Water Quality Dynamic above the Bottom Sediment under an Anaerobic State in an Organic Polluted Reservoir

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1. Introduction

An anaerobic state in a closed water body occurs due to thermal stratification resulting from an excess of organic matter. This state causes nutrients to be released from bottom sediment and the generation of sulfide, which deteriorates the water quality. Thus, a study of water quality dynamic above the bottom sediment arising from anaerobic decomposition of organic matter, such as denitrification, iron reduction and sulfate reduction is important for sustainably conserving and improving organic polluted water bodies. This study involved weekly observations of the vertical profile of water quality in a particular reservoir, in which overabundant organic matter was prominent due to humic acid. Qualitative estimations were made by comparing the variation in nutrient salts, including NO_3-N, NH_4-N and PO_4-P, and sulfide (S^{2-}), to other water quality parameters such as dissolved oxygen (DO), oxidation-reduction potential (ORP), iron ion, and dissolved organic matter during an anoxic period, focused on the water layer above the benthic zone.

2. Materials and methods

Observations of the vertical profile of water quality parameters were taken once a week between 1st April and 9th December 2015 at 1 m intervals in the center of the reservoir from the water surface to just above the bottom. Measurements were focused on DO, NO_3-N, NH_4-N, PO_4-P, sulfide (S^{2-}), and dissolved organic carbon (DOC) as parameters related to organic pollution. In addition, total iron ion (sum of Fe^{2+} and Fe^{3+}), SO_4^{2-}, sulfide (S^{2-}), ultraviolet absorbance of wave length of 254nm (E254) and ORP were measured to better understand the water quality dynamic under the anoxic state in detail. Total iron ion could be measured based on the knowledge that the increase of PO_4^{3-} under aerobic condition would primarily result from iron reduction, and E254 was used as an indicator of humic acid concentration. This study focusses on observed results at 8 m because at this depth the anoxic state can exist for a longer time period (more than 6 months), and this extended period has a larger impact on water quality through the release of nutrients from bottom sediment and generation of sulfide.

3. Results and discussion

As shown in Fig. 1, anaerobic state, where DO was almost zero and ORP decreased to negative values of around -150 mV, was observed for longer than a 5 month period at the depth of 8 m, which was just above the sediment. In addition, as is clear from the variation of EC over time, the increase of ionic species caused by the elution from the sediment during anoxic conditions was substantial. Therefore, ORP, nutrient salts, and sulfur compounds were measured to study water quality dynamics under anaerobic conditions. The results are summarized in Fig. 2.

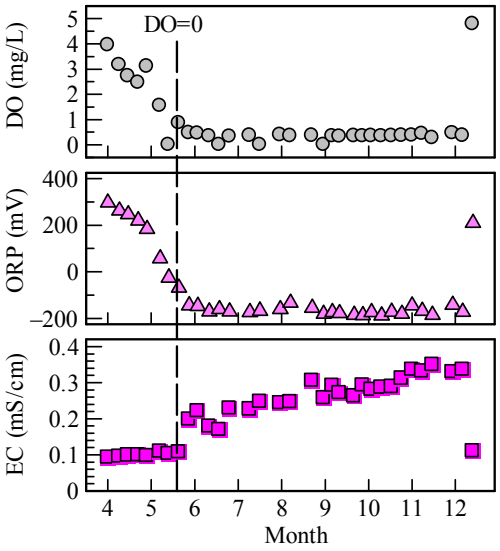

Fig. 1 DO, ORP and EC at 8m

Fig. 2 indicates that concentration of nutrient salts changed considerably under an anoxic condition. NO_3-N continuously reduced to zero in 70 days with average rate of 0.006 mg/L/d

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under denitrification time. In addition, NH_4-N started to increase when ORP dropped to approximately -150 mV and NO_3-N began to decrease. Furthermore, this increase was maintained during the anoxic period when concentrations of PO_4-P and sulfide obviously increased. This denoted that the increase of NH_4-N was due to the elution from the sediment caused as a result of the anaerobic decomposition of organic matter associated with denitrification, iron reduction and sulfate reduction. On the other hand, the concentration of PO_4-P remained constant until NO_3-N was almost zero. Once denitrification was completed, PO_4-P accumulated dramatically along with an increase of total iron ion. It is well known that iron and phosphate are held in the sediment by co-precipitation of iron phosphate and organic matters under an oxic condition (Mortimer, 1971). However, under the anoxic condition, the iron phosphate was broken apart by iron reduction, resulting in release of the phosphate ion and ferrous ion from the bottom sediment into the water. Fig. 2 indicates that such a process occurs after completion of denitrification under the strong reductive state of -150 mV. Moreover, suitable regression lines with means square error coefficients of determination over 0.7 were obtained by evaluating the increases in NH_4-N, PO_4-P and total iron ion using linear regression.

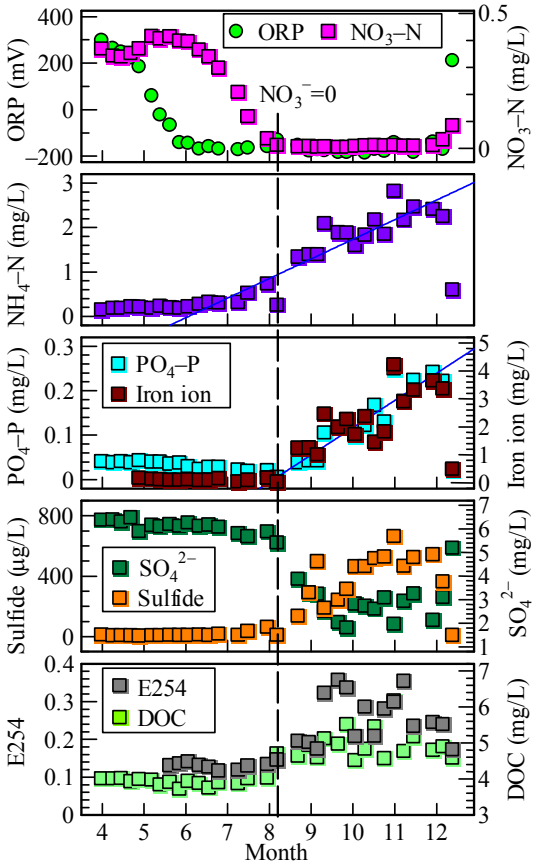

Fig. 2 Observation of ORP, NO_3-N, NH_4-N, $SO4^{2-}$, PO_4-P, Fe, Sulfide, DOC and E254 at 8m

Sulfide (S^{2-}) started to increase under conditions where ORP was approximately -150 mV and NO_3-N was virtually zero. In addition, the occurrence of sulfate reduction was verified by a significant decrease in SO_4^{2-} in conjunction with the increase in sulfide. Moreover, the increase in sulfide varied asymptotically over time before approaching a constant value of about 500 μg/L. The most striking result in Fig. 2 is that both DOC and E254 increased in correspondence with PO_4-P and sulfide after the completion of denitrification. The coefficient of correlation between DOC and E254 is 0.75, and both parameters have good correlation with concentrations of PO_4-P and sulfide. These results indicate that the high concentration of DOC represented by humic substances likely arises through elution from bottom sediment as a result of iron reduction and sulfate reduction.

4. Conclusion

This study demonstrates that the water quality dynamic above the bottom sediment in an anaerobic state in an organic polluted reservoir could be interpreted by variations in ORP as well as several water quality parameters such as iron ion, DOC and E254. Initially, the concentration of NH_4-N started to increase at the same time that ORP dropped to approximately -150 mV and NO_3-N began to decrease due to denitrification. This study also confirmed that PO_4-P and sulfide concentrations increased dramatically due to the iron reduction and sulfate reduction, respectively, after the completion of denitrification. Furthermore, the reduction of iron and sulfate which was caused by the aerobic decomposition of organic matter, resulted in humic substances being released from bottom sediment and a corresponding increase in DOC.

Reference

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