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Applicability of Bio-Agents to Control Algal Biomass: Bacteria, Zooplankton and Ciliates

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Presently, eutrophication in lakes is accelerating due to high organic loading of domestic and industrial wastewater into aquatic environments such as lakes and reservoirs. Algal blooms, one of the most representative phenomena, often occurs in eutrophic or hypertrophic waters, mainly comprising cyanobacteria, diatoms, dinoflagellates and cryptomonads. In lake management, it is very difficult to quantify economic and psychosocial damage affecting daily human activities. However, it has come to be one of the biggest problems in twenty-first century water management that the algal blooms give rise to bad odors, off-tasting water, increased turbidity and depletion of dissolved oxygen, and an environmental threat to zooplankton, fish, and ultimately, humans. Until now, many countries in temperate nations, have essayed development of algal removal techniques to preserve water quality and obtain good drinking water during algal blooms. Recently, many countries have used direct chemical methods such as cupric sulfate, dichromate and ozone to decrease or/and remove the algal biomass. However, they demolished the aquatic ecosystem, via a decrease of other plankton and even fish, and also produced the carcinogenic trihalomethanes (THMs), which required secondary treatment for its wastes. To solve this problem, various studies on the development of bio-agents have been carried out toward pan-ecological and environmental approaches of lake water conservation.

Since the 1980s, a high abundance of cyanobacteria (*Microcystis, Anabaena, Aphanizomenon*), diatoms (*Aulacoseira, Stephanodiscus, Fragilaria, Asterionella*), dinoflagellates (*Peridinium, Ceratium*) and cryptomonads (*Cryptomonas*) have been recored Koreawide. The blooms range in increasing severity in sluggish reservoirs used for drinking water, in the upstream of artificial dams and in small streams near metropolitan areas with slow currents, respectively. The algae used in this study are two; cyanobacteria *Microcystis* and the diatom *Stephanodiscus*. The reason for selecting these two species is that, the former is the most representative, often occurring at warm season water temperatures above 20^0C in Pal'tang reservoir, and the latter is often found at cold season water temperatures below 20^0C. Except ice-covering periods, phytoplankton biomass showed the high density in all seasons and produced green or brown colored water, bad odor, screen chapering, and finally contributed to high sludge production. Our research team, The National Research Laboratory, KISTEP, Korea (NRL) has developed a bio-agent from the water and sediments in marine and freshwater, to biotechnologically control algal blooms for periods up to 10 years. We have developed and sustained over 50 biota such as algicidal bacteria, zooplankton and ciliates, to effectively remove the algal biomass. This paper is offered to outline the experimental results of how much 1) a single treatment of bio-agent and 2) a double treatment, decrease the density of cyanobacteria *Microcystis* and the diatom *Stephanodiscus*. As a predators, one zooplankton; *Brachinous calyciflorus* and a ciliate; *Stentor roeseli* were used.

Experiment I

We first analyzed the antialgal effects of algicidal bacteria *Streptomyces neyagawensis* HYJMK0209-50 and the ciliate *S. roeselii* on *Microcystis aeruginosa* in CB media with single and double treatments. The effect of *S. neyagawensis* on *Microcystis* was 38.8 % of control in 2 days in CB media, which is similar to the value in Pal'Tang lake water (35.8%). The ciliate effectively inhibited the algal biomass in 3 days of inoculation paralleling the high growth of itself. Bacteria and ciliates often spent the 4~5 days without media. However, in the co-culture of ciliate and bacteria, both biota decreased in 2 days, maybe due to negative interaction. In mixed groups, comprising bacteria, ciliates and algae, *Microcystis* abundance increased opposite of our expectations. Our result suggests that the double application of bio-agent to remove the *Microcystis* biomass is less active than a single treatment. Thus, the algicidal bacteria *S. neyagawensis*, with its higher activity than ciliates, is more suitable for application in algal blooms with a low population of *S. roeselii*.

Experiment II

We also studied the antialgal effects of three bio-agents such as algicidal bacteria *Pseudomonas putida* (B), *S. roeselii* (C) and *Brachinous calyciflorus* (Z) on the small centric diatom *S. hantzschii* (A). In light of the predator, the experiments were largely divided into two groups, ABC and ABZ. First, (ABZ) in experiments of a single treatment, bacteria and zooplankton removed 80.4 %, 91.9 % of control algal biomass, while that of ABZ was 90.5%, respectively. Thus, the range of antialgal effect is AB<ABZ<AZ. Secondly (ABC), the level of antialgal effect of AB, AC and ABC on *Stephanodiscius* was 89.2 %, 96.1 % and 99.7 % (AB<AC<ABC), respectively. These results suggest that double treatment of the bio-agent is more effective than a single treatment, and is particularly more active in ciliates than zooplankton.

From these two experiments, the application of various bio-agents such as algicidal bacteria, zooplankton and ciliates to control algal blooms and increased biomass of lake waters and stagnant reservoirs, it is important to consider whether single treatment or double treatment of bio-agent, or more, should be used based on interaction among bio-agents.