Lake Biwa and its environment: eutrophication with special reference to P cycling

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1) Introduction

During the last generation, Lake Biwa has been eutrophicated as well as in many lakes in the world. Specially, eutrophication in the south basin of the lake is now very serious. Both the local government of Shiga Prefecture and the Japanese Government have already taken some measures for improving the water quality of Lake Biwa: the Water Pollution Control Law (1971), Shiga Prefectural Environmental Pollution Control Ordinance (1973), Eutrophication Prevention Ordinance (1979), Special Measure Law for Preserving Lake Water Quality (1984) and Water Quality Corruption Prevention Ordinance (1985). Probably due to these efforts, nitrogen (N) and phosphorus (P) loadings from inflowing rivers have been drastically reduced since 1985 and 1979, respectively. If we consider water quality as chemical oxygen demand (COD), transparency and concentrations of total phosphorus (TP) and nitrogen (TN), there has been almost no major change in these parameters during the last generation. However, unfortunately, we have had massive growth of nuisance cyanobacteria (Anabaena, Microcystis and so on), which is a typical sign of lake eutrophication, in harbours and small bays almost every summer since 1983. What has occurred in Lake Biwa? What is potential serious event which can occur in the lake in future? Here I discuss about these questions with special reference to the P cycling in Lake Biwa.

2) P cycling and sedimentation

Lake Biwa is a P limited lake, similar to many temperate lakes in the world. Phytoplankton in the lake is P limited almost throughout a year (Tezuka, 1985; Nakanishi et al., 1990). Although bacteria are superior competitors for P uptake among planktonic organisms, bacteria of the lake are not so rich in P (Nakano, 1994). Accordingly, P is a precious element for other heterotrophs in the lake. Hence, planktonic organisms in a pelagic area of the lake transfer P to organisms at higher trophic levels with high efficiencies (Nakano, 1995; Urabe et al., 1995). Also, most of phytoplankton in the lake belong to the size fraction >20 mm. Phytoplankton in this fraction are inedible for zooplankton, and sedimentation may be the main loss process of the large phytoplankton (Kawabata, 1994). P is also settled through chemical processes (Takahashi, pers. comn.). Thus, it is likely that particulate phosphorus which includes heterotrophs, inedible autotrophs and abiotic particles settles to bottom sediment (cf. Tezuka, 1992; Kawabata, 1994). Theoretically, 66 % of P to total amount of P supplied into Lake Biwa is accumulated in the lake sediment due to the settlement (Kunimatsu & Kitamura, 1981; Kunimatsu, 1995). Thus, Lake Biwa has a big P-pool in its pelagic sediment (cf. Tezuka, 1992). Miyajima (1994) has reported that P concentrations of sediment in a pelagic area of Lake Biwa were high compared with those of water.

3) P release from sediment

In Lake Biwa, most of P loaded from river inflow is consumed through chemical and biological processes, and settles around a river mouth (Takahashi, pers. comn.). Hence, P is accumulated also in the sediment of a river mouth, and its concentration may be much higher than that in a pelagic area. At harbours and small bays, water is often stagnant. As the increase in water temperature due to high insolation during summer, heterotrophic activities would also increase, and sediment at these areas would become anaerobic. It is well-known that P bound chemically in sediment is readily released under anaerobic condition. Nutrition of cyanobacterial blooms in some stagnant areas during summer may be explained by this series of these processes. However, it is still unclear why cyanobacterial blooms did not occur until 1983 in the south basin, and until 1994 in the north basin.

As mentioned before, there is a big P-pool in the sediment in a pelagic area of Lake Biwa. Unfortunately, there is also the possibility of P release from the pool, and this is to some extent related to global climatic change.

The northern part of watershed of Lake Biwa has a heavy snowfall during winter. Snow-thaw water intrudes into the hypolimnion of the lake, since it has high density due to low temperature and high mineral content (Kumagai, 1990). Also, it is highly oxygenated (Kumagai, 1990; Fushimi, 1993). Thus, the snow-thaw water in the watershed supplies oxygen into the hypolimnion (Kumagai & Fushimi, 1995).

Climatic warming is now a globally serious problem. Probably due to climatic warming, the amount of snow cover in the watershed has decreased gradually since 1987 (Fushimi, 1993). If there is only a small amount of snow cover in the watershed, the oxygen supply would also be reduced accordingly. In fact, concentration of dissolved oxygen at a station of the north basin of the lake was intermittently at 0 mg/l between September and October of 1990 (Kumagai, pers. comn). If the hypolimnion becomes anaerobic, a large amount of P bound chemically with bottom sediment is probably released to water column, and this would result in massive growth of phytoplankton (Tezuka, 1992).

Since the retention time of water in the north basin is long (15 - 20 years), it should take enormously long time to improve the water quality of the basin. To prevent the P-pool from growing, we must continue our effort. Further, some measures may be necessary to keep the bottom environment aerobic.

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