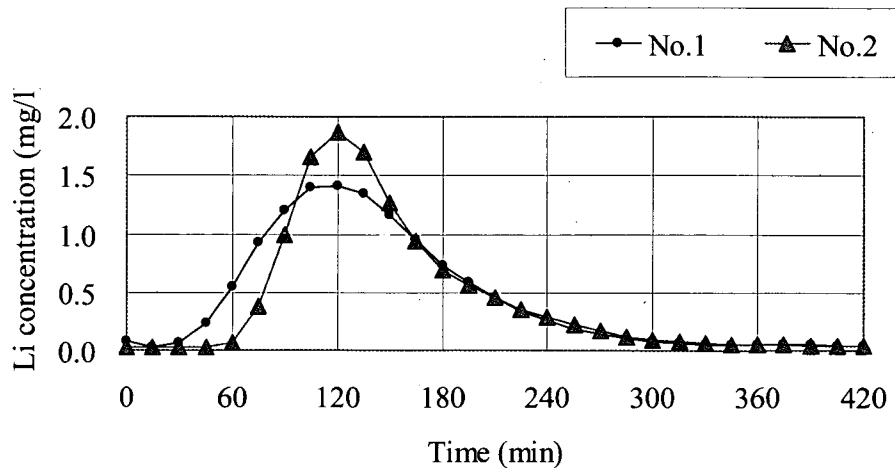


Figure 2 Tracer test

Utilization research of the monitoring technology in the measure against dioxin of river sediment

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

Project period: 2003 - 2005

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. It is necessary to take suitable correspondence to dioxin with establishment of the Law Concerning Special Measures Against Dioxins (Law No. 105 of 1999). Based on the Dioxins Law, stipulated the sediment quality standard (150pg-TEQ/g) for dioxins on July 22, 2002. When the sediment exceeding the standard is found, the contaminated area will be identified through the survey around there, and then remedial measures such as dredging will be conducted. It is expected that the number of samples for investigation on contaminated area survey increases. It is necessary to develop a quicker analysis method and continuity monitoring technology.

In this research, it aims at development of the simple detection technology which used the enzyme-linked immunosorbent assay method so on and a continuity monitoring technology.

RESULTS

In FY 2003, the following results were obtained.

- 1) The examination about the combination of the simple detection technology and the pretreatment was carried out using 20 samples that were obtained from four rivers where contamination of DXNs in the sediments were identified. It became clear that the combination of a Q pole GC/MS and pressurized fluid extraction, silica gel, activated carbon has the high correlation with the regulating method.
- 2) The field study of contentious monitoring of turbidity was conducted due to the secondary pollution, i.e. dredging by the novel turbidity meter, which proved the applicability of the turbidity meter to the contentious monitoring of turbidity in actual field for a long period.

Research Paper

- 1) Shusuke Ishibashi, Takashi Suzuki, Koya Komori, Hiroaki Tanaka, Continuous Monitoring of the Turbidity Changed by Dredge a River Bed, The Society of Environmental Instrumentation Control and Automation, Vol.8, No.2, pp.23-26, 2003 (in Japanese)
- 2) Y. Miyake, M. Kato, K. Urano, K. Komori, M. Minamiyama, Development of an Efficient Method for Investigating Dioxins in Sediments by Dioxin-like SNVOxs, Proceedings of the 38th Annual Workshop of the Japan Society on Water Environment, p.315, 2003 (in Japanese)

Figure 1 Flow diagram of analytical methods. Combination of extraction, clean-up and detection.

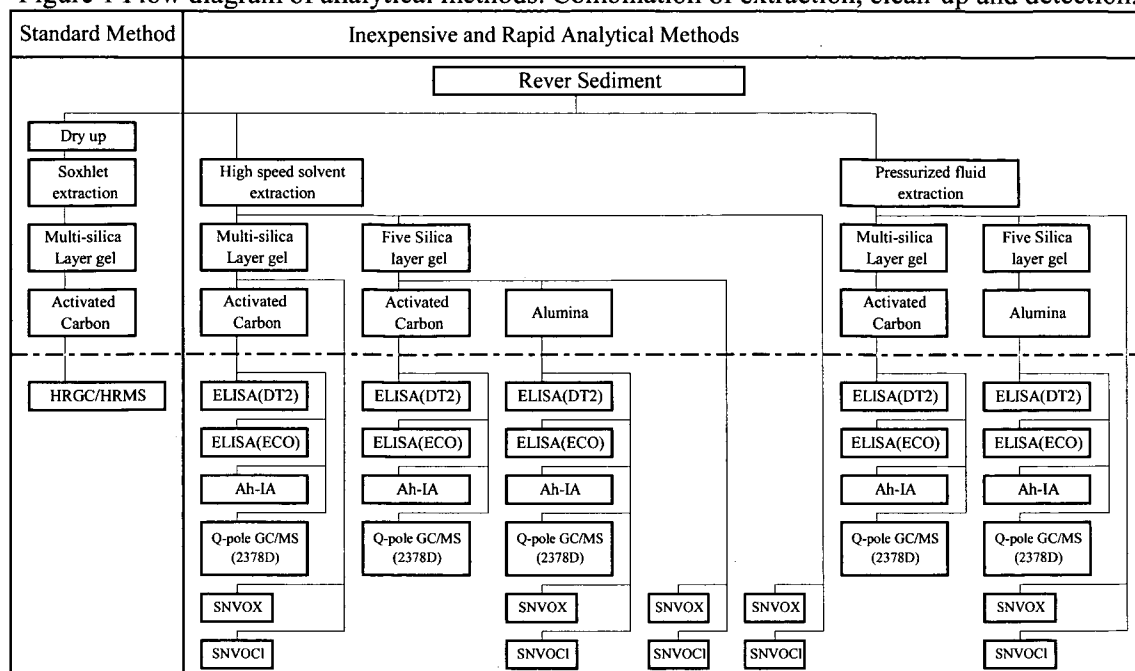


Table 2 Relationship between the standard method and the simple analytical techniques

Detection	Extraction	Clean-up	$y=ax^b$ (n=20)		
			a	b	r
ELISA(DT2)	HSSE	M AC	15.5	0.46	0.54
		F AC	5.30	0.56	0.59
		F AL	15.4	0.39	0.36
	PFE	M AC	12.8	0.47	0.59
		F AL	11.6	0.46	0.57
		F AL	11.6	0.46	0.57
ELISA(ECO)	HSSE	M AC	19.6	0.32	0.37
		F AC	1.26	0.66	0.61
		F AL	2.51	0.61	0.71
	PFE	M AC	6.74	0.41	0.67
		F AL	0.65	0.75	0.38
		F AL	0.65	0.75	0.38
Ah-IA	HSSE	M AC	5.61	0.56	0.61
		F AC	447	-0.14	0.22
		F AL	35.7	0.21	0.30
	PFE	M AC	11.6	0.38	0.61
		F AL	202	-0.03	0.04
		F AL	202	-0.03	0.04
Q-pole GC/MS (2378D)	HSSE	M AC	100	0.30	0.71
		F AC	105	0.27	0.77
		F AL	119	0.25	0.61
	PFE	M AC	79.7	0.37	0.89
		F AL	93.0	0.29	0.79
		F AL	93.0	0.29	0.79
SNVOX	HSSE	M	249	0.43	0.61
		F AL	239	0.63	0.65
		F	140	0.57	0.43
	PFE	None	32.5	0.50	0.59
		None	22.3	0.58	0.63
		None	22.3	0.58	0.63
SNVOCl	HSSE	M	254	0.44	0.62
		F AL	239	0.63	0.64
		F	165	0.72	0.60
	PFE	None	32.9	0.51	0.60
		None	32.9	0.51	0.60
		None	24.2	0.56	0.63

PFE: Pressurized Fluid Extraction method, HSSE: High-Speed Solvent Extraction method

M: Multi-layer silica, F: Five-layer silica, AC: Activated carbon, AL: Alumina

Evaluation of Ecotoxicological Effects of Chemicals in Aquatic Environment

H. Tanaka, K. Komori, K. Miyajima and N. Yamashita
Water Quality Team

Project period : FY 2003-2007

OBJECTIVES

In recent years, various kinds of chemicals are used widely, according to the progress of industry. It has been reported that various chemicals such as pesticide and endocrine disrupter exist in waste, sewage treatment and river water. From these backgrounds, the purpose of this study is to investigate the effects of chemicals to organisms in the aquatic environment.

RESULTS

The summary of this study conducted in FY2003 is as follows.

(1) Water samples were collected at the Tama River area. As the results of the experiments using algal growth inhibition test, toxic effect to algal growth was not detected as for the sewage treatment and the Tama River water samples. Meanwhile, toxic effect was observed for the sample from wastewater channel discharged into the Tama River. The inhibition ratio of algal growth was 20% compared with algal growth of the control. Although the toxicity was not strong, this indicated that toxic substance responsible for the algal growth inhibition would be contained in that sample. But toxic effect was not observed as for the samples of the Tama River after mixing of water from wastewater channel. Substances caused the toxic effect must be investigated in the next study.

(2) Concentration by solid phase extraction cartridge (PLS-2) was conducted for the Tama River and sewage treatment water samples. Figure 1 shows relationship between concentration ratio and algal growth inhibition. Toxic effect was detected when the values of concentration ratio become more than 3.1. Inhibition ratios were almost 100% in the case of the values of concentration ratio become more than 25. The value of EC50 was 6.6, which was calculated from the relationship between concentration ratio and algal growth inhibition. Table 1 shows the values of EC50 calculated for the other samples in the same manner. The values were 14-17 for river water samples and 5.4-9.1 for sewage treatment water samples. The EC50 values for sewage treatment water tend to be lower compared with river water. Table 1 shows the results of toxicity unit (TU) that is a reciprocal number of EC50 value ($TU=1/EC50$). The values of TU were 0.06-0.07 for river water and 0.11-0.18 for sewage treatment water. The TU values for sewage treatment water tend to be higher compared with river water. Since high TU value means high toxicity, the toxicity of sewage treatment water was higher than that of river water.

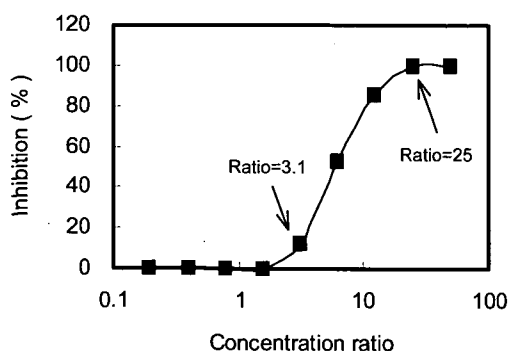


Figure 1. Relationship between concentration ratio and algal growth inhibition (%)

Table 1. EC50 and Toxicity Unit (TU) values at the Tama River area

Station	EC50	TU
St.3	14.0	0.07
St.4	16.5	0.06
St.5	17.0	0.06
STP-1	6.6	0.15
STP-2	5.4	0.18
STP-3	9.1	0.11

St.3-St.5: River water sample

STP1-STP3: Sewage treatment water sample

Investigation of the formulation of the estimation system to improve the efficiency of design and estimation for sewer construction

MIZOGUCHI Hiroki, NAKASUJI Yasuyuki
Construction System Development Division

Project period: 2002-2005

Objectives

The new estimation system of civil engineering work is a form to improve the transparency, the objectivity, and the adequacy of estimation and contract system of civil engineering work, and to reduce the workload. In sewer construction, the components of the works, the standard of estimation, the common specification, etc. have been formulated, but “Standard of Performance Management”, and “Procedure for Surveying Quantities and Form for Totaling Quantities” are not yet formulated.

It is necessary, for improving the efficiency of cost reduction, to reduce the cost of works that occupies large parts of construction expense. For that, it is effective to analyze the ratio of expense of each component, for example, piping work, excavation, materials, labors, etc.

This study is to formulate “Standard of Performance Management for Sewer Construction”, and “Procedure for Surveying Quantities and Form for Totaling Quantities for Sewer Construction” as part of this project, and to analyze cost structure of sewer construction based on estimation results.

Results

(1) Proposal of “Standard of Performance Management for Sewer Construction”

As Common Specification for Sewer Construction formerly formulated, the composition of “Standard of Performance Management for Sewer Construction” is based on that of “Common Specification for Civil Engineering, Ministry of Land, Infrastructure and Transport”, and formulated as an addition to this standard. However, it is compiled so that it is easy to be used independently. It is composed of four contents, the standard of performance management of schedule, figure, quality, and photo.

(2) Proposal of “Procedure for Surveying Quantities and Form for Totaling Quantities for Sewer Construction”

As “Standard of Performance Management for Sewer Construction”, its policy of compilation, contents, etc. is based on “Procedure for Surveying Quantities and Form for Totaling Quantities for Civil Engineering, Ministry of Land, Infrastructure and Transport”.

Procedure for Surveying Quantities is composed of four contents, the items of surveying quantities, the division of surveying quantities, unit code, and method of survey of quantity.

Form for Totaling Quantities is composed of files of four “Level 2” components of piping works, that are excavation work, small diameter hole drilling work, hole drilling work, and shielding works. Each level 2 work is composed of standard manhole work, special manhole work, fitting tube work, drainage pit work, ground improvement work, incidental work, and vertical holing work.

(3) Analysis of cost structure in sewer construction

The ratio of each type of piping work in sewer construction is analyzed based on estimation results in 2001.

In piping work by excavation, the expense of "Earth works" occupies the largest part of the whole construction expense, that is 25%. The following are "Protection works from earth collapse", "Precast manhole works", "Restoration works of pavements", "Fitting works of pipes", "Removal Works of pavements", "Foundation works of pipes" and others. The 7 works occupy about 90 %. In piping work by hole drilling, the expense share of "Hole drilling works of small diameter pipes" is about 25%, that is the largest. The following are "Hole drilling works with temporary pipes", "Hole drilling works of small diameter pipes with water", "Protection works from earth collapse" and others. The 4 works occupy about 60 %. Therefore, if the cost of these works is reduced, the cost reduction of piping work in sewer construction will be promoted effectively.

Keywords: the new estimation system of civil engineering work, cost structure, cost reduction

Survey of the Development of Runoff and Inundation Models for Urban Regions

Kenzo HIROKI, Yoshimitsu SASAKI, Koichi MIZUKUSA

Flood Disaster Prevention Division

Project period:2002 - 2005

OBJECTIVE

The Flood Disaster Division's ultimate objective in developing the NILIM model was to release it to the public so that it is effectively used and applied throughout Japan. There is a high probability that the NILIM model will be used for analysis, because inundation analysis of urban regions is essential in order to prepare a map of districts where inundation is predicted in designated urban river basins in particular.

When a model is released to the public, the organization releasing it permits users to assess the model's usefulness by also giving a guarantee of the reliability of the analysis results generally provided by the model. So before a model is released, the model's precision must be verified to confirm the reliability of the analysis results. And users require that when generally similar models already exist, differences between the properties, strong and weak points, and applicable regions of existing models be clarified in advance in order to simplify users' selection of a model. Therefore, the purpose of this survey is to accompany the public release of the NILIM model by an evaluation of the reliability of the analysis results of the model to clarify the properties of the NILIM model based on a comparison with other similar models.

RESULTS

To prepare for the release of the NILIM model, in 2003, an actual river basin and a virtual river basin were analyzed to compare the compatibility of inundation and water level measurement values etc. with a market model, to perform a verification in order to assure their functional reliability. The implementation of a designated urban river inundation damage countermeasure method must be accompanied by the preparation of a map showing districts where urban inundation is predicted in a designated urban river basin, but the analysis model used to do this was chosen by studying the optimum analysis method including market models.

According to a comparison of the quantity discharged inside pipelines and its maximum value in the virtual river basin, although some discrepancies are caused by differences between the calculation procedure of the NILIM model that performs a hydraulic calculation inside the pipeline based on the physical quantities of the water balance and that of the market model that is done using the energy balance based on the hydraulic gradient, generally roughly equivalent results are obtained.

Focusing on the results of inundation analysis (max. inundation depth of the virtual open channel in each mesh), shows that the market model that set a virtual channel on a road in the inundation area obtained deeper results than the NILIM model that set the inundation area in 50m meshes.(Table 1) It is hypothesized that this is a result of differences between the surface areas whose inundation is allowed according to the inundation water, and that as a result, the overtopping water quantity is divided by the allowed inundation area, creating differences when the inundation depth is calculated. This shows that it is extremely important to set the area of the ground surface where inundation is allowed, and that when using the NILIM model, it is necessary to pay close attention to the setting of the surface area where inundation water is removed in addition to the surface roughness, and when using the market model, to the setting of

the virtual road width that includes the surface area where inundation is allowed. This survey has shown that in a case where inundation analysis in an urban region is done accounting for sewage pipelines, if full attention is paid to setting the area of the ground surface that is inundated, whether the NILIM model or the market model is used, similar results are obtained with few differences between them.

Table 1 - Results of Analysis of a Virtual River Basin

Analysis model name			NILIM	InfoWorksCS	MOUSE	XP-SWMM
River basin name			Virtual river basin			
Rainfall			Virtual trapezoidal rainfall hydrograph (max. intensity: 200mm/hr)			
Water level condition			Free discharge			
Pump; Yes/No			None			
Pipeline flow volume	Peak volume	Upstream P1 (m ³ /sec.)	3.06	4.12	3.95	3.55
		Mid stream P2 (m ³ /sec.)	15.30	14.41	16.40	16.53
		Mid stream P2 (m ³ /sec.)	61.90	72.12	68.65	68.18
	Total volume	Upstream P1 (m ³)	14,585	13,010	19,190	15,835
		Mid stream P2 (m ³)	84,195	64,821	86,056	82,985
		Downstream P3 (m ³)	376,803	390,325	407,457	389,066
Overtopping volume	30 min. after rainfall starts (m ³)		4,500	3,444	2,284	3,763
	60 min. after rainfall starts (m ³)		79,400	85,130	72,747	72,615
	90 min. after rainfall starts (m ³)		119,000	107,954	80,239	100,338
	120 min. after rainfall starts (m ³)		68,800	25,693	20,552	34,357
	150 min. after rainfall starts (m ³)		29,200	5,201	5,425	9,446
	Max. overtopping (m ³)					
-Time of max. overtopping (after rainfall starts)		117,000	118,290	92,988	105,946	
Calculation time (Minutes)			5.0	0.1	3.5	3.8

Evaluation of earth pressure acting on a buried pipe in renewing sewerage facilities

Hidetoshi Kohashi, Reiko Kuwano, Kazushi Furumoto and Keita Yamauchi

Soil Mechanics Team, Material and Geotechnical Engineering Research Group, Public Research Works Institute

Project period: 2001-2004

Objective:

In considering the renewal of sewerage pipes after several tens years from the construction, it is questioned that the earth pressure originally considered 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 was investigated and the evaluation of time-dependent earth pressure, if any, was 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. Mechanism of the interaction between underground structure and the surrounding ground has been investigated by a long-term monitoring of earth pressure around buried pipes and a series of trap-door tests.

1. Long-term monitoring of earth pressures acting on buried pipes

The strain-gauged pipes (rigid and flexible pipe) were laid in the model sand ground in a soil chamber. During burying, earth pressure acting on the flexible pipe noticeably decreased due to the development of ground arching, after which there was no systematical change for more than one year observation period.

2. 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. Small cyclic loads applied on the ground surface did not affect the ground arching.

Lightly cemented sand was also used for the model ground in the long-term monitoring of pipe to evaluate the effects of ageing (cementation) of the ground on the earth pressure changes. As the cementation developed, the cemented ground behaved in one body and some large pressure (more than the overburden pressure) probably due to the change of temperature was observed. But those changes appeared to be reversible. There seemed to be no serious disturbance occurred in the ground around a pipe once the cementation had developed.

Conclusions:

In the case of uncemented ground, the earth pressure acting on a buried pipe may change as a result of arching action due to the deformation of the pipe. Once the stress distribution in the ground was stabilised, noticeable pressure change was not observed. The ground arching was not disturbed easily by the load on the ground but the deformation of pipe changed the state of stress in the ground, implying that the breakage of the old underground pipe may cause possible failure of surrounding ground. Cemented material showed more stabilised behaviour.

Application of New Materials for Sewage Treatment Facilities

Itaru NISHIZAKI and Tomonori TOMIYAMA (Advanced Materials Research Team)

Project Period: 2001-2004

Research objective

In order to manage sewage system efficiently, it is desired to develop more effective corrosion protection system for sewage with innovative durable materials. In this study, we have worked on seeking such materials applicable to sewage facilities, investigating the durability of them and developing the repair technique with them.

In the 2003 fiscal year, the repairing materials for sewage treatment facilities such as “acid resistant mortars”, “resin linings”, “FRP linings” and “titanium linings” were investigated. The main part of this study has been carried out by a collaboration of 11 private companies, and a public-service corporation and PWRI.

Results

1) We proposed the “sulfuric acid dropping test” in order to examine the corrosion behavior of acid resistant mortars in sewage environment. Corrosion characteristics of acid resistant mortars were summarized through this method. It was also confirmed that corrosion depth of acid resistant mortars was smaller than normal mortars. In addition, the relation between the concentration of sulfuric acid and corrosion rate of mortars was found out.

2) We carried out some experiments on adhesive quality of resin linings in order to improve the evaluation method for blistering performance of those materials. From these results, it was shown that the peeling adhesion test was a better method to evaluate blistering on resin linings than pull-off adhesion test (the method of Building Research Institute).

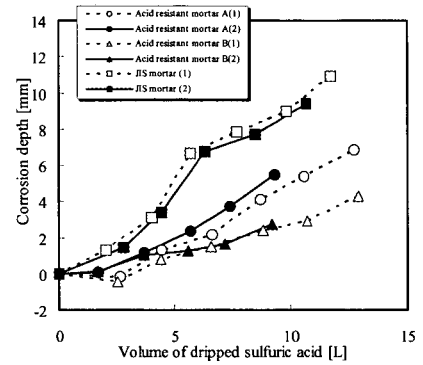
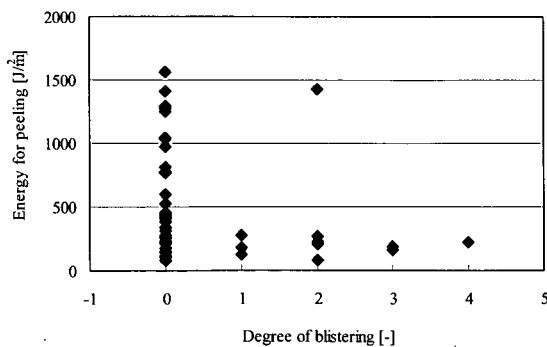
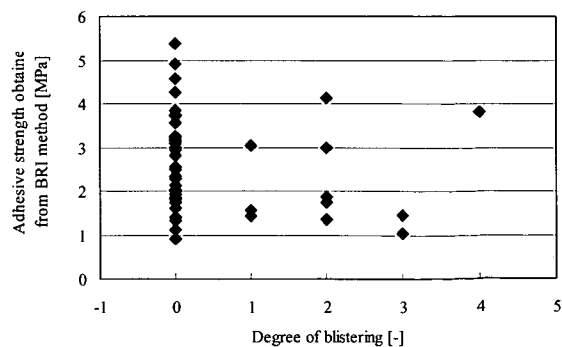


Fig.1 Relation between corrosion depth of mortars and volume of dripped sulfuric acid. (pH0, 40 degree C)



(a)



(b)

Fig. 2 Comparison between the experimental results obtained from (a) the peeling adhesion test and (b) the pull-off adhesion test.

DEFORMATION-BASED DESIGN METHOD OF COUNTERMEASURES AGAINST LIQUEFACTION FOR SEWAGE FACILITIES

K. Tamura, T. Sasaki and M. Ishihara
Ground Vibration Research Team

Project period : FY 2002-2005

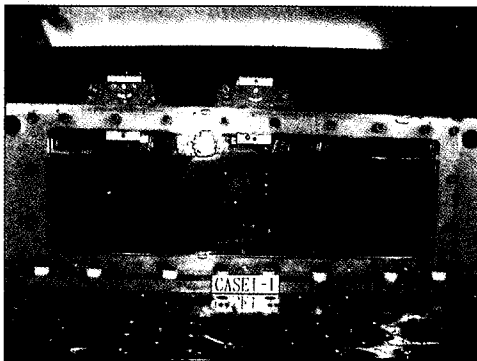
OBJECTIVE

Seismic damage of sewage facilities has been often caused by soil liquefaction. Many sewage pipes and manholes have been uplifted and damaged by buoyant force due to liquefaction. Development of countermeasures to mitigate such damage is required. In the research project, a series of dynamic centrifuge model tests of sewage pipes with and without a countermeasure using sheet piles was performed to reveal seismic behavior of sewage pipes and propose a deformation-based design method of countermeasures.

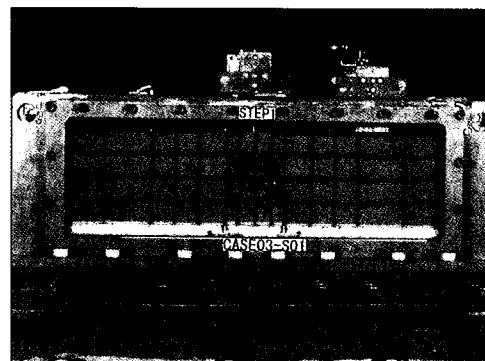
RESULTS

Figure 1 shows the deformations of the centrifuge models without and with sheet piles after shaking. It is clear that the countermeasure by sheet piles is effective to reduce uplift displacement of underground structure due to liquefaction.

The observed uplift displacements were caused by sheet pile bending and liquefied sand movement. We proposed a beam model to estimate the deflection of sheet piles, as illustrated in Figure 2 and a prediction method of uplift displacement due to liquefied sand movement. Figure 3 shows that the predicted uplift displacements by the proposed model agree quite well with the observations.



a) Without countermeasure



b) With countermeasure

Fig. 1 Deformation after shaking

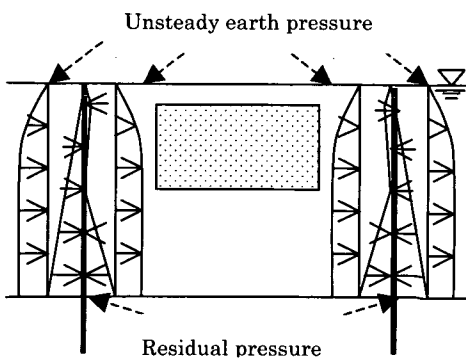


Fig.2 Model for design of sheet piles

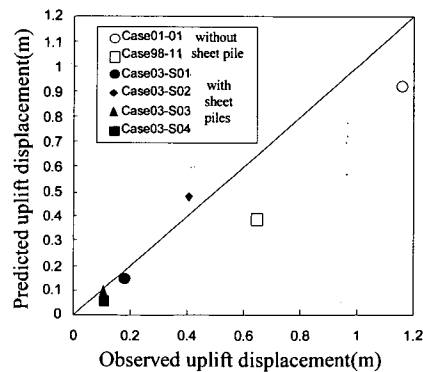


Fig.3 Predicted and observed uplift displacements

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Research Administration and Evaluation Division,
Planning and Research Administration Department,
National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure and Transport, Japan
Asahi 1, Tsukuba, Ibaraki 305-0804, Japan
Phone: +81-29-864-2675

Facilities Management and Research Information Division,
Planning and Research Administration Department,
Incorporated Administrative Agency Public Works Research Institute
1-6, Minamihara, Tsukuba, Ibaraki 305-8516, Japan
Phone: +81-29-879-6754