B-16.9.3 Development of CH_4 and N_2O Emission Control Using Ecoengineering Systems Such as Wetlands, Soil Trenches and Oxidation Ponds (Final Report)

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Abstract This international joint research project has been undertaken to develop counter-measure technology using an ecoengineering system that can control the generation of CH_4, N_2O and other gasses in soil trenches used to treat domestic wastewater. During 1996, CH_4 and N_2O gas generation characteristics were analyzed based on a field survey of the generation of CH_4 and N_2O gas in soil trench treatment facilities in Japan and China and on the clarification of the mass balance by laboratory bench scale soil trenches. In 1997 the mechanisms of the generation of CH_4 and N_2O gas were clarified based on an analysis of the mass balance by the same bench scale soil trenches constructed at national testing bodies in both countries, the relationship between the generation of CH_4 and N_2O gasses and ORP was analyzed, and research was performed to develop a circulating anaerobic bed soil trench system that controls the generation of CH_4 and N_2O by incorporating the micro ventilation method.

The results of this research have revealed that the principal mechanisms behind the high discharge of CH_4 and N_2O by soil trenches are structural factors, that it is possible to control the generation of N_2O by keeping the ORP above +150 mV or below -10 mV, that it is possible to keep the ORP between +300 and ＋400 mV by applying the micro

ventilation method, and that this can reduce the discharge of CH_4 and N_2O to about 1/2 and 1/3 respectively.

Key Words: CH_4, N_2O, ORP, Soil Trench, China

1. Introduction

Regardless of the fact that it is known that treatment systems such as wetlands, soil trenches and oxidation ponds used to treat domestic wastewater in China and other developing nations are extremely big sources of CH_4 and N_2O gas (Bartlett et. Al.), almost no research on specific technology needed to resolve this problem has been conducted either in Japan or overseas, and there are no reports of ways to reduce CH_4 or N_2O gas generation by soil trenches.

During 1996, this joint international research project analyzed CH_4 and N_2O gas generation characteristics based on a field survey of the generation of CH_4 and N_2O gas in soil trench treatment facilities in Japan and China and on the clarification of the mass balance by laboratory bench scale soil trenches.

In 1997 the mechanisms of the generation of CH_4 and N_2O gas were clarified based on an analysis of the mass balance by the same bench scale soil trenches constructed at national testing bodies in both countries, the relationship between the generation of CH_4 and N_2O gasses and ORP in soil trenches in particular was analyzed, and research was performed to develop a circulating anaerobic bed soil trench system that incorporates the micro ventilation method and can keep the ORP at a high enough level to reduce the generation of CH_4 and N_2O gas.

2. Research Objectives

This international joint research project has been undertaken to develop counter-measure technology using an ecoengineering system that can control the generation of CH_4, N_2O and other gasses in soil trenches used to treat domestic wastewater.

3. Research Method

The CH_4 and N_2O gas samples were obtained from the in soil trenches by treating the point in time when the sealed space in the top of each soil trenches was sealed from complete open state as zero minutes and finding the quantity of the gasses generated from the increase in the concentration of the CH_4 and N_2O gasses inside the sealed space for a 30 minute period.

4. Results and Discussions

(1) State of the discharge of CH_4 and N_2O gasses by soil trenches treatment facilities and by bench scale soil trenches

The average values of the CH_4 gas flux and N_2O gas flux from the soil trench treatment facility on the Japan side and from the soil trench treatment facility on the China side are 9.3 to 13.9 g CH_4/m^3 and 8.2 to 12.2 g N_2O/m^3, 3.3 to 4.5 g CH_4/m^3 and 3.3 to 5.0g N_2O/m^3. respectively, revealing that the CH_4 gas flux and N_2O gas flux from the soil trench treatment facility on the China side is low, at 32% and 40% respectively of the values for the Japan side.

The average values of the CH_4 gas flux and N_2O gas flux from the bench scale soil trench on the Japan side and from the bench scale soil trench on the China side are 7.4 g CH_4/m^3 and 5.7 g N_2O/m^3 and 7.1 g CH_4/m^3 and 4.6 g N_2O/m^3 respectively revealing that the CH_4 flux is identical in both cases, while the N_2O flux is about 20% lower in the China case, confirming that there little difference.

(2) Mass balance of the nitrogen in a soil trench

The mass balance of the nitrogen in the bench scale soil trenches was calculated, revealing that if the T-N of the source water is assumed to equal 100%, approximately 27% of the nitrogen is consumed in a soil trench. An analysis based on N_2O gas discharge data reveals that about 26% of the nitrogen consumed in a soil trench is discharged as N_2O gas, These values account for about 8.0 of the source water T-N of 100%, and converted to flux, provide a high pollutant load per unit activity of source of 4.0 g N_2O/m^3.

The results reveal that the conversion rate to N_2O gas in the bench scale soil trench case is between several times and several tens of times as high as the conversion rate between 0.4

and 1.1% for a household wastewater treatment system solely for night soil which is said to have a high N_2O gas conversion rate, and that this N_2O gas discharge pollutant load per unit activity of source is about 400 times as high as the discharge pollutant load pen unit activity of source of 10mg N_2O/m^3 from activated sludge method sewerage treatment plants (Ministry of Construction, Public Works Research Institute, Water Quality Control Department Survey, 1995) .

(3) Trial calculation of total quantities of CH_4 Gas and N_2O gas discharged by soil treatment processes in China

Based on a CH_4 and N_2O discharge pollutant load pen unit activity of source of 3.0 to 4.5 g CH_4/m^3 and 3.3 to 5.0 g N_2O/m^3 (domestic wastewater) from trench treatment facilities, It is calculated that when soil trench treatment facilities expanld to encompass the 200 million people living in the Northeast, Northwest, and North Regions of China, the total quantities of CH_4 and N_2O discharged will stand between 43,800T and 65,700T CH_4/ year and between 48,300T and 73,000T N_2O/ year respectively. The total quantities of CH_4 gas and N_2O gas generated in soil trenches are clearly massive volumes of gas, and appropriate counter-measures must be taken to deal with the problem.

(4) Soil trench CH_4 and N_2O gas generation mechanism

In soil trenches used to treat domestic wastewater, NH_4-N from an anaerobic filter Was converted to NO_3-N at more than 90%, and the ORP was in a range from + 100 to +400mV, with the result that the digestion reaction occurred appropriately in the soil trench. But the experiment revealed that even when the peds structure and facet of the peds of a soil trench are aerobic, the interior easily becomes anaerobic. And with the soil trench treatment method, contaminants in the source water first permeate the soil around the sprinkler pipes, then the remaining contaminants gradually moisten the surrounding soil, distributing the pollution load on an incline from the parts with high load near the sprinkler pipes to the parts with low load near the collecting pipes, so that the area around the sprinkler pipes became anaerobic. In brief, while overall, an aerobic digestion process occurs in a soil trench, anaerobic sections exist at scattered parts of its structure causing a simultaneous anaerobic reaction. This view is backed up by the fact that even when the ORP is +457mV, CH_4 gas is discharged.

(5) ORP, CH_4 and N_2O gas discharge relationship in a soil trench

In the third week of the soil trench experiment, ORP reached a high level of about + 457mV, and the CH_4 and N_2O gas flux were also found to be extremely high at 4.8 g CH_4/m^3, and 4.2 g N_2O/m^3 respectively, Later the ORP gradually declined until it was down to about + 48mV in the 32nd week, when the flux of the CH_4 gas and N_2O gas were respectively 7.5 g CH_4/m^3 and 7.1 g N_2O/m^3, representing increases of 56.3 % and 69.1 % respectively. After a year of operation, ORP was down to about -62mV or less, while the CH_4 gas flux was up to 13.4 g CH_4/m^3, an increase of about 3 times. While the ORP was falling from +150mV to -10mV, the flux of the N_2O gas changed little, as it ranged from 7 to 8 g N_2O/m^3, then as the ORP neared -10mV, the N_2O flux began to gradually decline, and after about one year of operation, the N_2O gas flux returned to 4.6 g N_2O/m^3, which was its level when the ORP was approximately + 457mV. To summarize above changes over time in the ORP and the discharge of CH_4 gas and N_2O gas, the discharge of CH_4 increases as the ORP value falls, while the discharge of N_2O gas tends to increase when the ORP is between + 150mV and -10mV (assumed to be the N_2O high discharge section) . In brief, it is possible to control CH_4 gas by maintaining the ORP at a high level with the capillary tube method, and the generation of N_2O can be controlled by keeping ORP in any mV range other than that between + 150mV and -10mV, But there are still a number of shortcomings ; if the ORP of a soil trench is operated under anaerobic conditions of -10mV or less, while the N_2O generation can be controlled, the quantity of CH_4 gas generated increases, and if a soil trench is easily plugged, its organic material decomposition capacity declines. There from a comprehensive performance including controlling both the N_2O, stabilizing the treatment performance of the soil trench, and maintaining high organic material decomposition ability the optimum operating condition to control the generation of CH_4 and N_2O by a soil trench is to operate it while maintaining a high ORP value.

(6) Maintaining a high ORP Value by micro-ventilation and its CH_4 and N_2O gas generation control effects

At the beginning of the micro-ventilation method test, the soil trench ORP was about + 490mV both with and without ventilation, and the flux of the CH_4 and N_2O with ventilation were 5.4 g CH_4/m^3 and 3.2 g N_2O/m^3, while without ventilation, the flux of the CH_4 and N_2O were 5.2 g CH_4/m^3 and 3.4 g N_2O/m^3, revealing that there was little difference in their flux in the two cases, but the results of operating the soil trench for 7 months reveal that although the ORP with ventilation gradually declined, it remained at about + 400mV, and the CH_4 and N_2O flux with ventilation were 6.6 g CH_4/m^3 and 3.7 g N_2O/m^3, respectively, indicating that they had increased by 22.2% and 15.6% respectively since the start of the operation. The ORP without ventilation gradually declined to about + 140mV. The discharge of CH_4 and N_2O gradually rose to 14.3 g CH_4/m^3 and 5.7 g N_2O/m^3 respectively, or to 175% and 67.6% of their levels at the start of operation. In brief, the results of seven months of operation demonstrate that with ventilation, it is possible to reduce generation of the two gasses by 53.8% and by 35.1% respectively of the levels generated without ventilation. As part of this international joint research project, between July 1, 1996 and March 3, 1998, the characteristics of the generation of CH_4 and N_2O were analyzed based a field study of the state of the generation of CH_4 and N_2O by soil trench facilities in China and Japan and by the clarification of the mass balance by bench scale testing ; the mechanisms of CH_4 and N_2O generation were clarified using the bench scale experimental equipment and CH_4 and N_2O control technology was developed as planned; and It was demonstrated that a micro-ventilation system equipped circulating anaerobic filter bed soil trench system that can control CH_4 and N_2O is a soil trench system that performs advanced treatment of domestic wastewater that can be applied in China. Plans for 1998 call for a micro-ventilation system equipped circulating anaerobic filter bed soil trench incorporating comprehensive counter-measures already developed to undergo corroborative testing in a large trench at the site of the employee's dormitory in the LiaoHe Oil Field in Liaoning Province in China.