TEMPORAL VARIATION OF STABLE ISOTOPIC VALUES FOR DISSOLVED NITROGEN COMPOUNDS IN PADDY WATER ENVIRONMENT

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Abstract:

Vietnam is the second-largest rice exporter worldwide and recently, amount of applied fertilizer is increasing rapidly. Overused amount of chemical fertilizers in the paddy fields is strongly contributes to the pollution of water bodies. This study aimed at understanding the temporal variation of nitrogen stable isotope values based on the observed data in a selected paddy field in Vietnam, which provided basic and useful clue for tracing sources and identifying processes of nitrogen. By applying isotope technique as an environmental tracer, this study presented the temporal variation of $\delta^{15}N$ values of ammonium and nitrate in ponded water and irrigation water in a paddy in Vietnam. The results showed that $\delta^{15}N$ values of ammonium and nitrate in ponded water drastically varied from -3.6‰ to 17.2‰ and from -18.2‰ to 8.5‰, respectively. In this selected paddy field, chemical fertilizers was not only the major source for nitrogen, but also irrigation water. Nitrification and denitrification processes were presumably observed.

Keywords: *Nitrogen source, Nitrogen processes, Environmental tracer*

1. INTRODUCTION

Vietnam is the second-largest (after Thailand) exporter worldwide and the world's seventh-largest consumer of rice. Forty percent of the agricultural land in Vietnam is paddy field. Recently, in Vietnam, amount of applied fertilizer is increasing rapidly, which resulted in the increase of rice yield [2]. Overused amount of chemical fertilizers in the paddy fields is strongly contributes to the pollution of water bodies [11]. For example, the loss of total nitrogen from paddy field due-to runoff accounts for approximately 66% of the total applied chemical fertilizer [3], and the nitrogen loss is related to nitrogen application rates in Taihu Lake [10]. In Vietnam, nitrogen runoff from paddy fields is also an alarming pollution source [4,13]. Identification of nitrogen sources and flows is needed for controlling the pollutions from paddy fields. However, nitrogen cycle in the paddy is very complex due to containing multiple sources and biochemical processes.

Nitrogen isotope analysis is a well-known tool for tracing the sources, and identifying physicochemical and biological reactions [14]. Dissolved nitrogen is the main form of nitrogen as 50 to 80% of total nitrogen in ponded water [8] and nitrate accounted for 48–92% of total nitrogen losses in runoff water [12]. Besides, isotope value of nitrate was observed in drainage and percolation water at outlet of Japanese paddy fields [9]. The authors stated that irrigation water was one of the nitrogen sources in drainage water during the irrigation period and then, implied that nitrate in percolation water affected by biological reactions. Nitrogen isotope value changes during a cropping season because of the transportation and/or transformation processes. The nitrogen processes were affected by regional characteristics such as hydro-meteorological conditions and agricultural practices [7].

This study aimed at understanding the temporal variation of nitrogen stable isotope values of ponded water based on the observed data in a selected paddy field in Hai Duong province, Vietnam, which provided basic and useful clue for tracing sources and identifying processes of nitrogen.

2. THE MAIN PART OF REPORT

2.1. Research subjects and methodology

The study area locates at 20.8°N and 106.8°E in Hai Duong Province, Vietnam, it includes an experimental paddy field (2.2ha) managed by four farmers as Figure 1.

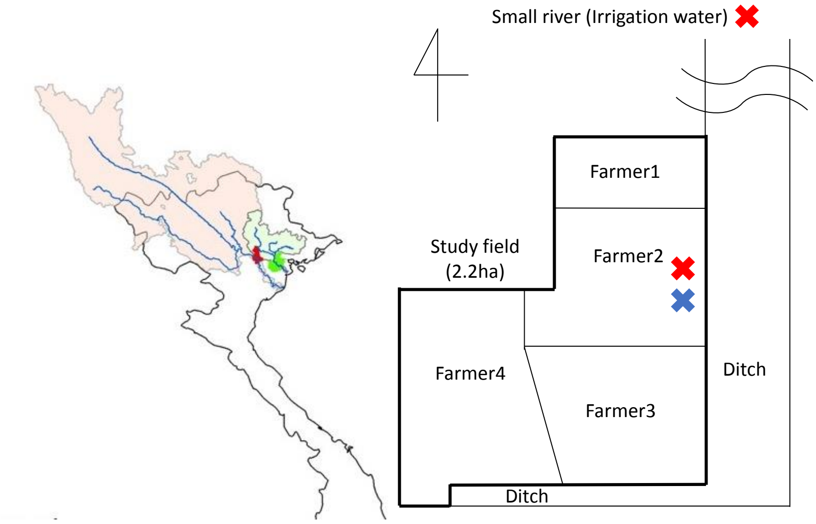


Figure 1. Study site location and sketch map of the four paddy fields. Red cross marks are sampling points for irrigation water and ponded water, and blue one is place of an installed water level sensor.

Irrigation water and drainage water flowed from/to small river to/from paddy fields through the same ditch. Agricultural practice, types and amounts of fertilizers, among the four farmers were sometimes different. Information of agricultural practice of Farmer2 was collected by interviewing the farmer in the field survey.

Monthly water sampling was conducted. Particularly, daily observation was taken place after 1st irrigation and 1st fertilization during spring season, from January to June 2016.In this study, only irrigation water and ponded water were focused, and drainage water was assumed as similar to ponded water in this study. The acidity and electric conductivity of ponded water and irrigation water, and the water level of ponded water were measured on site. The ponded water, irrigation water and fertilizer samples were collected in the field survey. After sampling, the concentrations of ammonium nitrogen (NH_4–N) and nitrate nitrogen (NO_3–N) in the water samples were measured by using ion chromatography mass spectrometer in the environmental laboratory at University of Yamanashi, Japan. The stable isotope values of NH_4-N ($\delta^{15}N$-NH_4) and NO_3-N ($\delta^{15}N$-NO_3) in the water samples were measured by diffusion method [1] and microbial denitrified method [9], respectively, when the samples determined as over 1.0mg/L of NH_4-N and 0.05mg/L NO_3-N. $\delta^{15}N$ in fertilizer samples was also measured by using elemental analyzer mass spectrometer [9].

2.2. Results

Agricultural practice

Schedule of water irrigation, water drainage, paddling and fertilization of Farmer2 paddy field was shown in Table 1.

Table 1. Agricultural practices of the experimental field (by Farmer2)

Month	Date	Practices	Fertilizer type, amount of nitrogen
Jan.	20	Irrigation	
	28	Paddling	
Feb.	7	Paddling	
	10	Drainage	
	11	Fertilization and transplanting	NPK chemical fertilizer, 18.8kgN/ha
Mar.	1	Irrigation	
	2	Drainage	
	27	Irrigation	
	29	Fertilization	Urea, 65kgN/ha
May	3	Fertilization	Urea, 32.2kgN/ha
	5	Fertilization and irrigation	Urea, 32.2kgN/ha
Jun.	10	Harvesting	

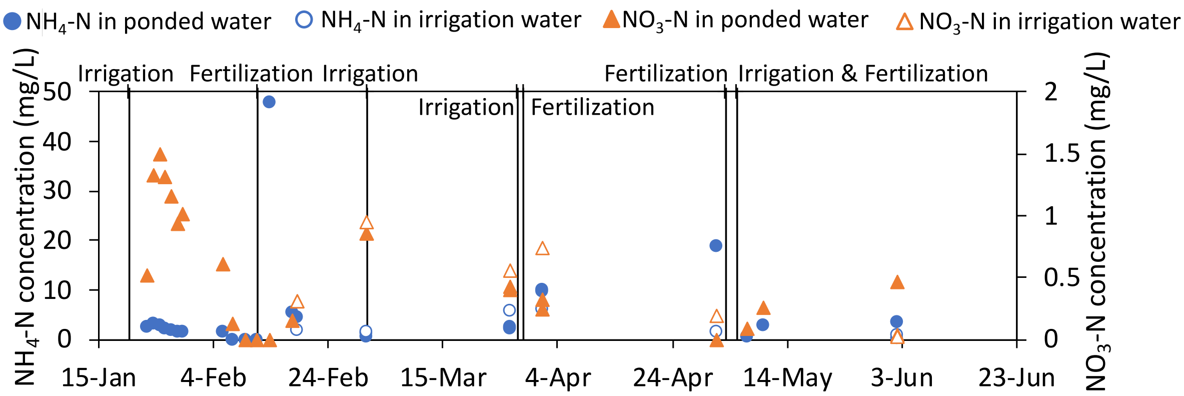
Nitrogen concentration in irrigation and ponded water

As can be seen in Figure 2, concentration of NO_3-N in irrigation water (river water) and ponded water in the paddy field were similar, and ranging from 0.02 to 0.95 mg/L.NH_4-N concentration in ponded water had highest value at the fertilization period (approximately 10-50 mg/L), but the one in irrigation water was much smaller, detected from 1.0 mg/L to 6.0 mg/L.

Nitrate-nitrogen isotope values of chemical fertilizer, irrigation and ponded water

The $\delta^{15}N$ value of fertilizer was -4.4‰ and -3.8‰ as NPK and Urea, respectively. Figure 2 also showed that range of $\delta^{15}N$ value for ammonium and nitrate in ponded water was from -3.6‰ to 17.2‰ and from -18.2‰ to 8.5‰, respectively. The range of $\delta^{15}N$-NH_4 and $\delta^{15}N$-NO_3 in irrigation water indicated from 7.2‰ to 13.1‰ and from -5.8‰ to 7.5‰, respectively.

(a)



(b)

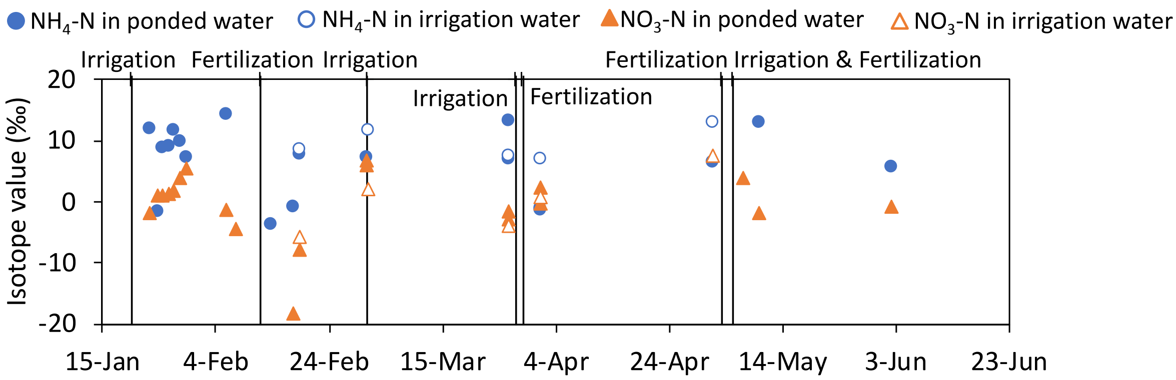


Figure 2. Temporal changes of concentration (a) and isotope values (b) of ammonium and nitrate-nitrogen in ponded and irrigation water during spring season (January to June 2016)

2.3. Discussion

Figure 2 revealed that value of $\delta^{15}N$-NO_3 in ponded water monotonically increased with decreasing concentration of NO_3-N in ponded water before the first fertilization. This could be explained by the possible denitrification, because no added nitrogen during this period.

After fertilization, both ammonium and nitrate-nitrogen isotope values in ponded water approached to the values of fertilizer. If there is a large amount of ammonium applied

(Table 1) in the paddy, nitrification is stimulated, and a large $\delta^{15}N-NH_4$ fractionation would likely be appeared [6]. In the 2^{nd} day after fertilization, no nitrate was detected in the ponded water sample, there was only ammonium, and $\delta^{15}N-NH_4$ was -3.62‰. After a week of fertilization, nitrate could be detected, and $\delta^{15}N-NO_3$ was -7.86‰.

Feigin [5] indicated that $\delta^{15}N-NO_3$ in the agricultural soil decreased to below -10‰ after application of anhydrous ammonia as a fertilizer. Hence, when $\delta^{15}N-NO_3$ value was the lowest one (-18.23‰), NH_4-N of fertilizer contained plenty amount of light nitrogen and was oxidized to NO_3-N with the lighter NO_3-N isotope values.

On the other hand, an input of nitrogen contained in the irrigation water was detected because the $\delta^{15}N$ values of ponded water were similar as $\delta^{15}N$ values of irrigation water when irrigation water came to the studied field.

3. CONCLUSION

By applying isotope technique as an environmental tracer, this study presented the temporal variation of $\delta^{15}N$ values of ammonium and nitrate in ponded water and irrigation water in a paddy in Vietnam. The results showed that $\delta^{15}N$ values of ammonium and nitrate in ponded water drastically varied from -3.6‰ to 17.2‰ and from -18.2‰ to 8.5‰, respectively. Fertilizer and irrigation water were identified as the major sources for nitrogen flow in the paddy field. Nitrification and denitrification process in the paddy were presumably observed.

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SỰ THAY ĐỔI GIÁ TRỊ ĐỒNG VỊ BỀN CỦA CÁC HỢP CHẤT NI TƠ HOÀ TAN TRONG CÁC MẪU NƯỚC RUỘNG

Việt Nam là quốc gia xuất khẩu gạo lớn thứ hai trên thế giới, và hiện nay lượng phân bón sử dụng cũng đang gia tăng đáng kể. Thói quen lạm dụng phân bón hoá học trong canh tác lúa đang khiến nguồn nước bị ô nhiễm nghiêm trọng. Nghiên cứu này tập trung vào đánh giá sự thay đổi giá trị đồng vị bền của Nitơ theo thời gian, dựa trên các số liệu quan trắc trên một mảnh ruộng tại Việt Nam. Số liệu thu được sẽ là những đầu mối cơ bản và hữu ích khi truy tìm nguồn gốc và xác định các quá trình chuyển hoá của nitơ. Thông qua ứng dụng phương pháp phân tích đồng vị, nghiên cứu này đã chỉ ra sự thay đổi theo thời gian của các giá trị đồng vị δ15N của amoni và nitrat trong các mẫu nước ruộng và nước tưới. Kết quả cho thấy giá trị đồng vị δ15N trong nước ruộng của amoni nằm trong khoảng từ -3.6‰ tới 17.2‰ và của nitrat từ -18.2‰ tới 8.5‰. Trong nghiên cứu này, phân bón và nguồn nước tưới được xác định là nguồn cung cấp nitơ chính cho mảnh ruộng. Quá trình nitrat hoá và quá trình khử nitrat cũng đồng thời được quan sát trong

nghiên cứu này.

Từ khoá: *Nguồn nitơ, quá trình chuyển hoá nitơ, chất đánh dấu dùng trong môi trường*