論　文

Yearly Changes in Nitrate Ion Concentration Responding to Annual Precipitation in the Uppersection of the Ishite River

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石手川上流部における年降水量に対応した硝酸イオン濃度の年変化

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要　旨　愛媛県下を流れる石手川の上流部に調査地点を２箇所設けて，７年間にわたって毎月１度，硝酸イオン濃度を測定した。その結果，特別の条件下にある場合を除くと，硝酸イオン濃度の年平均値と年降水量とが正の対応関係をもつことが示唆された。次に，単一の降雨が川水中の硝酸イオン濃度に及ぼす効果を，石手川源流で春と秋に検討したところ，降雨後に硝酸イオン濃度が高まることが認められた。多数の降雨の効果が集積して硝酸イオン濃度の平均値を高めるであろうことを考えると，この結果は，年間降水量と年平均硝酸イオン濃度との間にみられる，前述の長期的傾向を支持するとみられる。

Summary: At two stations in the uppersection of the Ishite River, Ehime Prefecture, Japan, nitrate ion concentration was examined once a month for 7 years. The results suggested the existence of a positive relationship between annual precipitation and annual mean nitrate ion concentration, involving an exception in a particular condition. Supplementary investigation on the effects of one rainfall on nitrate ion concentration was carried out in the headstream area in the spring and the autumn. Higher nitrate ion concentration was observed after a rainfall, which appeared to support the long-term tendency between annual precipitation and annual mean nitrate ion concentration, because the cumulative effects of many rainfalls would result in increasing mean nitrate ion concentration in the streamwater.

I　INTRODUCTION

Recently many lakes and reservoirs have become eutrophicated, and high loadings of

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phosphorus and nitrogen have generally been considered to be important causal factors (REYNOLDS, 1984). In the mountain forest area, forest clearcutting was found to bring about a high nitrate ion concentration as well as high nitrogen loading in the mountain stream (LIKENS *et al.*, 1970). Some investigations on the regulatory function of the forest upon the element discharge into a stream were then carried out from the standpoints of ecology (VITOUSEK, 1977), Forest working plan (MARTIN and PIERCE, 1980), and forest types (MARTIN *et al.*, 1984). In the present paper we report on a new point of view, an interesting

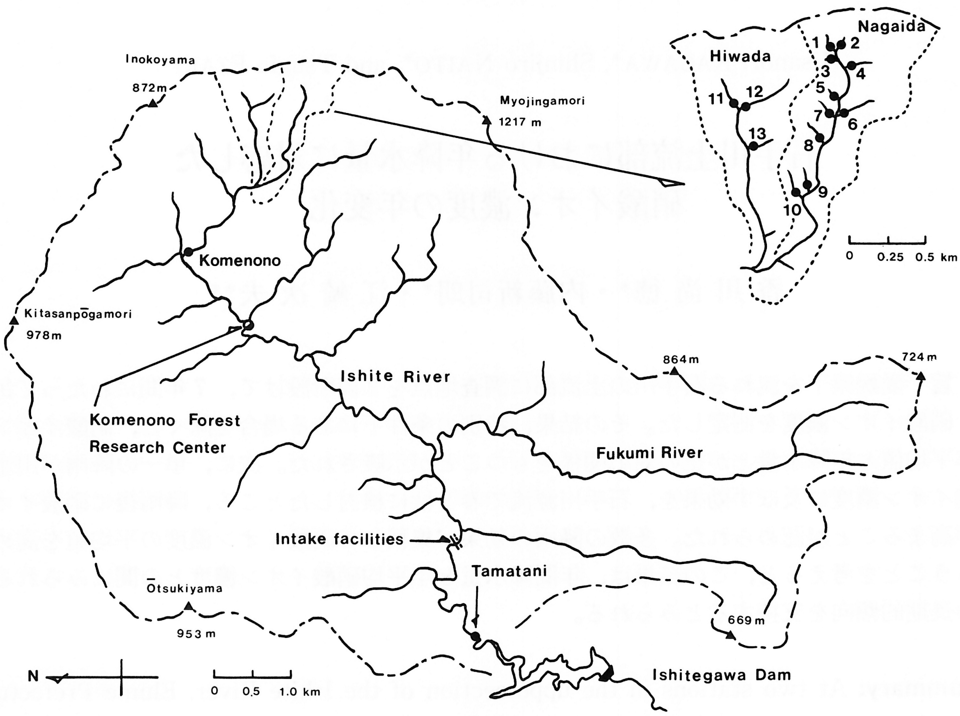

Fig.1. Map of study area. Broken and dotted lines show large and small watersheds concerned in this study. Solid circles indicate water sampling sites.

relationship between the annual mean nitrate ion concentration and the annual precipitation in the upstream forest area of the Ishite River, Ehime Prefecture, Japan.

II METHODS

1. Study area

The study area is shown in Fig.1. Above the Ishitegawa Dam Reservoir (33°53′N latitude, 132°50′E longitude), the Ishite River basin, an area of 59km², is surrounded by low forested mountains from 669m to 1217m above sea level. In this watershed, two water sampling stations, Tamatani and Komenono, were set up 214m and 450m above sea level, respectively, along the main stream for a 7-year water quality examination. Tamatani is located on the inflow site of the river to the reservoir. Upstream to Komenono, 9.6km from Tamatani, some settlements as well as arable lands exist, and the forest stretches above Komenono.

In the headwater area beyond Komenono, there are two small watersheds, Hiwada and Nagaida, as shown in Fig.1. In these two watersheds, 13 streams in the first order were used in comparative water quality examinations before and after a rainfall. In Hiwada 21.5% and in Nagaida 60.3% of the surface area is covered by natural forests consisting of deciduous broad-leaved trees, *e.g. Euptelea polyandra* SIEB. et ZUCC., *Quercus mongolica FISCH.* var. *grosseserrata* REHD. et WILS., and/or *Fagus crenata* BLUME, or of evergreen coniferous trees, *e.g. Abies firma* SIEB. et ZUCC. and *Tsuga sieboldii* CARR., depending on the lay of the land. The remaining areas are artificially forested with *Cryptomeria japonica* D. DON or *Chamaecyparis obtusa* SIEB. et ZUCC. Brown forest soil has developed on the bedrock of coarse-grained granodiorite in these watersheds.

2. Seven-year water quality examination

Once a month from January 1978 to December 1984, we sampled surface water for chemical analyses at Tamatani. Flood periods were avoided so that the stream was almost always shallow (*ca.* 0.2m in the maximum depth) and *ca.* 4m wide. Water sampling was also carried out at Komenono from June 1978 to March 1981 and from November 1983 to December 1984. The stream was shallow (*ca.* 0.2m deep) and narrow (*ca.* 2m wide).

3. Comparative water quality examination before and after a rainfall

In order to investigate the effects of a rainfall on the streamwater quality, two pairs of water examinations were carried out at 13 sampling sites in the headstreams and at Komenono in 1984. Samples were taken in the afternoon on 18 April after several days of

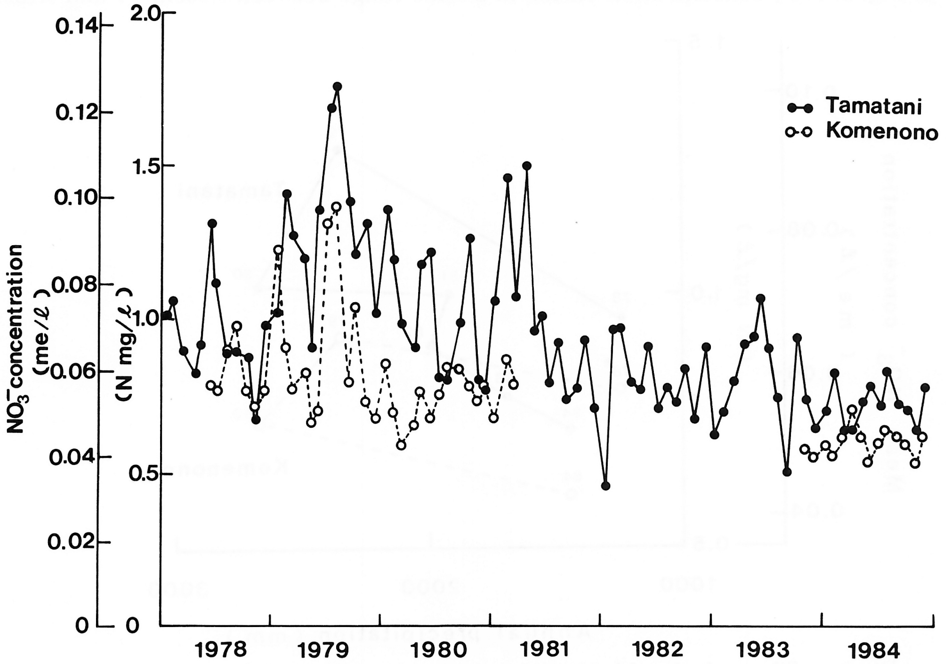

Fig.2. Monthly changes in the NO_3^- concentration in the streamwater at Tamatani and Komenono.

continuously clear weather and on 20 April after a rainfall of 59 ㎜ from 04:10 to 20:10 on 19. Samples were taken also in the afternoon on 17 October after a rainfall of 26 ㎜ from 13:30 on 16 to 06:25 on 17, and on 29 October after 12 days of no rain as a contrast instead of the day just before the rainfall.

All the water samples were brought to the laboratory within 3 hours for chemical analyses. The flow rate of the stream was not determined. Meteorological information regarding precipitation in this paper were provided by the Komenono Forest Research Center, the University Forest, Ehime University (see Fig. 1.).

4. Chemical analyses

Water samples were filtered through a 0.45μm membrane filter before chemical analysis. Part of the sample was treated by powdered zinc (until March 1981) or a cadmium-copper column (since April 1981) in order to reduce nitrate ion (NO_3^-) to nitrite ion (NO_2^-). NO_2^- concentrations in the treated and original samples were determined colorimetrically using GR reagent. The difference of these two determinations was used as the NO_3^- concentration in the original sample. The unit me/l was used in this paper from the chemical point of view, but mg/l was added in the figures for the convenience of pollution studies.

III RESULTS AND DISCUSSION

1. Seven years of changes in the NO_3^- concentration in the streamwater

Changes in the NO_3^- concentrations determined monthly at Tamatani and Komenono are shown in Fig. 2. NO_3^- concentration varied in a wide range between 0.033me/l and 0.126me/

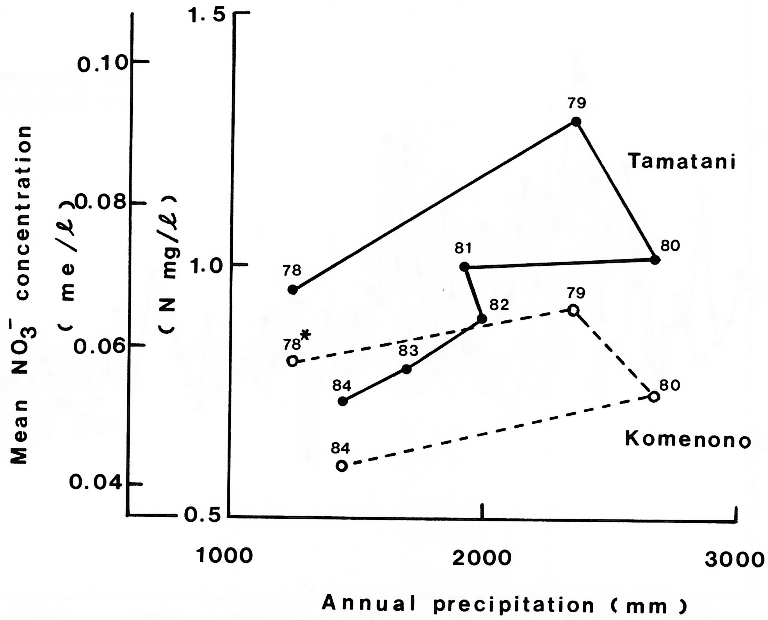

Fig.3. The relationship between annual precipitation and annual mean NO_3^- concentration. Numbers above circles indicate the year studied. In 1978 (asterisked), the mean NO_3^- concentration was calculated from 7 months of data from June to December instead of 12 months of data.

l at Tamatani, and in a narrower range between 0.039 me/l and 0.098 me/l at Komenono. Although many up-and-down changes were found month to month, one clear tendency — decreasing with time— was found since 1979 at both stations. It was droughty in 1978 but relatively rainy in 1979 involving a local severe rain in late June. After this severe rain NO_3^- concentrations in both stations reached their maximum values in August.

Using these observations we tried to compare the NO_3^- concentration with precipitation, and found an interesting trend between the annual precipitation and the annual arithmetic mean NO_3^- concentration calculated from 12 months of data. The results are shown in Fig. 3.

At Tamatani the mean NO_3^- concentration increased from 0.068me/l in 1978 to 0.092me/l in 1979 corresponding to the increase in the annual precipitation from 1242 mm to 2347 mm, and decreased from 0.073me/l in 1980 to 0.052me/l in 1984 corresponding to the decrease from 2674 mm to 1452 mm. Human activity such as settlements, arable land and intake facilities, from which most of the streamwater was taken for a power station downstream of the Ishitegawa Dam, might have complicated the influence of precipitation on the water quality at Tamatani. But at Komenono in the forest area the same trend was observed, though the mean NO_3^- concentrations were a little lower than Tamatani throughout the study period.

These facts suggest the existence of a positive relationship between the precipitation and the NO_3^- concentration, though a few exceptions must be permitted, considering the reverse phenomenon between 1979 and 1980, when the mean NO_3^- concentration decreased in reverse to the increase of precipitation. A similar positive relationship between the water discharge

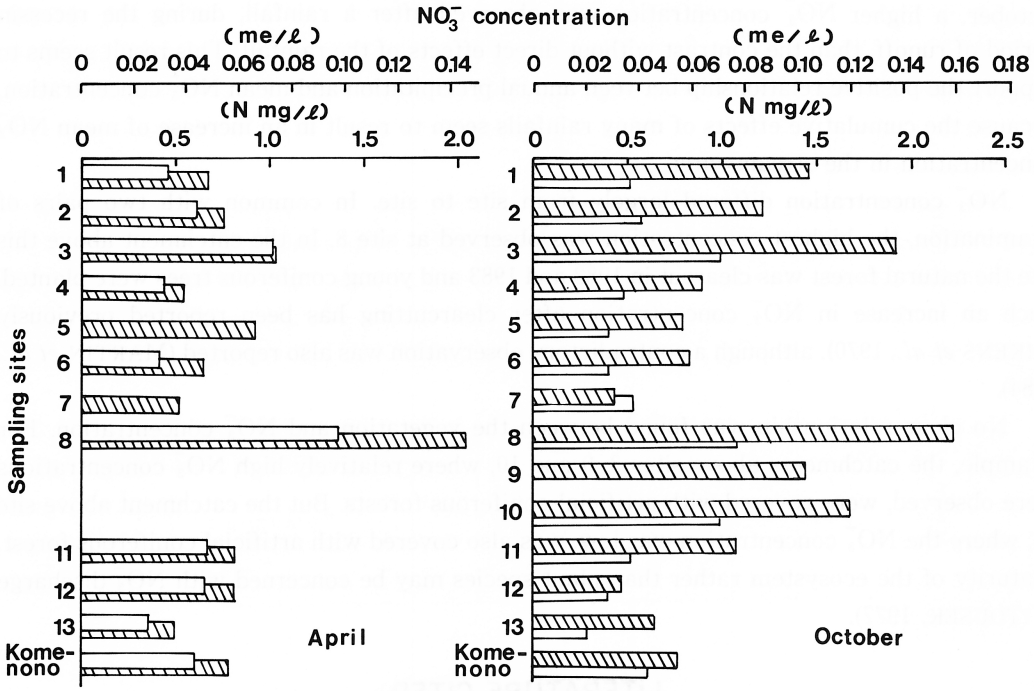

Fig.4. Effects of a rainfall on the NO_3^- concentration in the head-stream area. Shaded bars indicate the concentration after a rainfall. Open bars indicate the contrast not affected by the rainfall.

and the NO_3^- concentration was recently reported in an 8-year hourly examination in a grassland catchment (WEBB and WALLING, 1985), which seems to support our findings.

Some causal factors have been proposed (WEBB and WALLING, 1985), of which most important is the one that is able to explain all the phenomena, including exceptions in appearance. For example, the reverse phenomenon in 1980, as well as that of normal years, may be explained by the changes in the drainage network in the soil responding to the precipitation. It is supposed that a large part of infiltrated water has no connection to the main water paths in the drainage network in the soil, which participate in the subsurface runoff, in a dry year, resulting in evaporation and salt accumulation in the soil. In the next rainy year, such as 1979 following dry 1978, these accumulated salts, including nitrate, are thought to be washed out through a stretched drainage network, resulting in the high NO_3^- concentration in the streamwater. In a rainy year following an antecedent rainy one, such as in 1980, salt accumulation may be almost exhausted in the preceeding year, so that NO_3^- concentration may not increase. The factors participating in the NO_3^- concentration *vs.* precipitation relationship are under investigation.

2. Changes in the NO_3^- concentration in the streamwater before and after a rainfall

The effects of one rainfall on the NO_3^- concentration was investigated in the headwater area above Komenono. Results are shown in Fig. 4. At sites 5 and 7 in April and at site 9 in October, water samples were taken and analyzed only after a rainfall, because stream waters were too little to ladle out in ordinary days. At almost every sampling site in both April and October, a higher NO_3^- concentration was observed after a rainfall, during the recessin period of runoff, than the contrast without direct effects of the rainfall. This result seems to support the positive relationship between annual precipitation and mean NO_3^- concentration, because the cumulative effects of many rainfalls seem to result in an increase of mean NO_3^- concentration in the streamwater.

NO_3^- concentration differed largely from site to site. In common with two pairs of examination, the highest concentration was observed at site 8. In the catchment above this site the natural forest was clearcut in 1982 and 1983 and young coniferous trees were planted. Such an increase in NO_3^- concentration after clearcutting has been reported previously (LIKENS *et al.*, 1970), although a contradictory observation was also reported (MARTIN *et al.*, 1984).

No clear relationship was found between the vegetation and NO_3^- concentration. For example, the catchments above sites 3, 9 and 10, where relatively high NO_3^- concentrations were observed, were covered with artificial coniferous forests. But the catchment above site 13, where the NO_3^- concentration was low, was also covered with artificial coniferous forest. Maturity of the ecosystem rather than plant species may be concerned with NO_3^- discharge (VITOUSEK, 1977).

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