B-16.5 Evaluation of Technologies to Reduce the Emission of Green-House Effect Gases in Wastewater Treatment System

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Abstract The aim of this research is to evaluate the technologies to reduce the emission of the green-house effect gases(GHG), such as methane(CH_4) and nitrous oxide(N_2O), from the wastewater treatment facilities.

The emission of CH_4 and N_2O from conventional activated sludge process was compared with that of AO and A_2O process. The introduction of anaerobic tank was effective to reduce the emission of CH_4. The PO_4-P concentration in the anaerobic tank had little relation to the emission of CH_4.

The raise of furnace temperature in fluidized bed incinerators of sewage sludge was evaluated from the aspects of the effect and the cost. Half of the N_2O emission from sludge incinerators can be reduced with this countermeasure. The cost of the reduction of GHG was estimated around 10,000 yen/t-C.

Key Words Green-House Effect Gases, Methane, Nitrous Oxide, Wastewater Treatment, Sludge Incineration

1. Introduction

Sewerage system is constructed to improve both living environment and water environment. The national government promotes to increase the number of served population by sewerage system. The emission of GHG from sewage treatment plants is also increasing according to the number of served population and the quantity of sludge to be incinerated.

Besides CO_2 caused by electricity and fuels, the emission of N_2O from biological nitrogen removal process and sludge incineration, and CH_4 from biological wastewater treatment process are recognized to be quite important from the results of the researches already done. The purpose of this research is to evaluate the technologies which reduce the emission of GHG from wastewater treatment facilities.

2. Research Objective

The objectives of this research are as follows; to analyze the effect of the adoption of AO(Anaerobic-Oxic) process and A_2O(Anaerobic- Anoxic –Oxic) process on the emission of CH_4 and the effect of nitrification on N_2O emission in wastewater treatment, and to evaluate the countermeasures for incineration process from the viewpoints of its effect and its cost.

The introduction of anaerobic or anoxic zones to wastewater treatment process is supposed to suppress the emission of CH_4. The effect was evaluated through the experimental survey using pilot plants. Also, N_2O emission from a conventional activated sludge process with relatively longer HRT was measured through a year.

In sludge incineration process, one of the most effective countermeasures is to raise the temperature in furnace. The effect and the cost of this countermeasure were analyzed using the actual data of existing incinerators. With these results, the effect and cost of all incinerators for sewage sludge in Japan were estimated.

3. Research Method

WASTEWATER TREAMENT PROCESS

To compare the emission characteristics of GHG from conventional, AO and A_2O processes, experiments using pilot plants were carried out.

Operational conditions are listed in Table 1.

GHG were measured using gas chromatography; when the sample was exhausted gas from aeration tanks GHG was measured directly, but when the sample was dissolved gas in influent, effluent and mixed liquor of each aeration tank the GHG was measured through a head space method.

Phosphate, NH_4-N, NO_2-N and NO_3-N of influent, effluent and mixed liquor of each tank were measured.

Table 1 Operational conditions

process	Inflow rate(m^3/h)	HRT(h)	Return sludge ratio	SRT(d)
AO	1.45	6.9	0.4	8
A_2O	1.25	8	0.5	15
conventional	1.25~1.45	6.9~8	0.4~0.6	8~10

SLUDGE TREATMENT PROCESS

This survey is based on the assumption that the emission of N_2O decreases according to the raise of the temperature in fluidized bed furnace accepting polymer-coagulated sludge. This phenomenon is made clear through the researches already done. N_2O emission factor can be estimated by the equation [1] and [2]. The value of 0.0472g-nitrogen/g-sludge solids is applied to the facilities that have no data of nitrogen content ratio of sludge.

$$X = (-0.1403\,t + 123)/100 \quad \langle 700^\circ C \leqq t < 875^\circ C \rangle \qquad [1]$$

$$Z = 1.5711\,X \cdot w \cdot r \qquad [2]$$

in here,
- X : Converted N_2O ratio (N of N_2O/N of sludge)
- t : Combustion temperature in the furnace(℃)
- Z : Amount of N_2O discharge(g-N_2O)
- w : Supplied sludge weight(g-sludge solids)
- r : Containing nitrogen ratio(g-N/g-sludge solids)

For other types of incineration, N_2O emission factors are set as follows;

lime-sludge cake: 330g-N_2O/t-sludge cake

the others : 750g-N_2O/t-sludge cake

The action to raise the combustion temperature needs more fuels, and improvement of furnace if the furnace materials are not suitable for the operation under higher temperature. The data on the costs of fuels and furnace improvement were collected from the existing plants in Japan in FY1998 by questionnaire. The CO_2 emission from fuels is also calculated.

The effect of this action was estimated using the data of total volume of sludge to be incinerated in Japan in FY1998. The cost of GHG reduction was evaluated through the life cycle cost analysis. The value of operation cost was converted into the value in the constructed year.

4. Result and Discussion

WASTEWATER TREATMENT PROCESS

(1) Evaluation of AO and A_2O processes to reduce CH_4 emission

The ratio of the emitted CH_4 from aeration tanks to influent dissolved CH_4 was estimated to be 1.7, 1.0 and 0.9 for the conventional process, AO process and A_2O process, respectively.

The reason of this difference is that CH_4 was produced in the first tank of the conventional process but not in the anaerobic tank of the AO process. Also, CH_4 was decreased in the anaerobic or anoxic tank of the A_2O process. It was found that the AO and A_2O process were controlling CH_4 emission (Figure 1,2).

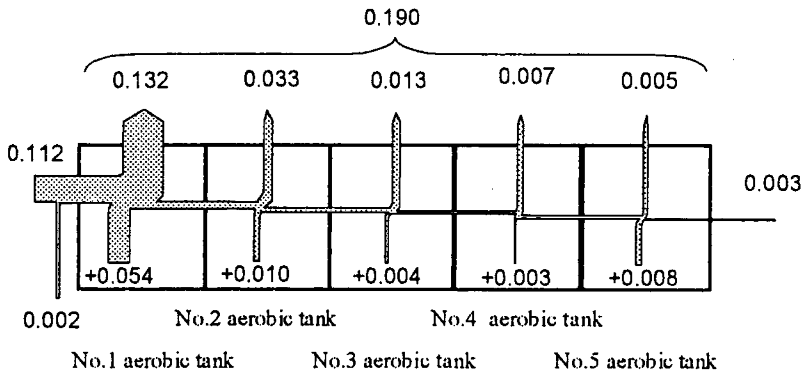

Figure 1 CH_4 balance of conventional process (g/m^3-treated water)

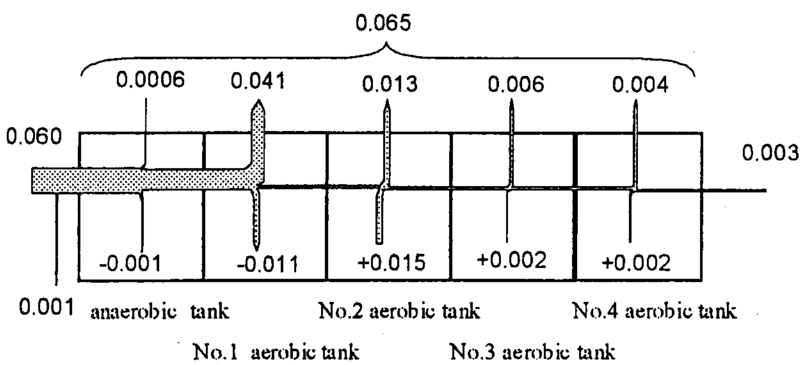

Figure 2 CH_4 balance of AO process (g/m^3-treated water)

(3) Effect of nitrification on N_2O emission

High N_2O emission was observed when NO_2-N concentration was high in the aeration tank (Figure 3). Maintaining low NO_2-N concentration is necessary to reduce N_2O emission, especially in winter.

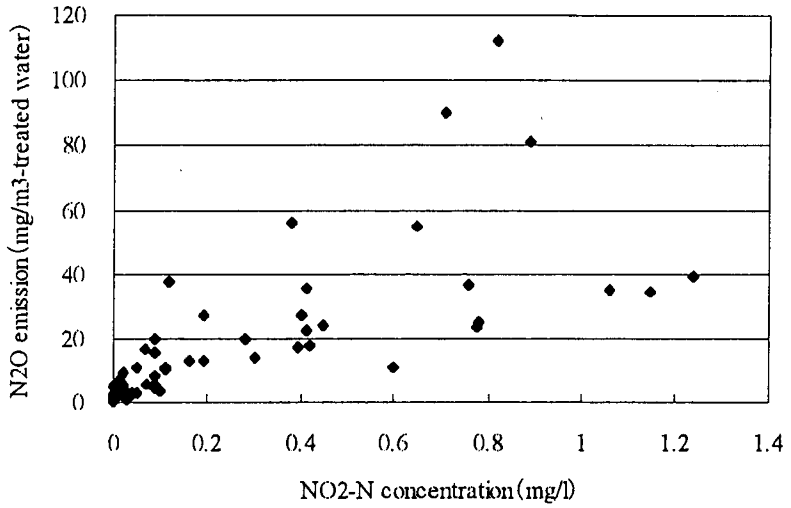

Figure 3 The relationship between NO_2-N concentration and N_2O emission

SLUDGE TREATMENT PROCESS

(1) The state of GHG emission.

The outline of sludge incinerators in Japan in FY1998 shows in Table 2, and the estimated GHG emission is shown in Figure 4. In FY1998, the GHG emission from sludge incineration facilities was estimated at 437Gg-C/year, which is composed of N_2O to 374Gg-C/year(86%) and CO_2 of fuels to 63Gg-C/year(14%). N_2O emission from the polymer-sludge cake fluidized furnace was 307Gg-C/year, and it amounts to 70% of GHG emission.

Table 2 The outline of sludge incinerators in Japan in FY1998

Types of Furnace	Sorts of Coagulant				
	polymer (A)	lime (B)	both (A) and (B)	the others	**Total**
Fluidized Bed Furnace					
Number of Furnace	145	8	8	3	**164**
Sludge Weight (10^3t-wet/year)	2,840	131	79	32	**3,080**
Multiple Hearth Furnace					
Number of Furnace	22	13	3	4	**42**
Sludge Weight (10^3t-wet/year)	613	166	26	38	**843**
Stoker Type Furnace					
Number of Furnace	6	4	0	5	**15**
Sludge Weight (10^3t-wet/year)	105	111	0	26	**242**
The others					
Number of Furnace	1	1	0	2	**4**
Sludge Weight (10^3t-wet/year)	12	31	0	7	**50**
Total Number of Furnace	**174**	**26**	**11**	**14**	**225**
Total Sludge Weight (10^3t-wet/year)	**3,570**	**439**	**105**	**103**	**4,220**

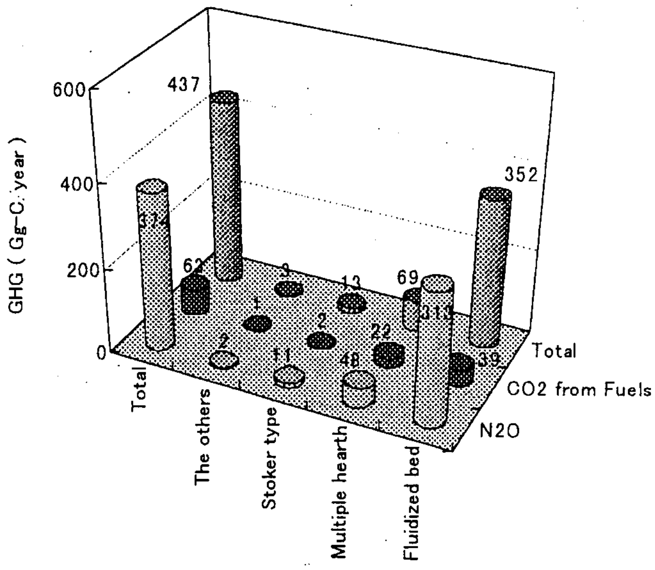

Figure 4 An estimate of the GHG emission from sludge incinerators in FY1998

(2) GHG reduction and its cost

The effect of the raise of operating temperature in furnace is shown in Figure 5.

The raise of temperature is assumed to be 50 degree in case of operation on under 825℃, 25 degree in case of operation on between 826℃ to 850℃. Under these conditions, the average of temperature becomes from 827℃ to 862℃, by raising 35 degree.

Though the CO_2 emission of fuels increases by 30%, the N_2O discharge decreases by 74%. The mean emission factor changes from 1245g-N_2O/t-sludge cake to 326g-N_2O/t-sludge cake. The annual GHG emission decreases from 437Gg-C/year to 221Gg-C/year. The GHG emission becomes half.

The cost necessary to raise the combustion temperature rises by about ¥800 from ¥7500/t-sludge cake, and the reduction cost per unit weight of carbon was estimated to be ¥ 10600/t-corbon(1$≒¥110).

(3) The future prediction of GHG emission.

The situation of GHG emission in the future (the year of 2010) is predicted as shown in Table 3. Concerning to the modes of incineration, two types were assumed. One was the case that old incinerators turned to fluidized bed furnace when they would be reconstructed, and the other was the case that working furnaces continue to work. In both cases, the increased sludge was coagulated by polymer and incinerated in fluidized bed furnace.

The GHG emission is estimated to be 725Gg-C/year by 1.7 times for FY1998 in the case of an unchanging combustion temperature. Though the case of a raising combustion temperature at condition with the assumption of the foregoing paragraph (2), GHG emission was estimated the greatest 317Gg-C/year. Therefore, it seems that the GHG emission on FY2010 could be controlled in previous level of FY1998 with the operation of a raising combustion temperature in the polymer-sludge cake fluidized furnaces by about 35 degree, even if the amount of incinerated sewage sludge would increase.

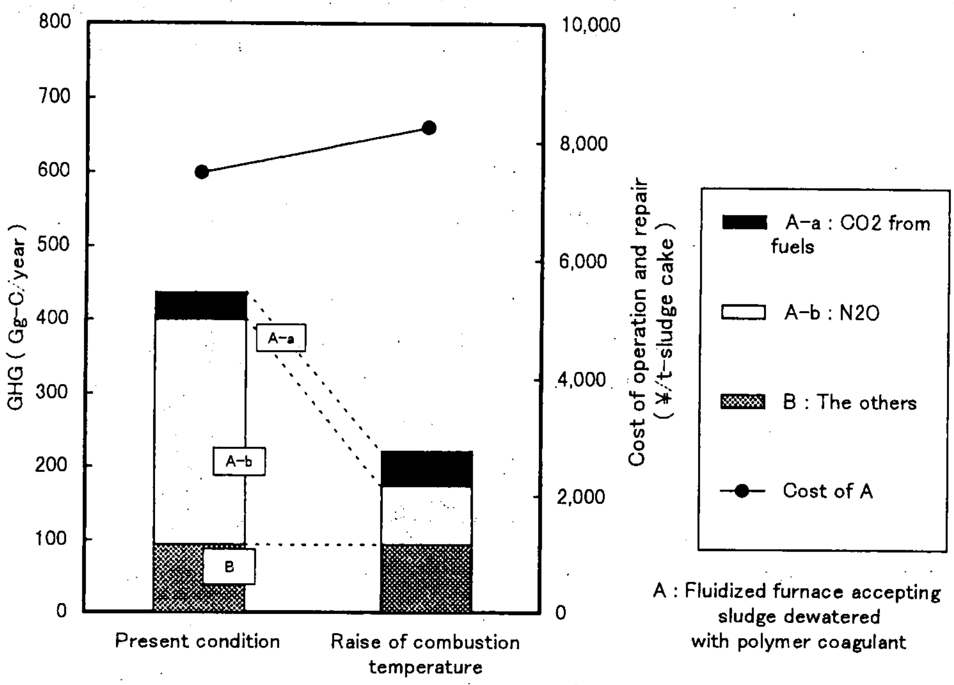

Figure 5 The GHG emission before/after the raise of fluidized furnace accepting sludge dewatered with polymer coagulant

Table 3 An estimate of the GHG emission from sludge incinerators in 2010.

	1998	2010	
		Case of Using Present Incinerators	Case of Improving Old Incinerators to Fluidized Bed Furnace
Sludge Weight (10^3t-wet/year)	4,220	6,410	6,410
Case of Present Operation			
N_2O (Gg-C/year)	374	605	642
CO_2 from Fuels(Gg-C/year)	63	91	83
Total(Gg-C/year)	**437**	**695**	**725**
Case of Raising Combustion Temperature			
N_2O (Gg-C/year)	147	208	192
CO_2 from Fuels(Gg-C/year)	74	110	104
Total(Gg-C/year)	**221**	**317**	**296**
Reduction Ratio (%)	**49.4**	**54.4**	**59.2**