B-16.7 Studies on Emission Control of CH_4 and N_2O from Solid Waste Disposal Facilities (Final Report)

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Abstract State and control methods of CH_4 and N_2O emission from solid waste disposal facilities were studied by means of *in situ* observation, laboratory experiments, published data and mathematical analysis. Firstly, the importance of the complete combustion in mechanical batch combustion type incineration facilities for the CH_4 emission control is confirmed by a *in situ* observation. Secondary, in night soil treatment plants with high loading dinitrification processes, it is suggested that some operation manners, such as the quality of substrate and duration of aerobic/anaerobic condition in reactor(s), would mainly control N_2O emission. Thirdly, at MSW landfill sites, the control of air filled porosity of cover soil is important for the CH_4 emission control by means of regulating the CH_4 consumption of soil.

1. Introduction

In the field of solid waste disposal, most CH_4 is emitted from MSW landfill sites by microbial digestion of organic wastes and N_2O is mainly emitted from incineration plants and night soil treatment plants by combustion and dinitrification, respectively. In this study, we attempt to extract some factors regulating the GHG emission by means of *in situ* observation, laboratory experiments, published data and mathematical analysis, and to establish control measures for the GHG emissions at facilities.

2. CH_4 emission control measures for MSW incineration plants

We observed the CH_4 emission from a mechanical batch combustion type incineration plant. Exhaust gas from the incinerator was piped to GC-FID via a automatic sampler with a syringe, and CH_4 concentration in composite gas samples (during 25 min) were continuously measured. **Fig.1** shows the changes of CH_4 concentration in exhaust gas from plants over 2 days. On 1st day, when waste load to the incinerator was low and combustion was completely shut down at the end of operation (i.e. the "burn-out" operation), CH_4 emission factor was relatively low (374 g-CH_4/ton-waste). On the other hand, CH_4 emission factor on 2nd day, when load was higher than that of 1st day and a flame was remaining in the residual

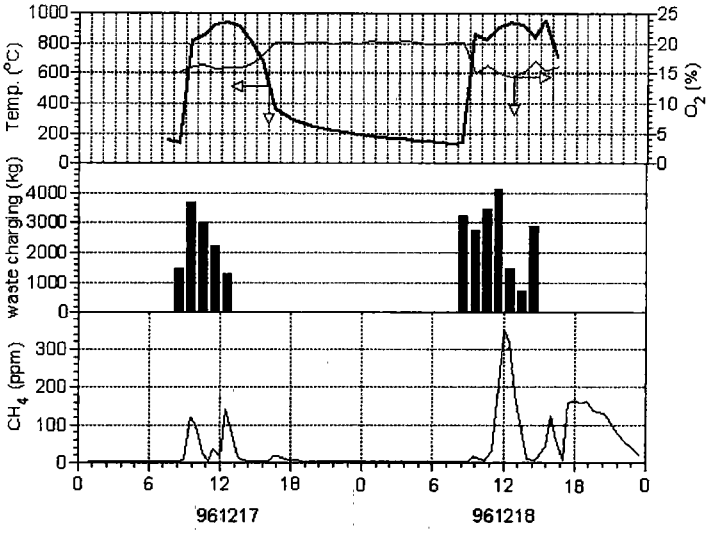

Figure 1 Changes of CH4 concentration in exhaust gas from mechanical batch combustion type incineration plant

waste in incinerator after the end of operation (i.e. the "stock fire" operation which is widely used in this type of incinerators), was relatively high (697 g-CH_4/ton-waste). It confirmed that the need for measures to complete combustion in incineration facilities as possible for the CH_4 emission control.

3. N_2O emission control measures for night soil treatment plants

(1) Potential N_2O emission from night soil treatment plants

Analyzing information in literature [1) 2)], we estimated the potential N_2O emission from night soil treatment plants in Japan. 25.6 % of total nitrogen (T-N) in night soil and gray water was charged into night soil treatment plants. Assuming the conversion factor of T-N to N_2O as 0.12-14%, potential N_2O emission form plants with high loading dinitrification processes was ca. 3% of total potential N_2O emission (0.014-1.6 Gg-N_2O/year) originated from night soil and gray water.

(2) N_2O conversion ratio at night soil treatment plants

We collected exhaust gas samples from selected 15 of night soil treatment plants with high loading dinitrification processes in Japan. Measurement of N_2O in gas and T-N in charged materials was used to estimate the conversion ratio of charged T-N to emitted N_2O. The ratio was ranged from 7.6% to 72%. **Fig.2** shows that the N_2O conversion ratio tended to decrease with increase in COD/T-N of charged waste. It suggests that N_2O production from nitrification/dinitrification processes in plants would attribute to the deficient of the electron supplier, in other words, the incompletion of

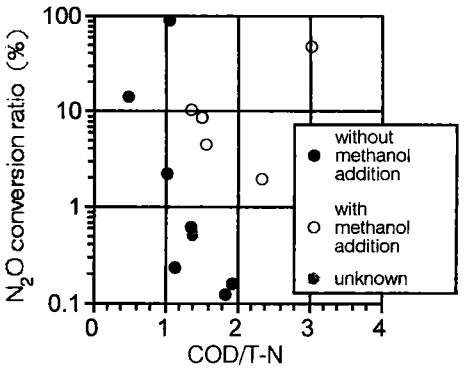

Figure 2 Relationship betwwen N_2O conversion ratio and COD/T-N

dinitrification process [3].

(3) Continuous observation of N_2O emission from a night soil treatment plant with the high loading dinitrification process

In order to observe the diurnal variation of N_2O emitted from a night soil treatment plant with the high loading dinitrification process and the UF membrane separator, exhaust gas from the single type biological reactor was piped and introduced to IR N_2O analyzer via moisture traps. The mean N_2O concentration in exhaust gas was 3 ppm (0-36.5 ppm) during observation periods. **Fig.3** shows the 2 patterns of N_2O fluctuation; sharp peaks of 10-40 ppm at intervals of 30 min and a broad peak of 10-20 ppm at 10:00 to 13:00. Former peaks appeared with decreasing step of air supplying to the reactor. While, duration of latter peak was consistent with the haulage period of new night soil and sludge from Joukasou. These trends are suggested that operation of the reactor and quality of substrate would be important in N_2O control measure in this type of plants.

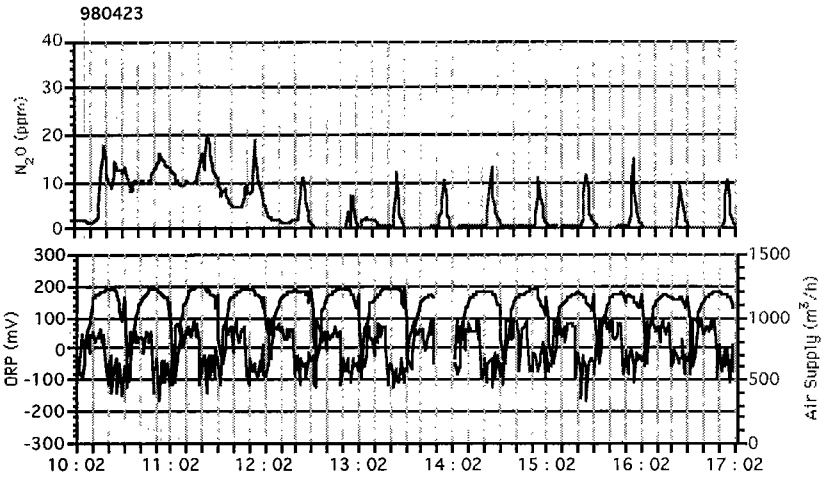

Figure 3 Changes of N_2O from exhaust gas from a night soil treatment plant with the high loading dinitrification process and the UF membrane separator

4. CH_4 emission control measures for MSW landfill sites

(1) CH4 emission from MSW landfill site in Japan, Korea and Indonesia

Field observation were performed at a MSW landfill site in Japan, Korea and Indonesia. CH_4 flux through the ground surface and from the gas suction pipe was estimated by the closed chamber and forced chamber method, respectively. Soil sample was collected at same point as surface flux measurement and biomass and activity of methane oxidizing bacteria (methanotrophs) in the cover soil were also estimated. For example, surface CH_4 flux in a Japanese landfill site is shown in **Fig.4**. These spatial and temporal distribution of CH_4 flux were also observed in Korean and Indonesian site, and we consider that it would depend on deposition period of refuse and physical status of cover soil, especially the air permeability of soil. Methane ratio ($CH_4/\{CH_4+CO_2\}$) of surface flux was mostly lower than that of gas from suction pipes, which is considered to represent original landfill gas from the garbage layer. Since methanotrophs were omnipresence through landfill cover soil and have relative high capacity of CH_4 oxidation (**Fig.5**) , methane oxidation in cover soil would also regulate the landfill gas flux.

(2) Development of Mobile Q-MS methane analyzer

Since surface CH_4 flux is substantially distributed in landfill sites, number of points for

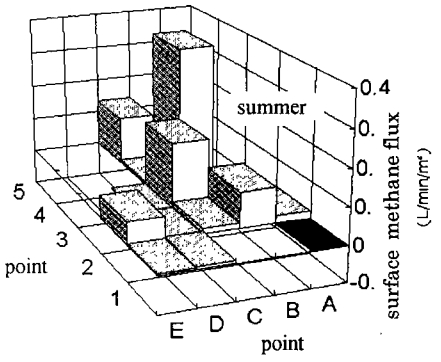

Figure 4 Distribution of suface CH_4 flux in a Japanese landfill site

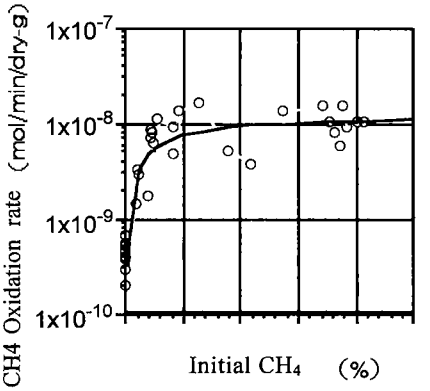

Figure 5 CH_4 oxidation rate of cover soil

observation are required to estimate the total CH_4 emission as possible. We, therefore, mobile CH_4 analyzer was developed using Q-MS detector. This analyzer has the detection limit of 100 ppm-CH_4 and principally not need the carrier gas.

(3) Numerical analysis of methane oxidation and migration in landfill cover soil

We theoretically estimated the surface CH_4 flux by a primary mathematical model including landfill gas migration and CH_4 consumption in cover soil. According to Tanaka and Kohyama [4], a model included the Darcy's law for the flow of soil gas in porous media under the pressure gradient between the refuse layer and atmosphere and Stephan-Maxwell equations for the bulk diffusion of multicompornent gas in porous media. CH_4 oxidation rate, which is formulated using Michaelis-Menten type equation depending on growth substrates such as CH_4 and O_2 in cover soil was also included in the model as the reaction term. Setting the several parameter and boundary conditions from our experiments, literature and some assumptions to the model, we calculated the CH_4 flux in the soil column of 1m at intervals of 0.1m using the finite difference method. **Fig.6** shows ratio of CH_4 emission at surface (top boundary) without to with CH_4 oxidation in cover soil. Calculations indicated that air filled porosity and total pressure of landfill gas should greatly affect to CH_4 oxidation in soil. Thus, the air filled porosity, i.e. air permeability of soil is considered as one of major and applicable factor in emission control measures. **Fig.7** shows the ratio of CH_4 oxidation when the pressure difference between atmosphere and garbage layer is 0 and landfill gas not passing through soil will directly release to atmosphere via short-cut passways such as gas suction

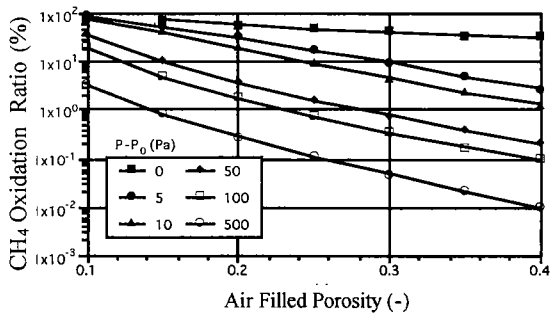

Figure 6 CH_4 oxidation ratio under various porosity and pressure conditions

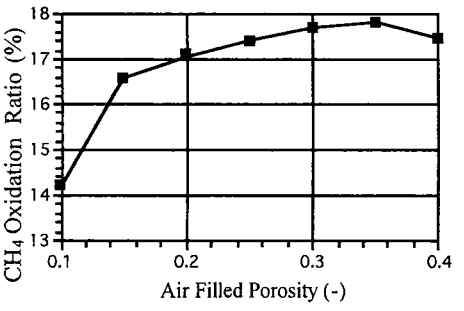

Figure 7 CH_4 oxidation ratio at pressure difference = 0 with assumption that landfill gas not passing through soil will directly release to atmosphere

pipes and cracks. We can find the optimal air filled porosity to maximize CH_4 oxidation in figure. This illustration would be one concept for design and application of cover soil with regards of CH_4 suppression.

5. Conclusion

State and control methods of CH_4 and N_2O emission from solid waste disposal facilities were studied by means of *in situ* observation, laboratory experiments, published data and mathematical analysis. Main findings are presented in follows.

(1) In a *in situ* observation, it is confirmed that the complete combustion in mechanical batch combustion type incineration facilities need for the CH_4 emission control.

(2) In night soil treatment plants with high loading dinitrification processes, it is suggested that some operation manners, such as the quality of substrate and duration of aerobic/anaerobic condition in reactor(s), would mainly control N_2O emission.

(3) At MSW landfill sites, the control of air filled porosity of cover soil is important for the CH_4 emission control by means of regulating the CH_4 consumption of soil.

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