B-16.8 Technologies Controlling Green-House Effect Gas Emission from Sewerage Systems

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Abstract The study was done to develop the control technologies of the emission of methane(CH_4) and nitrous(N_2O) oxide from a wastewater treatment plant. Beneficial use of sludge digestion gas was also studied. The emission of methane and nitrous oxide through the wastewater treatment processes was observed. The control measures to reduce the emission, however, could not be fully developed. The annual methane emission from the whole wastewater treatment plants in Japan was estimated as around 7,500 tons.

The incineration of sludge by a fluidized method brought relatively high emission rate of nitrous oxide. The increase in combusting temperature to up around 800～850℃ was found to reduce about 30 % of the nitrous oxide emission from the sludge incineration compared to the emission under the current operational condition. The effects of the higher temperature operation on the green-house effect as well as the cost and durability of an incinerator were investigated and it was concluded that the global warming potential(GWP) could be lowed and the durability and construction cost would be little affected.

A simulation model to predict the excess digestion gas was developed. According to the model, the seasonal variation of the excess gas could be predicted as a function of the site parameters. The storage and transport methods of the excess gas was studied, and the adsorbing method was found effective and applicable to small wastewater treatment plants.

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

1. Introduction

Global warming is becoming one of the most serious environmental problems we have ever met. Although carbon dioxide is one of the responsible agents causing green-house effect, methane and nitrous oxide are no less important in controlling global warming. In fact, the effects of methane and nitrous oxide on global warming on the unit mass basis for 20 years after are reported around 60 and 270 times as high as the carbon dioxide(CO_2), respectively.

Although the sewerage system is essential for the modern society, the emission of methane and nitrous oxide from the sewerage system is reported by a recent survey[1]. Considering the expansion of the sewerage systems, the emission of methane and nitrous oxide from the sewerage systems in Japan is predicted to increase. Since the sewerage works are done to preserve our environment locally and globally, it is urgent to establish the technologies to control the emission of green-house effect gas from the sewerage systems.

2. Research Objectives

This research is aiming, first of all, at the development of the technologies to reduce the emission of the green-house effect gas, such as methane and nitrous oxide, from the sewage treatment facilities, and secondly at the development of the ways of the beneficial use of excess methane gas, since the use of excess methane gas can reduce the consumption of energy supplied from the outside of treatment plants. The reduction of methane and nitrous oxide is focused on the wastewater treatment processes and the sludge incineration process[2].

3. Results and Discussion

3.1 Control of Green-House Effect Gas through Wastewater Treatment Processes

The public sewerage system in Japan covers around 55% of the nation's population at the end of FY 1996 and is expected to expand further more[3]. The emission of methane and nitrous oxide through the wastewater treatment processes is expected to increase along with the expansion of sewerage systems. The study was done to find the ways to control the emission of methane and nitrous oxide.

3.1.1 Estimation of methane and nitrous oxide by field surveys

The surveys were made to collect the data for the more accurate estimation of methane and nitrous oxide, since the past surveys[1] were made at the treatment works with anaerobic digestion process causing the suspect of over estimation of methane emission. The result of survey showed that the emission of methane was not so much influenced by the return of supernatant from anaerobic digestion tanks, hence the estimation of methane emission through the wastewater treatment process was confirmed around 7,500 tons/year throughout the whole POTWs in Japan.

On the other hand, the nitrous oxide emission varied among the treatment works surveyed. The level of accuracy of estimation of nitrous oxide was lowered than that of the methane. One of the causes of variation of nitrous oxide emission was in the seasonal change of the rate of nitrogen transformation as is shown in Figure-1. The nitrogen transformation rate is defined as the percentage of nitrogen transformed to nitrous oxide of the total influent nitrogen. In the conventional activated sludge process, nitrification is not so stable that nitrification proceeds incomplete resulting in the accumulation of nitrite nitrogen in the aeration tank. Although the mechanisms of nitrous oxide production are not yet revealed, the accumulation of nitrite nitrogen may increase the emission of nitrous oxide.

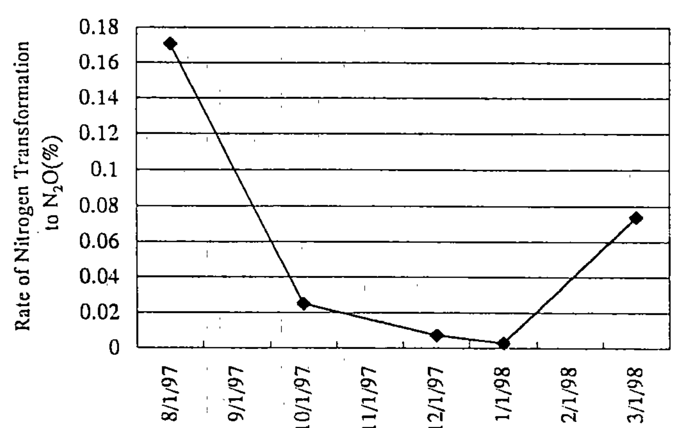

Figure-1 Change of the Rate of Nitrogen Transformation

3.1.2 Experimental study on nitrous oxide emission

The amount of nitrous oxide emission was observed through biological nitrogen removal wastewater treatment processes using the pilot-scale experimental plant having nitrification and denitrification tanks. The fluidized media for the immobilization of nitrifier were applied to the aerobic tank. The nitrous oxide production was relatively high when the denitrification activity became low. Average emission rate of nitrous oxide in this experiment was found 2.15 g-N/d through nitrification process, 0.023 g-N/d through effluent, and 0.012 g-N/d through excess sludge.

3.2 Reduction of Nitrous Oxide Emission through A Sludge Incineration Process

Fluidized bed incinerators, of which the number is increasing in Japan, produce more nitrous oxide as compared with other processes of sludge combustion when the sewage sludge is dewatered by cohesive polymer. The former studies show that combustion at higher temperature in a free board is successful for reduction of nitrous oxide released and that the amounts of nitrogen oxide(NOx) also scarcely increase while keeping the combusting temperature in a sand layer different from that in a free board. It is expected to extend the investigations of the operating conditions suitable for reducing the greenhouse effect gases.

Combusting at higher temperature which needs more supplemental fuel, however, induces carbon dioxide to increase. So it is necessary to evaluate green-house effect caused by a fluidized bed incinerator in all. On the other hand, it is to be desired that influence on incineration facilities from the viewpoint both of technology and of economics is clarified.

3.2.1 Combustion experiment in practical sludge incinerators

The emission behavior of nitrous oxide was measured about working fluidized bed incinerators for the dewatered sewage sludge dosed cohesive polymer. This experiment aimed at the development of the operating method to reduce the emission of the green-house effect gases from a sludge incinerator. Especially, we paid attention to the combusting temperature, which is considered the most important operating condition. We also investigated the quantitative relationship between the emission of the green-house effect gases and the addition of supplemental fuel.

It was observed that the emission of nitrous oxide depended on the combusting temperature in a free board most closely (Figure-2). It is considered that the combustion above 850℃ is suitable for reducing nitrous oxide released.

Concerning the operating condition of a fluidized bed incinerator except temperature, the amounts of nitrous oxide released was minimum when the quantity of supplemental fuel and sludge was adapted to designed capacities. This condition also minimized the fuel consumption, so that the reduction of the emission both of nitrous oxide and of carbon dioxide requires the operating condition to be suited to designed capacities.

3.2.2 Estimation of nitrous oxide emission from sludge incinerators

In order to confirm the reduction efficiency we did the trial calculation of the reduction rate of green-house effect when the combusting temperature was raised. The objects for green-house gases were carbon dioxide and nitrous oxide, besides the global warming potential(GWP) was considered. The green-house effect caused by the emission of nitrous oxide from one working fluidized bed incinerator was closer to that of carbon dioxide if considered GWP (Table-1). If the temperature in a free board was made to increase, the green-house effect could be reduced to 20% less as a whole though supplemental fuel consumption increased by 13%.

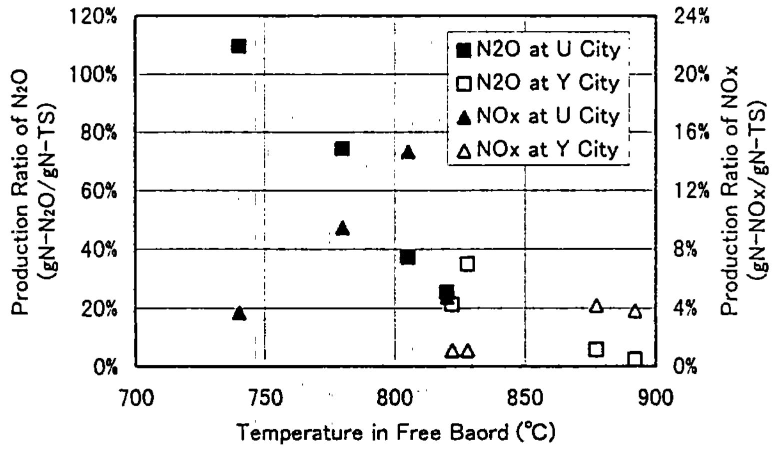

Figure-2 Relationship between Nitrous Oxide Emission and Free Board Temperature

Table-1 Relative Green-House Effect of Sludge Incineration (a case study)

Operation	Combusted Sludge (t/h)	Fuel Consumption (L/h)	Combusting Temperature (℃)	Emissions (kt/year) N_2O	Emissions (kt/year) CO_2	Green-House Effects (kt-CO2/year) N_2O	Green-House Effects (kt-CO2/year) CO_2	Green-House Effects (kt-CO2/year) Total
Designed Temperature	6.7*	230	846	0.041	27.4	11.9	27.4	39.3
Higher Temperature	6.7*	260	870	0.011	28.2	3.2	28.2	31.4

* : 70,070 t/year

3.2.3 Investigation of the influence on incineration facilities

We estimated the influence, involving costs, on incineration facilities in the case of raising temperature more than designed that. Working fluidized bed incinerators were chosen as the objects of this investigation and the life cycle costing(LCC) was applied to economic analysis. Moreover, we suggested the engineering countermeasure adapted to combusting at higher temperature.

According to the sludge incinerator manufacturers there is a much possibility that combustion at higher temperature in a fluidized bed incinerator may damage a heat exchanger rapidly, but fireproof materials will be hardly influenced. From the point of economic view the repair costs, becoming high at the beginning of the life cycle, will not rise much as time passes though the combusting temperature is raised (Figure-3).

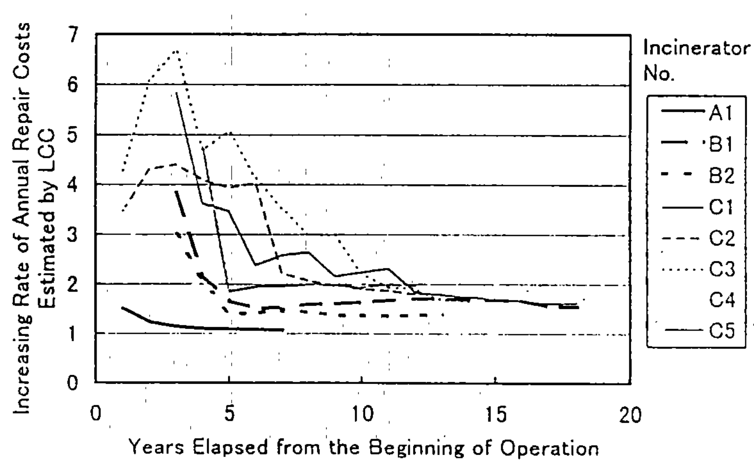

Figure-3 Change of the Relative Repairing Cost

Furthermore, it was derived from LCC analysis of some working fluidized bed incinerators that the economic life of those would not change. On the other hand, the construction costs of the incinerating system adapted to higher temperature will increase slightly.

3.3 Beneficial Use of Anaerobic Digestion Gas

Anaerobic sludge digestion process produces gasses which have 65 to 70 % in volume as methane. While the methane gas thus produced is first of all used for heating the digesters, the remainder of the gas becomes as the excess gas. Since the excess gas is relatively stable in the amount in large wastewater treatment plants, the excess gas is utilized for heating the other processes and driving the gas engine system. However, the excess gas in small wastewater treatment plants is not stable and the excess gas is not beneficially utilized. To promote the beneficial use of the excess gas in small wastewater treatment plants, the study was made to develop a simulation model of the excess gas production and the storage technologies of methane gas.

3.3.1 Simulation model of the excess gas production

To enhance the beneficial use of digestion gas, it is necessary to quantify the amount of excess gas. The factors affecting the excess gas production were analyzed through the data of actual wastewater treatment plants and a simulation model was developed to predict the excess gas production. Such factors as sludge supply rate and temperature were used in the model. Figure-4 shows an example of a simulation result.

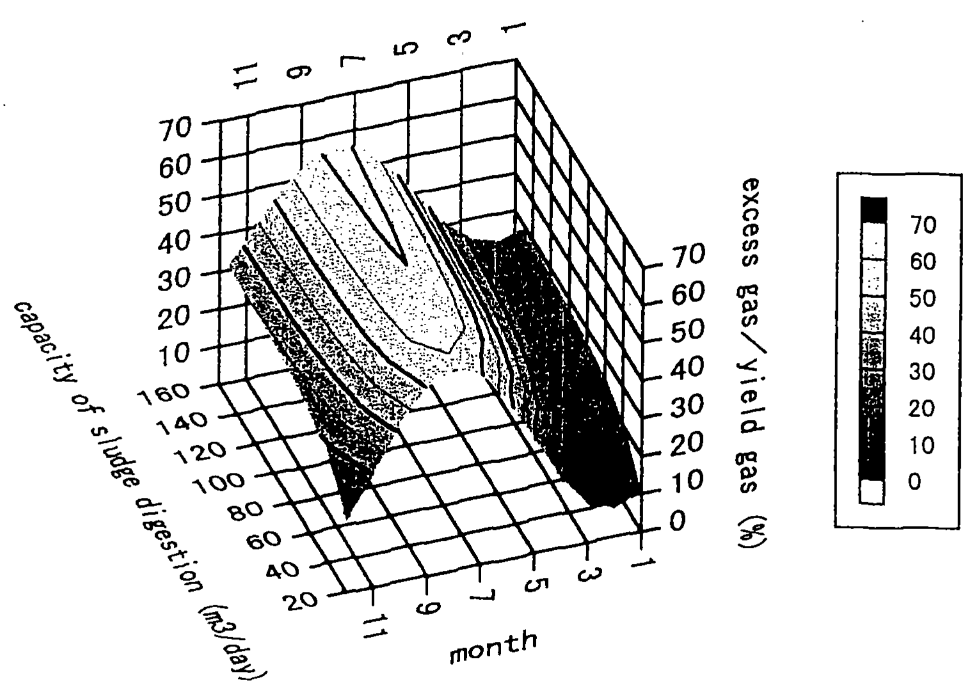

Figure-4 An Example of A Simulation Result

3.3.2 Storage technologies of the digestion gas

The gas holding tank system is widely used to store the excess gas. Since the capacity of holding tank is so designed as to simply supply the necessary amount of methane to heat the digesters, the beneficial use of the excess gas is hard in small wastewater treatment systems where the production of the excess gas is not stable. Other storage technologies than gas holding tank system were studied and the adsorbing storage method was found applicable and efficient for the storage of the excess gas.

Figure-5 shows the relationship between the relative required volume of storage and the pressure of storage, one for digestion gas without adsorber, another for methane with activated carbon.

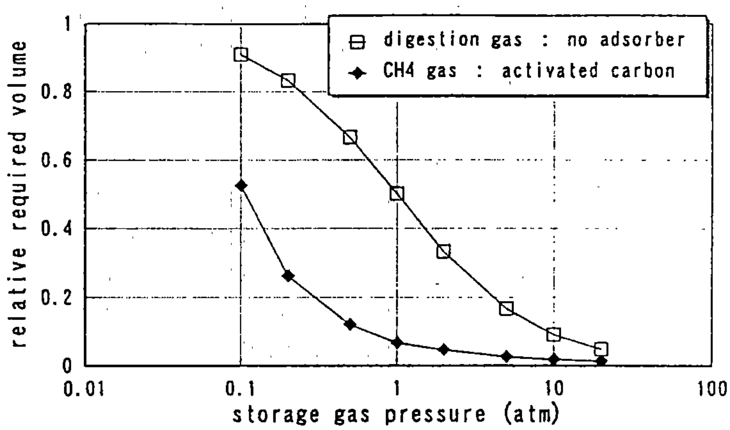

Figure-5 Relative Required Volume vs. Storage Gas Pressure

Reference

1) Takeishi, K. et al., Study on Amounts of Methane and Nitrous Oxide Released from Sewage Treatment Plant. Research Summary of Water Quality Control Department, Public Works Research Institute, 1995
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3) Ministry of Construction., Sewage Works in Japan., Japan Sewage Works Association, 1997