Research article

Characteristics of the River Water Quality Under Base Flow Condition in the Tokachi River Basin, Japan

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Received 15 November 2015 Accepted 11 April 2016 (*Corresponding Author)

Abstract The Tokachi River basin has an important role as a food base of Japan. It is one of the significant challenges that achieve a good balance between a food production and water quality conservation for the sustainable agriculture in this basin. Here, we carried out the river water monitoring in the Tokachi River basin and evaluated the river water quality under base flow condition. 37 sampling points in the main stream and the tributaries were monitored in late June, late August or early September, and late October 2007 to 2011. Five-year mean values and standard deviation of pH, BOD, SS and EC were evaluated. The water quality of the Tokachi River showed variations at each investigation period. However, there were no change trends of seasons or years. The mean pH values of the Tokachi River basin were the range of 7.1-7.5. The river water quality was neutrality and stable at each sampling point. The mean BOD showed comparatively low values in the Tokachi River basin (0.9-1.8 mg/L). However, the BOD values increased gradually with the main stream flow. The mean SS values were less than 25 mg/L at all sampling points. Also, the SS values tended to increase basically with the main stream flow. The mean EC values increased from upstream to downstream of the main stream (6.8-12.4 mg/L). Also, the EC values in 13 of 20 sampling points of the tributaries were higher than the main stream values (5.0-22.2 mg/L). There were significant correlations between the EC values and the proportion of the agricultural land or forest land. From these results, it was considered that the dissolved matter in the river water increased with a high proportion of agricultural land in the Tokachi River basin.

Keywords river water quality, base flow condition, the Tokachi River basin

INTRODUCTION

One of the most important challenges that the world is facing today is the development of a sustainable food system. The world population is expected to reach 9.1 billion people by 2050, and hence, we have to double the current food production to accommodate the world food demand. Japan has a lower self-sufficiency rate than the United States and EU and depends on food from overseas for domestic

consumption. The Tokachi River basin in the eastern part of Hokkaido, Japan, is a large area of cropland and dairy farming and is focused on as a food base of Japan. However, there are large challenges with not only increasing the crop production such as improving the cultivation method, crop breed and management of water resources but also reducing the environmental load from agricultural land. For example, hydrosphere pollution caused by agricultural activities has been widely reported (Parris, 2011). Increasing nutrient runoff from agricultural land causes eutrophication of lakes, ecosystem collapse and landscape deterioration. In the Tokachi River basin, increasing nitrogen concentrations in the river water and a positive correlation between agricultural land and nitrogen concentrations in the river water have been reported (Okazawa et al., 2011; Muneoka et al., 2013; Yamazaki et al., 2013). Also, the water pollution in the agricultural area is considered to be caused by materials other than nutrient salts, such as pesticides, minerals, bacteria and metals. Until now, there was no report of water quality evaluation by indicators other than nitrogen and phosphorus in the Tokachi River basin.

Here, we report the result of a 5 year observation of pH, biological oxygen demand (BOD), suspended solids (SS) and electrical conductivity (EC) measurements of the river water and evaluate the current status of river water quality in the Tokachi River basin to improvement of water quality with a goal of sustainable food system.

METHODOLOGY

This study was conducted in the Tokachi River basin located in the eastern part of Hokkaido, Japan (142.68–144.02°N, 42.55–43.65°E, 0–2,077 m altitude) (Fig.1 and Table 1). The basin has a total area of 9,010 km^2 and a total stream length of 156 km. The Tokachi River basin is characterized as a warm summer continental climate type (Dfb) according to the Köppen–Geiger climate classification with an annual mean air temperature of 6.8°C and an annual precipitation of 887.8 mm/y; measurements were performed at Obihiro city from 1981 to 2010. The soil types in the Tokachi River basin are volcanic soil, lowland soil, upland soil and peat soil. In particular, volcanic soil (andosols) is widely distributed in this basin. The main land uses in this river basin are agriculture and forests, with 60 % of the agricultural land used as cropland and the remaining 40 % used as pasture. Both chemical fertilizers and livestock manure are applied to the agricultural land.

The river water quality was monitored at 37 sampling points located on the main stream (nos. 1–17) and each tributary (A–T) of the Tokachi River basin in June, either August or September and October from 2007 to 2011 under base flow conditions. Water samples were analysed for pH, BOD, SS and EC.

RESULTS AND DISCUSSION

Mean pH, BOD, SS and EC Values and the Standard Deviations in the Tokachi River Basin

Figure 2 shows the mean values and standard deviations of the pH, BOD, SS and EC measurements of the main stream and the tributaries in the Tokachi River basin. The pH values of the main stream and the tributaries ranged from 7.2 to 7.3 and 7.1 to 7.5, respectively, indicating that the pH values in the Tokachi River basin were neutral and stable. The standard deviations of the pH values were small and stable.

The mean BOD values of the main stream ranged from 1.1 to 1.8 mg/L and gradually increased from upstream to downstream. The mean BOD values of the tributaries ranged from 0.9 to 1.8 mg/L and were comparable with the values from the main stream. Since there were some variations in the BOD values by each observation year and season, the BOD in the Tokachi River basin ranged from 0.5 to 3.0 mg/L.

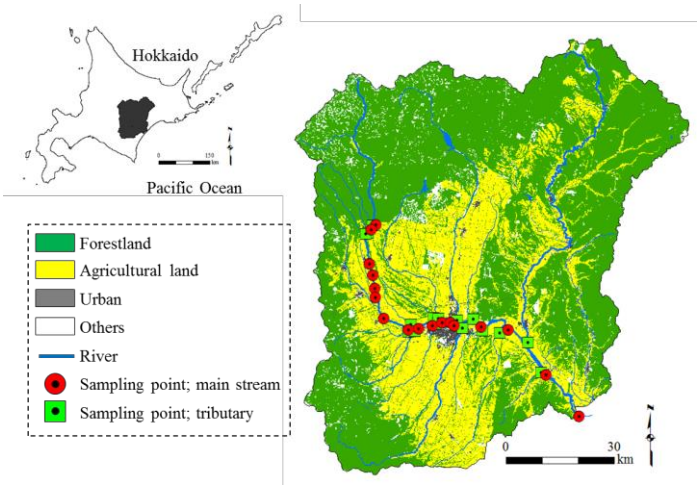

Fig. 1 Locations and land uses in the Tokachi River basin

The mean SS values of the main stream ranged from 4.2 to 18 mg/L. Although the values fluctuated at each sampling point, there was an increasing trend from upstream to downstream. The SS values of the main stream fluctuated by observation year and season, resulting in comparatively high standard deviations. On the other hand, the mean SS values of the tributaries ranged from 1.1 to 20 mg/L, and except 2 sampling points, the mean SS values were ≤10 mg/L. The standard deviations of 16 of the 20 sampling points were small, and the SS values of the tributaries were stable at these sampling points.

The mean EC values of the main stream ranged from 6.8 to 12 mS/m and increased from upstream to downstream. The mean EC values of the tributaries ranged from 5.0 to 22 mS/m. The tributaries located in the upstream area had lower EC values than the main stream; however, the tributaries located in the downstream area had EC values of approximately 20 mS/m. There were different trends in the EC values according to the location of the tributaries. The standard deviations of the EC values were small and stable.

From these results, the river water quality in the Tokahi River basin was at neutrality and stable with a pH value of approximately 7, and there were small variations between observation periods. However, the BOD, SS and EC values showed an increasing trend from upstream to downstream. In particular, the EC values of each sampling point of the tributaries had a different trend according to the upstream area or the downstream area. Based on these results, the river water quality in the Tokachi River basin was considered to have been affected by land use and anthropogenic impacts in the watershed.

Table 1 Watershed and land use information in sampling point

Name	Area (km^2)	River langth (km)	Forestland Proprotion (%)	Agricultural land Proportion (%)	*SC* ($\times 10^{-2} km^2$)
Mainstream					
1	632	613	94	1	29
2	658	637	94	1	25
3	801	773	93	3	55
4	806	777	92	3	60
5	840	815	89	4	112
6	858	832	87	5	128
7	1,289	1,247	78	14	187
8	1,531	1,546	73	19	244
9	1,777	1,782	71	21	266
10	1,798	1,801	70	21	272
11	2,669	2,664	60	32	425
12	2,683	2,678	60	32	427
13	2,686	2,679	60	32	421
14	4,479	4,243	59	35	399
15	5,098	4,714	54	39	471
16	8,224	7,074	62	33	241
17	8,982	7,856	58	31	228
Tributaries					
A	23	22	98	0	0
B	48	47	96	2	31
C	72	71	97	2	26
D	337	313	68	25	134
E	210	255	53	40	361
F	26	21	11	73	474
G	35	44	18	79	275
H	180	165	74	16	220
I	164	166	17	73	856
J	33	27	44	52	74
K	667	660	44	47	772
L	693	630	61	18	240
M	197	557	70	71	674
N	704	201	12	30	319
O	316	276	28	65	419
P	127	98	12	79	917
Q	449	333	25	70	899
R	2,850	2,104	76	19	90
S	173	145	73	23	90
T	66	54	51	44	101

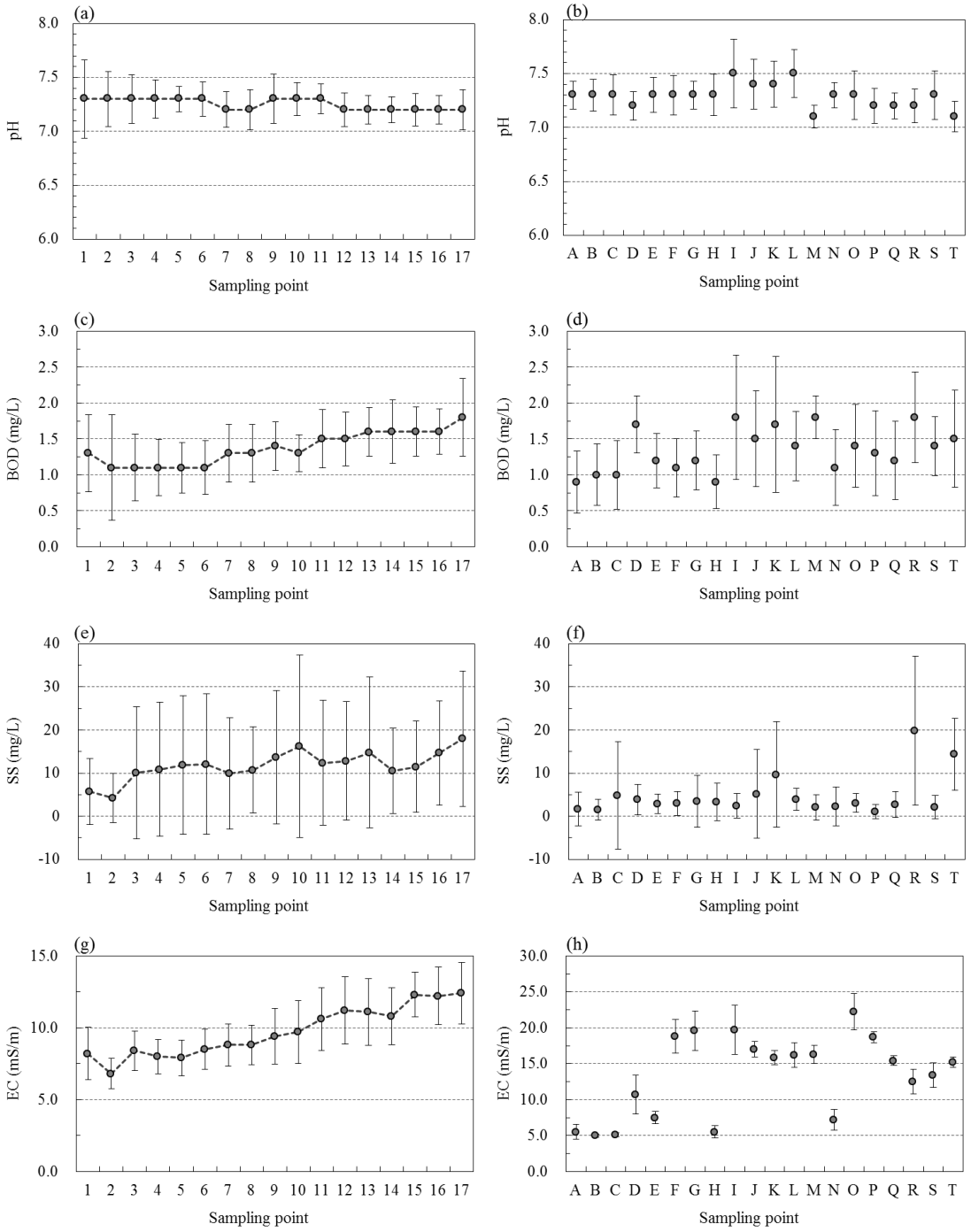

Fig.2 Results of water quality in the main stream (a), (c), (e) and (g); that of tributaries (b), (d), (f) and (h); mean pH values (a) and (b); mean BOD values (c) and (d); mean SS values (e) and (f); mean EC values (g) and (h).

Correlation Coefficients Between the River Water Quality and the Land Use in the Watershed

We further examined the relationships between the river water quality and the proportion of land uses (agricultural land, forest land and other land use). Table 2 shows the correlation coefficients of the relationships between the mean pH, BOD, SS and EC values obtained from the Tokahi River basin (i.e. the main stream and the tributaries), and the proportion of the agricultural land, forest land and other land use (such as urban areas) at each sampling point. The EC values had a significant correlation with the proportion of agricultural land and forest land ($p < 0.01$), where the EC values of the river water tended to be higher with a higher proportion of agricultural land and tended to be lower with higher proportions of forest land. In general, the EC of river water is correlated with dissolved materials such as ionic components in river water (de Sousa et al., 2014; Pawlowicz, 2015). The results indicated that the dissolved materials in the river water might have increased with the intensity of agricultural land use in the watershed because the fertilizer components, livestock manure and cropland soil runoff into the river easily in an agricultural watershed.

Table 2 Correlation coefficeints between the river water quality and the land uses in the Tokachi River basin

	Proprotion of land use (%)		
	agriculture	forest	urban
pH	0.08	− 0.08	0.00
BOD	0.26	− 0.28	0.21
SS	− 0.28	0.26	0.01
EC	0.78	− 0.76	0.22

The mean BOD and SS values of the Tokachi River basin had no correlation with the proportion of land uses. However, the BOD and SS values in the river water tended to increase with higher contents of dissolved materials and nutrients in the river water.

CONCLUSION

In this study, the river water quality in the Tokachi River basin, which is the most important area for agriculture in Japan, was determined to have deteriorated due to agricultural activity in the watershed. At the main stream, the BOD, SS and EC values tended to increase from upstream to downstream, with the EC values of the tributaries particularly showing higher concentrations in the downstream area. Since the EC values of the river water had a positive correlation with the proportion of agricultural land, the increase in dissolved materials in the river water was attributed to the presence of agricultural activities in the Tokachi River basin.

ACKNOWLEDGEMENTS

This research was supported by JSPS KAKENHI, Grant Number 15J04743, 2015.We would like to express our gratitude for the research assistance provided by the students and the Obihiro University of Agriculture and Veterinary Medicine.

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