Chemical partitioning of trace elements within freezing closed-basin lakes in Mongolia

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Alkaline saline lakes in the Valley of Gobi Lakes of Mongolia are known as closed-water environments with enrichments of elements through water evaporation in summer and/or freezing in winter. Chemical partitioning within these lakes have investigated for understanding geochemical changes in arid or icy environments (e.g., Yoda et al., 2021; Gankhurel et al., 2022). Previous winter field survey of these lakes shows that major elements (e.g., Na, Ca) are partitioned among ice, bottom-lake water, and precipitated minerals during freezing process. However, behaviors of trace and/or heavy elements (e.g., As, U, P) during freezing are not well-known. Adsorptions onto sediments could also remove such trace elements as other processes.

We report the results of winter filed survey of these lakes, including concentrations of trace elements, As, U, and P. We found that As and U accumulated in bottom-lake water through freezing, compared with their concentrations in summer. Maximum concentrations of As, U, and P in bottom-lake water are 180, 600, and 180 μg/L, respectively. Vertical varieties of As and U concentrations in icy layers show trends similar to those of Na. In addition, ratios of concentrations between bottom ice and water are equivalent values among Na, As, and U. On the other hand, we found that entrapments of P into icy layers were more effective than those of As and U. Previous study shows entrapments of Na in lake-ice pores as dissolved species of lake water (Yoda et al., 2021). This suggests that U and As were entrapped as dissolved species; whereas P could have been entrapped as precipitated or suspended minerals.

We also conducted geochemical modeling for chemical partitioning to compare with results of the winter field survey. Comparisons of the field results with geochemical modeling suggest that U concentrations in bottom-lake water can be reproduced just considering accumulation by freezing of ice. On the other hand, part of As could be adsorbed onto highly-suspended iron oxide particles in bottom-lake water. In addition, we predict P concentrations of the lakes in summer based on those in winter. Considering balances between ice freezing and adsorptions onto iron oxides, P concentrations could be around 100 μg/L in summer, suggesting nutrient enrichments in all seasons. However, P in lake water might also be removed through other processes (e.g., precipitations of phosphates). Thus, P concentrations in summer lakes are necessary to examine the possibility of nutrient enrichments.

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