Emission of Nitrous Oxide (N_2O) from Agro-Ecosystem

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There is concern that increased application of nitrogen fertilizer in soils to promote food production may affect the stratospheric ozone layer and the climate of the earth by increasing the amount of nitrous oxide evolved from agro-ecosystem to the atmosphere[6,7,14,24,25].

It has been accepted for a long time that N_2O is produced largely by denitrifying microorganisms in soil. Several recent studies have provided evidence that N_2O is produced during the nitrification of ammonium in well-aerated soils[2,4,19].

Although many studies have been conducted at several locations in the world to assess agriculture's contribution to global nitrous oxide emission from agro-ecosystem[1,3,5,8,9,11,17,21-23], very little attention has been paid to the N_2O emission in Japan[18,20].

The objective of the work reported here was to introduce a simple and highly sensitive method for determining the amount of N_2O evolved from soil and water surface and N_2O dissolved in water from agricultural land, and to obtain some examples of N_2O emission from soil and water surface.

Methods for measuring N_2O flux from agro-ecosystem and N_2O dissolved in water from agricultural land

1) Determining of N_2O dissolved in water and N_2O in air samples

The apparatus for stripping N_2O from the water

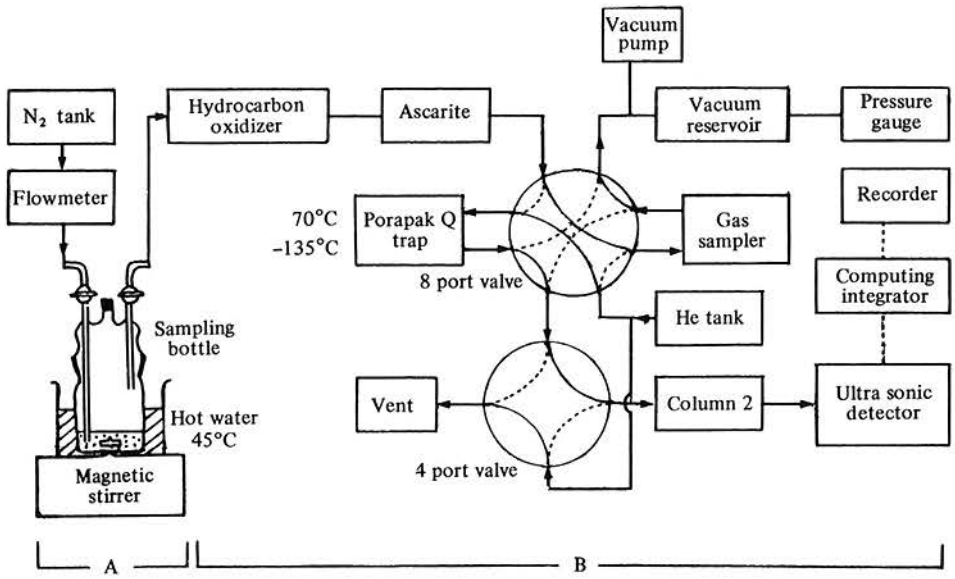

Fig. 1. Apparatus for stripping N_2O from water (A) and apparatus for trapping N_2O and gas chromatographic determination of N_2O (B)

sample, trapping of N_2O and gas chromatographic measurements are shown diagrammatically in Fig. 1[20].

Nitrous oxide dissolved in water samples can be stripped with an ultra-pure nitrogen gas (99.995%, Nippon Sanso Co., Ltd.). Efficiency of stripping is improved by stirring the water sample in a glass bottle kept in a water bath. Hydrocarbons and carbon dioxide in the sample are removed successively through the tubes of $KMnO_4 + H_2SO_4$ and Ascarite. Nitrous oxide and Xenon (Xe) are trapped quantitatively by passing through a Porapak Q column (5 cm long) cooled to −135°C in penten frozen with liquid nitrogen. Nitrous oxide and Xe are separated by gas chromatograph (Tracor MT-150G) equipped with a column of Porapak Q (4.5m long, 70°C) and detected by an ultrasonic detector (Tracor U-90). The concentration of N_2O is calculated using Xe as an internal standard. The method in detail is described in the literatures[15,18,20].

2) N_2O flux from water and soil surface

A chamber system used for the measurement of N_2O flux from the water surface is illustrated diagrammatically in Fig. 2. The system is used for field measurements of nitrous oxide emission from soils, except for the use of a rubber float filled with He[20].

The chamber is floated on the water surface or set on the soil surface for 20 min, and the air within the chamber is sampled at 5-min intervals by attaching an evacuated sample bottle to the sample port of the chamber and opening the stopcock of the vent port. The air sample removed from the chamber is analyzed for N_2O within 24 hr by the gas chromatographic procedure as described above. The rate of N_2O emission is calculated as follows:

$$F = k\left(\frac{273}{T}\right)\left(\frac{V}{A}\right)\left(\frac{\Delta c}{\Delta t}\right)$$

k; a coefficient for calculation of N_2O-N g/10a·day evolved
T; temperature (K) in the chamber
V; volume of the air in the chamber (cm^3)
A; area of the soil or water surface (cm^2)
$\Delta c/\Delta t$; N_2O ng/l·min

Determination of N_2O flux from soil and water surface, and dissolved N_2O in water from agricultural land

1) N_2O flux from water surface and N_2O dissolved in water from agricultural land

Fig. 3 and Table 1 supply data on the N_2O flux from the water surface and the concentration of N_2O in the surface water obtained in a drainage ditch at Yachiyo-cho, Ibaraki Prefecture, where vegetables were being grown in fields with volcanic ash soil to which a high amount of chemical fertilizers (50 kg

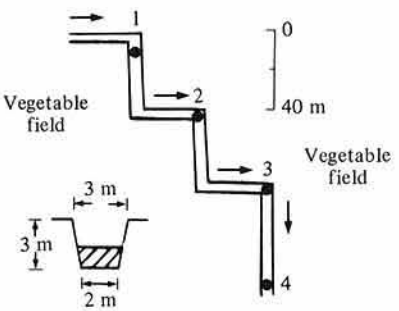

Fig. 3. Location of measuring points of N_2O flux and sampling water in drainage ditch

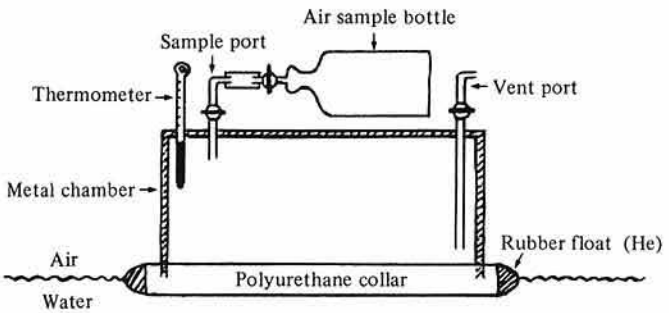

Fig. 2. Diagrammatic representation of the chamber

Table 1. N_2O flux from water surface and N_2O dissolved in drainage ditch water at Yachiyo-cho

Date of sampling	Drainage ditch site	N_2O flux ($N\,g \cdot 10\,a^{-1} \cdot day^{-1}$)	Dissolved N_2O ($N\,\mu g$/liter)	NO_3-N (ppm)	Temp. of water (°C)
Sep. 26	1	—	70	16.1	—
	2	—	61	17.2	—
	3	—	59	18.2	—
	4	—	52	21.8	—
Dec. 8	1	12.42	32	18.3	8.5
	2	—	13	18.5	—
	3	—	15	21.1	—
	4	7.25	14	21.7	10.0
Dec. 14	1	31.21	109	28.0	9.5
	2	—	—	—	—
	3	—	23	23.4	—
	4	5.66	19	26.5	9.0
Jan. 12	1	1.97[a)]	14	3.6	2.0
	2	—	—	—	—
	3	—	23	30.8	—
	4	5.03	16	27.3	10.5

a) The water surface was frozen. After removing ice, N_2O flux was measured. —, not determined.

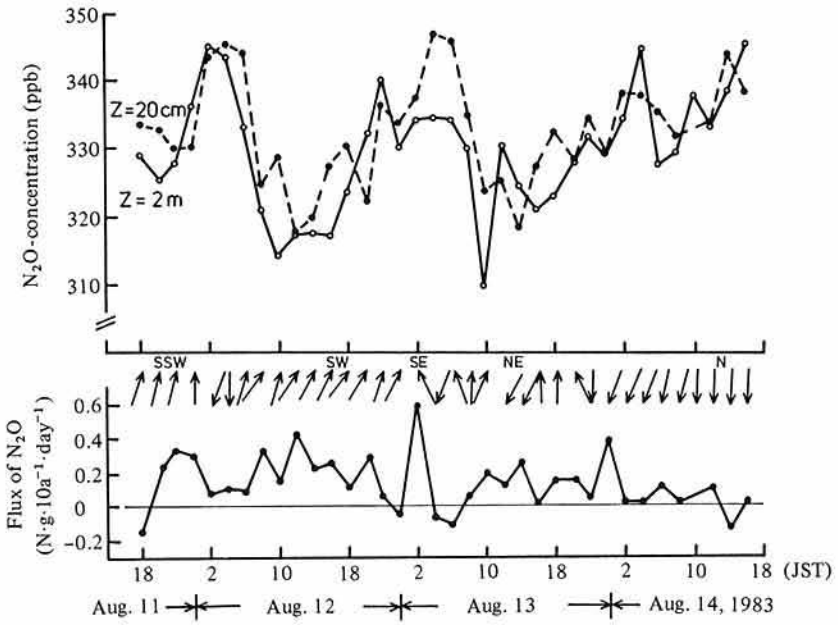

Fig. 4. Diurnal cycles of N_2O concentration and flux of N_2O at an unfertilized grassland soil (Z=height)

N/10a·year) was applied, from September 26, 1982 to January 12, 1983[20].

Samples were obtained according to numbers 1 through 4 in Fig. 3. It is evident that the high concentration of N_2O in the surface water and the high values of N_2O flux from the water of the drainage ditch can be attributed to the excess of fertilizers applied to the vegetable fields.

The nitrous oxide dissolved in the drainage water had probably been derived from the soil through

both nitrification and denitrification processes, and from bottom sediments through denitrification. The data obtained show that the N_2O dissolved in water was evolved to the ambient air when water flows downstream.

Although there are reports that such aquatic environments as oceans, rivers, and ponds provide both sources and sinks for atmospheric N_2O[10,13], there are few reports in the literature concerning the emission of N_2O from drainage water from agricultural land.

The data presented here indicate that a large amount of N_2O could be evolved to ambient air from the surface of drainage water derived from agricultural fields to which excessive amounts of fertilizer had been applied.

2) *N_2O flux from upland fields*

Fig. 4 shows the diurnal cycles of N_2O concentration and flux of N_2O at an unfertilized grassland volcanic ash soil (Tsukuba)[12]. The average concentration of N_2O in atmosphere is 333 ppb and 330 ppb in the height of 20 cm and 2 m from soil surface, respectively. Flux of N_2O showed the range from -0.1 to $0.3\ g\,N \cdot 10\,a^{-1} \cdot day^{-1}$. Fig. 5 supplies data on profiles of N_2O concentration at a fertilized grassland volcanic ash soil (Tsukuba)[12]. The difference of N_2O concentration between soil surface and 2 m atmosphere from soil surface is about 40 ppb on September 14. The maximum flux of N_2O showed $3.8\ g\,N \cdot 10a^{-1} \cdot day^{-1}$.

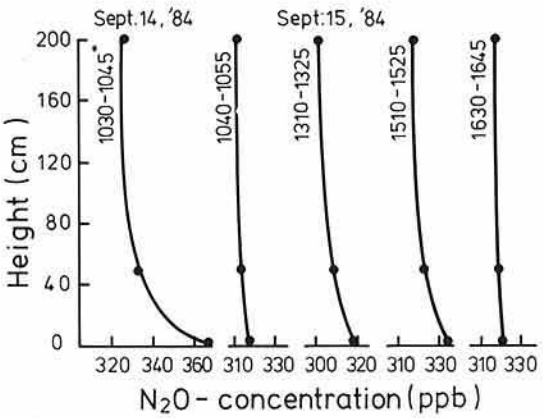

Fig. 5. Profiles of N_2O concentration on a fertilized grassland soil (* time)

Table 2 shows the results of measuring the amount of N_2O evolved and the percent of N_2O volatilized from applied fertilizer nitrogen on the upland fields. The range of the percent of N_2O evolved from applied fertilizer-N was 0.06 to 0.34 and the amount of N_2O evolved was from 8.9 to 59.6 g N_2O-N/10 a. The data were almost the same as Denmead et al.[8] and Matthias et al.[15,16] have already reported.

3) *N_2O flux from paddy fields*

Table 3 shows the results of measuring the amount of N_2O evolved and the percent of N_2O volatilized from applied fertilizer-N. The range of the percent of N_2O evolved from applied fertilizer-N was 0.33 to 0.55 and the amount of N_2O was from 25 to 33 g N_2O-N/10 a.

The measurement of nitrous oxide emission in the field provides direct evidence that nitrification-denitrification occurs under paddy fields. Although nitrous oxide is only a minor product of this process, the rate of evolution represents the same as in the upland field.

The data presented here indicate that pollution of the stratospheric ozone layer by nitrous oxide from fertilized upland and paddy fields may constitute an

Table 2. N_2O flux from upland fields

Soil	Plant	Period (days)	Fertilizer applied (N kg/10 a)	N_2O-N (g/10 a)	Volatilized N_2O-N (%)
Alluvial soil (Konosu)	carrot	116	20	47.5	0.31
Andosol (Tsukuba)	carrot	116	20	59.6	0.26
Andosol (Tsukuba)	rape	38	15	12.2	0.09
Andosol (Tsukuba)	rape	56	10	34.2	0.34
Alluvial soil (Konosu)	rape	38	15	8.9	0.06
Andosol (Tsukuba)	wheat	186	8	27.0	0.24
Alluvial soil (Konosu)	wheat	186	8	18.5	0.18

Table 3. N_2O flux from paddy fields

Soil	Plant	Period (days)	Fertilizer applied (N kg/10 a)	N_2O-N (g/10 a)	Volatilized N_2O-N (%)
Alluvial soil (Konosu)	rice	120	10	33.2	0.33
Andosol (Tsukuba)	rice	120	10	55.1	0.55
Andosol (Mito)	rice	139	9	27.0	0.33

environmental hazard.

It is not enough to get the whole phenomena of evolved N_2O in agro-ecosystem from these data. There is the necessity that systematic research of the evolution of N_2O from agro-ecosystem should be done in point of soil type, soil utilization and vegetation, and that research to diminish the evolution of N_2O from fertilized soil should be done in point of nitrification inhibition and cultivation.

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