Research article

Evaluation of River Water Quality in Agricultural Watershed with the Environmental Standards

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Received 20 January 2015 Accepted 25 April 2015 (*Corresponding Author)

Abstract Japan has general environmental standards for organic matter in its public water bodies. However, there are no environmental standards for nutrient salts such as phosphorus (P) and nitrogen (N) in river water. In this study, the water quality of rivers at normal water level was evaluated in agricultural watersheds by focusing on water quality standards. The investigated sites are in the Tokachi area (24 watersheds; upland and dairy farming) and the Nemuro area (11 watersheds; large-scale dairy farming), which are in Eastern Hokkaido. The investigations were carried out in the two agricultural areas in 2005, 2006 and 2012. Electrical conductivity (EC) and water temperature were measured at the same time as river water samples were collected in the two areas. Water quality was analyzed for potential of hydrogen (pH), biochemical oxygen demand (BOD), suspended solids (SS), total phosphorus (T-P), total nitrogen (T-N) and other values. Most of the values associated with organic matter, such as pH, BOD and SS, in river water were within the thresholds for the standards of The Environmental Standards Concerning the Conservation of the Living Environment (Rivers). In contrast, some values of nutrient salts (N and P) exceeded the thresholds (T-P≦0.1 mg/L, T-N≦1.0 mg/L). Many of the watersheds in the Tokachi area had T-N concentration in excess of 1.0 mg/L. This suggests that the concentrations of nutrient salts (P and N) increase with increases in agricultural land development in a watershed. For the evaluation of river water quality in agricultural watersheds, it was found to be necessary to measure both organic matter and nutrient salts as indices of water quality. And it was found that controlling the runoff of P and N from agricultural land is essential for water quality conservation in public water bodies.

Keywords organic matter, nutrient salts, agricultural watershed, environmental standard

INTRODUCTION

In countries around the world, the river water quality is seriously worsening. As is well known, agriculture has been pointed out as a cause.

The authors have long been researching the concentration of nitrogen in river water at normal water levels by targeting two areas with different agricultural land use (Yamazaki et al., 2013; Muneoka et al., 2013; Yamazaki et al., 2014; Muneoka et al., 2014). This research has been under way in Eastern Hokkaido, which has precious regional characteristics in the Asian monsoon region,

with consideration of study results pertaining to the concentration of nitrate nitrogen in river water from the study performed by Tabuchi et al. (1995). Based on the accumulation of these basic data, it is expected that study and research will make further progress toward measures for controlling the runoff of nitrogen into rivers in agricultural and forest watersheds.

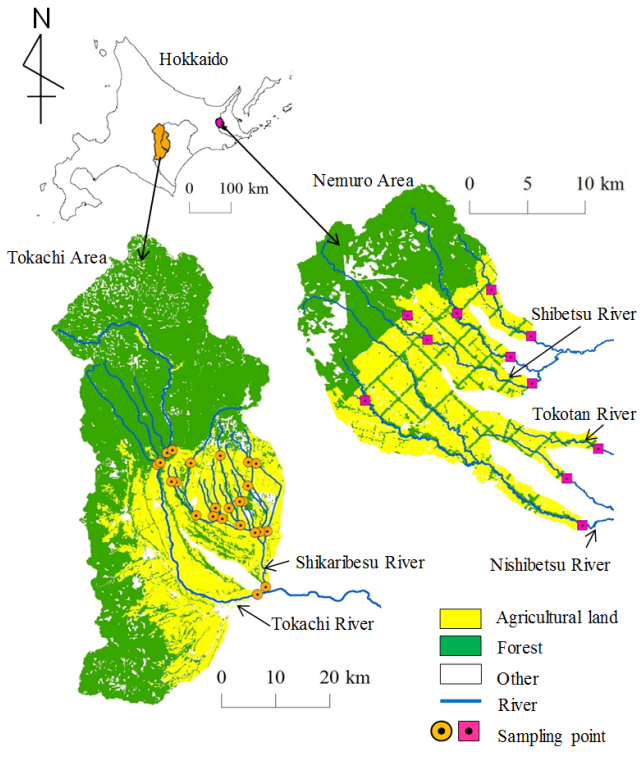
Japan sets general environmental standards for organic matter in its public rivers. However, there are no environmental standards for nutrient salts such as phosphorus (P) and nitrogen (N) in river water. Therefore, while the evaluation of land use in agricultural and forest watersheds that use nitrogen concentration in river water as an index has progressed, there are few cases that use other nutrient salts (e.g., P) as well as organic matter as indices for evaluating the water quality of rivers.

In this report, the present condition of river water quality at normal water levels in Eastern Hokkaido was evaluated within agricultural watersheds, with reference to water quality standards.

METHODOLOGY

General Description about the Studied Watershed and the Study on River Water Quality

The maps of study sites are shown in Fig.1. The Tokachi area, which has 24 watersheds on the Tokachi River system and the Shikaribetsu River system (No. 1 to 24), is located in the northwestern part of the Tokachi General Sub-prefectural Bureau, and it is an area with upland and dairy farming. The Nemuro area, which has 11 watersheds on the Shibetsu, the Tokotan and the Nishibetsu River systems (A to K), is located in the western part of the Nemuro Sub-prefectural Bureau, and it is an area mainly of dairy farming. In both of these areas, large-scale farming has been operated, 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	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

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 low rainfall.

The investigation of the river water quality was conducted at the normal water level at 35 sampling points. Electrical Conductivity (EC) and water temperature were measured at sampling points. And discharge was also measured on the rivers in small watersheds (varied between 22 and 25 by year). Items analyzed to determine water quality varied with each year. This study used potential of hydrogen (pH), biochemical oxygen demand (BOD), suspended solids (SS), total phosphorus (T-P) and total nitrogen (T-N) and other values as indices of water quality. The investigations were carried out during late August to early September in 2005, 2006 and 2012.

Environmental Standards for River Water in Japan

Water quality in Japan is regulated by the Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Rivers), which uses organic matter as indices (Table 1). The standard values are divided into 6 stages (Type-AA to Type-E) according to the suitable use of the water, with each acceptable range specified as follows: pH (always between 6.5 and 8.5), BOD (between 1 mg/L and 10 mg/L) and SS (between 25 mg/L and 100 mg/L).

Table 1 The Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Rivers (Extract))

	Standard values		
Type	pH	BOD	SS
AA	between 6.5 and 8.5	1 mg/L or lower	25 mg/L or lower
A	between 6.5 and 8.5	2 mg/L or lower	25 mg/L or lower
B	between 6.5 and 8.5	3 mg/L or lower	25 mg/L or lower
C	between 6.5 and 8.5	5 mg/L or lower	50 mg/L or lower
D	between 6.5 and 8.5	8 mg/L or lower	100 mg/L or lower
E	between 6.5 and 8.5	10 mg/L or lower	※

※ No floating matter on the surface of the water

Table 2 Some water quality standards on the nutrient salts (N and P)

(a) The Environmental Quality Standards
Concerning the Protection of the Human Health (Extract)

Combined concentration of NO_3-N and NO_2-N	10 mg/L or lower

(b) The Environmental Quality Standards
Concerning the Coservation of the Living Environment

		Standard values	
	Type	T-N	T-P
Lakes	I	0.1 mg/L or lower	0.005 mg/L or lower
(Appendix 2)	II	0.2 mg/L or lower	0.01 mg/L or lower
	III	0.4 mg/L or lower	0.03 mg/L or lower
	IV	0.6 mg/L or lower	0.05 mg/L or lower
	V	1.0 mg/L or lower	0.10 mg/L or lower
Seas	I	0.2 mg/L or lower	0.02 mg/L or lower
(Appendix 2)	II	0.3 mg/L or lower	0.03 mg/L or lower
	III	0.6 mg/L or lower	0.05 mg/L or lower
	IV	1.0 mg/L or lower	0.09 mg/L or lower

In Japan, there are two major water quality standards that use nitrogen, and nutrient salts, as indices. The Environmental Quality Standards Concerning the Protection of Human Health specifies the highest acceptable combined concentration of nitrate nitrogen (NO_3-N) and nitrite nitrogen (NO_2-N) as 10 mg/L (Table 2(a)).

As shown in Type-V in Table 2(b) of Appendix 2 of the Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Lakes) and Type-IV in Table 2(b) of Appendix 2 of the Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Seas), acceptable concentration of total nitrogen (T-N) is regulated at 1 mg/L or lower.

Further, in Type-V in Table 2(b) of Appendix 2 of Environmental Water Quality Standards Concerning the Conservation of the Living Environment (Lakes), which is the water quality standard that uses phosphorus as an index, the acceptable concentration of total phosphoru s (T-P) is regulated at 0.1 mg/L or lower, and in Type-IV in Table 2(b) of Appendix 2 of said standards (Seas), the acceptable concentration of total phosphorus (T-P) is regulated at 0.09 mg/L or lower.

However, there are no environmental standards for nutrient salts in river water of public water bodies. In this report, by referring to the water quality standards mentioned above, "threshold levels" that use nutrient salts (N and P) as indices were established by specifying T-P as 0.1 mg/L or lower and T-N as 1.0 mg/L or lower to evaluate water quality.

RESULTS AND DISCUSSION

Evaluation of Water Quality using Organic Matter as an Index

In Table 3, the pH of river water was within the range of 7.1 to 8.0 for the Tokachi area and 7.3 to 7.7 for the Nemuro area, both of which satisfied the standard values in Type-AA (betwee 6.5 and 8.5). BOD was within the range of <0.5 to 3.1 mg/L in the Tokachi area, which exceeded the standard values of Type-B (3 mg/L or lower) at only 1 spot. BOD was within the range of <0.5 to 1.2 mg/L in the Nemuro area, which satisfied the standard values of Type-A (2 mg/L or lower). SS was within the range of <1 to 39 mg/L in the Tokachi area, and <1 to 13 mg/L in the Nemuro area, which exceeded the standard values of Type-AA to B (25 mg/L or lower) at only 1 spot.

Therefore, the indices of organic matter for river water at normal water levels in agricultural watersheds in Eastern Hokkaido were mostly within the standard values in every year when the study was carried out, regardless of differences in size of watershed area or the area of upland and pasture as a share of the watershed.

Evaluation of Water Quality using Nutrient Salts as Indices

The T-P concentration in river water was within the range of 0.024 to 0.39 mg/L in the Tokachi area, which exceeded the threshold level at 9 spots, and 0.060 to 0.23 mg/L in the Nemuro area, which exceeded the threshold level at 5 spots (Table 4).

Next, T-N concentration was within the range of 0.25 to 10 mg/L in the Tokachi area, which exceeded the threshold level at 17 spots. In the Nemuro area, it was within the range of 0.19 to 3.2 mg/L, which exceeded the threshold level at 6 points (Table 4).

Therefore, the spots where the values exceeded the "threshold level" of nutritional salts saw a relatively high share of upland field and pasture in watersheds (22 to 95%), and runoff had high concentrations of T-N.

The authors consider that it is necessary to measure both organic matter and nutrient salts as indices to evaluate river water quality in agricultural watersheds. In addition, it was found that controlling the runoff of P and N from agricultural land is essential for water quality conservation in public water bodies. To accomplish these, systematic watershed management is required that gives consideration to both agricultural land use and farming.

Table 3 Water quality using organic matter as an index (2005, 2006 and 2012)

Investigate area (Sampling spots)	Measuring values		
	pH	BOD (mg/L)	SS (mg/L)
Tokachi Area (24 spots)	7.1 ～ 8.0	<0.5 ～ 3.1※	<1 ～ 39※
Nemuro Area (11 spots)	7.3 ～ 7.7	<0.5 ～ 1.2	<1 ～ 13

※ exceeded the standard value of Type-B at only 1 spot

Table 4 Water quality using nutrient salts an index (2005, 2006 and 2012)

Investigate area (Sampling spots)	Measuring values	
	T-P (mg/L)	T-N (mg/L)
Tokachi Area (24 spots)	0.024 ～ 0.39※ (9 spots)	0.15 ～10※ (17 spots)
Nemuro Area (11 spots)	0.060 ～ 0.23※ (5 spots)	0.19 ～ 3.0※ (6 spots)

※ the number which exceeded the threshold level
(T-P >0.10mg/L; T-N >1.0mg/L)

CONCLUSION

Evaluations of river water quality using the environmental standards in Japan show that organic matter at normal water levels in agricultural regions in Eastern Hokkaido are within the standard values. In contrast, it was confirmed that nutrient salts constantly run off at high concentrations. In order to consider measures for controlling the runoff of nutrient salts (especially nitrogen) with both sustainable agriculture and environment conservation in mind, constructing comprehensive watershed management is an urgent issue. In the future, we would like to contribute to measures for the evaluation of land and water conservation in wide water catchment areas with Asian monsoon climate by applying the environmental standards in Japan for the evaluation of river water quality in other agricultural regions.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the research assistance provided by the students, Obihiro University of Agriculture and Veterinary Medicine.

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