

Advanced Systems for Effective Use of Sewage Sludge Energy

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Project period: FY2000–2003

OBJECTIVES

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

METHODS AND RESULTS

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

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

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

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

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

Fate of Endocrine Disruptors in Sewage Sludge

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Project period: 2002 - 2005

OBJECTIVES

In recent years, there have been many reports on environmental problems caused by endocrine disruptors (EDs) discharged as trace chemicals in many countries and regions. Among the many manufactured chemicals necessary for daily lives and activities that are used and discharged, some can disrupt the endocrine system of humans and wildlife. Detailed investigations on this problem have been done around the world. The Ministry of Construction carried out a national investigation on the pollution of river waters and treated wastewater by EDs in Japan in FY1998; some trace chemicals suspected to be EDs were detected at almost all surveyed points. Research and investigation are needed to study countermeasures to deal with EDs in the sewerage system. This research aims to clarify the fate of EDs in the unit processes performed at sewage sludge treatment facilities and in the soil that includes sewage sludge compost.

RESULTS

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

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

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

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

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

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

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

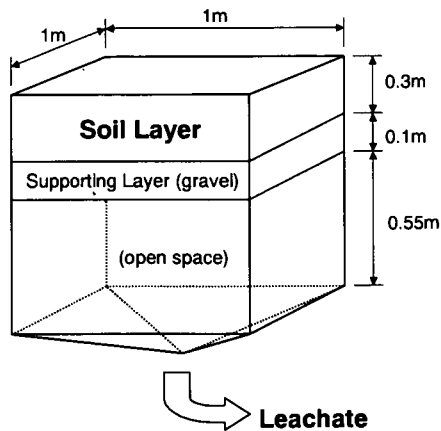


Figure 1 Schematic Diagram of a Lysimeter

Table 1 Experimental Conditions of Soil Layer in Each Lysimeter

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

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

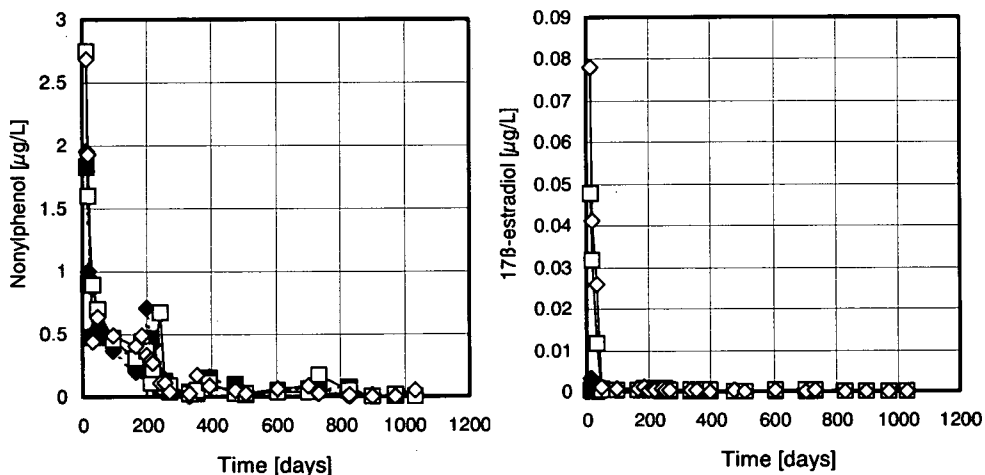


Figure 2 NP and E2 Concentration in the Leachate from Lysimeter

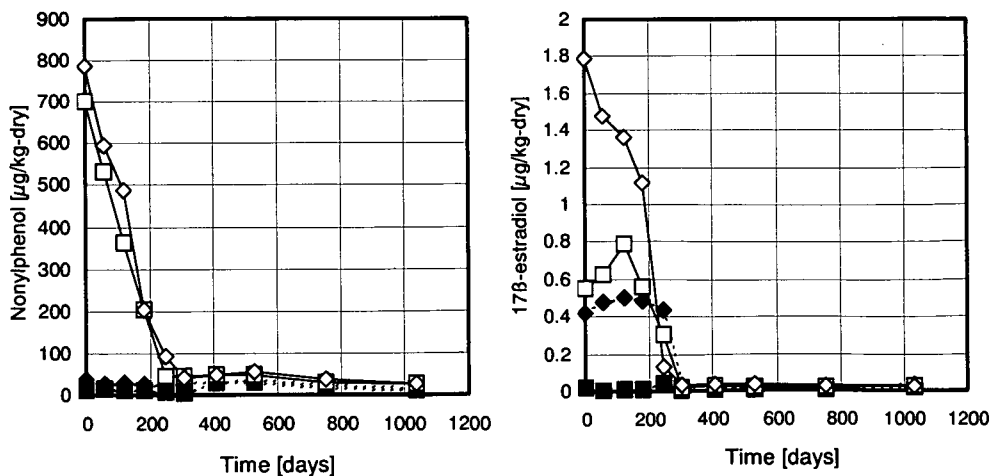


Figure 3 NP and E2 Content in the Soil Layer of Lysimeter

Recycling of Organic Wastes by Utilizing Bio-Solids Treatment System

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Project period: FY2002–2005

OBJECTIVES

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

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

METHODS AND RESULTS

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

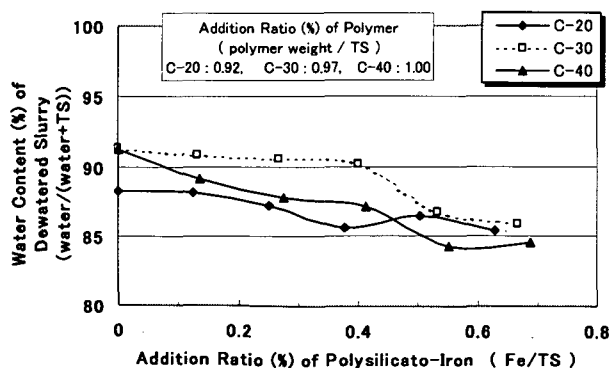


Fig. 1 Results of dewaterability tests of fermented bio-solids

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

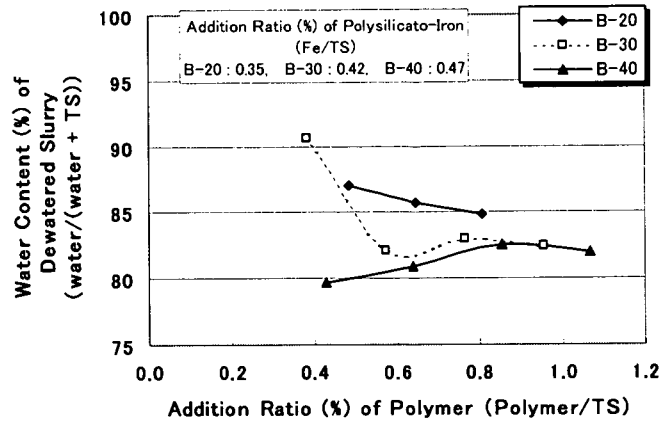


Fig. 2 Results of dewaterability tests of fermented mixture of bio-solids and steam-exploded hardwoods

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

Development of Simplified Analysis Method for Dioxins in Sediment Samples

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Project period: 2000 - 2002

OBJECTIVES

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

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

RESULTS

Water content is high for bottom sediment samples.

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

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

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

Table 1. Main procedures and required time

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

Study on Techniques for Identifying Pathogenic Microorganisms
and Analyzing Their Behavior

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Project period: 1999-2005

OBJECTIVES

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

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

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

RESULTS

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

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

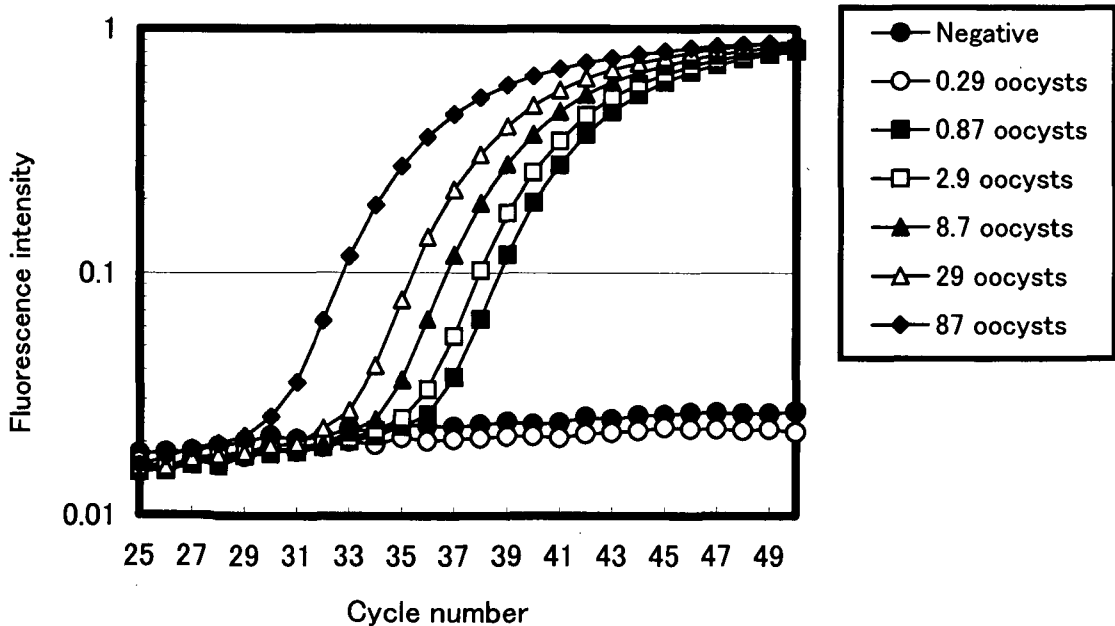


Fig. 1 Real-time PCR result of the *Cryptosporidium* oocysts

Study of Risk Assessment for Reuse of Sewage Sludge

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INTRODUCTION

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

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

OBJECTIVES

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

METHOD AND RESULT

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

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

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

The sidestream loads of heavy metals except for Se were in the range of 9 – 28% of the influent loads, but that of Se was almost the same as the influent load.

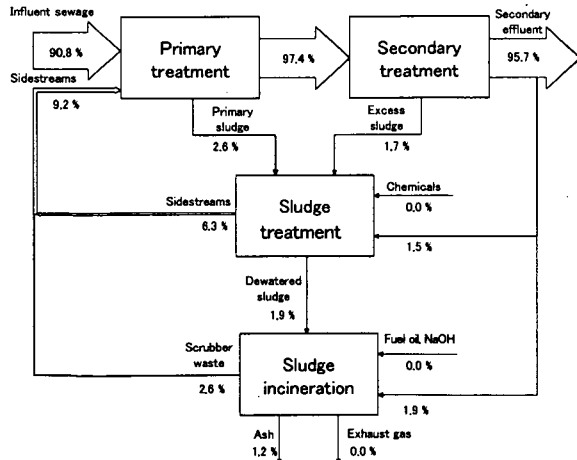


Fig. 1 Material balance of B in sewage treatment process

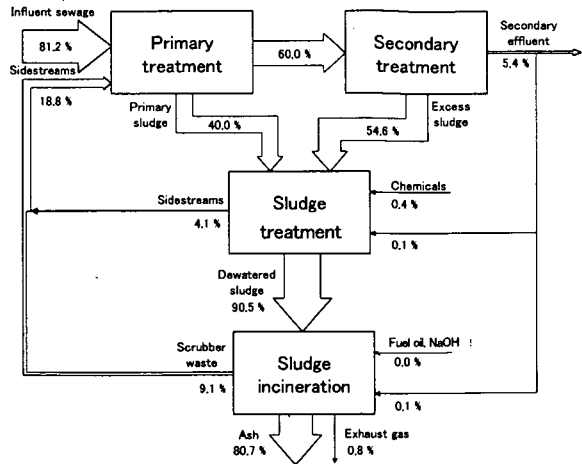


Fig. 2 Material balance of Ag in sewage treatment process

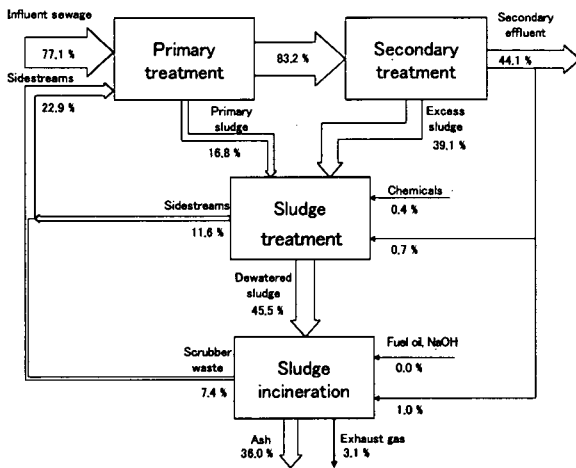


Fig. 3 Material balance of As in sewage treatment process

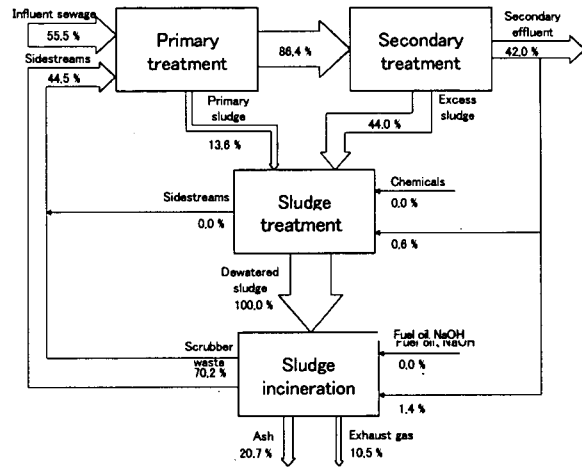


Fig. 4 Material balance of Se in sewage treatment process

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

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Project Period: 2002 - 2005

Objective

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

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

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

Results

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

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

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

The TOC difference in the treated water of the sequential immobilization reactor was quite little, and a very small quantity of microorganisms accumulated in the second reactor. It suggests that apparent bacterial regrowth potential is strictly controlled by the accumulation of effective microorganisms in the first reactor (Figure 3).

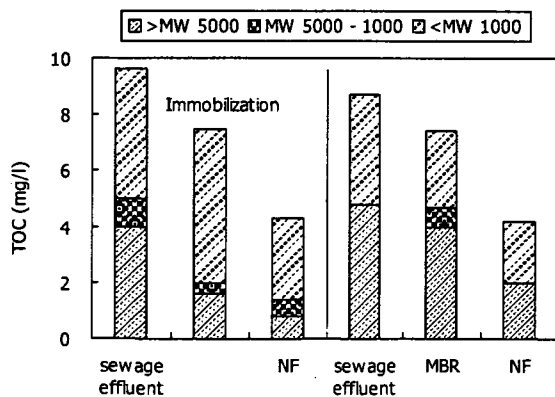


Fig. 1 Removal of MW fractions in advanced biological treatments (HRT; 3hrs) and NF treatment of both advanced biological effluents

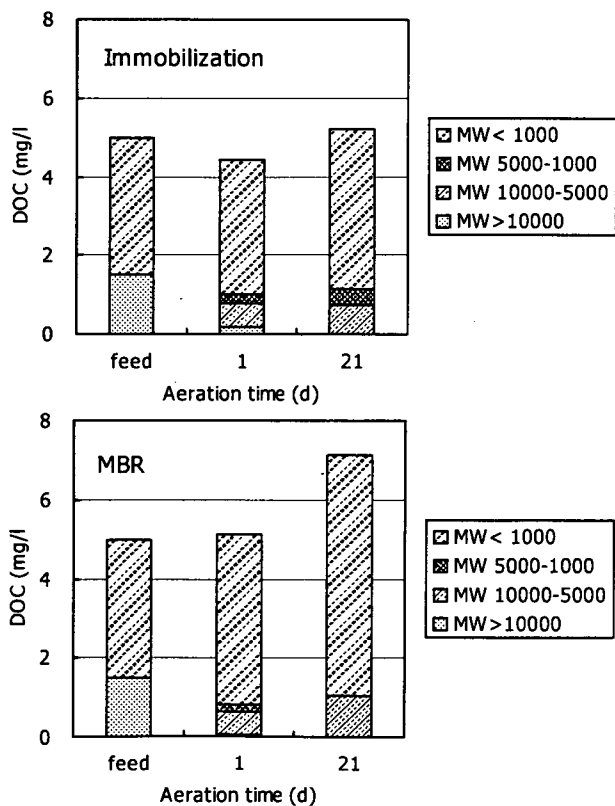


Fig. 2 Removal of MW fractions in the advanced biological treatments by long-term aeration

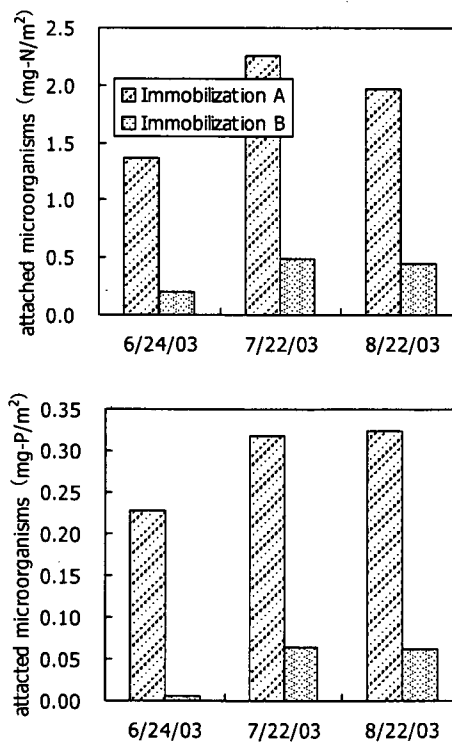


Fig. 3 Quantities of immobilized microorganisms of both immobilization carriers

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

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Project period: 2002 - 2005

OBJECTIVES

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

RESULTS

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

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

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

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

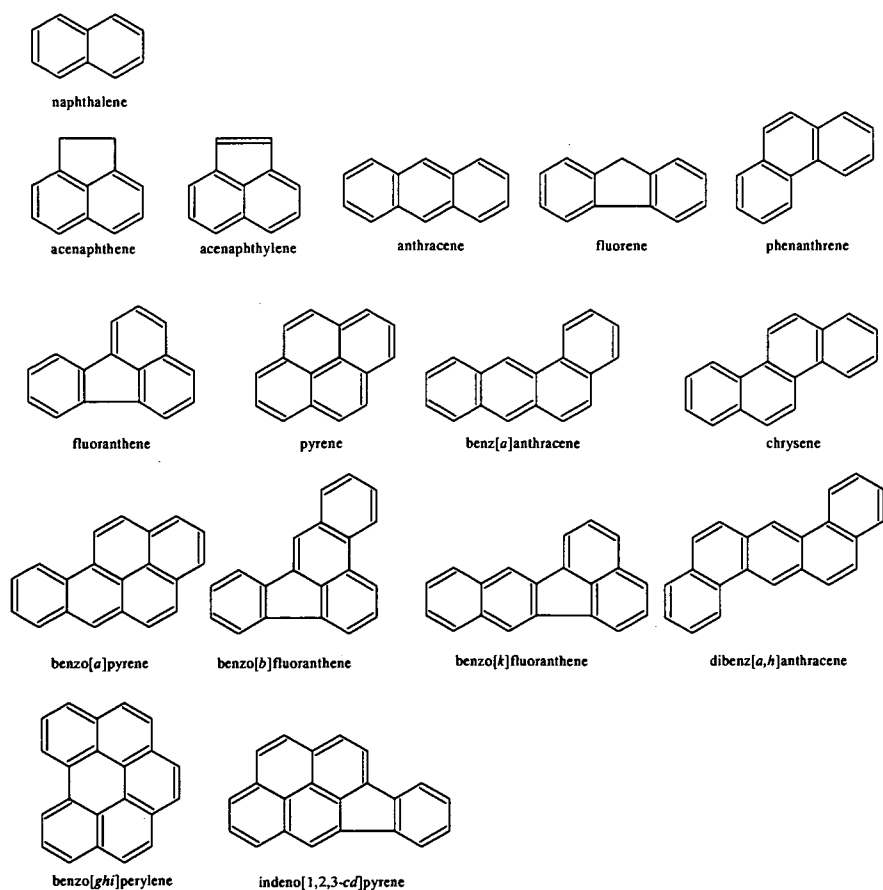


Figure 1 Examples of Structural Formulae of Polycyclic Aromatic Hydrocarbons

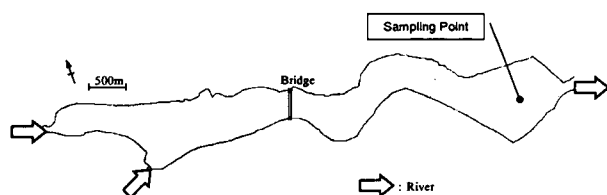


Figure 2 Schematic Diagram of the Lake and the Sampling Point

Table 1 Amount of PAHs in the Sediment

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