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Short communication

Ammonia Volatilization in Shihwa Wetland Soils

Sang-Mo Lee, Pan-Gun Kim[1] and Hee-Myong Ro[2,3,*]

National Instrumentation Center for Environmental Management, Seoul National University, Seoul 151-921, Korea
[1]Institute of Agricultural Technology, Dongbu Hannong Chemicals, Daejeon 305-380, Korea
[2]Department of Agricultural Biotechnology, Seoul National University, Seoul 151-921, Korea
[3]Research Institute of Agriculture and Life Sciences, Seoul National University, Seoul 151-921, Korea

Introduction

Since a constructed wetland is inexpensive to build and operate (Kadlec and Knight, 1996), it has been used as an alternative wastewater treatment in certain developed countries (Yun et al, 2003). In the wetland, both organic and mineral nutrients can be eliminated by efficiently through physical (e.g. sedimentation and filtration of particle bound N), chemical (e.g. denitrification and ammonia volatilization), and biological methods (e.g. plant and microbial uptake) (Davidsson and Ståhl, 2000).

Ammonium ions, loosely bound to water molecules, predominate in water, ionized NH_4^+ increasingly converts to nonionized ammonia, which may escape from the water as a gas. Ammonia, a readily identifiable product of nitrogen mineralization, is formed continuously in the soil and water of a flooded soil. The ready release of ammonia from organic matter decomposing in the absence of oxygen and the high pH associated with anaerobic decomposition favor ammonia volatilization from flooded soils that have had large amounts of organic matter added.

The Shihwa wetland was constructed recently to improve water quality of the Shihwa lake by removing pollutants originated from the Samhwa, Banweol, and Donghwa streams. A few studies on ammonia volatilization losses in flooded soils has been investigated. In this study, therefore, to evaluate the capacity of N removal through volatilization in wetland, ammonia volatilization in sediments of the constructed saline wetland, Shihwa wetland, was investigated.

Materials and Methods

Site description The Shihwa wetland was constructed on a tideland in Ansan, Gyeonggi-Do, Korea. The area covers approximately 75 ha, consisting of Samhwa, Banweol, and Donghwa streams. The areas of the Banweol and Donghwa streams are divided into upper and lower regions. Nutrients-riched water flows from upper regions to lower regions (Korea Water Resource Corporation, 2002). Several characteristics of the sites in the wetland were summarized in Table 1.

Table 1. General characteristics of sampling sites.

Site	Area	Flow rate	HRT†
	ha	m^3 sec^{-1}	day
Samhwa (S)	6.9	0.15	1.9
Banweol upper (BU)	19.0	0.10	7.9
Banweol lower (BL)	22.6	0.20	4.7
Donghwa upper (DU)	15.3	0.10	6.4
Donghwa lower (DL)	11.3	0.20	2.4

† Hydraulic residence time.

Soil sampling and analysis The surface soils samples were collected at the top 15 cm depth from five sites (i.e., Samhwa (S), Banweol upper (BU), Banweol lower (BL), Donghwa upper (DU), and Donghwa lower (DL)) (Fig. 1). Soils from five sites were air-dried and passed with 2 mm sieve. Soil pH and electrical conductivity (EC) were determined by pH and EC meter, respectively. Total nitrogen and organic matter contents were determined by

Table 2. Properties of soil samples collected from each site.

Parameter	Site†				
	S	BU	BL	DU	DL
Texture‡	SCL	SCL	SCL	SCL	SCL
pH (1:5)	7.1	7.0	7.0	6.9	7.1
EC (1:5), dS m^{-1}	1.43	0.42	0.36	0.56	0.24
Total N, g kg^{-1}	0.33	0.39	0.58	0.28	0.36
O.M., g kg^{-1}	7.0	9.8	9.4	7.4	7.6
NH_4^+-N, mg kg^{-1}	6.5	5.9	44.0	3.0	3.7

† Same as mentioned in Table 1.
‡ USDA classification.

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*Corresponding author: Phone : +8228804645,
E-mail : hmro@snu.ac.kr

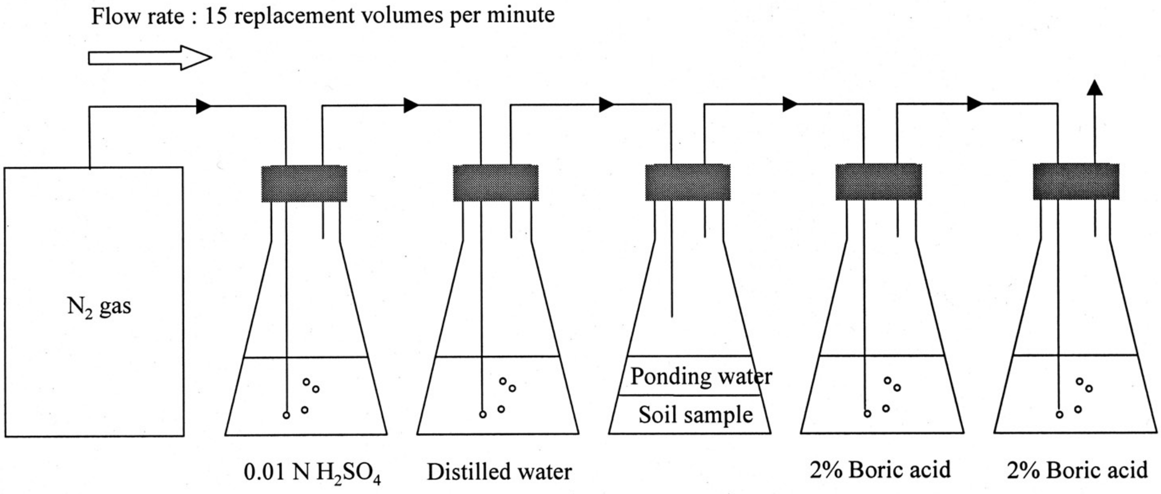

Fig. 1. Diagrammatic sketch of ammonia volatilization experiment.

Kjeldahl digestion method (Bremner, 1960) and by Walkley-Black method (Nelson and Sommers, 1982), respectively. The properties of soil samples were shown in Table 2.

Incubation study The amount of NH_3 volatilization was determined using the method suggested by Meyer et al. (1989) (Fig. 1). Twenty-five grams of soil sample from each site was placed in a 100 mL flask and added with 25 mL of distilled water. After capping with the porous foil, all samples were placed at 25℃ for 1 week. After the pre-incubation, the samples were mixed with 5 mL of 400 mg N L^{-1} $(NH_4)_2SO_4$ solution, and then capped with rubber stopper having glass tubes and 3-way cocks to control the gas flow. The samples were incubated at 25℃ with the cocks locked. The flow rate of incoming N_2 gas was 15 replacement volumes per minute. Ammonia in the incoming N_2 gas was removed using a 0.01N H_2SO_4 trap. The N_2 gas then flowed through distilled water trap to prevent acid carry-over to the soil sample. Ammonia in the N_2 gas flowing from the sample was trapped by a series of two traps containing 2% boric acid with bromocresol green-methyl red indicator. The volatilized NH_3 was collected for 2 min in every 6 hours and determined by titration with 0.005N H_2SO_4.

Results and Discussion

Patterns of NH_3 volatilization were different among soils, but NH_3 volatilization was not observed after 66 hours of incubation for all soils (Fig. 2). The losses of nitrogen by ammonia volatilization were greatest in Banweol stream and larger in upper region than in lower region. During 66 hours of incubation, the amounts of NH3 volatilization were 1.02 for S, 2.67 for BU, 0.88 for BL, 1.83 for DU, and 0.22 mg N kg^{-1} for DL. The percentages of N volatilized to added N through incubation were 1.2, 3.1, 0.7, 2.2, and 0.3% for S, BU, BL, DU, and DL, respectively (Table 3). Vlek and

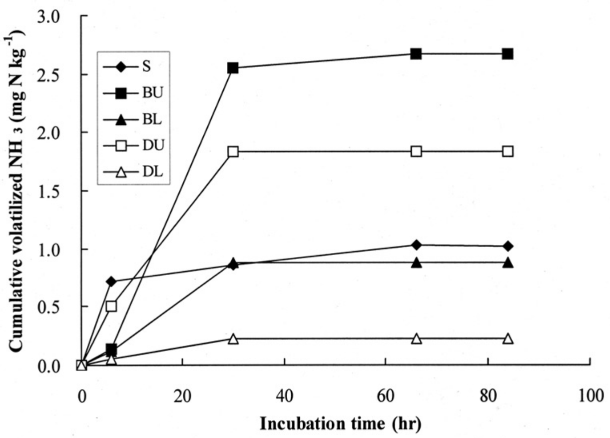

Fig. 2. Changes in nitrogen loss by ammonia volatilization during incubation (S: Samhwa, BU: Banweol upper, BL: Banweol lower, DU: Donghwa upper, DL: Donghwa lower).

Table 3. Amounts and percentages of NH_3 volatilization during 66 hours incubation.

Parameter	Site[†]				
	S	BU	BL	DU	DL
Amounts of NH_3 volatilization (mg N kg^{-1})	1.02	2.67	0.88	1.83	0.22
Percentages of N volatilized to added N (%)	1.2	3.1	0.7	2.2	0.3

[†] Same as mentioned in Table 1.

Stumpe (1978) said that NH_3 volatilization was a rapid process and nitrogen losses were expected to be severe during the first few days. In flooded soils, nitrogen loss by volatilization reported in the literature was affected by the applied nitrogen source, generally ranged from approximately 3 to 10% for $(NH_4)_2SO_4$ and from 5 to as high as 50% for urea (MacRae and Ancajas, 1970; Mikkelsen et al., 1978). Therefore, the low amount of volatilized N could be attributed to the application of $(NH_4)_2SO_4$. In actual wetland, however, the nitrogen losses through NH_3 volatilization can increase because litter on the soil surface can lead to significant NH_3 volatilization losses due to the increase in pH and NH_4^+ concentrations caused by a high rate of N mineralization (Cabrera et al., 1993). Because the reeds grow in the Shihwa wetland, the actual nitogen loss by NH_3 volatilization may be larger than that determined in this incubation study.

Ammonia volatilization loss may occur from floodwater on a soil moderately to slightly acid, although losses are usually highest on alkaline soils. The photosynthetic and respiratory activity of submerged aquatic biota, their biomass, and factors affecting their growth play a prominent role in regulating water pH by the reaction. When water pH rises above 7.4, ammonia volatilization losses may be appreciable. High pH induced by an active biota and ramifications of dissolution of carbon dioxide in the floodwater pertaining to an ammonium-nitrogen source are apparent (Mikkelsen et al., 1978). Salinity has a significant effect on nitrogen dynamics (Rysgaard et al., 1999). Electrical conductivity of soils in the Shihwa wetland is high (Table 2) because this wetland is constructed on a tideland. Therefore, the high salt concentration might affect the microbial activity in the soils. The volatilization of ammonia from a soil is a function of the various properties of the soil system involved, including moisture content, soil pH, cation exchange capacity (CEC), exchangeable cations, texture, temperature, and atmospheric conditions above the soil (Chao and Kroontje, 1964; Mikkelsen and De Datta, 1979).

Ammonia volatilization losses in flooded soils range from negligible to almost 60% of applied nitrogen. The differences in these values are due to many factors, but probably mostly to due to differences in the measurement techniques. Most of those studies were made in the laboratory where conditions may differ considerably from those in the field. Among the various techniques used or suggested, estimating volatilization by micrometeorological considerations is probably the most unbiased, but difficult to set up and use accurately.

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