STRATEGIC INVESTMENT IN SEWAGE WORKS

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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. With a view to application of benefit transfer function, a CVM survey targeting water quality improvement appraisal was conducted in this fiscal year.

RESULTS

The study site of the CVM survey was set in Town of Sakai, Ibaraki Prefecture. The site selection considered income and the other qualities in the Prefecture in comparison of the existing similar surveys for effective data collection. Mail method was adopted, and WTP for water quality improvement was asked in dichotomous choice. 1,500 mails were distributed and 402, i.e. 27% of 1500, responded to the questionnaire. Out of 402 respondents, 255 effective answers were utilized for WTP appraisal and analysis for further use.

The dichotomous choice method in this survey includes two questions and answers about bid amounts, which connote another answer to unquestioned bid amount. WTP model was assumed to be random utilization model as in **Eq.1**, and the parameters were estimated by the most probable method. The estimated parameters are shown in **Table 1**, and the graph of "Yes function" is **Fig.1**. The median and mean of estimated WTP is 1,633 yen/month/household and 2,109 yen/month/household, respectively.

$$\Pr(yes) = \frac{1}{1+\exp\left[-\left(C-\gamma \cdot PAY\right)\right]} \quad \cdots\cdots \textbf{Eq.1}$$

where Pr(*yes*): probability that WTP is larger than bid amount; C and γ : parameters; *PAY*: bid amount (yen).

Table 1 Estimated Parameters and WTP

C (t-ratio)	1.05083	(-9.04765)
γ (t-ratio)	0.000643	(9.40171)
Sample number	762	
Log likelihood	-449.782	
Goodness of fit	0.674541	
Median of WTP	1,633	
Mean of WTP	2,109	

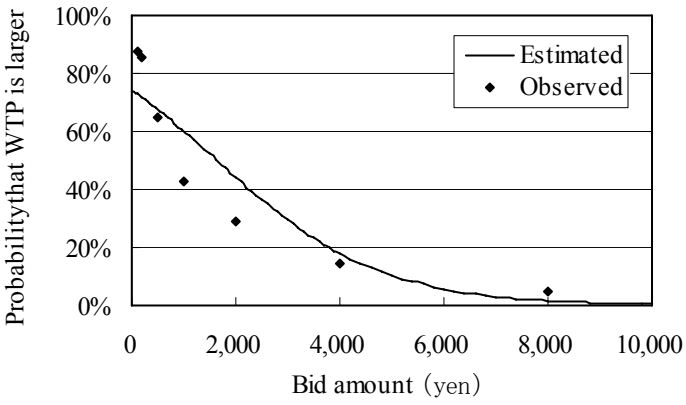

Fig.1 Estimated Parameters and WTP

Optimization of Urban Drainage System Planning and Design Methods

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(Project Period: 2004-2006)

・Objective

In Japan, a new law regarding flood control measure has been enacted in response to the frequent occurrence of urban floods. The new law requires that urban drainage measures be promoted with the close cooperation of sewer managers and river managers. However, till now, urban drainage measures have not always been set through cooperation with both managers. In the future, therefore, it will be necessary to examine concrete cooperation methods.

One unsolved issue is drainage control of pumping stations that discharge storm water into rivers. Drainage control means controlling drainage executed to prevent destruction of levees by river water when its level has risen to the danger level during a flood. When pumps are stopped to execute drainage control, an inner water inundation occurs and the river flow burden is lightened. In a basin where a high percentage of the river flow is water discharged by the pumping of drainage, the rules governing drainage control such as the location of the gauging station that observes the water level that is a criterion for drainage control, the method of setting the water level at which the pump is stopped or restarted has strong effects on flooding damage in the basin, increasing the importance of setting optimum rules to perform drainage control.

This research was undertaken to clarify the optimum rules for drainage control performed during floods by performing a simulation hypothesizing a simple drainage basin and estimating the influence on the rules for drainage control have on flooding damage. We evaluated flooding damage from the perspectives of both inside water inundation and river water flooding.

・Result

This study obtained the following results.

1) It clarified that the amount and the location of the flood differed greatly according to the location of the gauging station that observed the water level that is a criterion for the method of setting the water level at which the pump is stopped or restarted for drainage control.
2) It suggests that when drainage control is executed on the basis of a single water level on the downstream side of the pumping station, setting the location of the gauging station near the pumping station can suppress the rise of the water level and the amount of inside water inundation that occurs after the pump has been stopped.
3) It suggests that when drainage control is executed on the basis of the water level near the outfall at each pumping station, the maximum water level of the rivers is almost equal to the water level at which the which pump is stopped.
4) It suggests that when drainage control is executed on the basis of a single water level on the downstream side of the pumping station, the amount of inside water inundation is equal in all drainage basins, but when drainage control is executed on the basis of the water level near the outfall of each pumping station, the location of the flood differs greatly depending on the method of setting the water level at which the pump is stopped or restarted.

STANDARD FOR DISCHARGE OF DOMESTIC WASTEWATER WITH HIGH CONCENTRATION

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Project period: 2000-2003

Objectives

The purpose of this study is to clarify infulluence of the introduction of garbage grinders on sewage systems in regions where they are introduced.

Experimental Outline

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

1. Garbage Grinder's Use and Pollution Loads in Hotel's Kitchen

This study is to survey the actual situation of how a garbage grinder is used in a resort hotel's restaurant's kitchen in Utanobori Town, and to estimate the pollution loads from the garbage grinder's use.

2 Influence of Garbage Grinder Introduction on the Sewer pipe

This research, a study of the properties of the deposition of materials inside sewer pipes that is a factor contributing to the production of hydrogen sulfide, was conducted by sampling deposited material in districts where garbage grinders are installed and in districts where garbage grinders are not installed. The concentrations of hydrogen sulfide in pipes with large quantities of deposited material were measured.

Results

1. Pollution loads from Garbage Grinder Use in Hotel Kitchen in Utanobori Town

1) Water consumption by the garbage grinder use was too small to be detected through monthly water consumption records.
2) 94% of total garbage amount from the kitchen was processed by the garage grinder.
3) There was no significant difference between garbage-water quality conversion ratios of the restaurant kitchen and those of house kitchens.

2 Influence of Garbage Grinder Introduction on the Sewer pipe

1) The volatile solid content of material deposited in sewer pipes in districts where garbage disposers are installed ranges from 5% to 8%, indicating that the deposited material contains more organic material than in districts without garbage disposers where the volatile solid content is 2% or 3%.
2) It was predicted that the hydrogen sulfide concentration would be high at the outlets of pressurized feed pipes and at pumping stations because polluted water containing garbage is retained at these locations. But in Utanobori, hydrogen sulfide was not observed at these locations.
3) In pipes where eggshell fragments have accumulated, a maximum of 20ppm/second of hydrogen sulfide is produced in the summer when the temperature is high for several months. But Utanobori is in a cold region where the period of high temperature conditions that produce hydrogen sulfide is extremely short. And the pipes are PVC pipes that are not corroded by hydrogen sulfide. In the future, the impact of wastewater from garbage disposers on the corrosion of sewer pipes must be studied in regions where pipe corrosion is a problem.

GIS Application on Pollution Loads Estimation from Watersheds

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Project period: 2004-2006

OBJECTIVES

For effective ambience water quality control, it is relevant to establish master plans on pollution loads in units of watersheds, and Comprehensive Basin-wide Plans of Sewerage System (hereinafter, referred to as CBPSS) take a leading role for conducting sewage works. In practice of plan formulation, estimation of pollution loads on a watershed basis and load reduction in sewage works sector accompanies not a little time and works of data collection and calculation. On the other hand, as Geographic Information System (hereinafter, referred to as GIS) recently see a remarkable progress with large number of data digitized, environment of GIS application has been getting a stable ground.

This research aims to establish database for pollution loads and seek for a methodology of estimating pollution load accurately and in a more reasonable way. In the fiscal year 2004, as the beginning year of this research, current practices of pollution loads estimation in three CBPSS as well as GIS data availability were surveyed, and applicability of GIS utilization in pollution loads estimation was considered.

RESULTS

Through reviewing current practices of pollution loads estimation, items of generating pollution loads, their required data and GIS data availability were are summarised as in **Table 1**. Current situations see not all required data are available in GIS format or even in electronic format, so partial utilisation of GIS data, such as estimation of diffuse pollution loads, might well be promoted. Finally, it was considered that GIS utilisation has advantages of data handling efficiency, precision enhancement, better management of data, and effective output representation.

Table 1. Required data in estimation of generating pollution loads and GIS data availability

Item		Required data	Avail.	GIS/electoronic data	Source
Domestic	Excreta	Permanent population in each treatment type	△	Population 3rd or 4th mesh data, National Census	Website of Statistical Information Institute for Consulting and Analysis
	Grey water				
	Commercial				
Industrial	Large firms	Wastewater volume	×	—	—
	Other firms	Shipment amount of money	△	1km mesh data of middle classification, Industry Statistics in 2000 (firms with four workers or more)	Research Institute of Economy, Trade and Industry
Tourism	Overnight(s)	Number of trippers in each tourism type	×	—	—
	Day-trip				
Livestock		Numer of livestock heads	△	3rd mesh data, Agriculture Census in 1980 (dairy cattle, beef cattle, pigs, hens and broilers)	Website of Naitonal Land Numerical Information download service
Specific	Wastewater treatment plant	Effluent volume and quality in each plant	△	Site and effluent volume/quality of wastewater treatment plants	Road map and Sewerage Statistics
	Excreta treatment plant		×	—	—
	Others		×	—	—
Diffuse	Mountain / Forest / Plain	Area of Mountain / Forest / Plain	△	1km mesh data (nationwide) or 10m mesh data (three great metropolitan regions), Numerical Map in 2000	Japan Map Center
	Urban district	Area of urban district			
	Field	Area of field			
	Nature-origin	Area of watershed	○	Watershed boundary (with attributes of river names, etc.)	River Register, river location, Lake Register, etc. from Naitonal Land Numerical Information
	CSO	Area of combined sewer districts	×	—	—
	Precipitation	Precipitation amount	○	AMeDAS site	File of AMeDAS site list

Note. In Avail., ○: data exist, △: relatively old or insufficient data exist, ×: data don't exist.

Investigation concerning a design method for measures to prevent liquefaction at sewage facilities

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Project period: 2004

Objective:

After the 1995 Southern Hyogo Earthquake, the guideline for the seismic resistance of sewage facilities was improved. However, recent earthquakes such as the 2003 Off-shore Miyagi Earthquake, the 2003 Northern Miyagi Prefecture Earthquake and the 2003 Off-shore Tokachi Earthquake, caused extensive damage to sewers by causing the liquefaction of their backfilling.

In particular, the 2003 Off-shore Tokachi Earthquake caused liquefaction of backfilling in peat ground that was considered safe from liquefaction. The guideline, does not stipulate a method of backfilling for ground that is considered safe from liquefaction. Later, a questionnaire survey was held for cities, towns and villages etc. where sewers were damaged by earthquakes in recent years. It investigated the factors that cause severe damage.

Results:

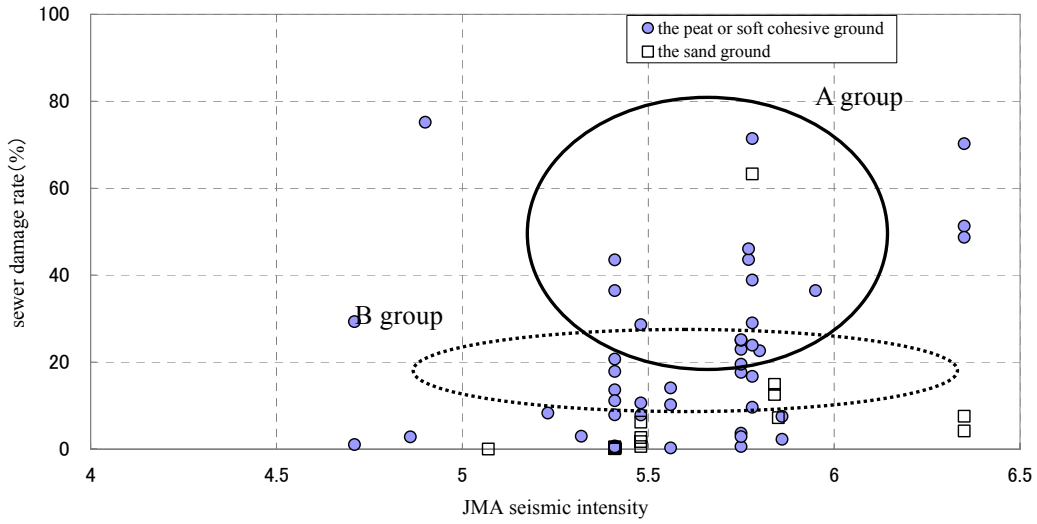
The following results were obtained from the questionnaire survey.

1) At places where the JMA seismic intensity is higher than 5.4, the sewer damage rate tends to be remarkably higher than that at places where the JMA seismic intensity is less than 5.4.

2) Many places where the JMA seismic intensity was higher than 5.4 and the sewer damage rate was high were places with peat or soft cohesive ground that was backfilled using sand for. (A group)

3) The sewer damage rate tended to be concentrated at less than 20% at many places where the ground was soft sand or where sand was used for backfilling and the JMA seismic intensity was higher than 5.4. (B group)

Figure 1 Relation between JMA seismic intensity and swere damage rate



Characteristics of Urban Stormwater Runoff Pollutants

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Wastewater System Division

Project Period: 2004-2006

OBJECTIVES

In urban areas served by separate sewer systems, runoff during rainfall that includes non-point pollution loads such as road surface drainage is almost always discharged without treatment into public waters through storm sewers. However, it is difficult to evaluate non-point pollution load, because of limited accumulation of relevant data prevents clarification of the actual situation.

This research aims to evaluate non-point source, which consists of heavy metals and endocrine disrupting chemicals, from urban areas.

METHOD

The investigation was carried out at the storm sewer outlets of three drainage areas simultaneously during the same rainfall, concerning two rainfall events. Table 1 presents characteristics of target rainfalls. The items of the water quality analysis were BOD, COD, SS, VSS, TN, TP, heavy metals (Cu, Zn, Pb, Cd), Bisphenol A and Benzo(a)pyrene. The sample was obtained by manually taking 20 bottles from each investigation point.

Table 1 Characteristics of subject rainfall and prior rainfall

	No.1			No.2		
	Prior fine weather days	Rainfall	Maximum precipitation intensity	Prior fine weather days	Rainfall	Maximum precipitation intensity
	(days)	(mm)	(mm/hr)	(days)	(mm)	(mm/hr)
Area A	5	14	2.5	10	6	2.5
Area B	5	15	3.5	4	9.5	2.5
Area C	4	14.5	3	4	8	2.5

Table 2 EMC and specific pollutant load

		Area A		Area B		Area C	
		No.1	No.2	No.1	No.2	No.1	No.2
Area (ha)		98		16		74	
Impervious surface (%)		69		67		61	
Event Mean Concentration (EMC)	BOD (mg/l)	12.8	19.8	3.9	20.7	4.4	17.7
	COD	15.5	29.3	5.7	27.2	8.9	23.7
	SS (mg/l)	65.5	85.9	27.7	61.7	31.7	27.9
	VSS (mg/l)	19.5	36.0	9.3	30.6	12.8	17.7
	TN (mg/l)	2.9	4.0	2.1	3.8	2.1	3.5
	TP (mg/l)	0.30	0.51	0.12	0.20	0.12	0.14
	Cu (mg/l)	0.02	0.06	0.003	0.026	0.034	0.057
	Zn (mg/l)	0.07	0.35	0.037	0.19	0.09	0.13
	Pb (mg/l)	0.0084	−	0.0024	0.0050	N.D.	0.0007
	Cd (mg/l)	0.001	−	0.0034	N.D.	N.D.	N.D.
	Bisphenol A (μg/l)	0.21	0.2	0.11	0.4	0.1	0.2
	Benzo(a)pyrene (μg/l)	0.007	0.025	0.018	0.024	0.014	0.027
Specific Pollutant Load	BOD (kg/ha)	0.72	0.52	0.02	0.16	0.02	0.13
	COD (kg/ha)	0.87	0.77	0.04	0.20	0.04	0.18
	SS (kg/ha)	3.68	2.25	0.17	0.46	0.13	0.21
	VSS (kg/ha)	1.09	0.94	0.06	0.23	0.05	0.13
	TN (kg/ha)	0.165	0.104	0.013	0.028	0.009	0.027
	TP (kg/ha)	0.017	0.013	0.00075	0.0015	0.00051	0.0010
	Cu (g/ha)	0.95	1.56	0.02	0.19	0.14	0.43
	Zn (g/ha)	0.47	9.12	0.23	1.43	0.37	1.00
	Pb (g/ha)	0.47	−	0.015	0.038	N.D.	0.0054
	Cd (g/ha)	0.03	−	0.021	N.D.	N.D.	N.D.
	Bisphenol A (mg/ha)	11.56	6.05	0.69	3.15	0.33	1.54
	Benzo(a)pyrene (mg/ha)	0.40	0.65	0.11	0.18	0.06	0.20

RESULTS

Table 2 shows the result of this survey. According to Table 2, both event mean concentration (EMC) and specific runoff pollutant load measured in Area A tend to be higher than the results in the other areas. Especially, pollutant load of heavy metals and endocrine disrupting chemicals in Area A were not ignorable value. It was suggested that this difference was caused by differences between traffic flow volume and land use etc. in each drainage area.

In the future, more data should be accumulated and analyzed.

LOW-COST SEWERAGE SYSTEM FOR DEVELOPING COUNTRIES

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Project period: 2001-2004

INTRODUCTION

As hygiene deteriorates due to 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 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.

CONCLUSION

We have explored an ideal low-cost sewerage system in this study, based on field investigations in Thailand and Indonesia and lagoon experiment results in Okinawa.

This study proposes an economical and simple strategy that has an immediate positive effect on the environment which has deteriorated rapidly in developing countries.

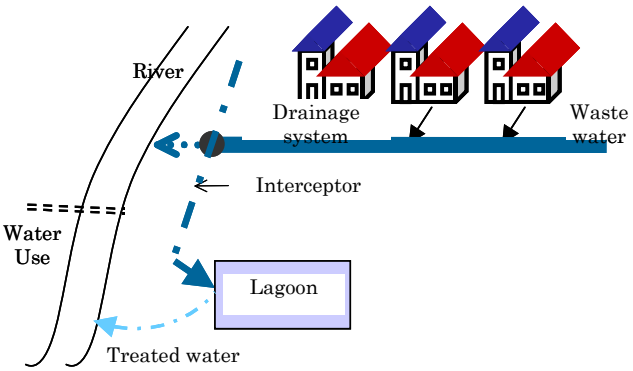

Fig. 1 Concept of low-cost sewerage system

(1) Promoting construction of new sewerage system using interceptors

Continuing with the construction of *interceptor sewerage systems* as an economical method with immediate results and that will be most effective.

However, it is necessary to solve the following four problems.

①Preventing sludge sedimentation in culverts

②Educational campaign for residents and contractors

③Developing legislation for preventing the inflow of plant effluents

④Development of technology for preventing the backflow of river water

Solving these problems will adequately demonstrate the function of *the interceptor sewerage system*, and will contribute to the lowering of administrative and maintenance expenses including future upgrading costs.

(2) Employing a low-cost and easy-to-maintain treatment method

This is necessary because in a developing country, there is a shortage of skilled engineers, and the power supply is unstable.

①Adoption of the lagoon (stabilisation pond) method

②Simplification of the pond structure

③Appropriate evaluation of sewage purification in interceptor culverts.

A STUDY TO DEVELOP TECHNOLOGY TO EVALUATE IMPACT ON CHANGE OF THE WATER CYCLE AND SUBSTANCE CIRCULATION

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Wastewater System Division

Project period: 2002-2004

INTRODUCTION

This project was a study of a method of evaluating the impact of combined sewer overflow (CSO) in river basins and cities where waters receiving CSO are located to improve the efficiency of combined sewer systems. This year, in a model river basin that includes ocean waters receiving CSO, a fact-finding survey of rivers that are the destinations of water from combined sewer districts that are the most important source of pollutant load was carried out, and a runoff analysis model from the land to the sea was studied.

CONCLUSION

The applicability of the distributed PWRI model was studied at the same time as the state of dispersion of the pollutant load discharged into Tokyo Bay from combined sewer systems was simulated.

The results revealed the following facts.

(1) The first flush of the runoff load from sewers during rainfall was confirmed, verifying that the load increases at almost the same time in rivers near the receiving waters.

(2) The breakdown of the pollutant load discharged from the combined sewer district shows that the impact of rainfall runoff at the purification center was the greatest, followed by upstream river water, combined outfall, and primary effluent in that order, but for SS, upstream river water had the greatest impact.

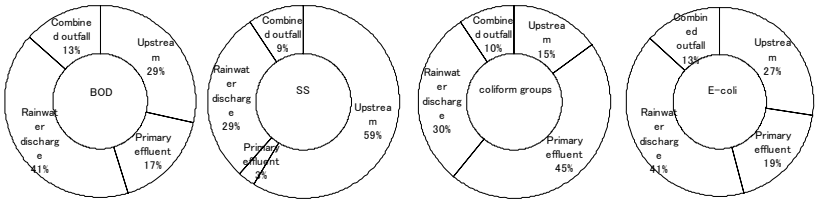

Fig. 1 Breakdown of Load Discharged from the CSO District (Rainfall 1)

(3) Of the loads at the river downstream location, 60% to 80% was runoff from the combined sewer district.

(4) The results of a simulation using the existing PWRI model (lumped model) revealed that the measured values of coliform groups could be reproduced in the same way as BOD, COD, SS, T-N, and T-P.

It was also learned that the Distributed PWRI Model provides reproducibility similar to that of the existing PWRI model.

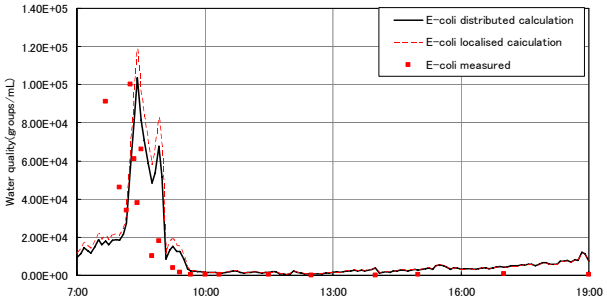

Fig. 2 Calculation Results

(5) It was also revealed that of the pollutant load from combined sewer systems flowing into Tokyo Bay, very little of that part flowing into closed water areas disperses offshore so it remains in the closed water area a relatively long time, while that part flowing into open water areas is dispersed offshore relatively quickly. It was also learned that near river mouths, it gradually declines in response to the tide level expansion.

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

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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

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Wastewater System Division

Project period: 2002-2004

Objectives and Experimental Outline

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

Documents have been a field survey conducted in cities in the United States where the garbage grinder penetration rate is already high to obtain information about efficient sewer maintenance technologies for use after the introduction of garbage grinders. In order to estimate the increase of the load of influent caused by the introduction of garbage grinder s, the quality of garbage grinder wastewater prepared based on the quantity of kitchen garbage placed in the garbage grinder and the kitchen garbage collected from households using garbage grinder s was analyzed in Utanobori Town where garbage grinder introduction trial has 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 grinders (household waste material only, not waste material from business offices) were studied by performing an overall evaluation based on LC-CO_2 and LCE (life cycle assessment).

Results

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

1) Garbage disposers have been installed in 44% of American homes and the penetration rate was high on the west coast.
2) In nine countries of Europe including Germany and France, the use of garbage disposers is restricted.
3) 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 grinder penetration rate – sewer main cleaning rate was low.
4) The amount of garbage processed with the garbage grinders was 99g/cap/day, which is about half the amount of garbage put out per person per day.
5) It is assumed that the introduction of garbage grinders 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 grinders

1) Because the introduction of garbage grinders 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 CO_2.
2) It is estimated that if garbage disposers were installed in 100% of the homes in the town of Utanobori, the cost of sewage treatment service would increase by ¥200,000/year, but the coast of disposing of waste material would fall by 340,000/year.