Development of Environmental Indicators Linking Lakes-Rivers-Humans and Watershed Diagnosis

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Despite various measures having been imposed, the water quality of Lake Biwa has not greatly improved. One reason is that what affects the lake water quality has not been elucidated. Environmental impacts on lake water imposed by humans are for the most part delivered by rivers. To identify the causes of degradation of the lake's water quality, therefore, it is necessary to investigate the water quality of influent rivers as well as Lake Biwa itself while linking it to human activities in the watershed. A variety of stable isotopes and multi-elements can be used as environmental indicators to trace qualitative links between lakes, rivers, and humans.

Substances with the same element but different masses are referred to as stable isotopes. It is known that the stable isotope composition of organisms living in water systems reflects the quality values of ambient environmental water. Research on the stable isotope composition of nitrogen, sulfur, and strontium contained in an annual fish, living in the northern part of Lake Biwa revealed that heavy nitrogen, light sulfur, and light strontium have gradually increased in the lake water over the past 40 years. In many cases, the compositions of stable isotopes and dissolved-constituents of influent rivers depend far more on regional changes than on seasonal changes. The river water quality at downstream points near the lake reflects the characteristics of each watershed environment.

A macroscale investigation of the Lake Biwa watersheds has revealed that the rivers that account for all the secular changes in the stable isotope composition of the lake water obtained from *Chaenogobius isaza* are mainly small and medium-sized rivers flowing through the agricultural region east of Lake Biwa. These rivers are heavily contaminated with acids such as sulfuric acid, nitric acid, and bicarbonic acid, as well as minerals including calcium and magnesium. The stable isotope composition of sulfur contained in agricultural fertilizers and that of strontium as an exchangeable component of the sedimentary rock and soil in the plain to the east of the lake correspond to their values in these rivers. These facts suggest a scenario in which the acids generated by agricultural activities have dissolved minerals out of soil and rocks in the plain, leading to changes in the lake water quality.

Although these small and medium-sized rivers have small watershed areas, and they contribute only 1 to 2% of the overall picture, they can account for the current concentration of sulfur and strontium in the lake water and the secular changes in stable isotope compositions. However, the concentrations of phosphorus and nitrogen that are usually contained in rural rivers are lower than those in miscellaneous runoff. Since phosphorus level is a limiting factor on biological activities in Lake Biwa, we need to verify, from different approaches, to what degree these small and medium-sized rivers influence the eutrophication of Lake Biwa. According to a microscale study, the water quality of small and medium-sized rivers varies according to environmental changes in the surrounding paddy fields, such as caused by fertilizer application and irrigation. The concentrations of phosphorus and nitrogen contained in agricultural muddy water depend greatly on water control patterns. Although muddy water is rapidly generated (in about one day), 0.8 to 5.3% of nitrogen and 13.5 to 42.3% of the phosphorus that flows into the northern part of Lake Biwa is attributable to agricultural muddy water. The reason for the high environmental impact of phosphorus caused by muddy water is that phosphorus accompanies fine-grained suspended matter such as organics and clay. Better insight into the dynamics in the lake is the key to elucidating oxygen deficiency on the lake floor. In spite of the declining effects of domestic wastewater due to improvements in sewerage, the environmental impact on the lake water exerted by muddy water and other agricultural activities appear likely to increase in the future.