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CHARACTERISTICS OF WATER QUALITY IN A FOREST RIVER DURING THE SNOW MELTING PERIOD

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Synopsis

The water quality of river Ogawa, which runs through the Sapporo area, was analyzed from data measured daily (except for the winters) from September 1986 to August 1988. In this report we focused our attention on the specific behaviors of nutrients during the snow melting period (April and May). The following are the results obtained during the snow melting period.

(1) The rate of river discharge during these seasons is about 60% of the annual discharge. The rates of nutrient loads to annual loads during this period are higher than those of the river discharge.

(2) The runoff of nutrients during this period are of the soil-scrubbing-type and/or elusion-type of accumulated matter in the soil.

(3) Nitrogen in the runoff is mainly in dissolved form and phosphorus in particulate form. Nitrates dominated the dissolved nitrogen. Variation of N/P is not so large. This shows that nutrients exist in a stable composition.

(4) The mean water quality during this period indicates the meso - eutrophic condition.

(5) Loads of nutrients, except ammonia nitrogen, increased with increasing discharge. Loads of ammonia nitrogen, and ordinary inorganic components were stable or somewhat decreased. These tendencies are almost the same as those occurring annually.

Introduction

In spring in cold regions the snow which has collected since winter melts, and a variety of substances are carried with the soil by the torrents of water into the rivers. Thus, the quality of river and lake waters subject to snowfall in winter shows distinct different seasonal changes from river and lake water not subject to snowfall. The quantity of snow melt run-off is receiving our attention as an essential resource of water. Its quality is no less than an essential factor. In Japan there are accurate reports on the water quality of forest rivers in regions without snow by Kunimatsu (1), Ebise (2) and Hirata (3). But reports on water quality during snow melting periods are very few. The present authors carried out a basic study of the water in a river during the snow melting period, focusing on nutrients (4). The study yielded an estimate of the balance of chemical components which may be of assistance in the management of forests.

Methods

Location of Survey

For the survey the authors chose the river Ogawa, with a discharge of about 1 m^3/s (for January 1st 1988 - December 31st 1988: mean discharge 0.78, medium discharge 0.85, maximum discharge 12.42, minimum discharge 0.04 [all figures in m^3/s]; catchment area 11.0 km^2, length 7.0 km). This is a small river running through the outskirts of Sapporo city and runs into the river Ishikari, as shown in Figure 1. The river Ogawa originates between Mt. Muine (1461 m) and Mt. Nagao (1205 m). It is a waste river with fragile rocks. The mountains in the catchment area are covered with snow until late spring. Its steeply sloping upper reaches are covered with spruce, white birch, alder and other varieties of trees.

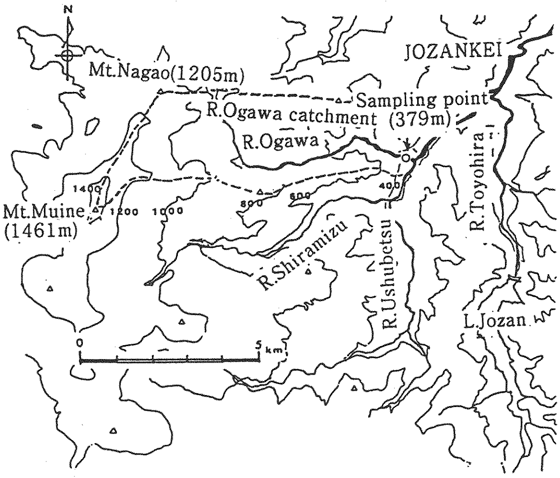

Figure 1 Map of the River Ogawa catchment

Sampling

Stream water was sampled at the mouth of the river Ogawa (alt. 370 m) from September 1986 to August 1988. Generally, samples were collected once every ten days during winter, once a day at an appointed time from spring through early fall, usually by an automatic sampler (ISCO-1680), and once a week in other seasons of the year. During wet spells, water was sampled up to twelve times a day, depending on the discharge change. At the same time, the air temperature, water temperature, and depth of snow were measured at the sampling point. From September 1986 to August 1987 is referred to as 'the 1986 period' and the following twelve months are referred to as 'the 1987 period'.

Chemical Analysis

Thirty chemical components related to eutrophication were analyzed, including total nitrogen (TN), total phosphorus (TP), some nutrient compounds (nitrate-N, nitrite-N, ammonium-N, organic-N, phosphate-P), organic carbon (OC), suspended solids (SS) and principal inorganic ions (e.g., chloride ion, sulfate ion, alkalinity (4.3Bx)). Analysis of these components was mainly by the Standard Method (5)

Classification of Seasons

The effect of snow runoff on the river flow was apparent until early June, but the snow melting period (hereafter called the snow melting period or the melt season) is considered to be April and May in this analysis, based on considerations of the yearly precipitation and river flow patterns. By the same standard, 'summer' is defined as June - August, 'autumn' as September - November, and 'winter' as December - March. Observations were carried out over two years, but the following analysis is mainly devoted to the 1987 period. Analysis of data from the snow melting period is based on the daily results of the auto-sampler. During the 1987 period, this was set in operation on April 8, 1988.

Results and Discussions

Hydrological Conditions and Water Quality during Snow Melt Period

Hydrological Conditions and Flow Fluctuations

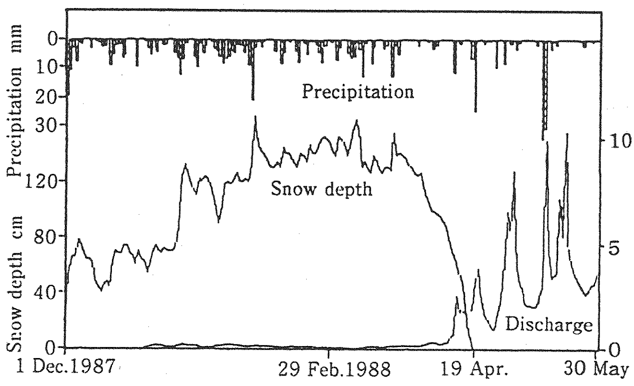

Figure 2 Changes in snow depth and precipitation (measured at sampling point)

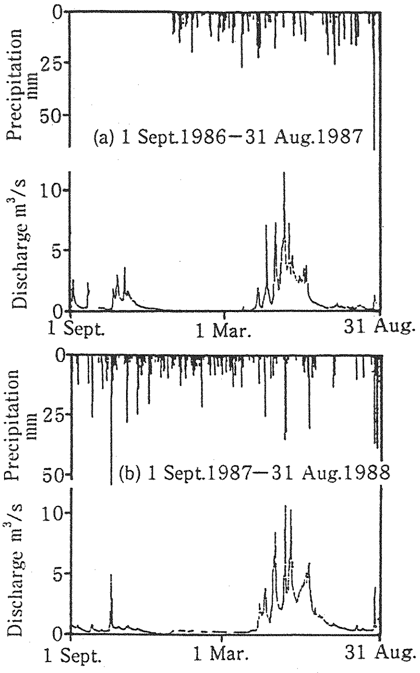

Figure 3 Daily discharge
(1 Sept. 1986 - 31 Aug. 1988)

Fig. 2 shows the variations in depth of accumulated snow at the sampling point. The snow depth was about 1.5 m in March when the average temperature was -10.2℃, but dropped as the ambient temperature rose to 84 cm by Apr. 8. The snow had all melted by Apr. 19. The presence of snow until mid-May on one of the mountain summits in the watershed was confirmed. Figure 3 shows the changes of daily discharge and precipitation at the sampling point. Snow melt continued to influence the discharge at this point until early June. When comparing the total discharge during the snow melting period of April and May to the total annual discharge, the total discharge during the snow melting period was 56.4% during the 1986 period and 60.1% during the 1987 period (see Table 3).

Figure 4 shows the ambient and water temperatures, daily precipitation and discharge of the Ogawa river at the sampling point during the 1988 melt period (the Roman numerals indicate times of high water flow, or 'floods'). Relating high discharge to the other variables in Periods I (April 11 - 15), II (April 18 - 21) and IV (May 12 - 15), rises in temperature and precipitation caused the increase in discharges, while in Periods III (April 26 - May 5) and V (May 17 - 22) only rises in temperature caused the increase in discharge. The highest discharge during the melt period was 10.6 m^3/s in Period III on May 1. The discharge stabilized at 2 m^3/s by the end of May.

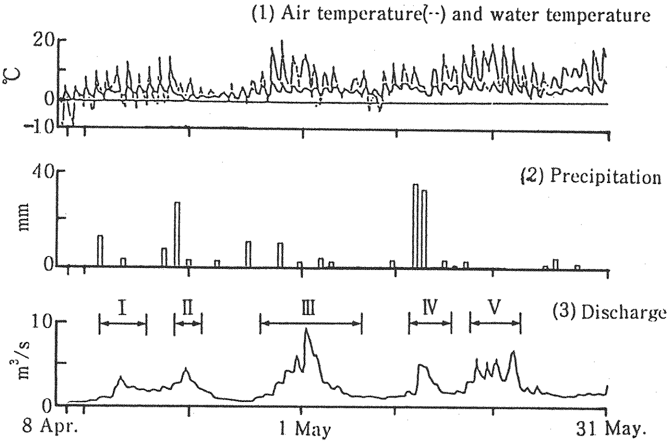

Figure 4 Changes (1) air temperature (--) and water temperature, (2)precipitation and (3) discharge

Electric Conductivity and Principal Inorganic Components (Figure 5)

The conductivity, an indicator for the total concentrations of dissolved substances, dropped gradually from 90 μs/cm at the beginning of the snow melting period to 50 μS/cm at the end of the period. Other drops in conductivity were observed during flood periods. After the end of the snow melting period, the conductivity steadily recovered and reached values of 80 to 100 μS/cm at the end of August. Discharge is compared with conductivity during periods of continuous sampling rates (periods of rainfall) in Fig. 6-1 - 4. There is a marked fall in conductivity with increase in discharge. Figure 6-2, which includes the highest discharge, shows a clear resemblance of the conductivity-discharge curve to a hysteresis curve; this is evidence of the gradual replacement of ground water in the river water by the runoff.

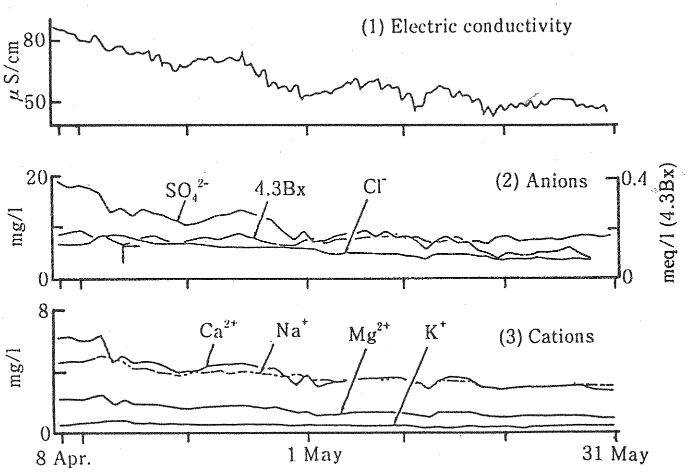

Figure 5 Changes in (1) electric conductivity, (2) anions and (3) cations

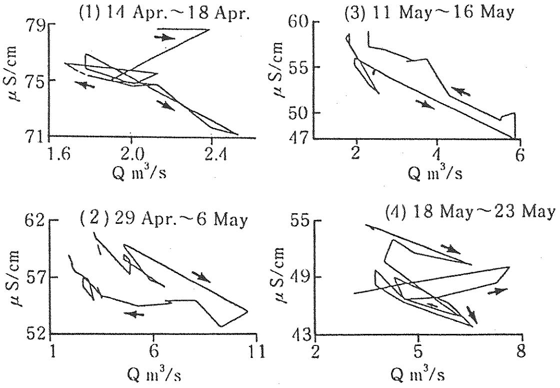

Figure 6 Relationship between discharge (Q) and electric conductivity

The inorganic components in the river water are influenced greatly by the ground water welling up from the Toyoha Seam, which lies within the catchment area. The sulfate ion (SO_4^{2-}) and the calcium ion (Ca^{2+}) corresponded with the electric conductivity; the changes in concentrations of other ions, such as the chloride ion or the sodium ion, were relatively small. The water from the seam is rich in sulfate and calcium ions. However, they, along with the other less abundant ions, are diluted by the snow melt. As shown in the comparison of chemical constituents in Figure 7, the concentration of the sulfate ion dropped toward average river levels (see point 29 May in the figure) as snow melt water entered the stream.

Suspended Solids and Organic Carbon (Figure 8)

The concentration of suspended solids (SS) corresponded to the discharge of the river, as can be seen by the increases in concentration during the three occurrences of high water (I, II and III) during the early part of the snow melting period. The increase did not occur during IV and V occurrences of high water. This is attributable to the dominance of the section of the stream in the mountains, where most of the snow fell on the plants, over the downstream portion of the river in the plain, where little snow fell. The concentration of total organic carbon (TOC) tended to be positively related to the concentration of the suspended solids, except during I. The absence of large changes in dissolved organic carbon (DOC) concentrations leads to the conclusion that the runoff load of total organic carbon depends mainly on suspended solids. The high values for suspended solids and particulate phosphorus during I (which will be commented upon later) are indications that the event was dominated by the runoff of soil particles from the lower parts of the watershed, while the total organic carbon accumulated in the forested area washed out later.

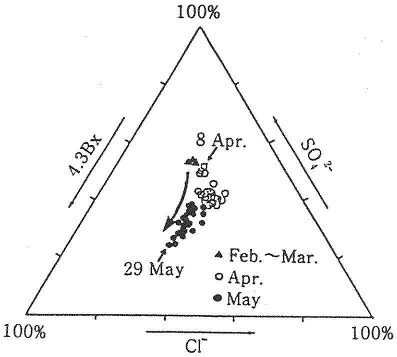

Figure 7 Ratio of anionic components during the snow melting period

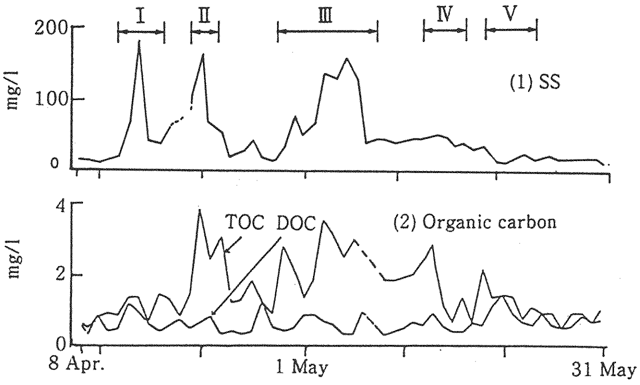

Figure 8 Changes in (1) SS and (2) organic carbon

Nitrogen and Phosphorus (Figure 9)

Changes in the concentration of the nitrogen and phosphorus compounds revealed a distinctly different pattern from the changes in the inorganic compounds during the process of snow melting. The total concentration of nitrogen (TN) and phosphorus (TP) compounds rose during the flood periods early in the snow melt period. This is because of the washingout of matter which had accumulated on

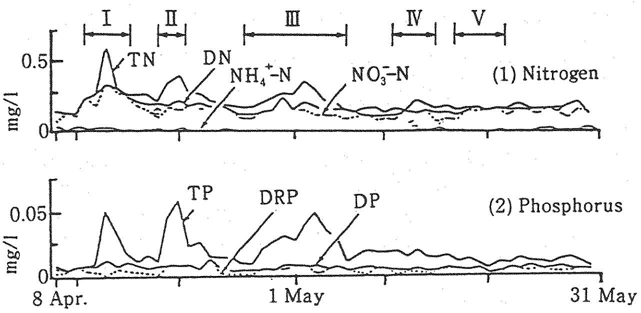

Figure 9 Changes in (1) nitrogen and (2) phosphorus

or near the soil surface. These release patterns are similar to runoff of suspended solids. This is clearly recognized in the case of particulate phosphorus (PP = TP - DP), upon which the tractive forces of the melt water running over the ground surface work to scour them away.

Much of the dissolved nitrogen was found to be in the form of the nitrate ion (NO_3^-), whose concentration was particularly high during the early part of the snow melting period. The nitrate ion which had accumulated in the soil under the oxidative condition was apparently washed out. During high water periods of II and III, the concentration of dissolved organic nitrogen (DN - TIN) increased, which was confirmed by the authors to have been washed out of the layer of organic soil. The main source of dissolved organic nitrogen was the organic substances contained in the soil and litter in the forest. That is the reason that the changes in the concentrations of all these are responsible for the changes in total organic carbon.

There were small changes in the total dissolved phosphorus (DP), but the concentration of dissolved reactive phosphorus (DRP) showed rather complex behavior during high water; for example, it decreased drastically in the occurrences of I and III, while during II it increased. Further, during III and especially I a high amount of dissolved organic phosphorus (DOP = DP - DRP) was observed, so it is hypothesized that an abundant amount of DOP was washed out of the surface layer with the suspended solids and other dissolved organic substances. Little was seen of the expected increase of nutrients during flood in the latter part of the melt period. This was attributed to the water from the area of the mountainous reaches thick with plants.

The N/P ratio is shown in Figure 10; both filtered and unfiltered samples showed only a narrow band of fluctuation. Nutrients were carried out in relatively stable composition. The mean value of nutrients in unfiltered samples was 11.8, and in filtered samples, 25.7.

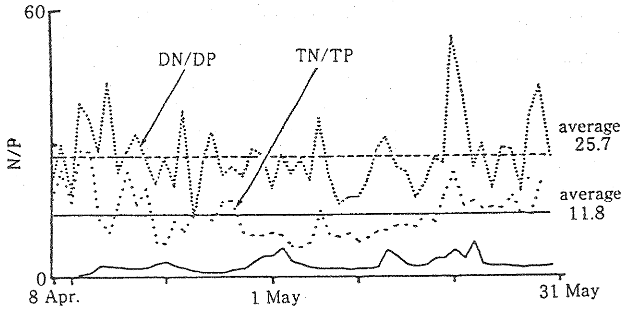

Figure 10 Changes in N/P ratio

Average Water Quality during Snow Melting Period

Table 1-1,1-2 shows the seasonal arithmetic mean values for chemical constituents in river Ogawa . The concentration of most of nutrients during the snow melting period was higher than the annual average, and was close to the summer value. The total nitrogen concentration during melting (0.222 mg/l in 1987, 0.236 mg/l in 1988) was within the meso-trophic condition (0.1 - 0.7 mg/l) (6), and the total phosphorus concentration (0.012 mg/l, 0.020 mg/l) was within eu-trophic condition (0.01 - 0.09 mg/l) (6). These values would undoubtedly have an impact on the ecology of the lower river and lakes.

The concentrations of carbon and chloride ion were relatively high during the snow melting period, probably due in the case of carbon to its runoff mechanisms being similar to those of nutrients. The large amount of chloride ion was probably observed because much of it came from atmospheric deposition and was trapped in the snow. The difference between the arithmetic mean value and the weighted mean value by discharage, which were calculated according to the load of nutrient runoff and river discharge, was not very large although the arithmetic mean of the particulate components was low.

Table 1-1 Seasonal and annual mean concentrations of chemical components (Sept. 1986 - Aug. 1987)

* Number of samples of some components are less than these values

unit: mg/l

	Seasonal mean					Annual mean	
	Autumn	Winter	Snow melting period	(weighted by discharge)	Summer		(weighted by discharge)
Numbers* of samples.	59	21	55		86	221	
Cl^-	4.6	4.7	7.2	6.4	4.5	5.2	5.7
SO_4^{2-}	13.1	17.4	11.2	8.9	10.7	11.9	9.6
Na^+	3.8	5.1	4.8	4.3	3.9	4.1	4.0
K^+	0.7	0.6	0.5	0.5	0.6	0.6	0.5
Ca^{2+}	4.4	6.4	4.6	4.0	4.2	4.4	4.0
Mg^{2+}	1.7	2.1	1.7	1.4	1.3	1.5	1.4
SiO_2**	15.4	20.6	11.4	10.2	17.1	15.3	12.1
DOC	1.7	1.2	0.9	1.0	1.4	1.3	1.2
POC	0.7	0.1	0.3	0.5	0.3	0.4	0.5
TOC	2.4	1.3	1.2	1.5	1.7	1.8	1.7
NH_4^+-N	0.013 (11.6)	0.013 (15.1)	0.026 (18.6)	0.023	0.024 (15.9)	0.020 (15.3)	0.019
NO_2^--N	0.004 (3.6)	0.003 (3.5)	0.004 (2.9)	0.004	0.004 (2.6)	0.004 (3.0)	0.004
NO_3^--N	0.095 (84.8)	0.070 (81.4)	0.110 (78.6)	0.116	0.123 (81.5)	0.108 (81.6)	0.106
TIN	0.112 [88.2]	0.086 [100.0]	0.140 [70.7]	0.143	0.151 [91.0]	0.133 [84.1]	0.130
DON	0.015 [11.8]	0.000 [0.0]	0.058 [29.3]	0.058	0.015 [9.0]	0.025 [15.5]	0.045
DN	0.127 <69.4>	0.086 < 94.5>	0.198 <89.2>	0.201	0.166 <70.9>	0.158 <75.5>	0.175
PON	0.056 <30.6>	0.005 < 5.5>	0.024 <10.8>	0.058	0.068 <29.1>	0.051 <24.3>	0.061
TN	0.183	0.091	0.222	0.258	0.234	0.209	0.236
DRP	0.006 (85.7)	0.003 (100.0)	0.002 (50.0)	0.003	0.002 (66.7)	0.003 (73.2)	0.003
DOP	0.001 (14.3)	0.000 (0.0)	0.002 (50.0)	0.002	0.001 (33.3)	0.001 (26.4)	0.002
DP	0.007 <53.8>	0.003 < 27.3>	0.004 <33.3>	0.005	0.003 <13.6>	0.005 <27.9>	0.005
PP	0.006 <46.2>	0.008 < 72.7>	0.008 <66.7>	0.015	0.019 <86.4>	0.012 <72.1>	0.014
TP	0.013	0.011	0.012	0.020	0.022	0.016	0.020

( ):per cent of TIN and DP、< >:per cent of TN and TP、 [ ]:per cent of DN

** determined by colorimetric method

Table 1-2 Seasonal and annual mean concentrations of chemical components (Sept. 1986 - Aug. 1987)

* Number of samples of some components are less than these values

unit: mg/l

	Seasonal mean					Annual mean	
	Autumn	Winter	Snow melting period		Summer		
Numbers*				(weighted by discharge)			(weighted by discharge)
of samples.	78	18	56		90	240	
Cl^-	4.9	5.2	6.2	5.7	3.6	4.9	5.2
SO_4^{2-}	13.0	16.8	10.5	8.5	14.2	14.2	9.5
Na^+	4.3	4.4	3.9	3.6	3.6	4.1	3.6
K^+	0.7	0.6	0.6	0.6	0.7	0.7	0.6
Ca^{2+}	4.6	5.3	4.1	3.7	5.3	4.9	3.9
Mg^{2+}	1.7	1.9	1.6	1.4	1.3	1.7	1.4
SiO_2^{**}	15.3	19.4	11.4	10.8	14.7	15.9	11.2
DOC	1.1	0.9	0.7	0.8	1.1	1.0	1.0
POC	0.4	0.1	0.9	1.0	0.8	0.5	0.9
TOC	1.5	1.0	1.6	1.8	1.9	1.5	1.9
NH_4^+-N	0.029 (25.2)	0.014 (15.4)	0.009 (5.6)	0.009	0.024 (14.7)	0.019 (15.3)	0.014
NO_2^--N	0.002 (1.7)	0.001 (1.1)	0.002 (1.2)	0.002	0.002 (1.2)	0.002 (1.3)	0.002
NO_3^--N	0.084 (73.0)	0.077 (84.6)	0.149 (92.5)	0.151	0.137 (84.0)	0.106 (83.5)	0.138
TIN	0.115 [85.2]	0.091 [91.0]	0.161 [85.6]	0.162	0.163 [100.0]	0.127 [91.0]	0.154
DON	0.020 [14.8]	0.009 [9.0]	0.027 [14.4]	0.025	0.000 [0.0]	0.013 [9.0]	0.020
DN	0.135 <90.6>	0.100 <90.1>	0.188 <79.9>	0.187	0.163 < 74.1]	0.139 <82.6>	0.173
PON	0.014 < 9.4>	0.011 < 9.9>	0.048 <20.3>	0.056	0.057 < 25.9>	0.029 <17.4>	0.051
TN	0.149	0.111	0.236	0.243	0.220	0.169	0.224
DRP	0.003 (60.0)	0.004 (57.1)	0.005 (71.4)	0.006	0.002 (18.2)	0.003 (45.6)	0.004
DOP	0.002 (40.0)	0.003 (42.9)	0.002 (28.6)	0.002	0.009 (81.8)	0.005 (54.4)	0.002
DP	0.005 <62.5>	0.007 <77.8>	0.007 <35.0>	0.007	0.011 < 52.4>	0.008 <55.2>	0.006
PP	0.003 <37.5>	0.002 <22.2>	0.013 <65.0>	0.015	0.010 < 47.6>	0.006 <44.8>	0.012
TP	0.008	0.009	0.020	0.022	0.021	0.014	0.019

( ):per cent of TIN and DP、< >:per cent of TN and TP、[ ]:per cent of DN

* determined by colorimetric method

Table 2 shows the variation coefficients of the concentrations of the various components for the full 1987 period and the snow melting period. The variation coefficients during the snow melting period are low. The differences between the two periods are very large in the case of ammonia nitrogen (NH_4^+ -N), dissolved phosphorus (DP, DRP) and dissolved organic carbon(DOC).

A notable characteristic was the low variations in concentration of the chemical components washed out during the snow melting period from where they had been collected in the snow and soil.

Runoff Loads of Chemical Components

Table 3-1,3-2 shows the seasonal specific runoff load. As the total discharge during the two months of the snow melting period was about 60% of the yearly loads, and the concentrations of the chemical components were near to the annual values, as described above, the immensity of the runoff loads during the snow melting period is apparent. The melt period runoff loads of total nitrogen and total phosphorus were 60 - 70% of the annual loads, being higher than the proportion of the discharge.

Table 2 Variation coefficients of chemical components
(Standard deviation/Mean value)
(Numbers of samples *192-239, **55-56)

	Sept.1987* - Aug.1988	Snow melting period.** (1988)
Cl^-	0.253	0.207
SO_4^{2-}	0.235	0.368
SiO_2***	0.233	0.149
Alkalinity(4.3Bx)	0.109	0.086
DOC	0.982	0.420
TOC	0.729	0.538
NH_4^{3+}-N	0.958	0.498
NO_2^--N	0.460	0.467
NO_3^--N	0.431	0.371
TIN	0.381	0.350
DN	0.355	0.273
TN	0.456	0.375
DRP	1.150	0.502
DP	0.861	0.286
TP	0.806	0.619

*** determined by colorimetric method

Nearly all nitrogen and phosphorus compounds were at high loads during the melt period. The ammonia nitrogen showed a low level of 38.1% during the 1987 period, but this is probably anomalous. Ammonia is usually at low concentrations and is extremely reactive, so its level is quickly influenced by climate and flow conditions.

The authors expected to find higher runoff loads of particulate nitrogen (PON) and phosphorus (PP), whose concentrations usually rose at times of high water, but these showed little difference in their proportion of runoff from normal levels. This was probably due to the lower amounts of materials washed out of the surface layer of the soil in the latter part of the snow melting period. Components other than nutrients washed out were also at or near their annual levels of proportion of the discharge. The proportion of dissolved organic carbon (DOC) was low, but this is to be expected as decomposition of organic substances is slow at the low temperatures of winter, resulting in little deposition of this constituent. A comparison of the runoff loads of total nitrogen and phosphorus in river Ogawa with those of other rivers in Japan (7) showed that the Ogawa is a little higher than average. Thus,it is clear that eutrophication occurs in cold regions.

The precipitation of 2000 mm in the Mt. Muine - Mt. Nagao area, 1.7 times the average for Hokkaido, is a unique feature of this environment.

Runoff Types of Chemical Components

The runoff loads of chemical components based on the samples from the whole two years and from the snow melting period of the 1988 period are arranged in the form $L = c \times Q^n$ in Table 4, where L is **specific load of component<concentrartion x discharge per area>, Q is discharage per area)**, C and n are constants. Comparing the values of c and n, there are only minor differences between the properties of samples during the snow melting period and the whole two years. In both periods the exponent n was larger than 1.0 for all the nutrients except NH_4^+-N, while n was

Table 3-1 Seasonal and annual specific loads of chemical components (Sept. 1986 - Aug. 1987) (*: x $10^3 m^3/km^2/day$, **: x $10^3 m^3/km^2/year$)

	Autumn	Winter	Snow melting period	Summer	(Sept.1986-Aug.1987)	
	kg/km²/day	kg/km²/day	kg/km²/day	kg/km²/day	kg/km²/day	kg/km²/year
Q	5.5*	0.6*	19.7*	4.4*	5.8*	2130**
%	21.4	3.3	56.4	18.9		
Cl^-	26.5	15.3	126.3	19.5	37.0	12000
%	18.1	3.0	64.0	14.9		
SO_4^{2-}	66.0	9.4	174.6	35.5	56.1	20500
%	26.4	5.6	52.0	16.0		
Na^+	20.5	2.7	84.0	2.2	23.5	8570
%	19.6	3.8	59.8	16.8		
K^+	3.8	0.3	10.0	2.2	3.2	1160
%	26.6	3.5	52.5	17.4		
Ca^{2+}	23.9	3.4	77.8	15.8	23.5	8570
%	22.9	4.8	55.4	17.0		
Mg^{2+}	9.2	1.2	27.2	5.0	8.2	3010
%	25.0	4.7	55.2	15.2		
SiO_2	76.4	10.9	200.0	63.7	70.3	25600
%	24.4	5.1	47.6	22.8		
DOC	8.8	0.7	19.7	5.3	6.8	2500
%	28.8	3.3	48.3	19.6		
POC	4.0	0.1	10.2	2.1	3.2	1150
%	30.7	1.0	52.1	16.1		
TOC	12.8	0.7	29.9	7.4	10.0	3650
%	28.8	2.4	50.0	18.7		
NH_4^+-N	0.064 (11.6)	0.008 (17.4)	0.458 (16.3)	0.088 (15.0)	0.116 (15.3)	42.2
%	12.4	2.3	66.2	19.1		
NO_2^--N	0.021 (3.9)	0.002 (3.5)	0.086 (3.0)	0.015 (2.6)	0.024 (3.1)	8.6
%	20.2	2.3	60.9	16.5		
NO_3^--N	0.466 (84.8)	0.037 (78.9)	2.276 (80.7)	0.484 (82.8)	0.619 (81.6)	226
%	16.9	2.0	61.4	19.7		
TIN	0.550 [81.1]	0.047 [100.0]	2.819 [71.2]	0.585 [78.2]	0.758 [84.1]	277
%	16.3	2.0	62.2	19.5		
DON	0.128 [19.9]	0.000 [0.0]	1.139 [28.8]	0.161 [21.8]	0.260 [15.5]	94.9
%	11.1	0.1	73.3	15.6		
DN	0.678 <61.9>	0.047 < 95.9>	3.958 <77.8>	0.746 <72.1>	1.017 <74.1>	371
%	15.0	1.5	65.0	18.5		
PON	0.417 <38.1>	0.002 < 4.1>	1.132 <22.2>	0.288 <27.9>	0.356 <25.9>	130
%	26.3	0.2	53.1	20.4		
TN	1.096	0.049	5.090	1.034	1.374	501
%	17.9	1.2	61.9	19.0		
DRP	0.025 (69.6)	0.002 (100.0)	0.055 (55.0)	0.006 (37.5)	0.017 (56.6)	6.2
%	33.2	4.4	54.0	8.4		
DOP	0.011 (14.3)	0.000 (0.0)	0.045 (45.0)	0.010 (62.5)	0.013 (43.4)	4.6
%	19.6	0.2	59.0	21.1		
DP	0.036 <41.9>	0.002 < 50.0>	0.100 <25.3>	0.016 <14.8>	0.030 <26.3>	10.9
%	27.5	2.6	56.1	13.8		
PP	0.050 <58.1>	0.002 < 50.0>	0.295 <74.7>	0.092 <85.2>	0.084 <73.7>	30.6
%	13.3	0.5	58.6	27.6		
TP	0.086	0.004	0.394	0.108	0.114	41.5
%	17.0	1.0	58.0	24.0		

( ):per cent of TIN and DP、< >:per cent of TN and TP、[ ]:per cent of DN

less than 1.0 for the principal inorganic ions. Consequently, the melting seasons have great runoff loads of nutrients.

Of particular note is NO_3^--N, an important source of nitrogen, whose correlation coefficient in the form of $L = C \times Q^n$ was 0.95 during the melt period (compared with 0.93 for all samples). These facts show that the nitrate ion is produced rapidly in forest areas and stored in abundance in soil and in accumulated snow. Because the concentration of NH_4^+-N was low compared with NO_3^--N, and n was under 1.0 (it was a runoff dilution type) for NH_4^+-N and the correlation coefficient was low at 0.82 which revealed high variation of production rate (0.83 for all samples), there is evidently a limit to the amount which can be produced and accumulate during winter.

The level of n for particulate phosphorus was 1.50, taking similar values for suspended solids (1.78). The result shows that phosphorus was bound to soil particles which were washed downstream. As explained earlier in the section on

Table 3-2 Seasonal and yearly specific loads of chemical components (Sept. 1986 - Aug. 1987) (*: x $10^3 m^3/km^2/day$, **: x $10^3 m^3/km^2/year$)

	Autumn	Winter	Snow melting period	Summer	(Sept.1986-Aug.1987)	
	kg/km²/day	kg/km²/day	kg/km²/day	kg/km²/day	kg/km²/day	kg/km²/year
Q	3.6*	0.6*	17.1*	3.9*	4.9*	1740**
%	18.6	3.9	60.1	17.5		
Cl^-	17.8	2.8	97.7	13.9	25.6	9020
%	18.0	3.9	66.1	12.1		
SO_4^{2-}	43.6	8.9	145.0	33.6	46.9	16600
%	24.0	6.5	53.5	16.0		
Na^+	15.0	2.4	61.5	11.6	17.9	20800
%	21.5	4.7	59.3	14.5		
K^+	2.7	0.3	9.5	2.1	2.9	6820
%	23.8	3.7	56.6	15.8		
Ca^{2+}	15.6	2.9	62.6	15.5	19.3	2470
%	20.8	5.2	56.0	18.0		
Mg^{2+}	6.0	1.0	24.4	3.9	7.0	6330
%	21.9	5.1	60.4	12.6		
SiO_2	51.1	10.5	184.9	45.7	59.0	1030
%	22.3	6.2	54.2	17.3		
DOC	5.6	0.5	13.0	4.4	4.8	1710
%	29.6	3.4	46.4	20.5		
POC	2.6	0.0	17.6	3.1	4.5	1560
%	15.2	0.0	66.8	15.8		
TOC	8.2	0.5	30.6	7.5	9.3	3270
%	22.8	1.9	57.1	18.2		
NH_4^+-N	0.097 (21.8)	0.008 (15.7)	0.147 (5.3)	0.060 (9.1)	0.067 (8.8)	23.5
%	37.7	4.0	38.1	20.2		
NO_2^--N	0.007 (1.6)	0.001 (2.0)	0.035 (1.2)	0.005 (0.9)	0.009 (1.2)	3.3
%	19.2	2.9	63.6	14.3		
NO_3^--N	0.343 (76.7)	0.042 (82.3)	2.588 (93.5)	0.585 (90.0)	0.682 (90.0)	241
%	13.0	2.2	65.6	19.2		
TIN	0.448 [85.1]	0.051 [100.0]	2.770 [86.5]	0.650 [99.6]	0.757 [88.6]	267
%	15.3	2.3	63.2	19.2		
DON	0.078 [14.9]	0.004 [0.0]	0.431 [13.5]	0.003 [0.4]	0.097 [11.4]	34.2
%	20.8	1.5	77.1	0.7		
DN	0.526 <83.4>	0.055 < 91.7>	3.201 <77.1>	0.653 <71.4>	0.854 <77.2>	301
%	15.9	2.2	64.8	17.1		
PON	0.105 <16.6>	0.005 < 4.1>	0.953 <22.9>	0.262 <28.6>	0.252 <22.8>	88.9
%	10.7	0.6	65.4	23.2		
TN	0.631	0.060	4.154	0.914	1.106	390
%	14.7	1.9	64.9	18.5		
DRP	0.011 (68.8)	0.002 (66.6)	0.094 (76.3)	0.007 (30.4)	0.021 (68.5)	7.5
%	13.6	3.7	75.8	6.9		
DOP	0.005 (31.2)	0.001 (33.4)	0.029 (23.7)	0.015 (69.6)	0.010 (31.5)	3.5
%	11.3	3.3	51.0	34.4		
DP	0.016 <40.0>	0.003 < 75.0>	0.123 <32.9>	0.022 <31.7>	0.031 <34.0>	11.0
%	12.9	3.5	68.0	15.6		
PP	0.024 <60.0>	0.001 < 25.0>	0.250 <67.1>	0.047 <68.3>	0.061 <66.0>	21.3
%	10.5	0.7	71.5	17.3		
TP	0.040	0.004	0.373	0.068	0.092	32.3
%	11.3	1.7	70.3	16.7		

( ):per cent of TIN and DP、< >:per cent of TN and TP、[ ]:per cent of DN

electrical conductivity and principal inorganic components, n was lower than 1 for the principal inorganic ions because many of these inorganic components originate from point sources.

Conclusions

A two-year survey of the river Ogawa and its catchment area (Sapporo, Hokkaido) was carried out to find the characteristics of water quality and discharge, focusing on nutrients, their influence on the lower river environment and control of eutrophication. The snow melting period is defined as from April to May based on the yearly pattern of river flow; summer is from June to August, autumn from September to November and winter from December to March.

Table 4 Relationships between flows and loads of chemical components
($L = c \cdot Q^n$, L: Load of component (g/s), Q: Discharge (m^3/s), c, n: Constant)
* CC: Correlation coefficient

	Sept.1986-Aug.1988				Snow melting period(1988)			
	c	n	CC*	Numbers of samples	c	n	CC	Numbers of samples
Cl^-	5.10	1.06	0.99	433	6.38	1.00	0.98	48
$SO_4{}^{2-}$	10.2	0.80	0.98	435	11.40	0.72	0.95	51
Na^+	3.88	0.95	0.99	425	4.03	0.90	0.99	50
K^+	0.59	0.91	0.99	424	0.60	0.93	0.99	50
Ca^{2+}	4.13	0.88	0.99	420	4.45	0.82	0.99	50
Mg^{2+}	1.43	0.94	0.98	419	1.72	0.83	0.98	50
SiO_2	12.8	0.86	0.99	433	11.97	0.89	0.99	48
DOC	0.96	0.97	0.91	422	0.59	1.11	0.95	52
TOC	1.50	1.05	0.93	435	1.26	1.20	0.93	52
POC					0.64	1.19	0.71	44
$NH_4{}^+$-N	0.014	0.89	0.83	431	0.57	0.81	0.82	53
$NO_2{}^-$-N	0.0025	1.06	0.91	436	0.0014	1.14	0.92	53
$NO_3{}^-$-N	0.10	1.03	0.93	438	0.14	1.06	0.95	53
TIN	0.13	1.02	0.95	439	0.15	1.05	0.95	53
DN	0.16	1.08	0.97	430	0.18	1.02	0.95	53
TN	0.20	1.11	0.96	427	0.21	1.08	0.96	53
PON					0.036	1.16	0.69	42
DRP	0.0025	1.06	0.87	440	0.0043	1.11	0.91	53
DP	0.0047	0.99	0.87	439	0.0071	1.00	0.97	53
TP	0.012	1.09	0.88	438	0.015	1.22	0.92	53
PP					0.0066	1.50	0.88	53
SS					180	1.78	0.87	50

Runoff during Snow Melting Period

(1) The snow melting runoff period of the river Ogawa was from early April to late May. The total discharge during this period amounted to 60% of the annual discharge.

(2) The change of the discharge showed a gradual decline as the ambient temperature rose and rainfall increased.

Water Quality during the Snow Melting Period

(1) Changes in the concentration of chemical components during the melting period indicated that nutrients consist mainly of soil particles and accumulated substances in the soil, while principal inorganic ions consist mainly of substances in the ground water and snow.

(2) During the snow melting period nitrogen was mainly carried to the river in solution, while phosphorus was mainly taken away in particulate form. Most of the dissolved nitrogen was in the form of nitrates. In early flood periods high concentrations of dissolved organic nutrients were observed, being attributed to the runoff of substances accumulated in the soil. The general stability of the N/P ratio indicates that nutrients exists in a stable composition.

(3) The average water quality during the snow melting period and summer were approximately the same; phosphorus was at eutrophic levels, while nitrogen was at mesotrophic levels.

Runoff Types of Chemical Components during the Snow Melting Period

(1) The runoff loads of discharge during the snow melting period were about 60% of the annual discharge, but the loads of nutrients apart from ammonium nitrogen were above this level. In general, inorganic constituents were at levels equal to or slightly lower than the annual discharge.

(2) The runoff types of chemical components during the snow melting period (described herein by L (c x Q) = C x Q^n) closely followed the year-round trends. Nutrients other than ammonia nitrogen and organic carbon showed a high tendency (with $n > 1$) to increase in concentration when river discharge increased. This tendency was particularly dominant for particulates. Most inorganic constituents showed fixed concentrations ($n = 1$) or were slightly lowered by dilution. Values of n for nitrate nitrogen, which are the dominant sources of nitrogen in river water, remained close to 1, which showed that an abundant quantity of nitrates are produced and stored in the forest area.

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