Research article

Evaluation of Nitrate Pollution in River Water at Agricultural Watershed

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Abstract Nitrate pollution of river water and groundwater in agricultural areas is a serious problem in many countries, and many people are unconcerned with, or ignorant of, the problem. In recent years, environmental education on the relationship between agriculture and water has been provided to the general public in many areas in Japan. In this report, the nitrate nitrogen (NO_3-N) concentration in river water at the normal water level was evaluated in two agricultural areas in Eastern Hokkaido. The concentration results obtained using an official analytical method were compared with those obtained using simplified methods. By focusing on the differences in the results of the measurement methods, the applicability of simplified methods for NO_3-N concentration to water environmental education was examined. The investigation was carried out in two agricultural areas in Eastern Hokkaido in late August 2006. NO_3-N concentration was measured using an official method and two simplified methods. The comparison between the two results showed the NO_3-N concentration values measured by using the simplified methods to be 64% to 72% of those measured by using the official analytical method. The values obtained from the simplified methods were slight underestimates. However, there was a significant positive correlation between the two sets of values. Even though some consideration is necessary regarding the accuracy of the simplified methods, it can be said that the use of such methods in water environmental education is sufficiently effective. It is also expected that by actively introducing experience-based environmental education in which river water quality is measured by learners using simplified methods, it will be possible to make environmental education truly useful in the conservation of desirable watersheds in which sustainable agricultural and forestry are developed and desirable water quality is maintained.

Keywords NO_3-N concentration, simplified method, official analytical method, environmental education

INTRODUCTION

It is well known that nitrate pollution of river water and groundwater in agricultural areas has grown to become a serious problem in many countries of the world. Another fact is that there are

many people who are unconcerned with, or ignorant of, the problems on nitrate pollution of river water. In considering the problem of agriculture and water in terms of environmental education and learning experiences for basic knowledge, it is necessary to evaluate nitrate nitrogen (NO_3-N) concentration in river water in a watershed with agriculture and forestry.

In Japan, there are two major water quality standards that use nitrogen as indices. "The Environmental Standards Concerning the Protection of the Human Health" specifies 10 mg/L as the highest acceptable combined concentration of NO_3-N and nitrite nitrogen (NO_2-N). "The Environmental Standards Concerning the Conservation of the Living Environment" specifies 1 mg/L as the highest acceptable concentration of total nitrogen (T-N).

The authors have been investigating the concentration of NO_3-N in river water at the normal water level for many years in two agricultural areas with different land-use characteristics in Eastern Hokkaido, which possesses valuable regional characteristics as a part of the region that is influenced by Asian monsoons (Yamazaki et al, 2013; Muneoka et al, 2013; Yamazaki et al, 2014). It is anticipated that investigations that lead to the development of measures for controlling the amount of nitrate flowing into river water in watersheds in agricultural and forestry areas will progress by using the basic data accumulated in such activities.

In recent years, university faculties have been providing environmental education to the general public as outreach activities for local communities. One theme is the problem of agriculture and water (Muneoka et al, 2007; Muneoka et al, 2012).

When researchers and engineers measure the NO_3-N concentration in river water for their investigations and studies, they generally follow official analytical methods, such as the Japan Industrial Standards (JIS). Such measurements involve burdens such as time and expense for obtaining and maintaining facilities and equipment for measurement. Training to foster technical skills that guarantee the accuracy of measured values is also indispensable.

Currently, a simplified method which makes use of inexpensive and easy-to-use water test kits is widely available in Japan. These make it possible for lay citizens to perform environmental surveys and for educators to use them in environmental education for children, who will be the main players in the environmental conservation activities of the future and in lifelong learning programs for adults. Few studies have tested the accuracy and reliability of these simplified methods.

This report discusses the evaluation of nitrate pollution in river water in two areas with different agricultural land uses in Eastern Hokkaido, based on the perspective of environmental education. The NO_3-N concentration in river water at the normal water level analyzed using the official analytical method and that measured using the simplified methods were compared. Examination was done on the applicability of simplified methods in water environmental education, focusing on the difference between the two types of measurement methods.

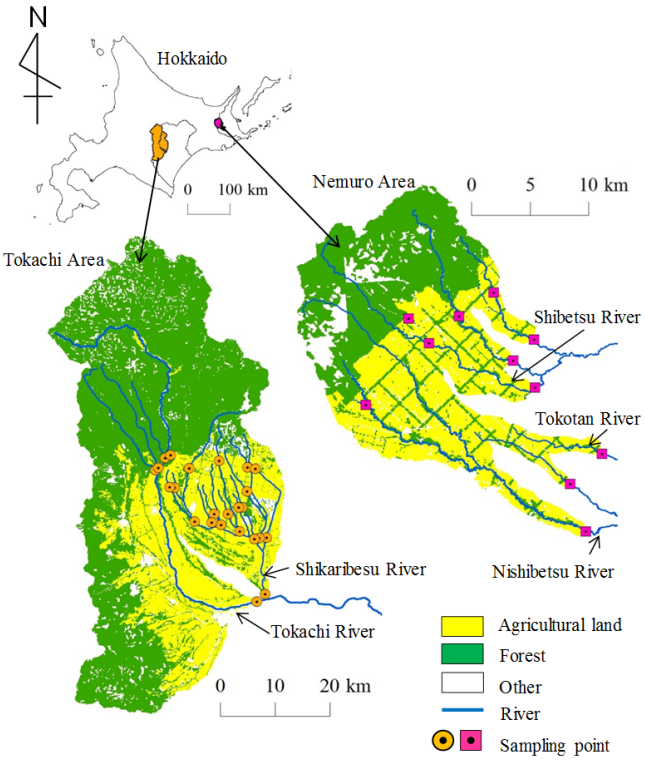
METHODOLOGY

The two investigated areas are outlined in Fig. 1. The Tokachi area, which has 24 watersheds (No. 1 to 24), is in the northwestern part of the area under the jurisdiction of the Tokachi General Subprefectural Bureau and is an area with upland and dairy farming. The Nemuro area, which has 11 watersheds (A to K) located in the western part of the jurisdiction of Nemuro Subprefectural Bureau, is an area mainly of dairy farming.

For the years 1981 to 2010, the annual mean air temperature and the yearly precipitation were 5.9 ˚C and 840.7 mm at Komaba in the Tokachi area, and 5.4 ˚C and 1158.0 mm at Nakashibetsu in the vicinity of the Nemuro area. Both areas have a relatively cold climate with less rainfall than other agricultural areas in Japan.

The proportion of land use were determined in the two watersheds, and the investigation of the river water quality was conducted at the normal water level at 35 sampling points in the two investigated areas in late August 2006. Later, NO_3-N concentration was measured in the laboratory, using the above-described official analytical method and two simplified methods. The details of the compared methods are shown in Table 1.

One simplified method for measuring NO_3-N is Pack Test, which use is extremely easy. First, the sampled water is put in a plastic tube that contains a reagent, and it is shaken several times to mix it well. After 3 minutes, the color of the contents of the plastic tube is compared with the color in the test kit chart, to determine which color in the chart is closest to the sample color. The closest color is the NO_3-N value for the sample. When the sample color is in between two colors in the chart, the value between the two colors is read. In this way, measurers can visually obtain the NO_3-N value at the range from 0.23 mg/L to 10 mg/L.



Sampling Point	River name	Bridge name	Area (km^2)	Land use (%)	
				Agricultural land	Forest
Tokachi area					
1	Tokachi	Oojika	632	1	94
2	Penkenai	Pennai	23	0	98
3	Penkenikorbetsu	Penkenikorobetsu	48	2	96
4	Penkenikoro	Minamiiwamatsu	72	2	97
5	Tokachi	Nakajima	1798	21	70
6	Shikaribetsu	Urimaku	217	4	91
7	Sikanosawa	Kikuchi	5	83	13
8	Kamihoronai	Kamihoronai	3	88	12
9	Shikaribetsu	Momiji	256	13	81
10	Minami1sen	Nakashikakann2gou	13	72	17
11	Iketo	Minamisawa	9	95	2
12	Pankebibaushi	Kousui	27	90	7
13	Urimaku	(no bridge)	9	13	66
14	Poronai	(no bridge)	3	90	7
15	Urimaku	Mutsu	49	58	32
16	Penkeutorei	Honnmaki	3	88	11
17	Pankeutorei	(no name)	5	93	6
18	Pankeutorei	Komadome	17	65	25
19	Penkechin	Okuyama	26	22	49
20	Ponchin	Kamimaki	13	75	18
21	Penkechin	Isami	63	46	33
22	Pankechin	Sinnei	10	52	32
23	Pankechin	Taneuma	72	72	15
24	Shikaribetu	Kunimi	667	48	45
Nemuro area					
A	Kanjiushi	Yourouushi	11	4	71
B	Keneka	Minori	41	7	81
C	Keneka	Hakuyou	82	32	57
D	Shibetsu	Nagori	54	3	91
E	Shibetsu	Kamisibetu	82	22	72
F	Masu	Masukawa	10	32	64
G	Masu	Kenebetsu	28	49	46
H	Tokotan	Houtoku	12	81	14
I	Nishibetsu	Kousai	19	10	60
J	Nishibetsu	Nishisyunnbetsu	149	54	32
K	Pononnebetsu	Akashi	19	73	21

Fig. 1 Outline of the Tokachi and Nemuro areas

Table 1 Measurement methods on the NO_3-N concentration

Measurement method	Official analytical method	Simplified method	
	Chromotrope acid method	Pack Test	Digital Pack Test
Measurement Equipment	Test tube / Reagents / Deionized water etc. (Absorptiometer)	Water Test Kit (Test kit chart)	Water Test Kit (Original absorptiometer)
Measuring range	0.2-30 mg/L	0.23-10 mg/L	0.2-5.0 mg/L
Sensitivity	0.1 mg/L	coarse precision	0.1 mg/L
Coloring time	5 minutes	3 minutes	5 minutes
Measuring value	Numerical value (Digitalized value)	Comparison with "Test kit chart"	Numerical value (Digitalized value)
N.B.		cf: Naphthylethylene diamine method after zinc reduction	cf: Naphthylethylene diamine absorptiometry after zinc reduction

Another simplified method is Digital Pack Test, which is an improved version of the conventional Pack Test, this method (absorptiometer) gives digitized value with an accuracy of 0.1 mg/L to 5.0 mg/L.

In this report, the values of NO_3-N concentration in river water obtained from both two simplified methods and the official analytical method were compared.

RESULTS AND DISCUSSION

Relationship between NO_3-N Concentration and Proportion of Agricultural Land Use

From the 35 sampling points in the two watersheds, a positive correlation has been found between the proportion of agricultural land in the watershed and the NO_3-N concentration in river water in each area as measured by the official analytical method (Fig. 2 (a), (b)). For the area with a high proportion of upland fields, the NO_3-N concentration in river water was found to exceed that specified in various water quality standards (i.e., total nitrogen concentration of 1 mg/L or lower).

When we consider the problem of agriculture and water and the effect of hands-on learning in environmental education, in which the learners actually measure the water quality, it is desirable that the NO_3-N concentration obtained using simplified methods have as high measurement accuracy as possible.

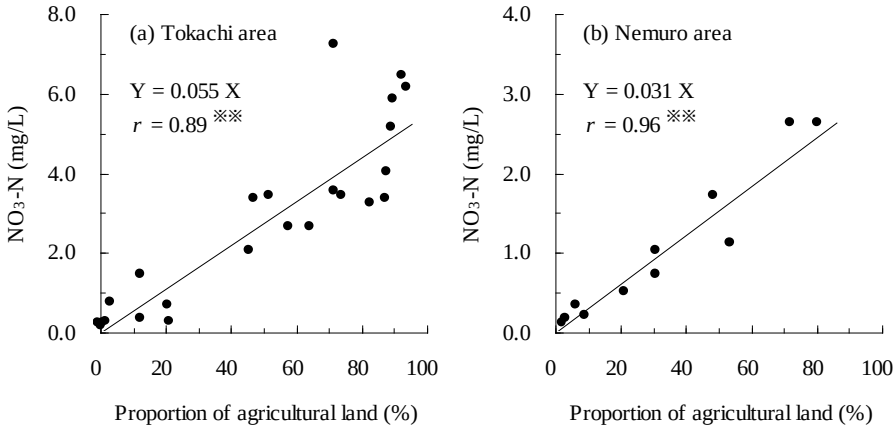


Fig. 2 Relationship between NO_3-N concentration and Proportion of Agricultural land use
(*Tokachi and Nemuro areas, 2006*)

Difference of Measurement Methods in Relation to the NO_3-N Concentration

To compare the NO_3-N concentration in river water as measured by the official analytical method (X axis) with that measured by the simplified methods using Pack Test and Digital Pack Test (Y axis), the regression line that represents the relationship between the two sets of values ($Y = aX$) and the coefficient of correlation r were obtained (Figs. 3 (a), (b) and 4 (a), (b)).

The comparison found a correlation with a significance level of about 1% between Y and X for both of the investigated areas. The NO_3-N concentrations in river water as measured by the simplified methods were 64% to 72% of those as measured by the official analytical method. The values as measured by the simplified methods were underestimates. However, it is sufficiently effective for water environmental education that using the simplified methods to objectively evaluate the water quality by actually measuring it to determine whether nitrogen levels are safe or not.

It is hoped that effective education of the general public of a wide range of ages will be possible by implementing water environmental education that combines conventional lecture-oriented learning of basic knowledge on problems of agriculture and water with hands-on learning

in which the learners measure the NO_3-N concentration of river water. The simplified methods-Pack Test, in particular-are very beneficial, because the general public is able to visually determine the NO_3-N concentration in river water easily and at low cost.

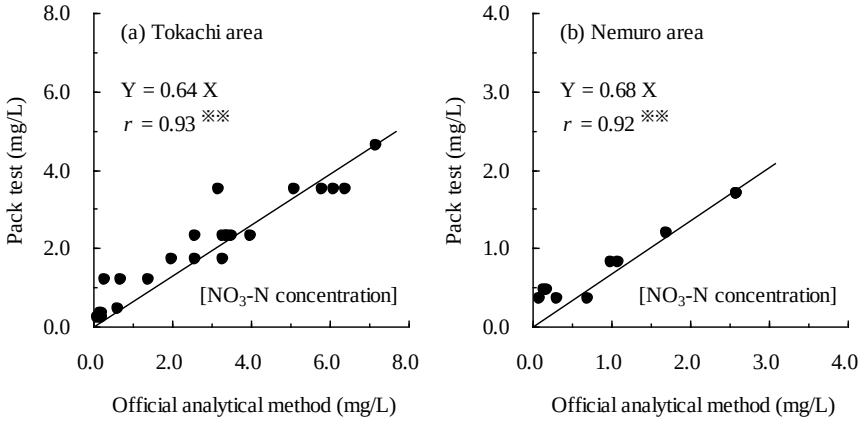


Fig. 3 NO_3-N concentration obtained by Pack Test and Official analytical method
(*Tokachi and Nemuro areas, 2006*)

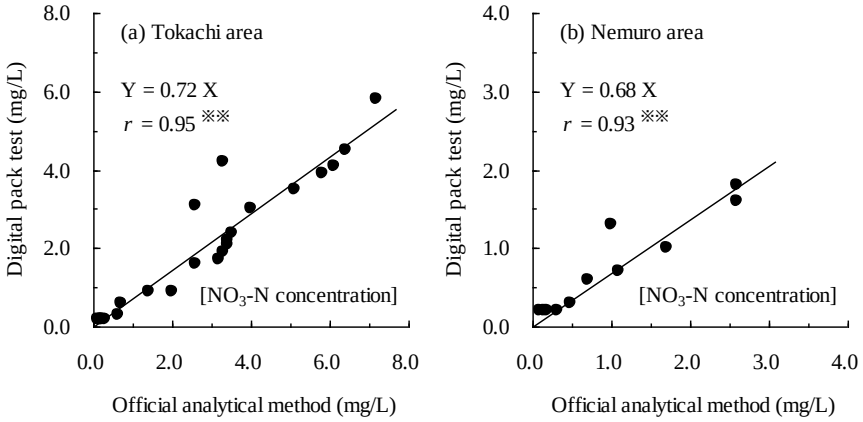


Fig. 4 NO_3-N concentration obtained by Digital Pack Test and Official analytical method
(*Tokachi and Nemuro areas, 2006*)

Desirable conservation of watersheds in agricultural and forestry areas that takes into consideration the realization of sustainable agriculture and the conservation of river water quality is also expected to be possible through the active introduction of hands-on environmental education in which river water is measured by using simplified methods.

CONCLUSION

In improving the effectiveness of water environmental education such that it combines lecture-oriented learning of basic knowledge with experience-oriented learning in which the participants measure river water quality, further improvement in the water measurement methods and the accuracy of such methods is an indispensable issue to be addressed. It is necessary to examine the applicability of the simplified methods to environmental problems related to agricultural activities and water quality indices other than NO_3-N concentration.

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