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A Preliminary Monitoring of the NO_3–N Concentration in the Surface Water in the Paddy–Cultivated Area of the Central Red River Delta, Viet Nam

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The NO_3–N concentration and pH in the surface water in the paddy–cultivated areas of the central Red River Delta, Viet Nam were monitored at 24 sites of 5 districts in March 2002 after the spring rice was transplanted. In the areas, fertilizer N of 100–150 kg/ha has been conventionally applied in each of the three cultivations in a year. The measured NO_3–N concentration was in the range of 0.11–3.03 mg/L and was below the permissible level of 11.3 mg/L for drinking water, but some samples exceeded the standard for pH (8.5). The districts could be separated from one another according to the combination of the NO_3–N and pH levels, but this separation was not due to the comparative land elevation. Relevant factors such as the soil pH, the amount and time of N application in every cultivation, and the NH_4 level are to be monitored in the future study. The NO_3–N concentration was negatively correlated with the pH level in some districts, possibly impacted by nitrification. No remarkable difference was observed in both the NO_3–N and pH levels between the ponding water of the paddy field and the water of the neighboring irrigation/drainage canal.

INTRODUCTION

In recent decades, the use of chemical fertilizers in Vietnamese cultivated land has rapidly increased. The amount of fertilizer N applied in 1992 in Vietnam increased by around 5 times as compared to the 1971 level; and the domestic demand (million tons) of fertilizer urea is expected to increase from 1.2 in 2000 to 2.6 in 2010 (Nguyen *et al.*, 1999b).

In the Red River Delta (RRD), rice is cultivated in the spring and also in the summer–autumn seasons, while the third crop (maize, sweet potato or vegetables) is cultivated in the winter. Fertilizer N is applied intensively during each rice cultivation in the RRD. For example, N of 122 and 96 kg/ha is applied for the spring and summer–autumn rice cultivations, respectively; however, these doses have been reported to be an over–application compared to the optimal level (Nguyen *et al.*, 1999b). Application of a larger doze of N to the field can cause groundwater pollution due to the leaching of

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NO_3–N that is produced in the surface water by the nitrification of NH_4. The occurrence of NO_3 pollution in groundwater has been reported in many countries. For instance, Zhang *et al.* (1996) showed that the NO_3–N concentration in groundwater exceeded 11.3 mg/L of the WHO standard at more than half of the surveyed locations in farmyards in China. Agrawal *et al.* (1999) observed the NO_3–N concentration as high as 406 mg/L in India in the groundwater where the consumption of N was high. According to the result of Madison and Brunett (1984), a NO_3–N concentration over 3 mg/L indicates the contamination from fertilizer or some other sources.

Groundwater is used for drinking in the central RRD (Hanoi province and adjacent areas). It is necessary to prevent the groundwater from the above-mentioned NO_3 pollution. Over-application of fertilizer N can also lead to eutrophication of the surface water and push up pesticide use, but there has been no public research on its effects on environmental pollution and the farmers' health in the areas (Nguyen *et al.*, 1999b). In the areas of the central RRD where fertilizer N has been intensively applied, the status of NO_3 in the surface water must be urgently clarified. In the present study, therefore, the NO_3–N concentration in the surface water of both the paddy field and neighboring irrigation/drainage canal was monitored along with the pH. The pH value is impacted by the transformation from NH_4 to NO_3, which will be discussed later. This paper aims to assess the current NO_3–N and pH levels in the surface water at the spring rice cultivation season, their local characteristics, the factors responsible for them, and the items necessary to be solved in the future study.

MATERIALS AND METHODS

Sampling sites and characteristics

The NO_3–N concentration and pH were monitored at 24 sites selected from 5 districts in and around Ha Noi City (Fig. 1). 2 to 7 monitoring sites were located in each district, including both the paddy field and neighboring irrigation/drainage canal.

As for the elevation of the locations, Me Linh 1 and Me Linh 2, belonging to different communes, and Soc Son are located at a comparatively high elevation of 8–11m, while Gia Lam is at a medium elevation of 3.5–5 m and Tien Du at a low elevation of 2–2.5 m. The irrigation network covers all the paddy-field area by conducting water from the Red River system. The rainfall levels of May–October (rainy season) and November– April (dry season) are about 1,500 mm and 350 mm, respectively, and the mean annual air temperature is 24 °C with the monthly average value changing from 17 °C in January to 29 °C in June at Ha Noi (as an average of 1994–96) (Nguyen *et al.*, 1999a). The soils are alluvial soils (VSSS–NIAP, 1996).

Monitoring of NO_3–N and pH

Monitoring was done in March 2002, at the end of dry season after the spring rice was transplanted. The fertilizer application was completed before and after transplanting. In monitoring, a water sample of 100 mL was taken from the surface ($<$10 cm deep) of the water in the paddy field and neighboring canal. The NO_3 concentration of the sampled water was measured by a spectrophotometer (UV–mini 1240, Shimadzu Co., Ltd.) and the pH level was by a pH meter (CyberScan 510, Eutech Instruments, Pte Ltd.) in the labo-

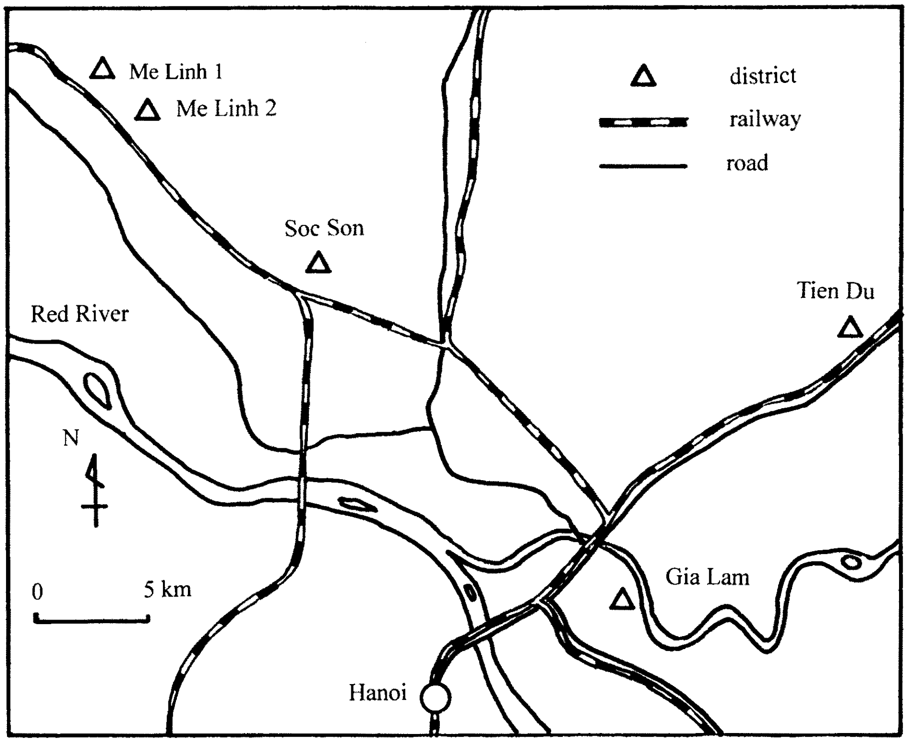

Fig. 1. Location of the districts for monitoring

ratory after bringing back it there. The NO_3 concentration (mg/L) was converted to a NO_3–N concentration (mg/L) by multiplying with a coefficient of 0.226 that is a molecular weight ratio of N to NO_3. For data analysis, the regression analysis and t–test were carried out to examine the correlation between the NO_3–N and pH levels and the mean difference between the districts.

RESULTS AND DISCUSSION

Amount of fertilizer N applied for spring rice cultivation

Table 1 shows the time of the spring rice transplanting, and the kind and amount of fertilizers applied before and after transplanting in the districts (Nguyen, 2002). As shown in the table, urea was applied at 3 different times with a spell of more than 35 days. Urea contains N of 46% of its weight. Therefore, 280–330 kg/ha of urea is equal to 130–150 kg/ha of N. This amount of N is considered a high level, since this is in the upper limit of N of 100–150 kg/ha, which is required for the full attainment of the yield potential of the high–yielding rice varieties (Yamada, 1975). Only 40–50 kg/ha of N is required for local varieties (Yamada, 1975), but most of the rice varieties cultivated in the RRD today are high–yielding ones (Nguyen *et al.*,1999b).

Table 1. Time of transplanting, and the kind and amount of fertilizers applied for the spring rice cultivation in the study districts (expressed as an averaged figure) (Nguyen, 2002).

Time of transplanting	February
Kind of fertilizers and their total amount applied (per ha)	urea: 280–330 kg calcium superphosphate: 420–470 kg muriate of potash: 80–140 kg
% amount of fertilizer applied with its time	1st: 50% of each fertilizer, before transplanting 2nd & 3rd: 30% & 20% of each fertilizer, 20 & 35 days after transplanting, respectively

NO_3–N and pH levels

Figure 2 shows the NO_3–N concentration and pH measured at each monitoring site. Table 2 gives the mean and range of the values for each district. The NO_3–N concentration was in a low level of 0.11– 3.03 mg/L. Only one site in Me Linh 1 showed a concentration over 3.0 mg/L, probably indicating contamination from N application. All values were below 10 mg/L with the satisfaction of the Vietnamese water standard for drinking use and were in the permissible level for irrigation use (<15 mg/L of NO_3–N is the standard for uses other than drinking).

The pH was in a range of 7.10–8.93. The pH values satisfied the standard for the uses other (5.5–9.0) than drinking use, but two cases in Me Linh 1 exceeded 8.5 and did not

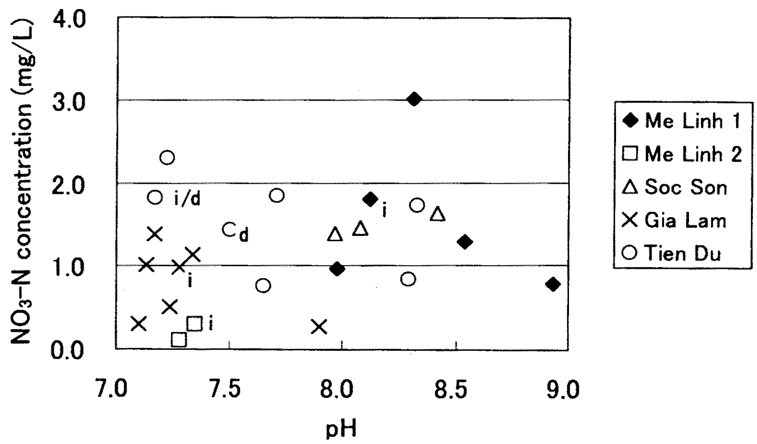

Fig. 2. Relationship between the NO_3–N concentration and pH between in the districts (Plots marked with i, d or i/d shows the water for irrigation, drainage, or both use, respectively, and others show the ponding water of the paddy field).

Table 2. Mean and range of the NO_3–N concentration and pH measured in the study districts.

District	No. of sampling	NO_3–N concentration (mg/L)		pH	
		Mean	Range	Mean	Range
Me Linh 1	5	1.58	0.79–3.03	8.38	7.98–8.93
Me Linh 2	2	0.21	0.11–0.31	7.32	7.28–7.35
Soc Son	3	1.51	1.40–1.65	8.16	7.97–8.42
Gia Lam	7	0.80	0.27–1.39	7.31	7.10–7.90
Tien Du	7	1.54	0.77–2.31	7.70	7.17–8.33
Total	24	1.22	0.11–3.03	7.75	7.10–8.93

satisfy the standard for drinking use of pH 6.6–8.5. A considerable number of the water samples, which showed the pH over 8.0, is not preferable for crop growth because N availability to crop becomes gradually lower in that pH range (Plaster, 1997).

The NO_3–N concentration of ponding water of the paddy field was usually higher than that of the neighboring irrigation canal, impacted by direct N application to the paddy field. However, NO_3–N concentrations of some of the ponding water were lower than that of the irrigation canal water in Me Linh 1, Me Linh 2, Gia Lam, and Tien Du districts in Fig. 2. On the other hand, the NO_3–N concentration of drainage canal water was neither the smallest nor the largest among the water samples in the Tien Du district. These trends show that there is no remarkable difference between the ponding water and irrigation/drainage canal water. One possible reason for this trend is due to the occurrence of a considerable amount of rainfall in March, though it is in the dry season. The monthly rainfall of March in Ha Noi was reported to be 108 mm as an average of 1994–96 (Nguyen *et al.*, 1999a). It may minimize the difference of NO_3–N levels between the paddy field and neighboring irrigation/drainage canal from the flooding of the canal to the paddy field or the paddy field to the canal.

Local characteristics of NO_3–N and pH levels

Based on the mean of NO_3–N and pH levels in Table 2, the 5 districts were attempted to be separated from one another by the criteria that the NO_3–N is low ($\leqq$0.80) or high (>1.5) and that the pH is low ($\leqq$7.70) or high (>8.16). According to this separation, Me Linh 1 was high in both NO_3–N and pH, Tien Du was high in NO_3–N but low in pH, and Gia Lam was low in both NO_3–N and pH.

Using the NO_3–N and pH values of Me Linh 1, Gia Lam and Tien Du districts having 5 or more sampling numbers, a t–test (non–paired) was carried out to identify whether there is a statistical difference in the mean values of NO_3–N and pH between these districts or not. The results are shown in Table 3. Gia Lam is differentiated significantly from Tien Du, but Me Linh 1 was not from Tien Du in the NO_3–N level. As for the pH level, on the other hand, Me Linh 1 was significantly differentiated from Gia Lam and Tien Du, but there was no significant difference between Gia Lam and Tien Du.

Although Me Lin 1 was located at a comparatively high elevation, different from Tien Du, the two districts were found to be in the statistically same group in the NO_3–N level.

The same trend was recognized between Gia Lam and Tien Du districts in the pH level. Therefore, the difference in the relative elevation of the districts hardly has any impact on the grouping. The difference in the NO_3–N concentration may be affected by some differences in the amount of fertilizer N applied among the communes belonging to the districts (Nguyen, 2002). A large difference of pH of the water between the districts may be reflected from the difference in the soil pH of individual district.

The NO_3–N concentration showed a decreasing tendency as pH increases for Me Linh 1, Gia Lam, and Tien Du districts, as shown in Fig. 2. The correlation coefficients between the NO_3–N concentration and pH are given for the respective districts in Table 4. There was a significant and negative correlation between them for both Gia Lam and Tien Du districts, but no significant difference was observed for Me Linh 1. A possible reason for the negative correlation is that as the NO_3 concentration increases with nitrification, number of hydrogen ions generated in the water also increases, lowering the pH value.

Table 3. T–test results (t value) on the mean difference of NO_3–N and pH between Me Linh 1, Gia Lam and Tien Du districts.

Item	Mean difference between the districts		
	Me Linh 1 & Gia Lam	Me Linh 1 & Tien Du	Gia Lam & Tien Du
NO_3–N	2.02	0.09	2.77*
pH	5.73**	2.69*	1.90

* and **: significant at 5% and 1% levels, respectively.

Table 4. Correlation coefficient between NO_3–N and pH for Me Linh 1, Gia Lam and Tien Du districts.

District	Correlation coefficient
Me Linh 1	–0.29
Gia Lam	–0.49**
Tien Du	–0.47**

**: significant at 1% level

Items to be solved in future monitoring

In addition to the spring rice cultivation mentioned previously, 100–130 kg/ha of N was applied two more times in the summer–autumn rice and the winter crop cultivations (Nguyen, 2002). Thus, N applied in a year amounts to quite a high level of 330–410 kg/ha. The important matter in the future to study, therefore, is to monitor the NO_3–N concentration during each of these cultivation periods.

The monitoring of NH_4, which remains in water after volatilization and is transformed to NO_3 hereafter, is also necessary. A volatilizing loss has some variation. For example in flooded rice, NH_3 volatilization can account for 20% to >80% of the total N loss from fertilizer sources (Simpson *et al.*, 1984; De Datta *et al.*, 1989; Freney *et al.*, 1990; Mosier *et al.*, 1989; Zhu 1992).

It is generally considered that fertilizer N changes rapidly to NH_4 and the conversion from NH_4 to NO_3 also occurs rapidly and completely within about a month of the application. The amount and time of N application are perhaps different among the communes even though it is not large. Since these differences will lead to the special and temporal differences in the NO_3 concentration in the surface water, these items should be investigated.

It is important to know eventually how significantly the groundwater is polluted by NO_3–N coming down from the surface water. In that, the monitoring of NO_3–N in the groundwater would be necessary.

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