B-16.3 Technological measures for controlling CH_4 and N_2O from domestic wastewater treatment by using a bioengineering and ecoengineering system

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Abstract

This study of the development and evaluation of technology to control the production of CH_4 and N_2O from domestic wastewater treatment systems has revealed that the nitrification capacity of a biological nitrification reaction declines and its N_2O production rate and conversion ratio rise as the water temperature decreases and the inflowing nitrogen load rises, and that the production of N_2O by a nitrification process can be simultaneously controlled by maintaining the nitrification efficiency at a high level. The study has also shown that by incorporating an intermittent aeration process based on the entrapped immobilization carrier *A. faecalis* that is an effective nitrifying and denitrifying bacteria, it is possible to simultaneously improve both the nitrification efficiency and denitrification efficiency without increasing the N_2O conversion ratio. It also suggests that it is possible to achieve high speed denitrification that sharply cuts the quantity of N_2O produced by adding a small quantity of copper, and that a polyethylene cross-lined type porous cellulose carrier with superior copper absorption capacity can provide a new method of removing nitric acid from ground water. The pollutant load per unit activity of source of N_2O in the swine wastewater treatment process is greater than it is the case of sewage treatment, presumably because NO_2 -N is accumulated temporarily in the wastewater treatment process. In order to control the production of N_2O, it is important to prevent the accumulation of NO_2 -N by performing well balanced nitrification and denitrification. The quantities of CH_4 and N_2O from wetlands that have been polluted by artificial sources fluctuate widely between seasons. This phenomenon is assumed to be a result of fluctuation of organic matters and nitrogen metabolism caused by microorganism and vegetation in wetland ecosystems: absorption activity caused by CH_4 oxidation or vegetation, denitrification reactions, or the absorption of nitrogen compounds, etc. The study has also suggested that it is possible to develop technology to reduce these gasses from wetlands polluted from artificial sources caused by the activity of wetland microorganism ecosystems. And it has shown that anaerobic filters and soil trenches provide superior organic matters, nitrogen, and phosphorus removal capacity, and that it is possible to sharply reduce the production of CH_4 and N_2O by performing ventilation.

Key Words Greenhouse Gas Reduction, Methane (CH_4), Nitrous oxide (N_2O), Bio-engineering, Eco-engineering

1. Introduction

Among many kinds of greenhouse gasses, CH_4 and N_2O have global warming potential (GWP) that is far greater than that of CO_2. Therefore, controlling the production of these two gasses is an extremely significant way to prevent global warming. To achieve this goal, effective technologies for each source must be developed, but it is also important to clarify the reaction principles common to these various treatment methods to bring them into wide use. This also applies to the water treatment and water environment fields that are important sectors of CH_4 and N_2O countermeasures, and it is assumed that the establishment of high level technologies to control greenhouse gas production and technologies to remove nitrogen and other nutrient salts can encourage the improvement of global warming prevention measures and water environment restoration on a world-wide scale. This study and evaluation, undertaken in consideration of the above facts, was performed to contribute to research and development on CH_4 and N_2O production restriction technologies for domestic wastewater systems and treatment processes that take advantage of bio-engineering and eco-engineering systems.

2. Research Objectives

During FY 1998 and 1999, the following items were developed, studied, and evaluated.

(1) The analysis and evaluation of the effects of water temperature and the nitrogen load on nitrification activity and the N_2O production rate in biological wastewater treatment.

(2) Research on the improvement of denitrification processes and the N_2O production restriction effects from the introduction of an effective nitrification and denitrification bacteria as an entrapped immobilization carrier.

(3) Research and development of high efficiency denitrification processes based on the addition of minute quantities of metal and research on its N_2O production control effects.

(4) Fact-finding survey of the characteristics of N_2O production in swine wastewater treatment processes and research and development of production reduction measure technologies.

(5) Evaluation of quantities of CH_4 and N_2O from wetlands polluted by artificial sources and development of technologies to restrict their production.

(6) Development of CH_4 and N_2O production control type wastewater treatment processes based on the use of soil.

3. The analysis and evaluation of the effects of water temperature and the nitrogen load on nitrification activity and the N_2O production rate in biological wastewater treatment

This part of the study concerned the effects of water temperature and the inflowing nitrogen load on nitrification activity including the production of N_2O during the nitrification reaction unit process where the biological nitrogen removal process is the factor determining the speed of the process.

3.1 Research Method

The study was based on the activated sludge process performed by installing a total of six 2 L aeration tanks in pairs in three thermostatic chambers set at 10°C, 20°C, and 30°C. Synthetic wastewater prepared to simulate domestic wastewater was used as the specimen wastewater. The set value of the inflowing load was varied. The pH was set at 7.0 and adequate aeration was performed. The inflowing nitrogen loads per unit MLSS for each temperature condition were set by two methods. In one case, the concentration of the mixed liquor suspended solids (MLSS) was set at 2,000 $mg*L^{-1}$, the hydraulic

retention time (HRT) was constant at 8 hours, and the nitrogen load was increased by raising the concentration of the incoming water in steps. These were called Run 1, Run 2, and Run 3 (experiment series A) for temperatures of 10°, 20°, and 30° respectively. In the other case, the concentration of the mixed liquor suspended solids (MLSS) was set at 500 mg*L^{-1}, the nitrogen concentration was constant at T-N 40 mg*L^{-1}, and the nitrogen load was increased by shortening the HRT in steps. These were called Run 4, Run 5, and Run 6 (experiment series B) for temperatures of 10°C, 20°C, and 30°C respectively. The experiment runs were performed so that the nitrogen load per MLSS unit in both experiment series A and B at each step were identical. **Table 1** summarizes the experiment conditions.

3.2 Results and Discussion

The effects of the water temperature on the nitrification reaction and N_2O production at stage 1 of experiment series A (referred to below as experiment conditions A-1) and stage 1 of experiment series B (referred to below as experiment conditions B-1) were analyzed. Under both experiment conditions A-1 and B-1, the lower the water temperature, the lower the nitrification ratio. The ratios of conversion of the incoming nitrogen to N_2O in each series of experiments were calculated. The lower the water temperature, the higher the speed that N_2O is discharged and the higher the ratio of conversion of nitrogen to N_2O. Under low water temperature conditions, the nitrification bacteria activity is low, obstructing the progress of the nitrification process, the metabolism process changes from $NH_2OH \rightarrow NO_2$-N to $NH_2OH \rightarrow NOH \rightarrow N_2O$, and the percentage that is converted to N_2O that is a byproduct of the reaction rises. This finding suggests that it is possible to effectively perform the nitrification reaction while controlling the production of N_2O by maintaining the water temperature at a level where the microorganism reaction occurs appropriately.

Table 1 Experimental condition

Operating condition \ (stage)				1	2	3	4
		Water temperature	MLSS	HRT (h) T-N concentration (mg · ℓ-1) TN-MLSS Load (kg-N · kg-MLSS-1 · day-1)			
	(Run)	(℃)	(mg · ℓ-1)				
A	1	10	2,000	8 40 0.06	8 80 0.12	8 107 0.16	8 160 0.24
	2	20	2,000				
	3	30	2,000				
B	4	10	500	32 40 0.06	16 40 0.12	12 40 0.16	8 40 0.24
	5	20	500				
	6	30	500				

Observations of the effects on the nitrification efficiency of the inflowing nitrogen load in experiment series A show that at each set of temperature conditions, the higher the inflowing nitrogen load, the lower the nitrification efficiency. Under high nitrogen load conditions in particular, the nitrification efficiency declined to about 10% regardless of the water temperature. The higher the inflowing nitrogen load, the greater the conversion ratio to N_2O of the nitrogen that has been nitrified (**Fig. 1**). It is hypothesized that this occurs because as in the case of low temperature water, an excessive nitrogen load reduces the speed of NO_3 production, and that this is accompanied by a rise in speed of N_2O formation. And judging from the results of Run 3, a rise in the nitrogen load is accompanied by a fall in the speed of nitrification and an increase in the speed that N_2O forms. In other words, it is possible to simultaneously restrict the production of N_2O by maintaining an adequate nitrification capacity.

And even in experiment series B where HRT was a parameter, the same results were obtained: a rise in the nitrogen load was accompanied by rises in the speed of the discharge of N_2O, the ratio of conversion of inflowing nitrogen to N_2O, and the percentage of nitrogen nitrified as N_2O-N.

4. Research on the improvement of denitrification processes and the N_2O production restriction effects from the introduction of an effective nitrification and denitrification bacteria as an entrapped immobilization carrier

Because the physiological properties of the bacteria, *Alcaligenes faecalis* include both nitrification and denitrification, an experimental device combining the intermittent aeration activated sludge process and the three-phase fluid layer process was used to study ways to enhance and improve efficiency of nitrification – denitrification processes by introducing a biological treatment reaction tank containing this bacteria as an entrapped immobilization carrier.

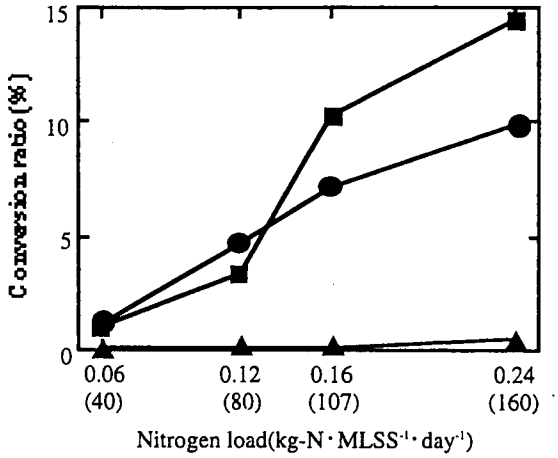

Fig. 1 Relationship between the inflow nitrogen concentration and the conversion ratio from nitrificated nitrogen to N_2O-N at experimental condition A
Each value in the parentheses shows the inflow nitrogen concentration (mg· ℓ -1), respectively. Symbols, ●, ■ and ▲ denote the Run1, Run2 and Run3, respectively.

4.1 Research Method

An experimental intermittent aeration activated sludge system was used to perform a comparative analysis of denitrification properties and N_2O production properties in a case where activated sludge with nitrification bacteria prioritized (referred to below as "nitrifier dominant activated sludge") is immobilized and introduced and a case where *A. faecalis* is immobilized and introduced. Actual domestic wastewater was used for the experiment and the HRT of inflowing load was initially set at 8 hours then lowered to 4 hours in stages. The return sludge ratio was set at 50% and the DO value of the aerobic process was set so that it was initially 4.0 mg*L^{-1} or more then changed appropriately. The experiment conditions are as shown in **Table 2**; the set HRT, DO value, and times allotted to the aerobic and anaerobic phases of each process varied in the sequence: A, B, C, D, and E. The experiments were designated as Run 1 during which a polyethylene glycol (PEG) carrier entrapping and immobilizing the nitrifier dominant activated sludge is introduced in a quantity equal to 10% of the capacity of the aeration tank, and as Run 2 during which a PEG carrier entrapping and immobilizing *A. faecalis* such that 1 X 10^{11}CFU* carrier cm $^{-3}$, is introduced in a quantity equal to 10% of the capacity of the aeration tank. The MLSS was set at 2,000 mg*L^{-1} and the water temperature was kept between 20 °C and 23 °C throughout the period of the experiment.

A three-phase fluid layer type wastewater treatment system was used to perform a comparative analysis of the denitrification properties and N_2O production properties when the quantity of *A. faecalis* introduced was varied. The experimental system was cylindrical, its effective capacity was 1.8 L, and it was constructed so that air was supplied to the inside

Table 2 Experimental condition

Condition	A	B	C	D	E
HRT; (h)	8	6	4	4	4
Oxic/Anoxic; (min./min.)	60/60	60/60	60/60	60/60	90/30
DO; (mg L^{-1})	4.0	4.0	4.0	1.0	1.0

through a draft tube with an internal diameter of 3.6 cm. Carriers consisting of activated sludge and *A. faecalis* immobilized by PEG and activated charcoal with a grain sizes ranging from 0.71 to 0.84 mm were placed inside the reaction tank to establish three systems: a conventional activated sludge system, an activated sludge system that has been injected with an immobilized carrier, and a fluid bed system. Artificial waste water prepared to simulate domestic wastewater was used to keep the pH at a minimum value of 7 and the system was operated at a total of 18 phases as the HRT was gradually reduced from 8 to 4 hours. **Table 3** shows the experimental system operating conditions.

Table 3 Experimental conditions

Reactor No.	1	2	3	4	5	6
System	AS	AS	FB	FB	FB	FB
Carrier	NO	IAF	IAF	IAF	IAF	AC
Packing ratio, %	NO	10	10	20	30	30
HRT, hr	4~8					

AS : Activated Sludge
FB : Fluidized Bed
IAF: Immobilized *A. faecalis*
AC : Activated Carbon

4.2 Results and Discussion

During the intermittent aeration experiment, under HRT conditions from 8 to 6 hours, the nitrification rate was 90% or higher and the denitrification ratio ranged from 70% to 80% in both runs, but under 4 hour HRT conditions, the nitrification and denitrification rates were about 60% in both runs. The results show that the immobilization of *A. faecalis* obtained results identical to those from the case of immobilized nitrifier dominant activated sludge. It also revealed that under HRT conditions from 8 to 6 hours, ratios of conversion of the inflowing nitrogen to N_2O ranged from 0.3% to 0.4% and differed little between the two runs, and that if the nitrogen load was increased, the N_2O conversion ratio rose to about 0.6% in both runs. For this reason, not only the denitrification capacities but the N_2O conversion ratios do not differ very much between the case where *A. faecalis* was introduced and the case where the nitrifier dominant activated sludge that prioritizes the nitrification bacterial was introduced. The experiment also demonstrated that in the domestic wastewater treatment case, it is possible to achieve good treatment efficiencies even if the HRT is raised to 6 hours with the *A. faecalis* immobilization method and with the nitrifier dominant activated sludge immobilization case. And in order to optimize the method of introducing *A. faecalis* , it is necessary to conduct further studies and evaluations of operating conditions.

Fig. 2 shows the T-N removal efficiency and the N_2O emission rate in each run using the three-phase fluid layer

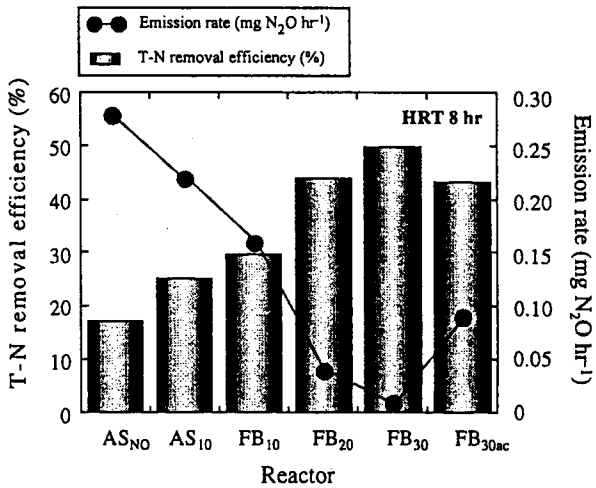

Fig. 2 T-N removal efficiency versus N_2O emission rate at each.

experimental system. It shows that the higher the T-N removal efficiency, the slower the N_2O emission. The N_2O emission rate was fastest using the activated sludge method, slower in a fluid reaction tank containing activated charcoal, and slowest in a fluid reaction tank containing an *A. faecalis* immobilized carrier. It has also been shown that in a fluid reaction tank containing a carrier made by immobilizing *A. faecalis*, the larger the quantity of the carrier placed in the treatment systems, the higher the T-N removal efficiency and the slower the generation of N_2O. Judging from these facts, *A. faecalis* is clearly related to the T-N removal efficiency and the speed of generation of N_2O. And as the nitrogen load rises, the N_2O emission rate and the N_2O conversion ratio both rise, but this increase is related to the denitrification efficiency.

5. Research and development of high efficiency denitrification processes based on the addition of minute quantities of metal and research on its N_2O production control effects.

This phase of the project studied changes in the properties of N_2O emission accompanying a rise in speed of the treatment during an immobilization denitrification process using a porous cellulose carrier and methods of restricting its production.

5.1 Research Method

Three-millimeter square charged porous cellulose carriers with a mean pore diameter of 500 μm were used to absorb and fix activated sludge as the initial seed bacteria, then inserted at a ratio of 20% by volume in a jet pump reactor. The electron donors were methanol and isopropanol and their concentrations were varied within the theoretical required quantity range from 120% to 160%. Synthetic wastewater with a nitrate nitrogen concentration of 40 mol*m^{-3} was supplied as the HRT was varied, to study the effects of the nitrogen load. The effects of minute quantities of the metals, Fe, Mn, Mo, and Cu were studied.

Next, 30 mL of immobilized carriers initially cultured by wastewater containing copper and wastewater not containing copper were transferred to 300 mL of sterilized wastewater containing copper and wastewater not containing copper, then batch experiments were performed to study differences between the denitrification efficiency and N_2O generation properties depending on whether copper was or was not present. The immobilized biomass initially cultured in the wastewater containing no copper was moved to wastewater containing copper, and cyclic batch processing was performed to study changes in denitrification efficiency and N_2O generation. Then wastewater containing copper was used to study the relationship of the pH and temperature conditions with the N_2O production properties.

5.2 Results and Discussion

When methanol and isopropanol were used as the electron donors, the increase in the nitrogen load was accompanied by an increase in the N_2O concentration and the quantity of N_2O emitted. And in the isopropanol case, the values were 4 times as high as those achieved using methanol. Also the effects of minute quantities of metal on N_2O production were studied. With added quantities of $FeSO_4 * 7H_2O$ (1 ppm), $MnSO_4 * H_2O$ (0.35 ppm), $Na_2MoO_4 * 2 H_2O$ (0.5 ppm) as 100%, reducing these quantities by 50% sharply lowered the denitrification rate and increased the N_2O concentration in a case where the electron donor was methanol. Later the denitrification rate recovered remarkably and the N_2O concentration fell to 1/13 of its level at the start of the experiment as a result of adding copper sulfate up to 3 mg*L^{-1}. In the case where the electron donor was isopropanol, the decline of the denitrification rate was not as marked, but the N_2O concentration was multiplied 39 times. The addition of copper resulted

in the recovery of the denitrification rate and the fall of the N_2O concentration in this case as well. The above findings reveal that the production of N_2O varies remarkably according to the type of denitrification bacteria and that the addition of copper is an extremely effective way to control N_2O production and improve denitrification capability.

Changes in the nitrate reduction and flask gaseous phase N_2O concentration caused by immobilized microorganisms initially cultured by wastewater containing copper and by wastewater not containing copper were examined. The nitrate reduction capacity in the case of wastewater containing copper was higher than in the wastewater without copper case, and the N_2O accumulated at the beginning of the experiment was rapidly reduced. In the case of the immobilized biomass in wastewater without copper, there continued to be N_2O in the gaseous phase until the nitrate was almost exhausted. When the immobilized biomass initially cultured in the wastewater without copper was transferred to wastewater containing copper, little change in the speed of the nitrate reduction was observed. In contrast, the maximum N_2O concentration immediately after the transfer was $8*10^3$ ppm, but this dropped steeply to 0.2 ppm during the processing of the 7th batch. It was also discovered that 70% of the copper taken in by the biomass was in the cell membranes and cell walls, and that a large quantity of the copper was adhering to the carrier.

The nitrate removal efficiency was almost unaffected by the pH, but the concentration of N_2O at a pH of 6.0 was 7 times the N_2O concentration at pH of 8.0. The optimum operating conditions in the case of wastewater containing copper were, from the perspective of denitrification efficiency and the N_2O concentration, 30 °C and pH 8.0, and $3.2*10^{-4}$% of the reduced nitrogen was converted to N_2O.

6. Fact-finding survey of the characteristics of N_2O production in swine wastewater treatment processes and research and development of production reduction measure technologies

A sewage treatment plant and a pilot swine wastewater treatment plant were used as the wastewater treatment systems to examine the state of the production of N_2O in order to study their N_2O production properties and methods of preventing this production.

6.1 Research Method

At the sewage treatment plant studied, the treatment was the conventional activated sludge process + sand filtering while the method employed by the swine wastewater treatment plant was the aeration lagoon method (low load semi-batch activated sludge method). The survey and experiments were also done using a pilot plant equipped to perform anaerobic – aerobic batch activated sludge treatment to treat swine wastewater.

6.2 Results and Discussion

The calculations of the N_2O produced based on results of the survey at the sewage plant were 8.33 to 11.2 (mg N_2O-N/capita/day) as the quantity produced per person per day. The quantity produced per 1 m^3 of inflowing wastewater was calculated as 21.5 to 29.2 (mg N_2O-N/ m^3 inflow). According to existing documents concerning similar surveys at sewage treatment plants, most of the N_2O that was discharged came from the aeration tank, but this study discovered that large quantities of N_2O were released from the grit chambers of all the systems. During this study, gas from the grit chambers was sampled using a deodorization duct, but because the absorption of the gaseous phase by the duct inside the system applied negative pressure on the water inside the system, it is possible that an environment in which dissolved N_2O was easily discharged into the atmosphere was formed. And because water

produced by sludge filtration, surplus sludge, and crude sludge flowed through the grit chamber as sidestreams in this system, changes in the water quality caused by the sidestreams also contributed to the discharge of a large quantity from the grit chamber. Judging from these facts, it is possible that the properties of the discharge of N_2O vary sharply according to the structure of the treatment plant, and more detailed studies are necessary.

N_2O was discharged outside the treatment system at the swine wastewater treatment plant during aeration, during non-aeration, and in the discharged treated water, with the quantity discharged during aeration dominant, accounting for most of the discharged N_2O. The quantities of N_2O per unit MLSS in the reaction tank found during the study were $4.97 * 10^{-6}$ to $7.07 * 10^{-4}$ (mg N_2O-N/mgMLSS/day) for the swine wastewater treatment plant, $1.07*10^{-4}$ to $5.31*10^{-4}$ (mg N_2O-N/mgMLSS/day) for the pilot plant, and $6.06*10^{-6}$ to $2.21*10^{-5}$ (mg N_2O-N/mgMLSS/day) for the sewage treatment plant. The fact that the quantity of N_2O produced per unit quantity of microorganisms was greater in the swine wastewater treatment plant case than in the sewage treatment plant indicates that the N_2O production potential of a swine wastewater treatment plant may be greater than that of a sewage treatment plant.

Because this has confirmed that a large quantity of N_2O is produced in the aeration state in both a sewage treatment plant and a swine wastewater treatment plant, the relationship of the NH_4-N oxidation speed / NO_2-N oxidation speed ratio (a/b ratio) with the N_2O production rate under aerobic conditions was obtained (**Fig. 3**). This figure reveals that N_2- is necessary for the formation of N_2O, because the higher the a/b ratio, or in other words, the greater the accumulation of NO_2-N, the faster the production of N_2O. And because the a/b ratio in the swine wastewater treatment case was scattered while the a/b ratio in the sewage treatment case was almost 1, it can be concluded that the difference between the quantities of N_2O produced by the normal and swine wastewater treatment plants was not dependent on variations in the nitrogen load, but on whether or not NO_2-N had accumulated. It is known that an effective denitrification process restricts the production of N_2O. An examination limited to the quality of the treated water shows that almost the same level of denitrification occurred in the swine and the sewage treatment processes. But while no NO_2-N accumulation was observed during the sewage treatment process, in the swine wastewater treatment case, a temporary accumulation of NO_2-N was observed although it was consumed by the end of the process. In other words, this suggests that it is not the resulting water quality that restricts the production of N_2O; rather the important characteristic is that NO_2-N not be accumulated during the process.

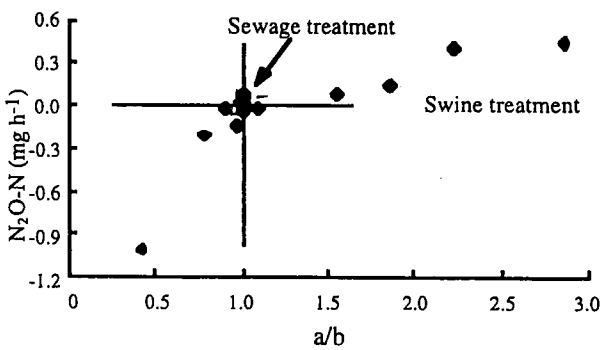

Fig. 3 Relationship between the ratio of oxidation rate of NH_4-N and NO_2-N, and N_2O emission rate

7. Evaluation of quantities of CH_4 and N_2O from wetlands polluted by artificial sources and development of technologies to restrict their production

Annual fluctuations in the quantities of CH_4 and N_2O from wetlands and their discharge mechanisms have been analyzed based on the results of a wetland field survey in the Izunuma Marsh in

the northern part of Miyagi Prefecture. A technical study of the use of wetlands vegetation and microorganisms to reduce the discharge of CH_4 and N_2O from wetlands was also performed.

7.1 Research Method

Measurements were performed once a month in the Izunuma Marsh wetland at measurement locations set where there is and is not vegetation and at the locations of each kind of vegetation. Laboratory experiments using a jar-shaped microcosm designed to simulate a wetland microorganism ecosystem were performed to study the possibility of encouraging the activity of wetland ecesic CH_4 oxidation bacteria and introducing cumulatively cultured CH_4 oxidation bacteria to wetland ecosystems. Denitrification bacteria were cumulatively cultured using bottom sediment and soil taken from the Izunuma Marsh as the culture source and vial experiments performed to study the properties of the removal of N_2O by converting it to N_2 gas in order to determine the feasibility of encouraging the decomposition and activity of N_2O by ecesic denitrification bacteria and the introduction of denitrification bacteria to wetlands.

7.2 Results and Discussion

The quantity of discharged CH_4 per unit surface area of the Izunuma Marsh varies according to the wetland vegetation (including parts with no vegetation), and the annual quantity of CH_4 discharged from the water surface of the Izunuma Marsh ($3.87 \times 10^6 m^2$) has been estimated at approximately 2.8 tons. It can, therefore, be estimated that approximately 3,860 m^3 of CH_4 gas is discharged annually into the atmosphere from the surface of Izunuma Marsh under standard conditions. It is known that the quantity of CH_4 gas discharged from the Izunuma Marsh fluctuates widely from season to season. The maximum discharge occurs in the late Autumn months of October to November, and CH_4 is absorbed during the summer months of July, August, and September, a season marked by a rise in absorption activity caused by the oxidation of CH_4 and by vegetation.

The estimated quantity of N_2O discharged is highest at 6.02 mg/m^2/year on dry areas where ditch reeds grow, followed by 4.75 mg/m^2/year on dry and wet land where wild Indian rice grows. The quantities of N_2O discharged from the water surface from wetland without vegetation, wetland where Indian lotus grows, and wetland where Japanese irises grow are estimated to be 0.63, 0.45, and 0.51 mg/m^2/year respectively. It has been estimated that the quantity of N_2O discharged is about 3 orders lower than the quantity of CH_4 discharged. It is known that the quantity of CH_4 discharged is, inversely, low at points where bottom sediment has formed. This occurs because the decomposition and removal of N_2O by the denitrification reaction etc. in the bottom sediment occurs simultaneously. The quantity of N_2O discharged peaks in May, June, and December on all water covered parts of the Izunuma Marsh (including parts with no vegetation). Seasonal fluctuations in the quantity of N_2O discharged of this kind are influenced not only by fluctuations in the quantity of N_2O produced, but also by fluctuations in the denitrification reaction in lake and marsh waters and in the sediment on the bottom of lakes and marshes, and fluctuations in the nitrogen metabolism caused by microorganisms and vegetation that absorb nitrogen compounds.

As a result of attempts to perform cumulative culturing and separation culturing of CH_4 oxidation bacteria from the bottom sediment of the Izunuma Marsh, three kinds of CH_4 oxidation bacteria with differing forms were separated from bottom sediment at locations of the growth of wild Indian rice and Indian lotus plants, but pure culture of these in large quantities was impossible. So the CH_4 oxidation activity produced by the CH_4 oxidation bacteria cumulative culturing achieved by the cumulative

culturing of these bacteria was measured. The CH_4 oxidation speed of the culturing obtained from the results of repeating cumulative culturing four times was approximately 0.80 g CH_4/g cumulative culturing biomass/day.

Denitrification bacteria were cumulative cultured using bottom sediment from waters where Indian lotus grow and soil from dry land where ditch reeds and wild Indian rice grow in the Izunuma Marsh as the culture sources, 100 mL specimens of these cumulative cultures were sealed in 700 mL vial bottles, and anaerobic vial experiments in which head space gas was replaced by argon gas were performed in order to study the properties of the removal of N_2O by converting it to N_2 gas by the cumulative culturing of denitrification bacteria. The reaction temperature was 25°. The N_2O removal speeds per 100 mL of the cumulative culture obtained in the Indian lotus area bottom sediment, the ditch reed soil, and the Indian rice soil were 0.83, 1.59, and 0.76 mg/day respectively. The fact that the N_2O removal capacity of the specimens from the dry land and wetland ditch reed areas were high suggests that the N_2O removal capacity differs according to differences in the type of denitrification bacteria used and differences between the culturing density of the bacteria.

8. Development of CH_4 and N_2O production control type wastewater treatment processes based on the use of soil

Corroborative experiments were performed in order to boost the treatment capacity of anaerobic filter bed – soil trench treatment processes and to establish optimum operating conditions for the control of CH_4 and N_2O production. This study was accompanied by a comparison of the results with the results of a survey of soil trench treatment systems in China.

8.1 Research Method

The system used for the experiments was an anaerobic filter bed – soil trench experimental system capable of handling hydraulic loading from 100 to 200 L*day^{-1}: the treatment system that collects treated water in capillary tubes and is equipped with an anaerobic filter bed HRT of 24 hours shown in Figure 10. In the soil trench, the ventilation properties of the soil were improved by using ventilation soil consisting of a 9:1 mixture of volcanic ash soil and rice chaff. Three experiment runs were performed: an unventilated run, forced ventilation run, and natural ventilation run in the part of the soil where microorganism reactions occurred.

8.2 Results and Discussion

The winter treatment capacity results showed BOD of 9.6 mg*1^{-1} and BOD removal efficiency of 96%; nitrogen load T-N of the inflowing water of 43 mg*1^{-1} and T-N of the treated water of 11.3 mg*1^{-1} indicating a removal efficiency of 74%; T-P of the inflowing water of 4.6 mg*1^{-1} and treated water T-P of 0.16 mg*1^{-1} indicating a removal efficiency was 97%; and an inflowing water SS of 355 mg*1^{-1} and treated water SS of 4.2 mg*1^{-1} indicating a removal efficiency of 99%.

The mean values of the CH_4 and N_2O discharge speeds ranged from 1.75 to 3.07g CH_4* m^{-3} and from 0.50 to 1.01g N_2O *m^{-3} respectively. The quantities of CH_4 and N_2O discharged during the forced ventilation and the natural ventilation runs were approximately half as much as during the unventilated run (comparison run), and the ORP during the unventilated run tended to continually decline, showing that the CH_4 and N_2O gas production control effects of the ventilation runs tend to be improved.

Properties of the production of CH_4 and N_2O from the soil trench systems in China and in Japan were compared. Because the ORP of the soil trench treatment system in Japan fell from between

approximately 420 and 435 mv in November to between approximately 221 and 235 mv in January, the CH_4 and N_2O production rates tended to increase from between 0.45 and 0.48 g CH_4* m^{-3} and between 0.42 and 0.72g N_2O *m^{-3} in November to between 2.66 and 5.13 g CH_4* m^{-3} and between 0.55 and 1.18g N_2O *m^{-3} in January. In other words, it revealed that the water quality treatment capacity was stable from the start of operation of the soil trench systems until three months after the start-up, but the ORP continued to fall, and the quantity of CH_4 in the unventilated system in particular, rose abruptly. Because the ground temperature in the soil trench treatment system in China fell from about 25 °C in August to less than 4.6 °C in November, the CH_4 and N_2O production rate declined abruptly from between 1.85 and 3.38 g CH_4* m^{-3} and between 1.95 and 2.40g N_2O *m^{-3} in August to between 0.20 and 0.40 g CH_4* m^{-3} and between 0.10 and 0.20 g N_2O *m^{-3} in October. And as at the fact-finding survey stage in 1996, the CH_4 and N_2O discharge speeds from the soil trench treatment system in China were lower than in Japan: specifically 72% and 49% lower than Japan respectively in the forced ventilation system. In the unventilated system, the CH_4 discharge speed was low at 66%CH_4, but inversely, the N_2O discharge speed was higher at 134%. It is assumed that this is a result of the practice of constructing soil trenches in China as deep under the ground as 1.8 m in order to avoid the 1 m or thicker frozen layer that forms in the winter, resulting in the absorption, decomposition and oxidization of gas by deep soil and microorganisms.

9. References

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