Screening Effect of the Diffusive Boundary Layer in Sediments of Lake Aha in the Suburbs of Guiyang City, Guizhou Province*

WAN GUOJIANG (万国江), HUANG RONGGUI (黄荣贵), PU YONG (普勇)
(State Key Lab. of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, 550002)
AND WAN XI (万曦)
(Institute of Soil and Fertilizer, Chinese Academy of Agricultural Sciences, Beijing, 100081)

Abstract: The redox cycle of iron and manganese is a major geochemical process at the boundary layers of lake sediments. Lake Aha, which lies in the suburbs of Guiyang City, Guizhou Province, China, is a medium-sized artificial reservoir with seasonally anoxic hypolimnion. Long-term sedimentary accumulation of iron and manganese resulted in their enrichment in the upper sediments. In the anoxic season, Fe$^{2+}$ and Mn$^{2+}$, formed by biological oxidation, would diffuse up to overlying waters from sediments. However, the concentration of Fe$^{2+}$ increased later and decreased earlier than that of Mn$^{2+}$. Generally, sulfate reduction occurred at 6 cm below the sediment-water interface. Whereas, in the anoxic season, the reduction reached upper sediments, inhibiting the release of Fe$^{2+}$. The Fe concentration of anoxic water is quickly decreased from high to low as a result of reduction of the sulphur system.

Key words: Fe-Mn cycle; diffusive boundary layer; screening effect; Lake Aha; Guizhou

Introduction

The redox cycle of iron and manganese is a major geochemical process at the boundary layers of lake sediments. The major sources of iron and manganese in the hypolimnion of seasonally anoxic lakes are the diffusive boundary layers of lake sediments. However, iron and manganese show different geochemical behaviors at the sediment boundary layers (Stumm and Morgan, 1981; Davison, 1985; Wersin et al., 1991; Yagi, 1993).

Lake Aha, which lies in the suburbs of Guiyang City, Guizhou Province, China, is a medium-sized artificial reservoir built in 1960. It is a drainage basin covering an area of 190 km$^2$, and its surface area is 3.4 km$^2$ with a mean depth of 13 m and a maximum depth of 24 m. The total capacity of this lake is about 0.445 $\times$ 10$^8$ m$^3$. Its mean water flux is 1.02 $\times$ 10$^8$ m$^3$•a$^{-1}$, and the residence time of water is 0.44 a. Lake Aha slightly remains thermally stratified in the summer and autumn.

Exposed rocks around Lake Aha are the Permian limestones and coal layers, which are overlain by sialic or/sifeic yellow soils. In the yellow soil the contents of iron and manganese are within the range of 4.3% - 5.6% and 0.1% - 0.14%, respectively.

Through long-term accumulation, Fe and Mn are enriched in the diffusive boundary layer with a thickness of 2 cm so that the Fe and Mn contents of sediment particles in this layer are

* The project was financially supported by the National Natural Science Foundation of China(49333040).
as high as to be 12% and 1.5%, respectively. Therefore, Lake Aha is regarded as the best candidate for research on the geochemical behavior of Fe-Mn at the sediment/water interface.

**Difference in Seasonal Release Between Iron and Manganese**

When water in the epilimnion and hypolimnion of Lake Aha is anoxic in late summer and early autumn, iron and manganese are released to overlying water from the Fe-Mn-enriched layer, leading to an increase in Fe, Mn concentrations of the water column. However, the changing pattern is different between iron and manganese in this lake. Although the Fe, Mn concentrations show an increase mainly from July to October, the latter (Mn) appears earlier and longer than the former (Fe) (Fig. 1).

![Fig. 1. Seasonal changing trend of the Fe-Mn concentrations in the water of Lake Aha.](image)

**Relationship Between Hydrochemical Conditions & Concentrations of Fe and Mn in the Anoxic Season**

Seasonal variations of Fe and Mn are closely related to physico-chemical conditions in lake waters. During July to September, water temperature goes up obviously and the difference is 10°C between the upper and lower layers (Fig. 2a), pH value is obviously lower (Fig. 2b), saturation of dissolved oxygen is declined to minimum (< 30%) (Fig. 2c), and the concentration of SO₄²⁻ is decreased more violently owing to dilution by rainwater or SO₄²⁻ reduction (Fig. 2d).

In order to ascertain the mechanism of differential release of iron and manganese from the sediments to the overlying water column, we first analyze the relationship between hydrochemical conditions and high Fe-Mn concentrations.

**The relation between dissolved oxygen and Fe-Mn concentrations**

From Fig. 3 we can see that during anoxic seasons, higher Mn concentrations mainly appear under the condition that the saturation degree of dissolved oxygen is 20% – 60%, and that of iron is 30% – 50%. Under this condition, however, lower Fe concentrations are observed, too.