Korean J. Limnol. 38 (Special issue): 58~61 (2005)

Environmental Pollutants Drained From Highway Pavement Road

Takemura, Shinsaku, Naoshige Goto and Osamu Mitamura*

(Limnological Laboratory, Department of Environmental Science, University of Shiga Prefecture, Hikone, Shiga 522-0057, Japan)

Environmental polluting materials from road surface drainage are a significant nonpoint source influenced to the eutrophication of lake and ecosystems with a transport development in recent years. To elucidate the discharge characteristics, the changing patterns in concentrations of polluting materials such as suspended solid (SS), chemical oxygen demand (COD), nitrogenous and phosphorus nutrients in drainage waters, were investigated during rainfall. Load variation of COD concentration in drainage water samples was closely related to that of SS concentration. This indicates that SS contained a greater part of organic matter. A quite difference between the past pavement and the new well-drainage pavement system was observed in the concentrations of SS and COD in drainage waters. Appreciable concentrations of nitrite and nitrate were determined in drainage waters. The present results indicate that the drainage water from road surfaces is a significant nonpoint source, and that the well-drainage pavement system introduced to skid prevention has an effect on the decreases of pollutants.

Key words : nonpoint source, road surface drainage, nutrient

INTRODUCTION

Because runoff loads from nonpoint source are irregularly generated over time, it is difficult to identify the pollution source (Kunimatsu and Muraoka, 1989), the measures taken to reduce corruption loads from such sources remain inadequate. Considering the growing urbanization of many regions over the last few decades, the levels of pollutants from the nonpoint source in urban areas have steadily continued to climb (Wada, 1990). The runoff loads and concentrations of nutrients, suspended solid (SS), and other pollutants from nonpoint sources in urban areas have become significantly greater than those in rural areas (Sarter and Boyed, 1972).

Particularly in urban areas, high levels of pollutants accumulating on roads are one of the major nonpoint sources. Various pollutants (nitrogen and sulfur oxides, particulate matter, dregs of tires, etc.) from automobiles accumulate on roads, eventually are flowed into public waters following a rainfall. Currently, drainage containing various pollutants flows directly into rivers and lakes without being purified. The purpose of this study is to estimate the properties in the runoff of polluting materials on rainy days from three points along dissimilar stretches of road.

MATERIALS AND METHODS

Samples of road drainage were taken from a drainpipe under an elevated section of the Meishin highway (2 stations: "Ishiyama" and "Taga") and from the Route 1 Keiji by-pass (1 station: "Keiji by-pass") in Shiga Prefecture (Fig. 1).

* Corresponding Author: Tel: +81-749-28-8261, Fax: +81-749-28-8247, E-mail: mitamura@ses.usp.ac.jp

Sampling for measurements of chemical analyses of drainage (SS, COD: Chemical Oxygen Demand, nutrients) was carried out 5 times on rainy days from 13 October to 12 December 2003.

Water samples were immediately filtered through Whatman GF/F glass fiber filters preignited at 450°C. The filters were used for the measurement of SS. The filtrates were stored at −20°C in a freezer until chemical analysis. Ammonia was determined by the method of Sagi (1966) nitrite after Bendschneider and Robinson (1952), nitrate after Wood *et al.* (1967), and phosphate after Murphy and Riley (1962). COD for water samples from which SS was either removed or not removed by GF/F glass fiber filters was measured by the method of wet chemical oxidation with $KMnO_4$.

RESULTS

Characteristics of suspended solid in outflow on each pavement

Figure 2 shows the changes in the SS concentration and rainfall intensity over time at "Keiji by−pass" on Route 1 Keiji by−pass on 29 December 2003 and "Taga" on the Meishin Highway on 24 December 2003. The pavement method was different at each place. The former was used the past pavement and the latter was used the new well−drainage pavement.

At "Keiji by−pass", that concentration reached its maximum value (380 mg L^{-1}) at the beginning

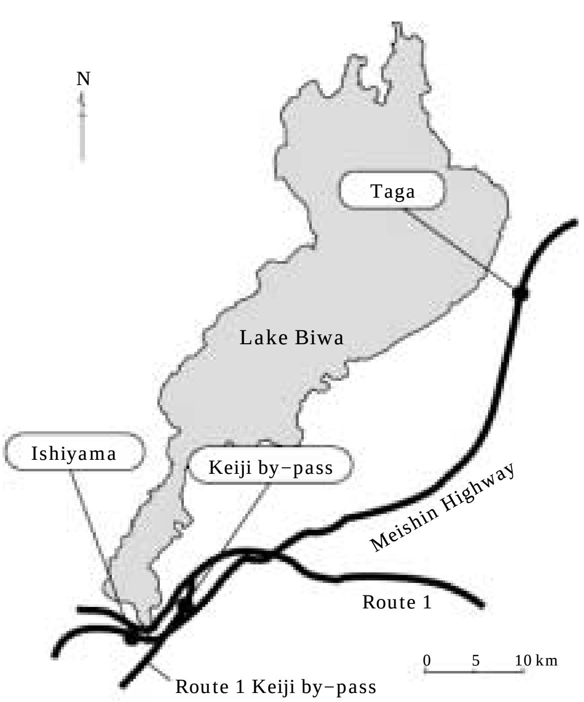

Fig. 1. Study area and sampling stations.

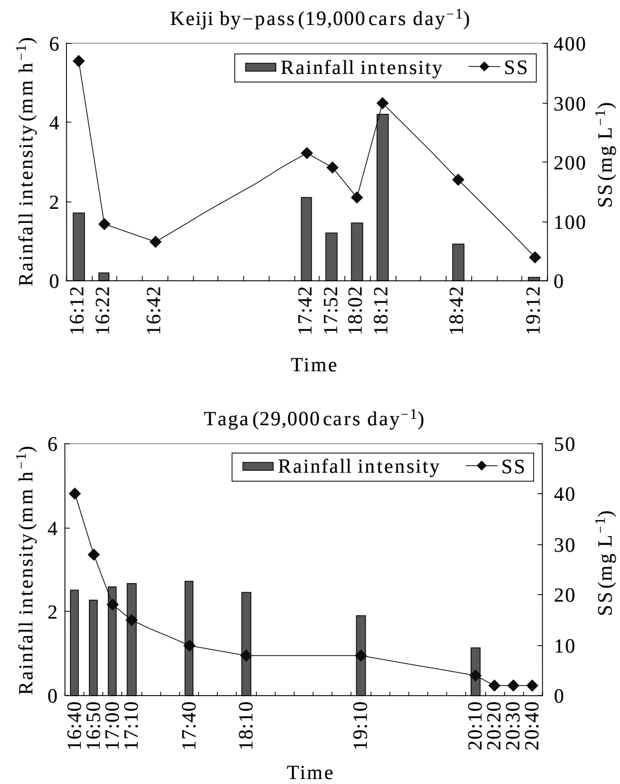

Fig. 2. Changes in the concentrations of SS and rainfall intensity over time at Taga on the Meishin Highway on 24 December 2003 and at the Keiji by−pass on 29 December 2003.

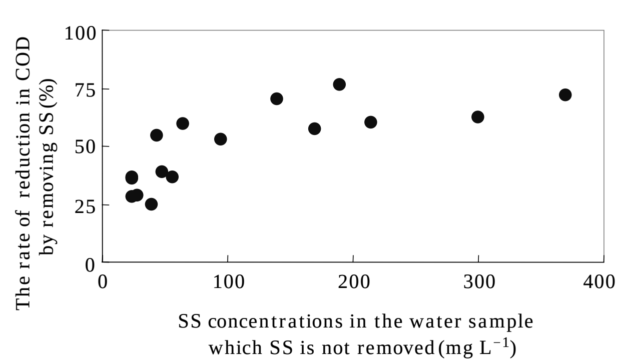

Fig. 3. The relationship between the concentrations of SS and the rate of reduction in COD (divided into COD from which SS was removed from the water sample and COD from which it was not).

of drainage due to the effect of “First Flush” on rainy days. That same tendency was also observed at the other two sites.

The SS concentrations in drainage differ depending on the method used in paving a road. The maximum concentration of SS in the road paved using the past pavement (Keiji by−pass) reached 380 mg L^{-1}, whereas, on a road paved using new well−drainage pavement system (Taga) the maximum concentration of SS reached only 40 mg L^{-1}. The volume of traffic was 19,000 cars per day at Keiji by−pass, and 29,000 cars per day at Taga. Therefore, the volume of traffic was irrelevant to the SS concentrations.

We can recognize from these results that the pavement method has a connection with the reduction in the SS concentrations. To know the effect caused by reduction in SS, we tried the following experiment. Figure 3 shows the relationship between the concentration of SS and the rate of reduction in COD (divided into COD from which SS was removed from the water sample and COD from which it was not). COD in drainage samples containing more than 100 mg L^{-1} SS were curtailed by more than 50%, indicating that SS contains a variety of organic matters.

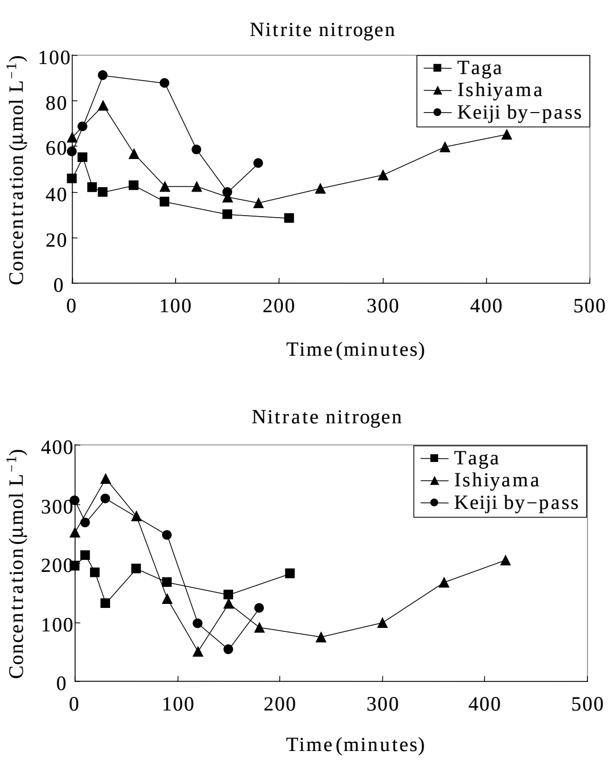

Fig. 4. Changes in the concentrations of dissolved inorganic nitrogen (nitrite, nitrate) over time on the Meishin Highway (2 stations) and on the Route 1 Keiji by−pass (1 station).

Characteristics of nutrients in outflow

These concentrations of nitrite and nitrate nitrogen, which ranged from 29 to 91 μmol L^{-1} and 50 to 340 μmol L^{-1}, respectively, were much higher than those generally measured in lakes or rivers (Fig 4). Comparative concentrations of dissolved inorganic nitrogen obviously failed to exhibit the “First Flush” phenomenon.

DISCUSSION

The SS concentrations differed depending on the type of road pavement used, suggesting to the drainage system of each paved road. In the past pavement system, most of the rainwater falling on the road flowed across the road surface without percolating into the asphalt and then directly into a drain (Fig. 5). On the other hand, most of the rainwater falling on roads using the new well−drainage pavement system infiltrated below the road surface, since the new well−drainage pavement has a bigger void than the past pavement (Fig. 5). Namely, it is considered that SS in drainage water is removed as it passes through the surface layer of the new well−drainage pavement. In this study, SS in the drainage water was rich in organic matters. Thus it appears likely that the spread of the new well−drainage pavement has been effective in curtailing the level of organic matters in the drainage water.

In the present study, the concentrations of

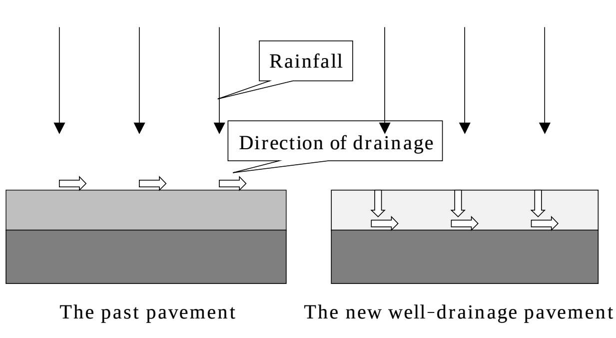

Fig. 5. The difference in the method of drainage of the past pavement drainage and the new well−drainage pavement system.

nitrate and nitrite nitrogen were high compared to those of ammonia nitrogen and phosphate phosphorus. This is attributed to the fact that the nitrogen oxide (NO_X) in the exhaust gas of automobiles dissolves into the water draining from the road. In addition, nitrate and nitrite nitrogen maintained high concentrations throughout the sampling period. Vaze and Francis (2002) reported that there are both accumulative and adhesive substances on the road surface. Although the former is easily flowed by a usual rain, the latter is less susceptible to an outflow by a usual rain. Consequently, since the nitrate and nitrite contained in adhesive substances were gradually dissolved into the drainage over time, their concentrations remained high throughout the sampling period. From this study, it is reasonable to conclude that the environmental loads produced by an automotive society have affected not only the atmospheric environment but the hydrospheric environment as well.

ACKNOWLEDGEMENTS

We wish to thank the members of Limnological Laboratory, the University of Shiga Prefecture, for their generous assistance in chemical analysis and water sampling. Thanks are also due to the staff of Japan Highway Public Corporation, for the offer of various information about the road and pavement system.

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(Manuscript received 10 December 2004,
Revision accepted 25 February 2005)