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Wide Area Distribution of Nitrogen Concentrations in Mountain Streams of Hyogo Prefecture, Japan

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Abstract

To study the relationship between the concentrations of nitrogen in mountain streams, and anthropologic and natural factors, the water chemistry of the mountain streams in the entire Hyogo Prefecture, Japan, were investigated. A thousand mountain streams were investigated between 1998 and 2001. The concentrations of nitrate nitrogen ranged from 2.92 to 0.1 mg/L, with an arithmetic mean value of 0.45 mg/L. A number of streams showing more than 1.0 mg/L of nitrate nitrogen accounted for 8% of the mountain streams investigated. These results indicated that the concentrations of nitrate nitrogen in the mountain streams were low in the entire Hyogo Prefecture. In general, the mountain stream water in Hyogo Prefecture appears to not have been affected by wet and dry deposition originating from anthropologic sources in mountain streams and Japan. On the other hand, sites with more than 0.8 mg/L nitrate nitrogen were distributed over the entire Hyogo Prefecture, which were classified into five groups. Each group showed unique geographical, geological and anthropological characteristics. No common characteristic among five groups were discover. These results suggest that the cause of high concentrations of nitrogen in mountain streams is not from a uniform set of conditions.

Keywords: Nitrogen, Mountain stream, Geography, Geology, Vegetation, Dry and wet deposition

1. Introduction

The nitrogen concentrations in mountain streams are generally low. Streams showing higher concentrations of nitrogen, that is more than 1 mg/L, have recently been reported in mountains encircling Tokyo metropolitan area, Japan [1, 2], as has been found in both Europe and North America [3, 4]. This phenomenon might be caused by nitrogen saturation in forested areas, which is a hypothesis connected with increasing deposition of nitrogen oxides gases derived from anthropologic sources, such as automobiles and industry [3, 4]. Kawakami et al. [5]discovered the higher concentrations in some mountain streams of Toyama Prefecture, and they think that it would be caused by nitrogen saturation. This fact suggests that much of the nitrogen absorbed and accumulated in forest ecosystems will flow out of forested areas. Some hypotheses suggest that soil microbial activity [6] or weathering of sedimentary rock that include high concentrations of nitrogen are potential origins [7]. However, no hypothesis has currently succeeded in a unified explanation for why there should be high nitrogen in mountain streams compared to that from precipitation.

Conversely, lower concentrations of nitrogen in stream water have been reported in Kansai area, western Japan. As a result of vigorous investigations, Mt. Rokko near Kobe [8] or Kinki district [9] has shown high concentrations of nitrogen. Recently, Sindo et al. [10] investigated the nitrogen concentrations in mountain stream water over all of Japan. They also found higher concentrations of nitrogen in urban areas, such as Tokyo and Osaka, and in areas of heavy precipitation facing continental Asia opposite the Japan Sea. They also think it may be caused by wet and dry deposition originating from domestic anthropologic sources and long distant transportation from continental Asia, respectively. There is: however, data relating to the concentrations of nitrogen in mountain streams in Kansai area, western Japan, are limited. For instance, they obtained data from only twenty to thirty mountain streams in each prefecture, but far more mountain streams need to be study to find the relationship between high concentrations of nitrogen and various sources.

Therefore; herein, high density sampling of mountain streams in Hyogo Prefecture, Japan, was undertaken, with the

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relationships between concentrations of nitrogen and natural and anthropologic factors studied.

2. Materials and Methods

Mountain stream water was taken once a year, between October and December from 1999 to 2001 from the sampling sites shown in Fig. 1. As a general rule, sampling was avoided on rainy days. The sampling sites were chosen in advance using a topographic map supplied by the National Geographical Survey Institute. Mountain stream water was store in polypropylene bottles in refrigerator until analyzed. Anthropologic evidence, such as houses, electric poles, farm land, dams and gavages, was confirmed on site, with samples only collected from sites showing no such markers.

Water chemistry, including electro-conductivity (EC) and water temperature, and pH, were measured on site using an EC meter and pH meter, respectively, with major ionic species

analyzed in the laboratory by ion chromatography after filtration using a membrane filter, with a 0.22 μm pore size. Nitrate, nitrite and ammonium were calculated as nitrogen.

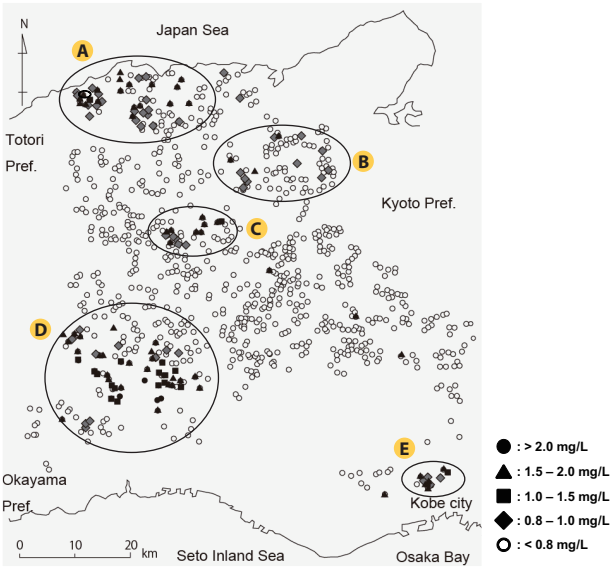

Fig. 1. Sampling sites and concentrations of nitrate nitrogen in mountain streams of Hyogo prefecture, Japan.

3. Results and Discussion

3.1. Concentrations of Nitrogen

The concentrations of nitrate nitrogen are shown in Fig. 1 as the horizontal distribution of nitrogen. A histogram, which is a close logarithmic normal distribution, is shown in Fig. 2, with the associated statistics. The maximum and minimum nitrate nitrogen values were 2.92 and 0.1 mg/L, respectively, with an arithmetic mean value of 0.45 mg/L. Seven hundred and ten sampling sites showed less than 0.5 mg/L, accounting for 68% of all sites. On the other hand, sites showing more than 1.0 mg/L nitrate nitrogen accounted for 8% of the total sampling sites. This result indicated that the concentrations of nitrogen nitrate were lower in mountain streams in Hyogo Prefecture, Japan.

The sites showing more than 0.8 mg/L were classified into five groups, as shown in Fig. 1. The natural features of these five groups are summarized in Table 1.

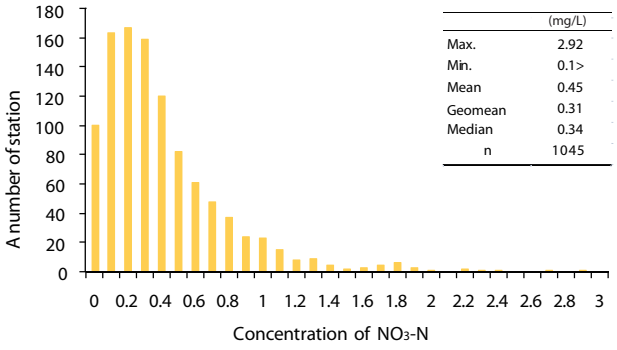

Fig. 2. Histogram of the concentrations of nitrate nitrogen in mountain streams of Hyogo Prefecture, Japan.

Table 1. Characteristics of the five groups showing high concentrations of nitrogen in mountain stream water, Hyogo Prefecture, Japan

Group	District in Hyogo	Climatic type	Precipitation (mm/y)	Major geology	Major vegetation
A	North and north west	Japan Sea coast	1,900~2,000	Granite (San-in), cenozoic sedimentary rock	Deciduous broad-leaved tree
B	Northeast	Japan Sea coast	1,300~1,500	Granite (San-in), rhyolitic tuff	Japanese cypress, cryptomeria, deciduous Zbroad-leaved tree
C	Middle	Japan Sea coast	1,300~1,400	Metamorphic rock, paleozoic sedimentary rock (Maizul group)	Japanese cypress, cryptomeria, deciduous broad-leaved tree
D	Southwest	Seto Inland Sea coast	1,100~1,500	Metamorphic rock, paleozoic sedimentary rock (Tanba group)	Deciduous broad-leaved tree
E	Southeast	Seto Inland Sea coast (Mt. Rokko)	1,500~2,000	Granite (Rokko)	Red pine, deciduous broad-leaved tree

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3.2. Relationship Between Natural and Anthropologic Characteristics and Concentrations of Nitrogen

The geographic dimensions of these groups differed greatly. For example, the groups were distributed from north to south, west to east and middle in whole Hyogo Prefecture, as shown in Table 1. Groups A and B, in the north and northeast, were located near the Japan Sea. Group C was in the mountain area in the middle of Hyogo Prefecture, Group D the eastern area and Group E was southeast of Mt. Rokko, in the area of Seto Inland Sea National Park. The altitudes of these groups were between less than 100 m and about 1,000 m. The major directions of the small watershed also differed.

The geology is a basic factor relating to water quality. The five groups were distributed in areas with different geologies, such like igneous, sedimentary and metamorphic rock. The major geology in Group A area was the Yadagawa Group, a Tertiary system and volcanic sediment, that in Group B area was San-in granite, that in Group C was Yakuno complex and Paleogic sediment, and called the Maizuru group, that in Group D area was Paleozoic and Mesozoic sediment, known as the Tanba Group, as well as basic metamorphic rock known as the Yakuno complex, and that in Group E was Rokko granite. The ages of Rokko and San-in granites are similar. It is well-known that the nitrogen concentrations in Paleozoic and Mesozoic sediments and basic metamorphic rocks are higher than those of granite. These results suggest that each group showing higher nitrogen concentrations were did not have common geological features.

The five groups also exhibited different forms of major vegetation. Groups A, B, C, and E consisted of secondary forest, including broad leaf and conifer trees, Japanese cypress and cryptomeria planted forest.

The districts of Groups A, B, and C had small populations and little industry. The sampling sites in these groups were far from arterial roads as shown in Fig. 3 ; therefore, direct air pollution due to automobiles would be negligible. On the other hand, the Chugoku Highway passes through the middle of Group D area, which faces the Hanshin industrial district, with many roads running through the mountain. However, the quality of the stream water located near roads did not indicate higher concentrations of nitrogen.

As the area is subject to heavy snow and strong wind from continental East Asia in winter, the water quality of the mountain streams might be affected by the deposition of air pollutants, such as NO_x and SO_x from continental Asia.

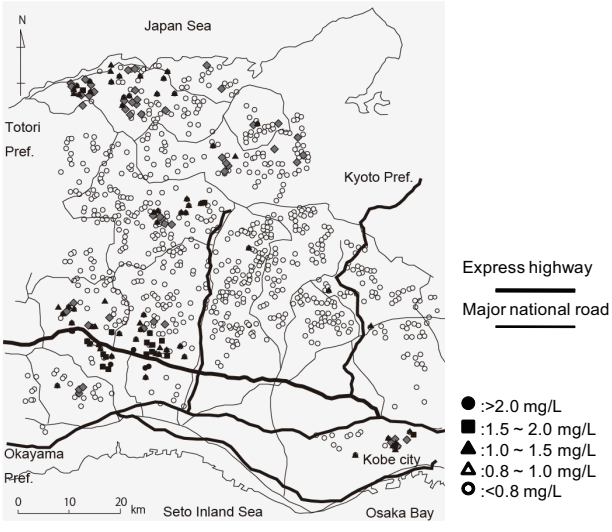


Fig. 3. Express highway and major national loads in Hyogo Prefecture, Japan.

3.3. Relationship Between Sites Showing More Than 1 mg/L of Nitrate Nitrogen in Five Groups

The Geographical feature of sites showing more than 1 mg/L of nitrate nitrogen in five groups is summarized in Table 2. No relationship between the concentrations of nitrate nitrogen and the distance from the Japan Sea or the Seto Inland Sea, farmland, and main roads was found out as shown in Fig. 4. The cluster analysis was applied to classify these sites, which parameters were altitude, inclination, direction of watershed on each site, precipitation, geology, vegetation. The dendrogram is shown in Fig. 5. As a result, group A, D and E was classified into different

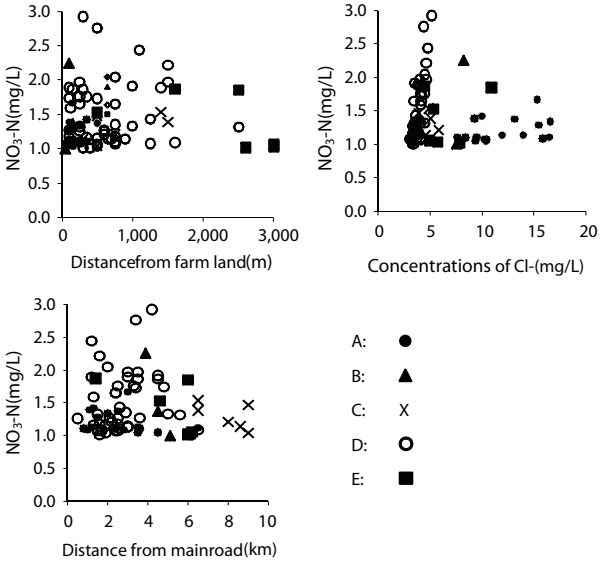
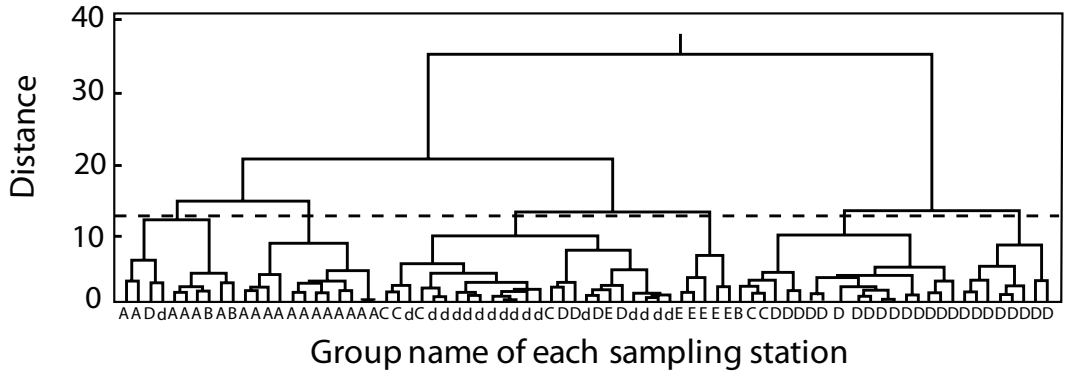


Fig. 4. Relationship between the concentrations of nitrate nitrogen and the distance from the Japan Sea or the Seto Inland Sea, farmland, and main roads.

Table 2. Geographical feature of sites showing more than 1.0 mg/L of nitrate nitrogen in five groups

Group	A number of sites	Major direction of watershed on each site	Inclination (rad.)	Altitude(m)
A	18	E:6,NE:3,W:3,N:2, SW:2, SE:1, NW:1	0.10-0.73	40-230
B	3	NW:2,N:1	0.10-0.27	150-240
C	6	NE:3, SE:2,W:1,	0.16-0.23	190-370
D	46	S:15, SW:7, NW:6, SE:6, N:5, E:4, W:3	0.06-0.73	140-420
E	6	E:2, S:2, N:1, NW:1	0.08-0.25	200-800



*1: A~E show Group name of sampling stations which concentrations of NO_3-N is more than 1 mg/L.
*2: d means Aioi Group (Rhyolitec faces) in Group D.

Fig. 5. Dendrogram by cluster analysis for five groups.

group. Especially, group D was separated to two subgroups by geology. These results demonstrate that no common characteristic among five groups were discover.

3.4. Annual Changes in the Concentrations and Depositions of Nitrate

The annual changes in the concentrations and depositions of nitrate in Hyogo Prefecture are shown in Fig. 6. The three sites are located in different regions; Kobe in a typical urban area, Toyooka near to the Japan Sea, and Tanba in the middle of Hyogo Prefecture. Toyooka, which has the most precipitation, showed the highest concentration and deposition of nitrate. Kobe and Tanba had similar concentrations and amounts of deposition. However, except for this geographical fact, no clear evidence proving the influence of long distance transportation from continental eastern Asia was recognized.

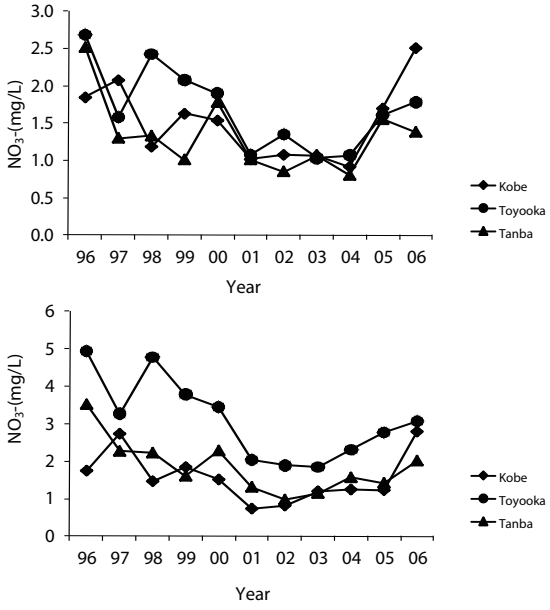


Fig. 6. Yearly changes of concentrations and deposition of nitrate in Hyogo Prefecture, Japan.

4. Conclusions

These results indicated that the concentrations of nitrate nitrogen in mountain streams were lower over the entire Hyogo Prefecture. In general, the mountain stream water in Hyogo Prefecture does not appear to have been affected by wet and dry deposition originating from anthropologic sources in mountain streams. On the other hand, the sites with more than 0.8 mg/L nitrate nitrogen were distributed over the entire Hyogo Prefecture. The sites were classified into five groups, with each showing different geographical, geological and anthropological characteristics. However, no common characteristics between the five districts were discovered. These results suggest that the cause of high concentrations of nitrogen in mountain streams was not due to a uniform set of conditions.

Acknowledgements

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