

Water Environmental Assessments for Bactericidal Effect of Copper Ions and Reduction Effect of Nutrients Inflow Loadings on Controlling Algal Blooms in a Hypertrophic Reservoir

トラン ティ ラン フォン

<https://hdl.handle.net/2324/7329535>

出版情報 : Kyushu University, 2024, 博士 (農学), 課程博士
バージョン :
権利関係 :



氏 名 : トラン ティ ラン フォン (TRAN THI LAN HUONG)

論文題名 : Water Environmental Assessments for Bactericidal Effect of Copper Ions and Reduction Effect of Nutrients Inflow Loadings on Controlling Algal Blooms in a Hypertrophic Reservoir
(過栄養貯水池でのアオコの発生制御に向けた銅イオンの殺菌効果と栄養塩流入負荷の削減効果の水環境学的評価)

区 分 : 甲

論 文 内 容 の 要 旨

Many agricultural reservoirs have recently received excessive inflow loadings of dissolved inorganic nitrogen (DIN) and phosphorous (DIP) resulting from fertilization of farmlands and have experienced serious eutrophic phenomena, such as the abnormal proliferation of phytoplankton. In particular, mat-like cyanobacterial blooms flocculated on water surfaces have caused serious environmental problems, such as damaging landscapes, obstructing agricultural water use, generating fetid water, and damaging aquatic ecosystems, owing to a dysoxic or anoxic state derived from low transparency. Therefore, effective techniques for suppressing phytoplankton overgrowth are required for the environmental remediation and conservation of eutrophic water areas. This study presents significant insights regarding water environmental assessment for preserving agricultural reservoirs by focusing on two research approaches: a method for inhibiting algal overgrowth using the bactericidal effects of copper ions (Cu^{2+}) and the influence of nutrient inflow loading on the increase in phytoplankton chlorophyll-a (Chl-a).

In the first approach, water quality experiments were conducted using water tanks to examine the effectiveness of Cu^{2+} in controlling algal overgrowth under hypereutrophic high levels of DIN and DIP while exploring the inhibitory effect on the increase in Chl-a level, the reduction effect of high cyanobacteria concentrations, and the elimination effect of mat-like algal blooms. In the experimental condition characterized by low initial Chl-a level and high nutrient concentrations, Cu^{2+} concentrations over 200–400 $\mu\text{g/L}$ effectively suppressed the proliferation of cyanobacteria, which was more susceptible to the bactericidal action of copper ions. However, high DIN and DIP concentrations promoted the growth of Chlorophyceae, which was insusceptible to the bactericidal action of Cu^{2+} . To adequately control algae under high nutrient concentrations, Cu^{2+} concentrations exceeding 600 $\mu\text{g/L}$ were necessary as the suitable concentration. In addition, for elevated initial concentrations of nutrients and Chl-a with a high composition ratio of cyanobacteria, it was possible to inhibit phytoplankton proliferation over a long period of approximately four weeks by adjusting the Cu^{2+} concentration to a high level of approximately 1000 $\mu\text{g/L}$. Although Chl-a increased owing to the overgrowth of Chlorophyceae four weeks or later after Cu^{2+} addition, a high-level supplementation of Cu^{2+} reduced nitrogen and phosphorous return rates from organic matter to available DIN and DIP for algal photosynthesis. Furthermore, cyanobacteria, which form mat-like algal blooms on the water surface, was effectively eliminated by the bactericidal effects of Cu^{2+} in environments with extremely high concentrations of DIN and DIP. However, Chlorophyceae dominated the cyanobacteria because of interspecific competition owing to its non-susceptibility to bactericidal action, resulting in a notable increase in Chl-a levels under high concentrations of DIN and DIP, supplied by the extinction of the excessive cyanobacterial population. The first research approach provided significant outcomes by

quantitatively evaluating the risks and advantages of applying the bactericidal effects of Cu^{2+} . Therefore, for the aquatic environmental remediation of hypertrophic water resources in agricultural areas, a hybrid countermeasure with a reduction in nutrient concentrations is required to control algal blooms based on the bactericidal effect of Cu^{2+} .

In the second approach, water environmental analyses in a hypertrophic nitrogen-limited reservoir were conducted based on field observations and numerical simulations to evaluate the influence of nutrient inflow loadings on the abnormal proliferation of phytoplankton. First, the periodic water quality survey focused on seasonal changes in the Chl-a level, the abundance ratio of the dominant algal class, and concentrations of DIN and DIP in the reservoir where long-term cyanobacterial blooms occurred at the water surface during autumn. The field observation results indicated that cyanobacteria Chl-a particularly had an exceptionally sensitive response to the temporary supply of nitrate-nitrogen ($\text{NO}_3\text{-N}$) via the inflow loadings derived from heavy rainfall events while maintaining high DIP concentrations exceeding 0.1 mg/L, resulting in a significant increase in Chl-a level beyond 1000 $\mu\text{g/L}$. Therefore, the control of $\text{NO}_3\text{-N}$ elevation during the summer and autumn periods in nitrogen-limited eutrophic water bodies could link to one of the crucial countermeasures for inhibiting cyanobacterial blooms. Next, in the numerical simulation, the water quality prediction model based on the one-box-type ecosystem model was applied to scenario analyses to assess the extent to which reductions in inflow loadings of DIN and DIP influenced the inhibition of phytoplankton overgrowth. When simulating seasonal changes in Chl-a based on the ecosystem model, it is necessary to uniquely determine the parameters related to photosynthesis for seasonal changes, such that the dominant species would alter significantly at algal class-differentiated levels corresponding to water temperature and solar radiation. In this study, several temperature zones were set, and the optimal values of the model parameters for phytoplankton growth were determined for each zone. In particular, the difficulty of model application to the hypertrophic reservoir was solved by deciding the dependencies on the water temperature, underwater light intensity of photosynthesis, and maximum algal growth rate, characterized by a dominant species corresponding to the water temperature zone. The validity of the proposed ecosystem model was confirmed because it could reproduce seasonal changes in Chl-a according to the abrupt appearance or disappearance of algal blooms in response to meteorological conditions for the observed results over two years. The scenario analyses provided the numerical target of reduction rates in the inflow loadings of DIN and DIP from the current situation for lowering Chl-a in the hypertrophic level (Ave: over 25 $\mu\text{g/L}$, Max: over 75 $\mu\text{g/L}$) to eutrophic level (Ave: 8–25 $\mu\text{g/L}$, Max: 25–75 $\mu\text{g/L}$) or mesotrophic level (Ave: 2.5–8 $\mu\text{g/L}$, Max: 8–25 $\mu\text{g/L}$). The outcome of the second approach demonstrates that the reduction of nitrogen in hypertrophic nitrogen-limited reservoirs has a substantially more pronounced effect on curbing phytoplankton growth than reducing phosphorus levels.

This research provides important knowledge on water environmental engineering for quantitatively assessing the bactericidal effect of copper ions on inhibiting mat-like algal blooms and the reduction effect of nutrient inflow loadings on preventing an increase in Chl-a levels to hypertrophic status in nitrogen-limited reservoirs. These results can be used to develop a technique for suppressing phytoplankton overgrowth and to integrate existing methods into a hybrid approach for more effective algal control in eutrophic agricultural reservoirs from excessive inflow of phosphorous and nitrogen. Therefore, they will contribute to the environmental remediation and conservation of regional water resources, ensuring sustainable agricultural development in rural areas.