Bacterial contribution to dissolved organic matter in a large monomictic lake (Lake Biwa) indicated by amino acids enantiomers

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Dissolved organic matter (DOM) plays crucial roles in the biogeochemical cycles in aquatic environments. A number of past studies have strongly indicated that heterotrophic bacteria represent a major source to the ocean DOM pool, suggesting that microbial processes may underlie the mechanisms for DOM preservation ("microbial carbon pump"). In particular, enantiomeric (D/L) analysis of amino acids (AA) in DOM has been used to characterize sources of DOM, and high abundance of specific D-AA bacterial biomarkers have suggested that bacterially-sourced organic matter may be a key in formation of the ocean's recalcitrant DOM pool (e.g., McCarthy et al., 1998; Kaiser & Benner, 2008; Yamaguchi & McCarthy, 2018). In contrast to the marine environments, the distribution of D-AA bacterial biomarkers in DOM has been severely understudied in lacustrine environments. To our knowledge, there has been just one report of D-AA concentration in DOM for a freshwater lake water column (Kawasaki et al., 2013: in eutrophic Lake Kasumigaura, Japan).

Our study explores the use of D-AA bacterial biomarkers as an effective approach to estimate bacterial contribution to the DOM pools in lacustrine environments. First, we have developed a new analytical approach using GC-MS for D-AA concentration in the total DOM pool of lake water. This method can detect unusual D-AA molecules (e.g., D-Val, D-Phe, D-Tyr) together with the major four bacterial biomarkers (D-Ala, D-Glu, D-Asp, and D-Ser) which have been analyzed by the conventional HPLC method. Second, we determined vertical and seasonal variations in the D-AA concentrations of DOM in a large monomictic lake (Lake Biwa, Japan). To our knowledge, this study is the first report of D-AA concentrations of DOM in a meso/oligotrophic lake. Finally, we conducted an incubation experiment using natural microbial community in Lake Biwa to estimate the D-AA yields in freshly-produced bacterial DOM in the lake environment, which are essential for the calculation of bacterial contribution to the natural DOM pools.

From the vertical distribution of D-AA concentration during the stratified period (summer and fall), we estimated that a substantial fraction (30-40%) of the recalcitrant pool of dissolved organic carbon (DOC) is bacterial origin. In contrast, the bacterial contribution was less than 20% to the semi-labile DOC pool which accumulates in the lake epilimnion during summer. These results suggest that the "microbial carbon pump" (production of recalcitrant DOM by heterotrophic bacteria) is an important process in the biogeochemical cycles of lakes.

Keywords: Dissolved Organic Matter, Amino Acids, Enantiomers, Microbial Loop, Microbial Carbon Pump, Organic Geochemistry

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