*Journal of Environmental Sciences* Vol. 5, No. 4, pp. 491－497, 1993 ISSN 1001-0742

# Measurement of nitrous oxide emission dynamics from soil

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**Abstract**— A simple laboratory device which simulates environmental factors that affect $N_2O$ emission from soil has been constructed. It is convenient to use it to observe the $N_2O$ emission dynamics from soil cores while simulating some factors such as different fertilizer sources, management, temperature, and chemical inhibitors, etc. The detect limit was 2.5mg $N_2O$-N $m^{-2}$. $s^{-1}$ with maximum error about 10%, so it could be used for agricultural soils. It was found that fertilizer source, fertilizer management and native soil type were preliminarily important factors on $N_2O$ emission fluxes in some of our experiments.

**Keywords:** nitrous oxide emission; agricultural soil; nitrogenous fertilizer.

## 1 Introduction

The mixing ratio of atmospheric nitrous oxide, a catalyst of destroying ozone shelf in the stratosphere and greenhouse gas, has been continuously increasing since the industrial revolution (Blackwell, 1989/1990). It is certain that soils, especially agricultural soils which are treated with nitrogenous fertilizer, play an important role of the atmospheric $N_2O$ sources, but many researchers think that soil heterogeneity, many factors and their interactions make it very difficult to estimate the intensity of soil source and to model the emission flux, and we must primarily try to find the key factors which determine the emission process and to get modelling parameters. So far, no laboratory method is reported to investigate the effects of factors(Mosier, 1981). In this experiment, we construct a simple device and observed the effects of two nitrogen sources and organic matter on $N_2O$ emission pattern.

## 2 Material a method

### 2.1 Device and method

Experimental device shown in Fig. 1 is an open style i.e. "continuous-flowing" style. As indicated by the arrows, the compressed air is first humidified by *B*, then enters the upper part of soil core where it will be mixed with $N_2O$ gas

from soil, and then goes out through a glass capillary (Φ2mm). The gas samples will be gotten at G using sampling pockets, or connecting the outlet G with gas chromatograph sampling tube directly. E and F are used to eliminate the resistant effect of sampling pocket. All glass pipes except the outlet one are wide with 8 mm internal diameter. The air flow rate will be determined by D, and can be adjusted according to emission rate and GC sensitivity. In this experiment, the air flow rate is adjusted to about 20 ml/min with the resident time of air in core about 8 minutes, so about 30 minutes would be taken for each gas sample. The $N_2O$ emission rate is derived from the following formulas:

$$\Delta C = C_{\text{sample}} - C_{\text{compressed air}},$$

$$F = \Delta C\ (v/A)\ \cdot\ K \cdot\ \Phi,$$

where $F$ is $N_2O$ emission rate; $v$ is air flow rate, $A$ is surface area of soil core; $K$ is unit transferring factor; $\Phi$ is temperature adjusting factor.

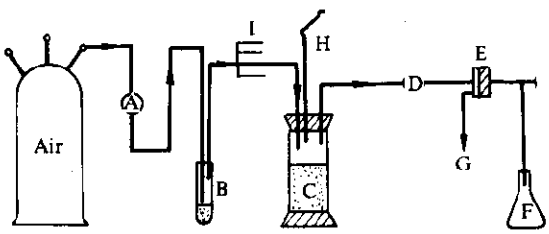


Fig. 1 A schematic diagram of the simulating experiment installation
A: steady flow valve; B: humidification tube; C: soil core (Φ8.2cm × 27cm high); D: flow meter; E: steady pressure valve; F: vessel for adjusting pressure; G: sampling outlet; H: thermometer; I: manifold

2.2 Soil core sampling

The intact soil cores are sampled by inserting hard plastic pipes (Φ8.2mm × 27cm high) with sharpen brink into winter wheat field. 0 − 22 cm soil is taken, and some 0 − 10 cm soil from spots nearby is sampled to make physical and chemical analysis.

In this work, two kinds of soil from 24* winter wheat field on Experimental Farm of Genetics Institute, the Northern Suburb in Beijing and in Daiying Village, Tongxian County, Beijing, were sampled on March 27 and 31, 1989, respectively. Some of their properties are listed in Table 1.

2.3 $N_2O$ analysis

$N_2O$ concentration of gas sample is detected by using (Shridruka) GC-9A with ECD ($^{63}Ni$) detector at 280 ℃. 3m × 4mm glass column supported with 5Å molecule sieve is used at 250 ℃, with high purity nitrogen as supporting gas at 100ml/min. The resident time is about 5 to 6 minutes, so that $CO_2$ and other nitrogen oxides

have no disturbance. The detect limit is about 30 ppb (L/L) $N_2O$ with error below 5%.

**Table 1 Some physical and chemical properties of the experimental soils (mixtures from 0 to 10)**

| Spot | Structure | Color | Moisture, g/g dry soil | pH | Water capacity | O.M. | Total N |
|---|---|---|---|---|---|---|---|
| BJ* | Sand fluvioaquic | Light brown | 14% | 7.5±0.1 | 23±1% | 0.70% | 0.08% |
| DY* | Light loam fluvioaquic | Light brown | 19% | 7.7±0.1 | 29±1% | 0.75% | 0.08% |

| C/N | Bulk density, g/cm³ | K, $K_2O$[1] | P, ppm[1] | Fe, $Fe_2O_3$%[1] | S, ppm | Ca CaO%[1] |
|---|---|---|---|---|---|---|
| 8.8 | 1.30±0.03 | 2.37 | 1688 | 3.33 | 488 | 5.93 |
| 9.4 | 1.35±0.03 | 2.67 | 1027 | 5.07 | 211 | 2.33 |

[1]These items are detected by X-fluorescence technique

The concentration of the standard $N_2O$ imported from USA is 940 ppb (L/L).

2.4 Soil routine analysis

These methods are all introduced from references.

## 3 Results and discussion

### 3.1 Error analysis

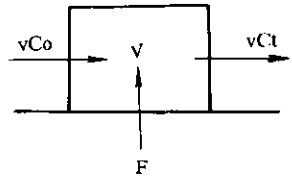


Fig. 2 Model of flow chamber technique
V: air volume of soil core;
Co: input $N_2O$ concentration;
F: $N_2O$ flux from soil;
v: air flow rate
$C_t$: output $N_2O$ concentration at time t

As shown in Fig, 2, the detect error can be derived from the following:

$$\frac{dc}{dt} = (F + vCo)/V - \frac{v}{V} C,$$

integrate with limit condition $Ct = Co$, then

$$Ct = \frac{F + vCo}{v} - \left(\frac{F + vCo}{v} - Co\right)_e \frac{v}{V} t;$$

$$C_{\text{equilibrium}} = C_{t=\infty} = \frac{F + vCo}{v}.$$

If $Co << C_{equilibrium}$, i. e. when emission rate is very high, and $t = 3(V/v) = 3t'$, then $\delta_3 = 4.9\%$ where $t'$ is the resident time of air. If emission rate is not high, in other words, there is no great difference between $Co$ and $C_\infty$, then $\delta_3 < 4.9\%$. All possible error sources and their estimated values are given in Table 2. In general, total error of this method is about 10%, which is acceptable to be used for agricultural soil. The error could be minimized by increasing equilibrium time, but this will cause long sampling time. Practically, we could adjust the air flow rate to reduce the sampling time.

**Table 2 Error analysis of flow chamber technique**

| Error source | $\Delta C$, equilibrium | $\Delta C$, GC analysis | A(area) | $v$ (flow rate) |
|---|---|---|---|---|
| Estimated value | $\delta_3 < 5\%$ | <5% | <1% | <1% |
| Total | | ~ 10% | | |

### 3.2 $N_2O$ emission dynamic

#### 3.2.1 Emission pattern

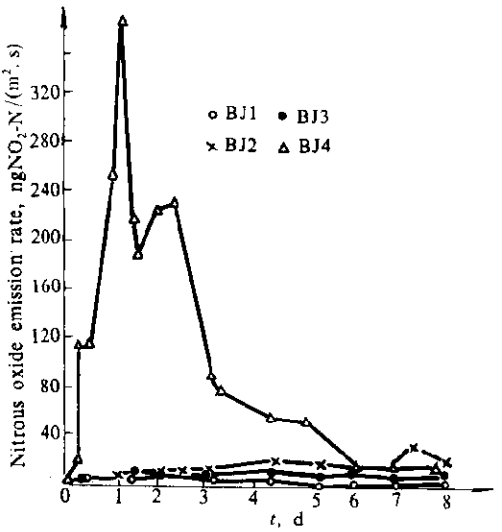


Fig. 3 $(NH_4)_2SO_4$ treatment
BJ1: reference + 10mm $H_2O$; BJ2: 300kg $(NH_4)_2SO_4$/ha mixing with surface soil; BJ3: 300kg $(NH_4)_2SO_4$/ha + 10mm $H_2O$; BJ4: 300kg $(NH_4)_2SO_4$/ha + 0.06% glu. + 10mm $H_2O$

$N_2O$ emission patterns from various treated soil cores are shown in Fig. 3 to Fig. 6, and Fig. 7 shows the variation of the soil moisture during observation. $N_2O$ emission rates increased after adding nitrogenous fertilizer especially of the treatment also with glucose, such as BJ4, BJ8, DY2, DY3, DY4 and DY5. The emission is also accelerated by adding more glucose, including that of BJ8, DY3 and DY4.

When ammonium fertilizer (urea or ammonium sulfate) is added, the $NH_4^+$ concentration of soil would increase, and $NH_4^+$ could be nitrified and transformed into $NO_2^-$ or $NO_3^-$ with $N_2O$ as an intermediate (Khdyer, 1983). Nitrification of $NH_4^+$ would be accelerated by available organic matter such as glucose, so this process is an energy consumption style, and the participating

microorganisms need organic matter as their energy source. Like these results, some field reports state that $N_2O$ emission rate would be high at organic soil or when $NH_4^+$ fertilizer and manure are simultaneously added (Sahrawat, 1986). Otherwise, plant roots in agricultural field can excrete large amount of organic matter, so that $N_2O$ emission rate in root region will also be high (Smith, 1982), and it is important to measure the rate of root region in field observation.

Different soil types and nitrogen source also cause contrast of emission dynamics.

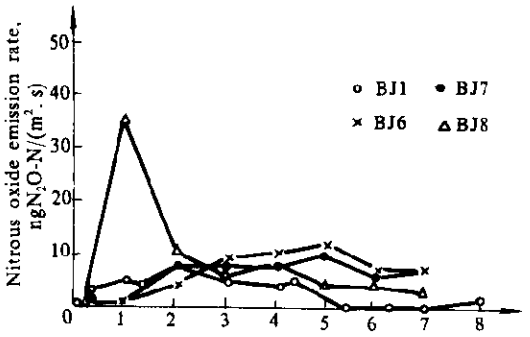


Fig. 4 Urea treatment

BJ1: reference + 10mm $H_2O$; BJ6: 150kg urea/ha + 10mm $H_2O$; BJ7: 150kg urea/ha + 0.007% glu. + 10mm $H_2O$; BJ8: 150kg urea/ha + 0.06% glu. + 10 mm $H_2O$

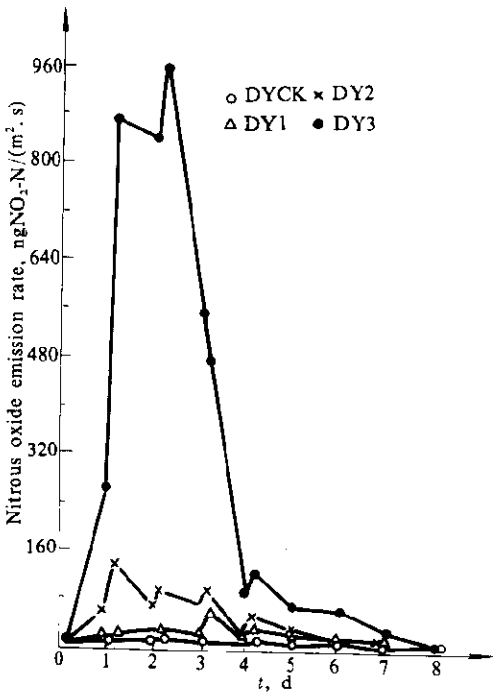


Fig. 5 Urea treatment

DYCK: reference + 10mm $H_2O$; DY1: 150kg urea/ha + 10 mm $H_2O$; DY2: 150kg urea/ha + 0.007% glu. + 10mm $H_2O$; DY3: 150kg urea/ha + 0.006% glu. + 10mm $H_2O$

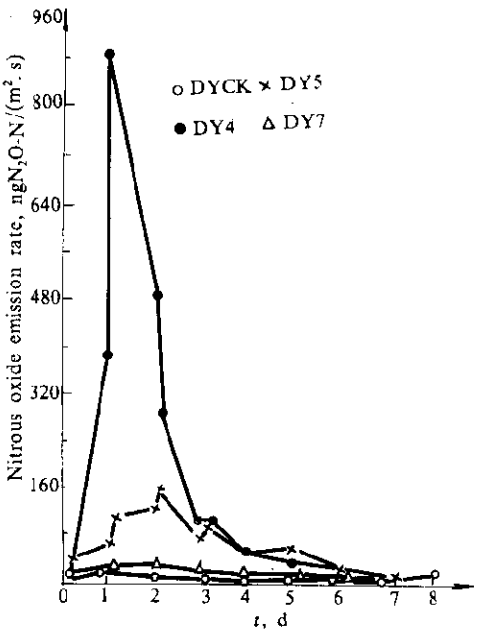


Fig. 6 $(NH_4)_2SO_4$ treatment

DYCK: reference + 10mm $H_2O$; DY4: 300 kg$(NH_4)_2SO_4$/ha + 0.06glu. + 10mm $H_2O$; DY5: 300kg$(NH_4)_2SO_4$/ha + 0.007% glu. + 10mm $H_2O$; DY7: 300kg$(NH_4)_2SO_4$/ha + 10mm $H_2O$

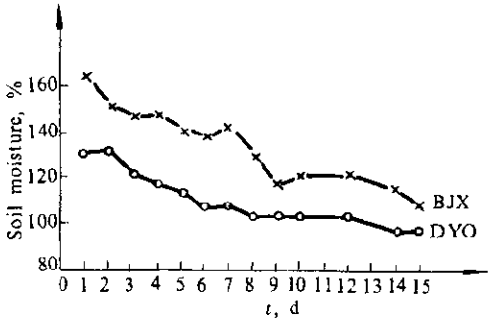


Fig. 7 Trend of soil moisture

It is probably due to the slow hydrolysis of area to $NH_4^+$ in BJ* that area treatment showed low $N_2O$ emission rate. The two soils are very similar, as shown in Table 1, but their emission patterns are very different. It makes us suggest that there may be some other undiscovered properties controlling the process such as soil biological characteristics, available concentrations of some elements affecting microorganism enzyme system, etc. It is necessary to do further work on relevant element analysis microorganism population structural measurement and their physiological property analysis.

3.2.2 Emission amount

From Table 3, we realize that the total amount of emitted $N_2O$ from each soil core in one week is little, and the ratio ($N_2O$-N/N) to the amount of the added nitrogen is also very small. But the added nitrogen would probably keep on affecting $N_2O$ emission. Therefore, the field measurement needs to last a long time in order to estimate the complete effect of the fertilizer addition.

**Table 3 Total $N_2O$ emission from soil cores in one week**

| Treatment | BJ1 | BJ2 | BJ3 | BJ4 | BJ5 | BJ6 | BJ7 | BJ8 |
|---|---|---|---|---|---|---|---|---|
| $N_2O$, mg | – | 0.046 | 0.026 | 0.341 | 0.005 | 0.022 | 0.019 | 0.030 |
| $N_2O$-N/N, % | – | 0.01 | 0.008 | 0.10 | – | 0.006 | 0.005 | 0.008 |
| | DYCK | DY1 | DY2 | DY3 | DY4 | DY5 | DY6 | DY7 |
| $N_2O$, mg | 0.039 | 0.078 | 0.155 | 1.05 | 0.527 | 0.217 | – | 0.052 |
| $N_2O$-N/N, % | – | 0.021 | 0.041 | 0.28 | 0.16 | 0.06 | – | 0.015 |

## 4 Conclusion

Because of the simplicity and the adequate precision of this method, it is good and convenient to apply it to observe the $N_2O$ emission from agricultural soil, and to do simulating experiments of some factors. $N_2O$ emission modelling needs the key factors and the parameters of processes, and the simulating experiments of factors may

be used to do this work.

As to some factors tested in our experiments, native soil type and nitrogen source can apparently affect emission intensity, and some soil properties may determine the emission pattern. It is important to systematically measure emission flux in field for a long time, especially during the time of nitrogenous fertilizer addition and manure management. Furthermore, the effect of plant root must be considered with field measurement.

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(Received July 14, 1992)