Research article

Evaluation of the Ion Components for the Estimation of Total Nitrogen Concentration in River Water based on Electrical Conductivity

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Abstract It is generally known that the nitrogen concentration in river water is higher in agricultural areas. However, measurement of the nitrogen concentration is time- and cost-intensive. This study estimated total nitrogen (T-N) concentration based on electrical conductivity (EC) in river water at two agricultural watersheds area which are the Tokachi area, the main land uses are upland and daily farming and the Nemuro area, the main land use is daily farming. The ion components in river water were also considered. The investigation was carried out from August to early September in 2003 to 2006 and in 2012, and T-N concentration, EC and ionic components in river water were measured. In the two areas, there was a positive correlation between T-N concentration and EC in the river water. From this result, T-N concentration was able to be estimated from EC. However, the slope of the regression line differed between the two areas. It is causally related to the effect of the ionic components, because there was a very strong correlation between the concentrations of cationic and anionic components in river water and the EC. In the Tokachi area, SO_4^{2-} and NO_3^- account for a high percentage of the anionic components. These derive from fertilizer, which correlates positively with T-N concentration. In the Nemuro area, Na^+ accounts for a high percentage of the cationic components. In comparison with sea salt, the Na^+ concentration is higher than Cl^- concentration. In addition, there was no correlation between Na^+ and T-N concentration. In the Nemuro area, the outflow of ion component of geological origin affects EC. In light of the above, T-N concentration was able to be estimated based on EC; however, it is necessary to consider the difference in the concentrations of water quality components for each region.

Keywords T-N concentration, EC, cationic components, anionic components

INTRODUCTION

Large-scale farming has long prospered in Eastern Hokkaido, whose natural environment differs from those of other Asian monsoon regions. In recent years, water contamination, including nitrate pollution of river water and groundwater, has been pointed out there (Tabuchi et al., 1995; Matsumoto and Tou, 2006).

The authors investigated the long-term river water quality in the Tokachi area and the Nemuro area, where the agricultural land use is mutually different. It was shown that the trend of nitrogen concentration in the river water differed between the two areas because of their mutually different agricultural land use (Yamazaki et al., 2013, Muneoka et al., 2013).

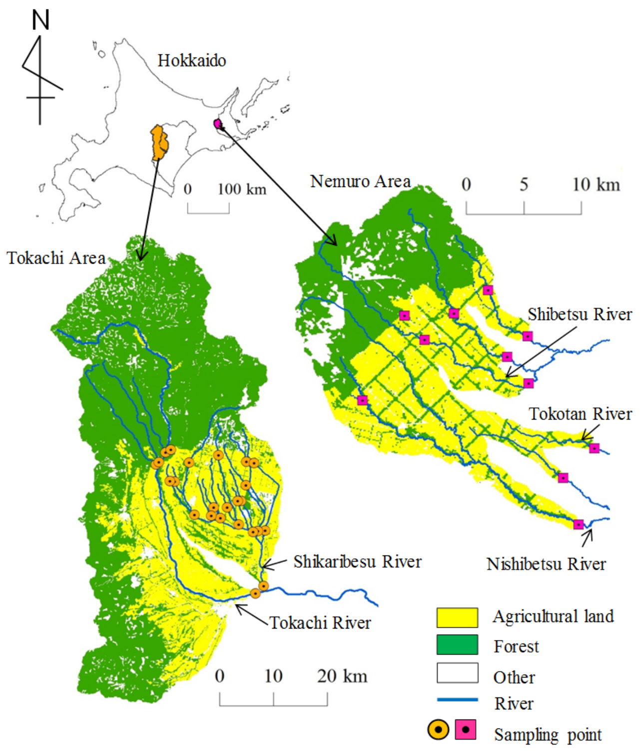
The nitrogen concentration in river water is usually measured by ion chromatography and spectrophotometry, which are time- and cost- intensive. In contrast, electrical conductivity can be measured relatively easily in the field.

This study estimated the total nitrogen (T-N) concentration based on the electrical conductivity (EC) of the river water. EC had been used to estimate the T-N concentration in irrigation water (Tomita et al., 2008). However there are not many examples of applying the method to river water.

In this study, we examined whether the T-N concentration could be estimated from EC values. To do this, based on the results of water quality investigations (2003 - 2012) in the Tokachi area and in the Nemuro area of Eastern Hokkaido, the relationship between T-N concentration and EC was expressed by using a linear regression. In addition, we considered the impact of the ionic components in river water on the coefficients of the regression line.

METHODOLOGY

The study sites are outlined in Fig. 1. The Tokachi area, which consists of 24 watersheds in the Tokachi river system and the Shikaribetsu river system (No. 1 to 24), is in the northwestern part within jurisdiction of the Tokachi General Subprefectural Bureau. It is an area of upland and dairy farming. The Nemuro area, which consists of 11 watersheds in the Shibetsu river system, the Tokotan river system and the Nishibetsu river system (A to K), is in the western within jurisdiction of the Nemuro Subprefectural Bureau. It is an area mainly of dairy farming. In both of these areas, large-scale farming has been pursued, and there have been no considerable changes in agricultural land use in either area since 1985.



Sampling Point	River name	Bridge name	Area (km²)	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	Honmmaki	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	Ponomebetsu	Akashi	19	73	21

Fig. 1 Outline of the Tokachi and Nemuro areas

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 investigation of the river water quality was conducted at the normal water level at 35 sampling points. EC and water temperature were measured using a digital conductivity meter at sampling points. Discharge was also measured on the rivers in small watersheds (varying between 22 and 25 by year). The investigations were carried out from late August to early September in 2003 to 2006, and in 2012. River water samples were analyzed for T-N concentration with spectrophotometer using the cadmium reduction method and chromotropic acid method.

In addition, in late August 2005, ion components of river water were analyzed. These components were Cl^-, NO_3^-, NO_2^-, SO_4^{2-}, HCO_3^-, CO_3^-, PO_4^{3-}, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+}. They were analyzed by liquid chromatography.

RESULTS AND DISCUSSION

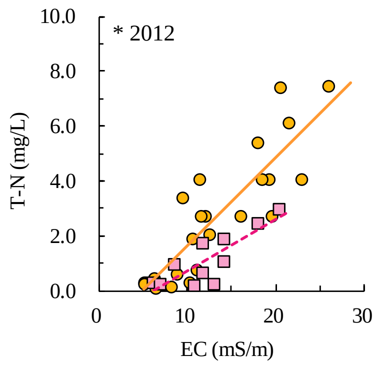
The results of the relationship between T-N concentration and EC in river water for each year in two areas are shown in Fig. 2. The graph is an example of the results for 2012 (Fig. 2(a)).

Since there was a positive correlation between T-N concentration and EC in river water through the study period in the two areas, it was possible to estimate the T-N concentration from the EC of the river water in these agricultural watersheds. The slope and intercept of the regression line were virtually constant throughout the study period in the Nemuro area. In the Tokachi area, the slope and intercept of the regression line were increased from 2005. After the full implementation of "The Law on Animal Waste Regulation" in 2004, significant increases in nitrate nitrogen concentration in river water from some sampling points in the Tokachi aera were confirmed (Yamazaki et al., 2013). The increasing trend of the slope and intercept since 2005 is considered to reflect the changes in the behavior of farmers.

The slope of the regression line is small in the Nemuro area through the study period comparing the two areas. This indicates that the increase in the EC due to change in the T-N concentration in the Nemuro area is higher than in the Tokachi area.

The coefficients of the regression line for estimating the T-N concentration from the EC in both areas were different. As reasons for the differences, the influence of the ionic components other than inorganic nitrogen can be considered. Therefore, cationic and anionic components in river water were analyzed.

In the two areas, there was a very strong correlation between the cations and anions in the river water and the EC (Fig. 3). The percentages of the cationic and anionic components in river water are shown in Fig. 4(a), (b) and Fig. 5(a), (b).



Investigated year	Tokachi area (Y = *a* X + *b*)			Nemuro area (Y = *a* X + *b*)			N.B.
	a	*b*	*r*	*a*	*b*	*r*	
2003	0.24	-0.96	0.85 ※※	0.17	-1.00	0.87 ※※	
2004	0.24	-1.25	0.80 ※※	0.17	-1.19	0.79 ※※	
2005	0.38	-1.92	0.87 ※※	0.17	-0.97	0.83 ※※	
2006	0.37	-1.65	0.92 ※※	0.19	-1.02	0.85 ※※	
≈							
2012	0.32	-1.60	0.87 ※※	0.19	-1.13	0.82 ※※	*

Tokachi area ··· Nemuro area　　※※significnace of 1%

Fig. 2 Relationship between T-N concentration and EC in river water

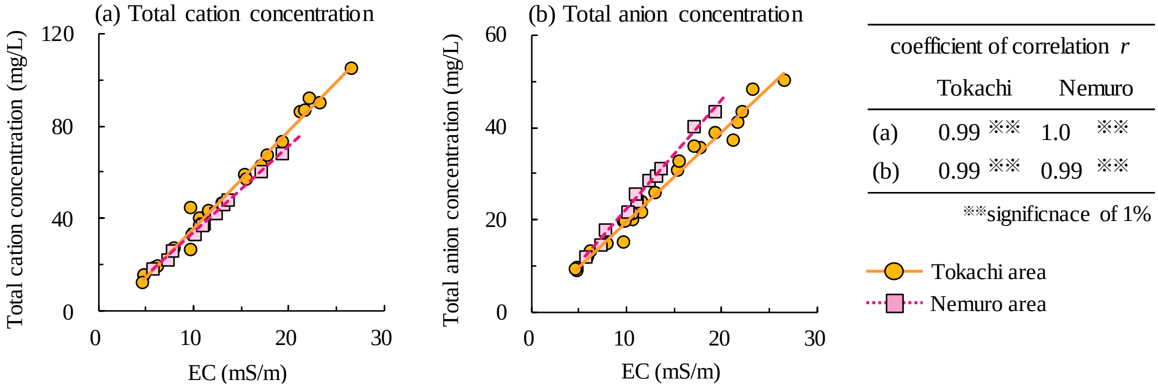
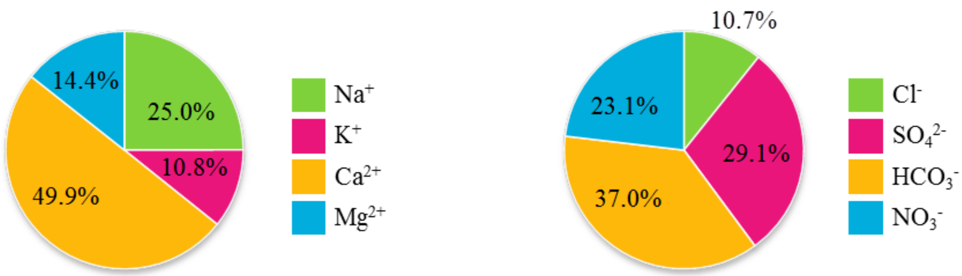


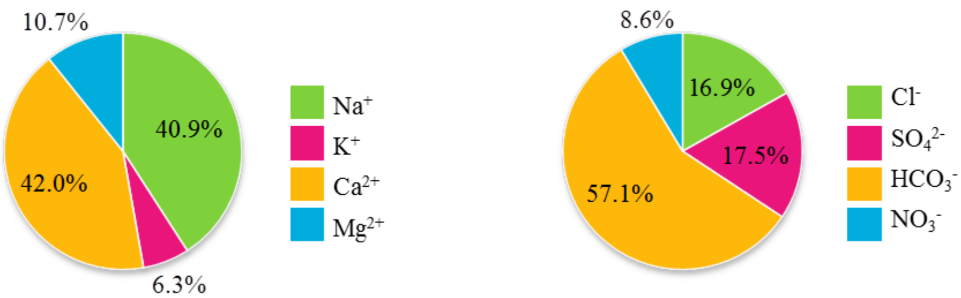
Fig. 3 Relationship between ionic components and EC in river water

Ca^{2+} and HCO_3^- are the main ionic components in the river water. The trend of the percentage of the ionic components differed between the two areas. The percentage of SO_4^{2-} and NO_3^- were higher in Tokachi area (Fig. 4(a), (b)). These components correlated positively with T-N concentration. They are derived from the outflow of fertilizer component. The runoffs of SO_4^{2-} and NO_3^- were increased, because upland farming has been practiced on a large scale in the Tokachi area. In the Nemuro area, the percentage of Na^+ is comparable with the percentage of Ca^{2+} (Fig. 5(a), (b)). In general, most of the Na^+ and Cl^- are supplied from sea salt, and the ratio of Na^+ concentration to Cl^- concentration in sea salt is 1:1.16. However, in comparison with sea salt, Na^+ concentration is higher than Cl^- concentration in the Nemuro area. In addition, the Na^+ in the Nemuro area had no correlation with T-N concentration. From the above results, why the slope of the regression line of T-N concentration and EC in the Nemuro area is smaller than in the Tokachi area, because the outflow of ionic components derived from the geological features of each area rather than agricultural origin affect the EC.



(a) Percentage of the cationic components (b) Percentage of the anionic components

Fig. 4 Percentages of the ionic components in river water in Tokachi area



(a) Percentage of the cationic components (b) Percentage of the anionic components

Fig. 5 Percentages of the ionic components in river water in Nemuro area

CONCLUSION

The relationship between T-N concentration and EC was examined for two areas of eastern Hokkaido with mutually different agricultural land use. Since there was a positive correlation, T-N concentration in river water was able to be estimated from EC, and comparing the slope of the regression line, it is different in two areas. When the ion components of river water are compared between the two areas, the percentages of SO_4^{2-} and NO_3^- in the fertilizer component are higher in the Tokachi area. In the Nemuro area, the outflow of ion components of geological origin affects EC. From the above consideration, T-N concentration was able to be estimated based on EC; however, it is necessary to consider the difference in the water quality components of each region.

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