Control method of water bloom using characteristics of reservoir ecosystem

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ABSTRACT

In the management of the dam reservoir, water bloom is often produced by an abundance of nutrient salts and causes significant damage on water supply including poor scenery, unfavorable water taste and production of toxic substance. Cyanobacteria belongs to bloom forming Microcystis and most frequently occurs in the reservoirs. They are also known to grow rapidly in high temperature environment and are, in fact, in increasing trend in the world because of the green house effect. This paper introduces the control method of the bloom, including Jet-Shock System for dispersing colony cells into the isolated cells, UV radiation Ship for stopping cell division and cooperation system to improve ecological purification function.

1. INTRODUCTION

Water in dam reservoirs is used for many purposes, such as raw water for the public water supply, water for irrigation, industrial water, and water supply for the maintenance of downstream rivers. Some reservoirs serve as recreational sites for fishing and swimming, and as water parks. However, in dam reservoirs, water blooms often occur due to eutrophication or other such causes, and pose problems to dam management such as unappealing scenery or water use hampered by foul smelling or tasting substances, toxic substances, etc.

Water blooms that most frequently occur are blooms of the *Microcystis* genus in the family of cyanobacteria. As high temperatures are favorable to their growth, such blooms are increasing worldwide with the rise in water temperatures brought by global warming. The aerating circulation method has been implemented in dams in Japan mainly as an eutrophication countermeasure. In many of these dams, the occurrence of water blooms is often observed in inlets in upstream end areas and other areas of the reservoir where there is little water circulation effect. Fresh water red tides, which are blooms of dinoflagellates that grow using the flow characteristics of dam reservoirs, often cause problems as well. As measures to control these blooms, this paper introduces the Jet-Shock System and Ultraviolet (UV) Radiation System, as well as the Bloom Control Fence, Ecological Dam, and Light Emitting diode (LED) Radiation Systems that are used in coordination with them. Among these systems, the Ecological Dam is designed to ecologically help clean-up water blooms, as described in detail in 4.3.2.

2. EUTROPHICATION OCCURRENCES IN DAM RESERVOIRS IN JAPAN, AND CURRENT COUNTERMEASURES

2.1 Status of Eutrophication of Dam Reservoirs in Japan

A questionnaire-based survey of dams in Japan was conducted in 2002 by the MLIT. Target dams are owned by Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the Japan Water Agency (JWA) and prefectural governments. According to this survey, eutrophication occurred in 104 out of all 423 dams, accounting for 24.6% of the total. Compared with all dams, dams owned by the MLIT and JWA had a higher ratio, 33.3%, of eutrophication, occurring in 31 dams out of 93. This is partly due to their larger size (Figure 1.) . Meanwhile, in the latest questionnaire-based survey, conducted in 2011 for 117 dams under the control of the MLIT and JWA, eutrophication was shown to have occurred in roughly 50% of the dams, indicating an increasing trend in recent years.

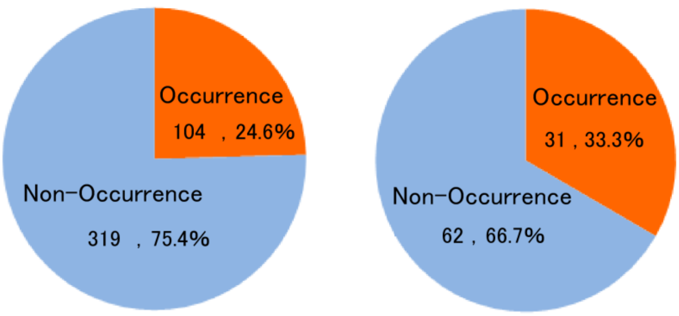


Figure 1. Status of eutrophication of dam reservoirs (Left chart – all 423 dams; Right chart – 93 dams of MLIT and JWA large-scale relatively)

2.2 Impact of Eutrophication

According to the aforementioned 2002 survey, the most frequently cited impact of eutrophication was unappealing scenery at the reservoir, occurring at 71 dams, followed by a foul smell and taste problem in the downstream water sources, occurring at 38 dams, and then by a foul smell problem at the reservoir, occurring at 31 dams. Among the 93 dams under the control of the MLIT and JWA, the most frequently cited impact was unappealing scenery at the reservoir, at 24 dams, followed by a foul smell and taste problem in the downstream water sources, at 12 dams, and then by a foul smell problem at the reservoir, at 11 dams (Table 1.) . The aforementioned latest (2011) survey showed a pattern similar to the 2002 survey, as roughly 70 percent of the cited impact of eutrophication was unappealing scenery induced by cyanobacteria blooms and fresh water red tides.

Table 1. Impact of eutrophication at dam reservoirs

Damage		Number of dams	
		Among 104 dams	Among 31 dams
Reservoir	Foul smell	31	11
	Unappealing scenery	71	24
	Degraded fish habitat	4	0
	Other	4	1
Downstream rivers, water sources, tap water, etc.	Clogged filters	11	4
	Hampered coagulation and sedimentation	2	1
	Increased injected volume of chlorine	3	1
	Foul smell and taste	38	12
	Other	12	5

2.3 Present Status and Effects of Countermeasures against Eutrophication

Among measures used to counter eutrophication, the methods shown in Table 2 are the ones most often applied in Japan (MLIT 2005, Water Resources Environment Center (WEC) 2006, WEC 2015). The 2011 survey revealed that countermeasures had already been implemented at roughly two-thirds of the dams suffering from problems associated with eutrophication. Among these countermeasures, suppression of the overgrowth of causal algae by changing the physical environment of the reservoir water with the use of a mechanical circulation facility (epilimnetic or overall), fence, selective intake system or other such means accounted for the majority, a little under 80%. As for the efficacy of these measures, while roughly 60% of the facility administrators responded, “the water quality control facility displayed a certain level of effectiveness,” some responded, “there are many dams with problems unsolved.” Using only the current water quality control measures, it is apparent that an acceptable solution to the problems has not been achieved.

Table 2. Major eutrophication countermeasures employed in Japan

Method	Aim and Principle
Epilimnetic Aeration	Air is injected from the mid-depth or epilimnetic layer of the water column in the reservoir. The buoyancy of the air bubbles generates upward flow to form a circulating mixed zone in the reservoir. This brings about a lowered water temperature in the epilimnetic layer, drawing phytoplankton to layers below the euphotic zone, as well as algae diffusion and other phenomena, thereby suppressing the growth and accumulation of phytoplankton.
Hypolimnetic Oxygenation	Oxygen is supplied to the hypolimnetic layer while water column stratification is maintained. This inhibits the release of iron, manganese, hydrogen sulfide and nutrients from the sediment to prevent the occurrence of rust-colored water or black (manganese-infused) water and the diffusion of nutrients across the reservoir during the turnover seasons.
Overall Aeration	Aerating and circulating the entire water body in a reservoir to forcibly move water in the hypolimnetic layer to the epilimnetic layer. The forced migration of phytoplankton to the aphotic zone and the lowered water temperature in the epilimnetic layer lead to suppressed phytoplankton growth. However, caution is required, as the process may disturb sediment and cause nutrients to migrate.
Fountain System	Pressure, agitation, and the percussive effect of falling water generated by the fountain pump damage phytoplankton cells, thereby inhibiting the proliferation of algae. In addition, the sun-screening effect of the falling water, evapotranspiration, and the stirring of water inside the reservoir prevent an increase in the epilimnetic water temperature and lower the thermocline, which leads to inactivation of phytoplankton and the suppression of its growth.
Floating Artificial Wetlands and Artificial Ecology Reef	Floating wetlands are man-made floating mats covered with wetland plants. Those designed to prioritize water purification are called artificial ecology reefs. The overgrowth of algae is inhibited by the absorption of nutrients by the plants and algae attached to the plants and mats, and algae control is facilitated by the relationships between diverse organisms (competition for nutrients, zooplankton grazing on phytoplankton, etc.), and by suppressed photosynthesis due to blocked light penetration.
Selective Water Intake System	In a reservoir where thermal stratification has been formed, effluent water quality (primarily, water temperature and turbidity) is controlled by changing the water intake height to allow water to be selectively taken from any layer of the water column. In addition, the entry depth of turbid influent water is controlled as the status of stratification in the reservoir is changed by the operation of the selective intake system. The effects of this system help mitigate cold water and warm water phenomena, as well as prolonged turbid water phenomenon.

Table 2. (Continued) Major eutrophication countermeasures employed in Japan

Method	Aim and Principle
Flow Control Fence	A fence is installed at the end of the inflow zone in a reservoir to guide highly turbid and nutrient-rich influent water into the hypolimnetic layer when floods occur. With this, turbidity in the epilimnetic layer is reduced, the supply of nutrients to phytoplankton is inhibited, and the growth of phytoplankton is suppressed. Meanwhile, the combined use of the fence with the selective intake system is effective in preventing nutrients from re-ascending into the euphotic zone.
Bypass (Diversion)	There are several types of bypasses. A clean water bypass is used when water turbidity inside the reservoir has increased, to bypass the reservoir and discharge low-turbidity upstream water directly downstream. A turbid water bypass is used during flood periods to bypass the reservoir and discharge turbid water directly downstream, to prevent water in the reservoir from becoming turbid. A counter-eutrophication bypass is used to prevent effluent and other water from entering the reservoir by diverting it to the downstream area near the reservoir, to prevent eutrophication.

3. CHARACTERISTICS OF CYANOBACTERIA BLOOMS AND FRESH WATER RED TIDES

Cyanobacteria blooms that cause a yellow-green discoloration of the water surface, and fresh water red tides that cause a brownish-red discoloration of the surface, are often observed in dam reservoirs in Japan. The Japanese word for cyanobacteria blooms is aoko, which literally means blue (or green) powder. Fresh water red tides have their moniker because they cause discoloration similar to that of red tides in marine water (though the actual color is usually blackish brown rather than red). In internationally used terminology, cyanobacteria blooms and red tides are defined as water blooms or algal blooms, as they are likened to vivid-colored flowers blooming from buds on the water surface, changing the water surface color in a short period of time. Meanwhile, fresh water red tide is the term often used for a red tide in fresh water, to distinguish it from a red tide in marine water. The red or brownish-red water surface is caused by microscopic phytoplankton.

3.1 Cyanobacteria Bloom

Cyanobacteria blooms occurring in Japan are usually caused by a species of the *Microcystis* or *Anabaena* genera. Cyanobacteria used to be classified as algae, specifically as blue-green algae, due to their color. However, systematic microbiology has classified them as prokaryotes (bacteria), because they do not have a nucleus, while algae are eukaryotes. Unlike other major species of bacteria, cyanobacteria characteristically contain chlorophyll (chlorophyll pigment) in their cells, and carry out primary production through photosynthesis to synthesize organic matter from inorganic matter. They thrive in waters where there has been progress in eutrophication, and which are rich in the nutrients of phosphorus, nitrogen and iron.

Some of these cyanobacterial species intracellularly produce a toxin called microcystin-NR, or anatoxin, as well as foul smelling and tasting compounds such as geosmin. It is already known that microcystin-NR may cause acute abdominal pain, headache and may trigger liver cancer. Anatoxins, may cause such symptoms as tingling, numbness, or even respiratory paralysis leading to death. Geosmin and other foul smelling or tasting compounds often give tap water a moldy odor, which imposes a hindrance to water use.

In the past, cases of mass mortality among livestock from drinking water containing cyanobacteria blooms in Australia and deaths of dialysis patients caused by cyanobacteria blooms entering the dialysis water in Brazil have been reported. In recent years, wild animals, including more than a dozen zebras, have died from drinking cyanobacteria blooms consisting mainly of the *Microcystis* species out of reservoirs in Africa. In the North American Great Lakes, occurrences of toxic and foul smelling and tasting cyanobacterial blooms have impaired water use, and in China countermeasures against cyanobacteria blooms are being implemented mainly at Lake Taihu as a national project. As can be seen, cyanobacteria blooms are a global problem, and constitute an important issue that needs to be urgently addressed for the continued survival and progress of humankind.

3.2 Fresh Water Red Tides

Freshwater red tides in Japan occur because of massive growths of dinoflagellates, similar in species

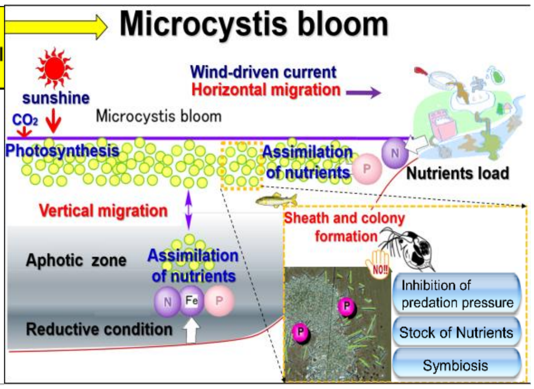
to some red tides in marine waters. The principal factor contributing to their occurrence is the water flow morphology peculiar to dam reservoirs constructed on river channels, rather than eutrophication, and they occur more often in dam reservoirs in mountains with relatively little anthropogenic pollution. The majority of fresh water dinoflagellates in Japan are nontoxic and free from foul smell or taste, rarely hampering water use. However, the blackish-brown discoloration of surface water creates an unpleasant sight, and draws frequent complaints from nearby residents and visitors. Hence, we are sometimes required to cope with fresh water red tides in dam reservoirs where measures against cyanobacteria blooms have suppressed eutrophication.

3.3 Growth Advantage of Bloom-Forming Species

Microcystis, which is a representative genus of bloom-forming cyanobacteria, has numerous advantages in growth over other types of phytoplankton, as shown in Table 3. *Peridinium*, which is a typical genus of dinoflagellates, has similar advantages in forming seed populations, vertical and horizontal migration, and use of nutrients in organic forms. Their acquisition of these growth advantages leads to their specific proliferation, enabling massive growth of a single species.

Table 3. Growth advantages of *Microcystis*

Character	Photo synthesis	Obtain nutrients	Obtain CO_2	Early development	Inhibirion of predation pressure	Survival
Seed population				●		●
Vertical migration	●	●	●	●	●	
Horzontal migration		●		●		
Colony					●	
Sheath		●			●	
High−temperature endurance						●
Toxiciity					●	
Usable organic phosphate		●				
Usable bicarbonate			●			



Phytoplankton in dam reservoirs emerge from a seed population when the environmental conditions become favorable to growth, and die after going through logarithmic and stationary phases. In their death phase, some *Peridinium* cells sink to the bottom, where they quickly transform into pseudo-cysts with different physiological functions and go into a special phase of quiescence. Unlike *Peridinium*, *Microcystis* cells remain in the sediment as vegetative cells waiting for the environment to become favorable again. In waters where blooms routinely occur, there are a great number of bloom-forming cells in the sediment that form a seed population even during seasons when blooms do not appear. This ability to form stable seed populations leads to *Microcystis*' preferential and predominant growth in the early phase.

During the logarithmic phase when blooms expand and the stationary phase, the appropriate water temperature (high), sufficient light and a supply of nutrients and carbonic acid, etc. are needed for growth and maintenance.

Cyanobacteria have a buoyancy bag called a gas vesicle in their cells. Following a decrease in intracellular turgor pressure brought about by the consumption of carbohydrates at night, the gas vesicles begin to inflate before dawn until they gain enough buoyancy to float on the water's surface. In the daytime, the production of carbohydrates by photosynthesis increases turgor pressure, which deflates the gas vesicle and reduces buoyancy, leading them to sink from early evening into the night. Fresh water red tides are also phototactic. They swim by flagellar rotation to migrate toward the sunlight in daytime, and sink at night due to their own weight. As seen above, the ability to migrate vertically in circadian periodicity is a common feature of both cyanobacteria blooms and fresh water red tides.

Their ability to migrate vertically allows them to be active during the daylight hours, near the sun-warmed water surface where the light and carbonic acid supply conditions are favorable for photosynthesis, and to position themselves at night in the lower layer, which abounds with nutrients. This behavior gives them a considerable advantage in proliferation over common types of non-migratory phytoplankton.

4. MEASURES AGAINST WATER BLOOMS AT UPSTREAM END, INLET AREA

The aerating circulation method has been mainly used in dam reservoirs in Japan as a fundamental eutrophication countermeasure. However, as water blooms occur at the upstream ends and inlets beyond the reach of aeration, further measures are called for. New technologies that are currently being applied to control these water blooms, as well as coordinated application technologies employed to enhance control effects are described below.

4.1 Jet-Shock System

The features of *Microcystis* that are advantageous for growth, especially those contributing to its dominant proliferation, include the avoidance of predators through the formation of colonies as well as photosynthesis and nutrient acquisition with vertical migration based on buoyancy adjustments using the gas vesicle. The Jet-Shock System eliminates these advantageous features by applying physical shock. While activating the natural food chain in the dam reservoir water, it ecologically suppresses occurrences of blooms by enhancing the competitive power of rival algae. While many physical measures against *Microcystis* blooms have been devised so far, including the use of ultrasonic waves, cavitation, etc., the Jet-Shock System is a pioneering method employed at the practical application level to counter *Microcystis* blooms in dam reservoirs in Japan. (Recognized by the Ministry of Education, Culture, Sports, Science and Technology as an invention worthy of attention.)

The Jet-Shock System sucks in *Microcystis* blooms with raw water, and propels them against the impact board, destroying the *Microcystis* bloom colonies and dispersing the cells (Figure 2.). Although it is possible to decompose the cells with high pressure, this method uses pressure conditions in which cells are deprived of their buoyancy while still retaining the cell form. In this way the cells are turned into feed for protozoa and zooplankton that graze on *Microcystis* blooms.

With the destruction of the colonies and dispersion of the cells, a *Microcystis* bloom suppression effect based on predation by protozoa and zooplankton has been confirmed (Figure 3.). In a large-scale site isolation experiment, increased elimination of *Microcystis* blooms, and an increasing trend of green algae and diatoms, which are competitive algae, as well as zooplankton was observed when compared to untreated water (control) (Table 4.). This system has achieved the elimination of around 10,000 m^2 of *Microcystis* blooms when conditions are favorable for treatment, such as during the stable formation of a wind-induced current (Figure 4).

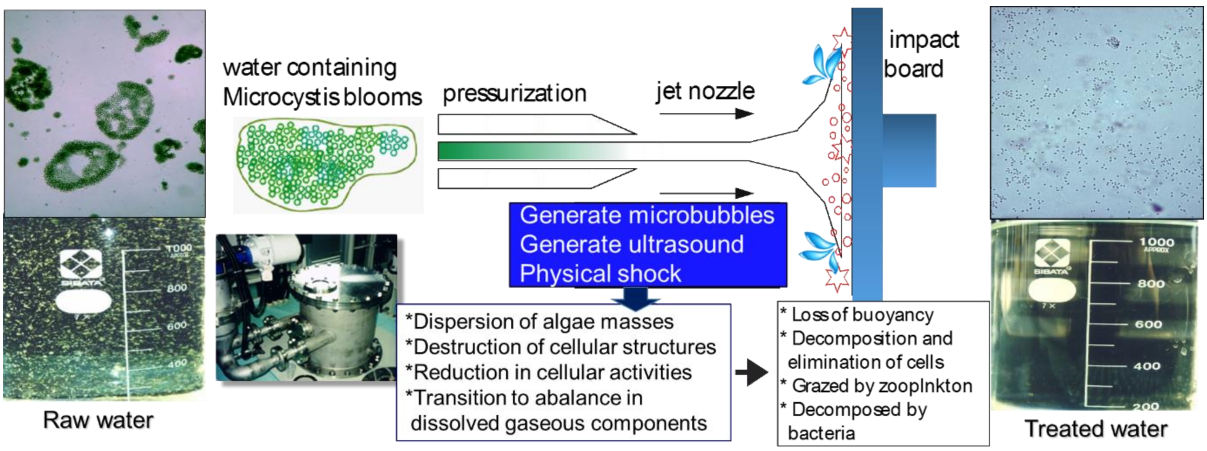


Figure 2. Principle of Jet-Shock

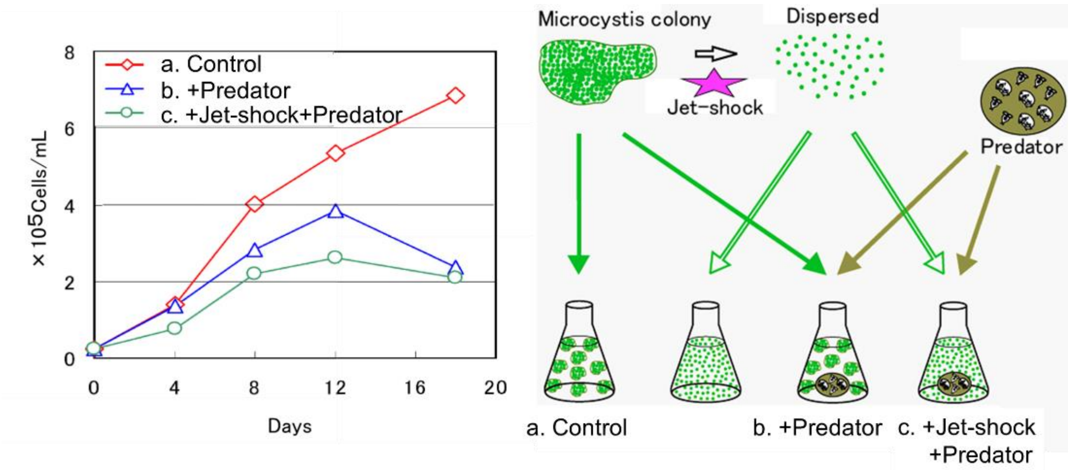
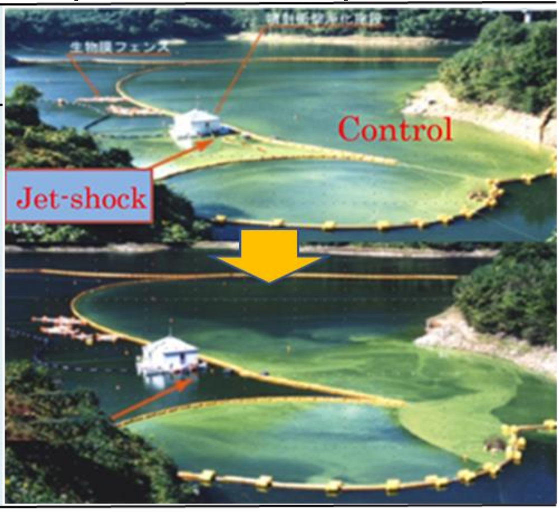


Figure 3. Predation promotion effect by Jet-Shock (Cultured at 3,000 Lux, 25 degrees Celsius)

Table 4. Field verification on test results (one month treatment)

Predator Zooplankton	Multiple Number of Population (Jet-Shocked Area /Control Area)
Amphileptidae sp.	New *
Monodinium balbianii	New
Peritrichida sp.	31.3
Brachionus angularis	4.4
Brachionus rubens	3.7
Brachionus Leydigi f. tridentatus	1.5
Tintinnopsis cratera	New
Diurella sp.	New
Filinia longiseta	New
Synchaeta sp.	New
Lepadella sp.	New
Copepoda nauplius stage	3
Tardigrada sp.	2
Diacyclops sp.	New



* "New" refers to species that were not confirmed in the control area but emerged in the Jet-Shocked area.

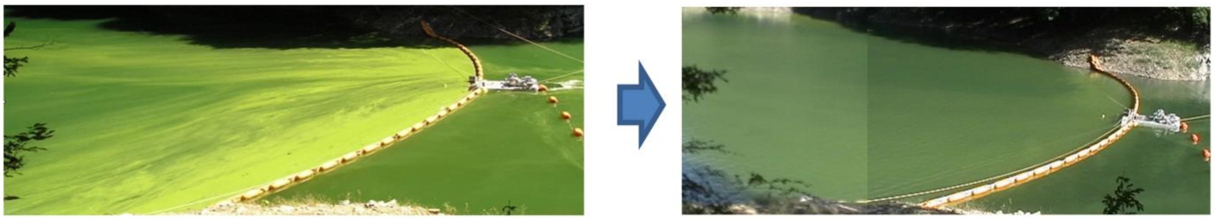


Figure 4. *Microcystis* bloom elimination by Jet-Shock

The low-pressure UV treatment boat is a 13-meter catamaran that has two UV treatment tubes installed between the two hulls. The UV tubes each have 20 submersible 15-watt UV lamps inside. This boat is equipped with a sequencer (Programmable Logic Controller), in which data has been input regarding the relationship between the minimum amount of UV exposure required to inhibit cell division and the cell density of abnormally increased plankton. This data was determined in advance through cultivation experiments. Using the sequencer for control, the rotation speed of the water-jet propeller is adjusted, and this makes it possible to control the amount of UV exposure in a system that can provide a continuous and stable effect. As shown in Figure 5, a nearly 99% or greater control effect has been maintained by changing the flow rate inside the treatment tubes and controlling the amount of UV exposure in response to plankton cell density readings obtained by the sensor.

This boat can provide meticulous treatment across the reservoir surface. While moving, it sucks in and treats the excess plankton that tend to accumulate on the water surface. As the system comprises a simple construction based on the UV lamps, it is easy to operate and maintain. It is also equipped with a memory to automatically record the number of treated cells, so that treated plankton quantity data on a frequency ranging from daily to monthly is available. It has been proven that the use of this treatment system reduces the sedimentation of targeted plankton to extremely small amounts when compared with natural sedimentation in other dam reservoirs, with little secondary effect on the reservoirs. The results of plankton growth simulations for the target dam reservoir and field surveys have clearly indicated that intensive implementation of treatment at the beginning of overgrowth of plankton can efficiently reduce the annual volume of plankton blooms. One boat can treat up to 1,000 m^3 of fresh water red tides per hour or around 700 m^3 of cyanobacteria blooms per hour. This UV radiation system will contribute to comprehensive prevention measures for eutrophication, as it is effective not only in disinfection, but in decomposing foul smelling and tasting substances and toxic matter as well.

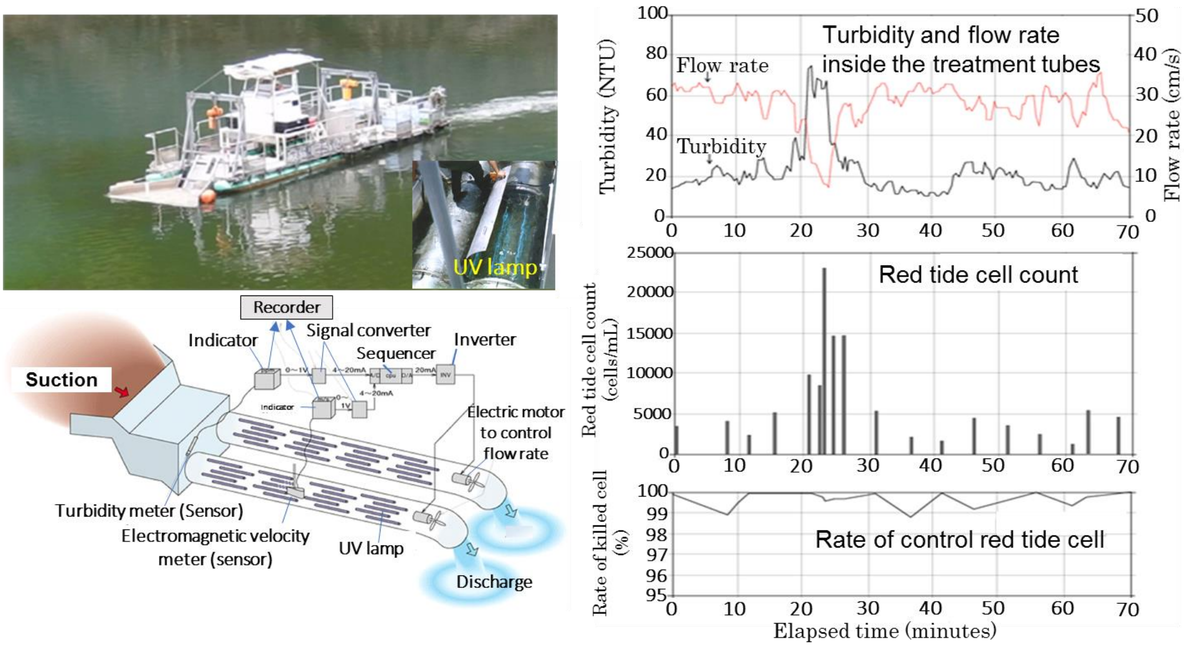


Figure 5. UV treatment boat for blooms (fresh water red tide treatment status)

4.2 Coordinated Application Methods

Below, we propose some coordinated application methods that were developed in line with eco-engineering findings, with the aim of promoting the water bloom inhibition effects of both the Jet-Shock and Ultraviolet Radiation Systems described above.

4.2.1 Bloom Control Fence

A bloom control fence is equipped with a valve that is opened/closed using the energy of the wind-induced current near the water surface, and channels the blooms carried by the wind-induced current (Figure 6.) in a particular direction. By applying this method after confirming the horizontal migration of cyanobacteria blooms in a dam reservoir, the blooms can be restrained to any designated water area. With this, the efficiency of the aforementioned measures to inactivate blooms can be enhanced. In addition, by confining the blooms to a water area with no supply of nutrients, a reduction in the amount of blooms throughout the reservoir can be expected. This fence can be installed in addition to the flow control fence system, which is one of standard measures used.

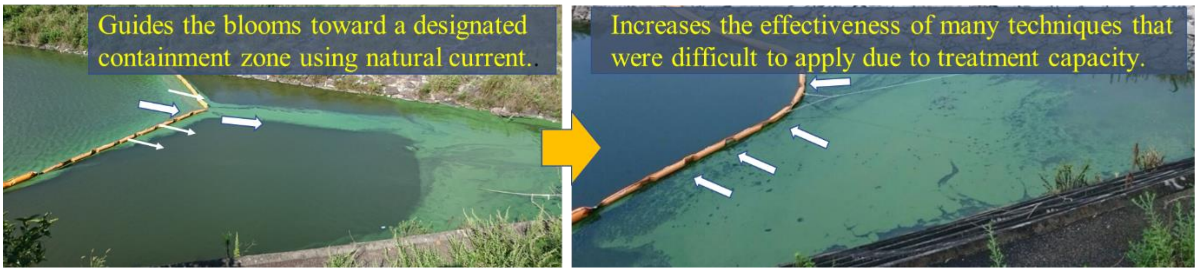


Figure 6. Bloom control fence

4.2.2 Ecological Dam

We created the Ecological Dam to prevent any secondary negative impact from *Microcystis* and *Peridinium* cells that have been inactivated by the Jet-Shock or UV Radiation System in surrounding waters, to efficiently transfer these cells into an ecological purification system, and to block organic matter and nutrient flux that may impact the surrounding waters. The principle of the Ecological Dam is to activate the native organism colonies to improve the natural ecological cycle of substances in the water, and to encourage a new cycle of materials that can lead to the reactivation of local industry (Iseri Y et al. 2011). To prevent the introduction of non-native plants and those of the same species as the native ones but not genetically identical to them, the structure is designed with root-shaped artificial fibers serving as organism carriers as the main component. At Yangcheng Lake in China, which belongs to the Lake Taihu water system, the Ecological Dam is being applied to Chinese mitten crab farms, which are a local source of pollution (Figure **7**.). Here, its efficacy in inhibiting sediment disturbance and in water purification has been confirmed. The most important achievement in terms of the Ecological Dam concept is the improved material cycle in the aquafarms, where the growth of the Chinese mitten crabs has improved. As this measure is directly beneficial to business interests, the operators of aquafarms, which are the source of nutrient-rich effluents, began to voluntarily participate in the maintenance and management of their facilities. The artificial roots in the Ecological Dam have been confirmed to have the effects of promoting protozoa growth, adsorbing cyanobacteria blooms, and improving water clearness.

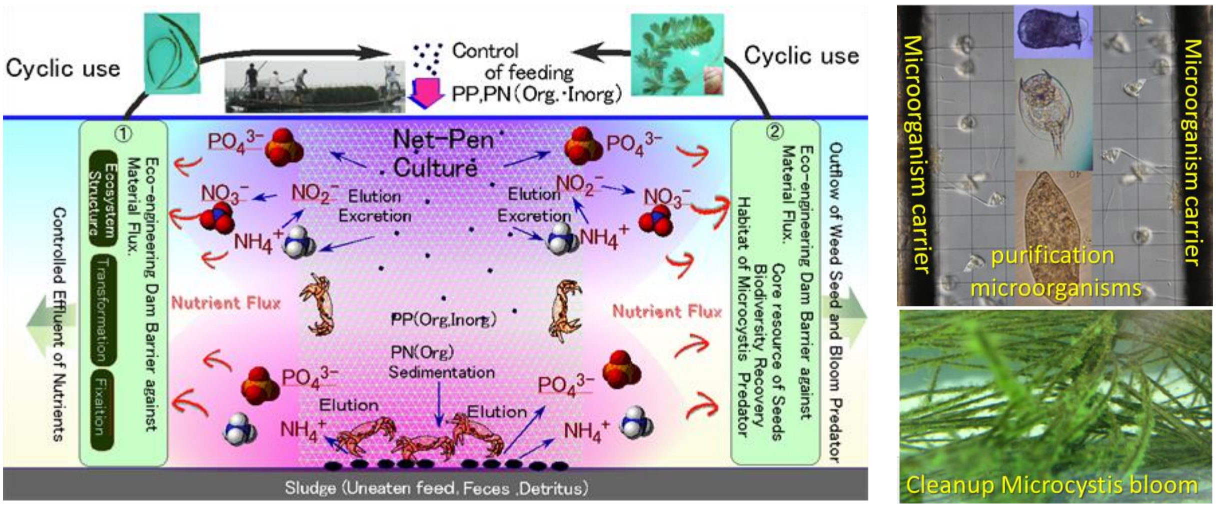


Figure 7. Ecological Dam (Example of application to aquafarm, in the Yangcheng Lake)

4.2.3 LED Radiation

Inactivated cells sink, which may lead to increased pollution levels in the sediment. In particular, an organic load causes dysoxia in the bottom layer, leading to deterioration of the water environment. Aiming to activate native photosynthetic microorganisms, we developed our LED Radiation System to improve the bottom layer and sediment environment. Laboratory experiments and field pilot experiments have confirmed that this method works to supply dissolved oxygen and reduce nutrients. Even in conditions where degradation of *Microcystis* was assumed, the water quality improvement effect was demonstrated.

A culture experiment using LED radiation was conducted by placing artificial roots in a beaker of lake water containing dead Microcystis blooms. It was observed on the 22nd day of culturing that green algae and other photosynthetic microorganisms had grown, and that the lake water had turned green. Photosynthesis and anabolism of these microorganisms caused an increase in the dissolved oxygen level with a decrease in phosphorus concentrations. Red LED radiation in particular brought about supersaturation of dissolved oxygen, and was also greatly effective in the reduction of phosphorus (Figure 8.). Currently, field applications of the system are underway . Figure 9 shows the LED radiation units used in the field experiment and how they were arrayed in the experimental pond.

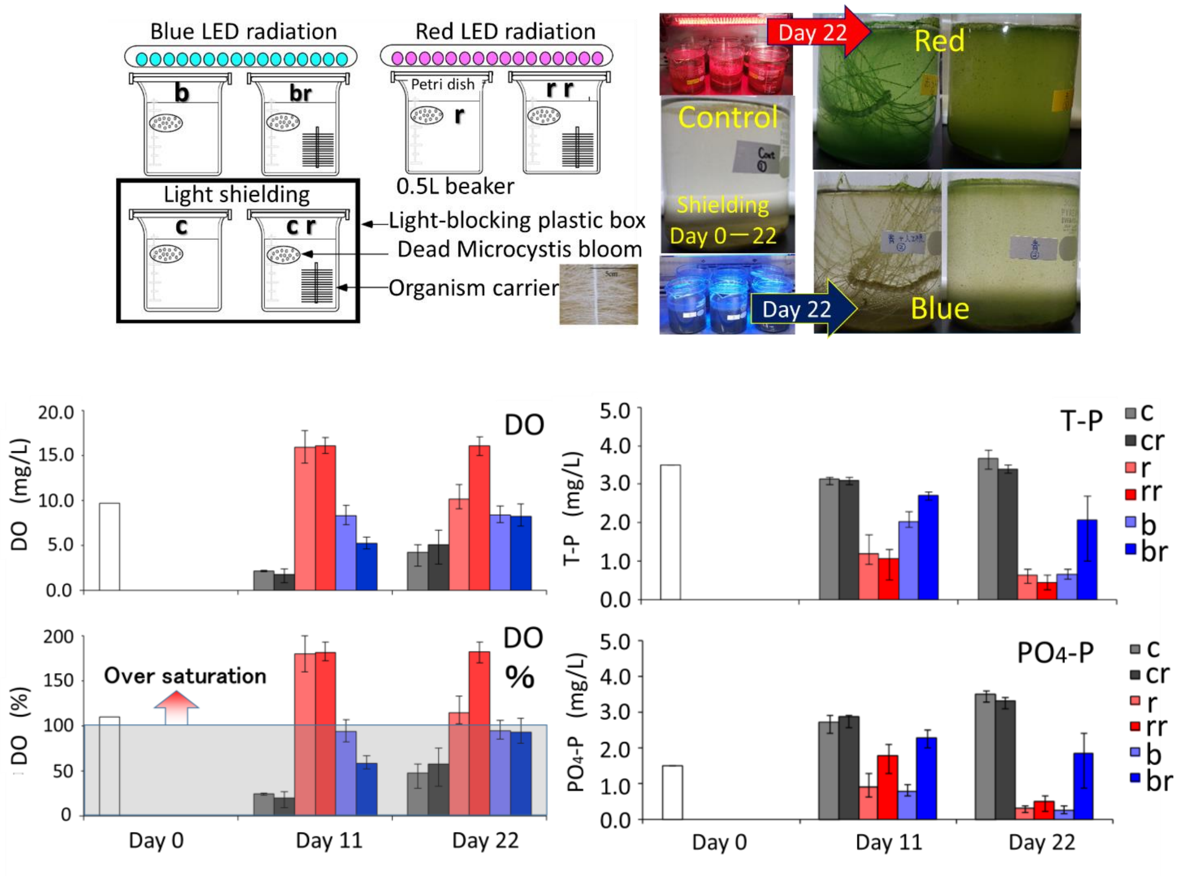


Figure 8. Water purifying effect of LED Radiation in a degradation test of *Microcystis*

Figure 9. Field verification testing equipment for LED Radiation efficacy and its operating status at the experimental pond

4.3 Bloom Control System Using Eco-Engineering

We propose a comprehensive bloom control method to counter water blooms in the upstream ends and inlet areas of dam reservoirs, formulated by incorporating technologies that we developed and introduced in this paper in a coordinated system (Figure 10.). This is an eco-engineering system in which blooms are confined in a designated water area by the Bloom Control Fence to create a water purification zone, where water is purified by treating blooms with the UV Radiation and Jet-Shock Systems, and by activating native microorganisms with the Ecological Dam and LED Radiation Systems.

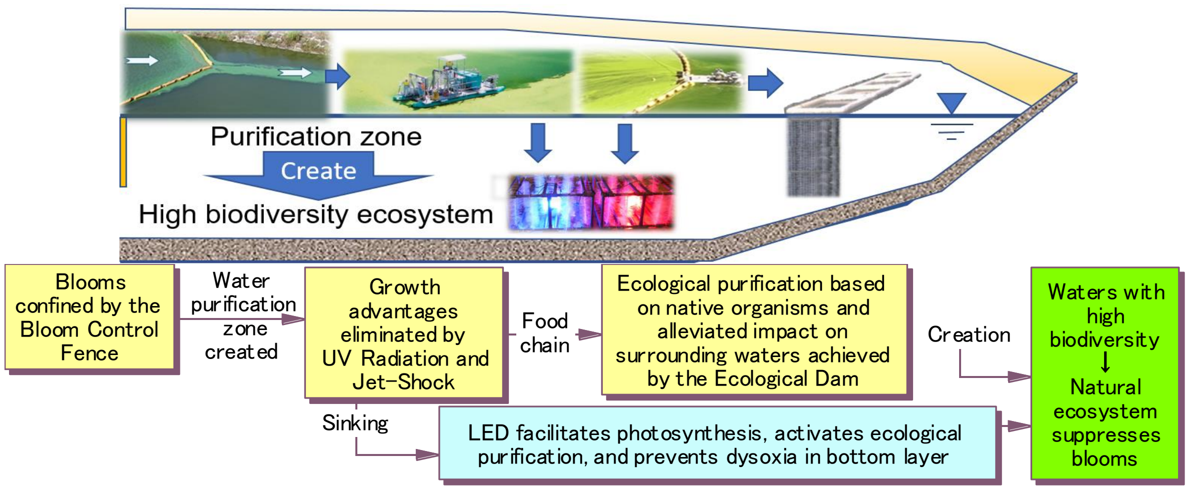


Figure 10. Water bloom countermeasures in the upstream ends and inlet areas of dam reservoir

5. CONCLUSION

Cyanobacteria blooms in eutrophic waters are far more fertile than other types of phytoplankton, hampering prevention and removal efforts. The aerating circulation method has been commonly used as a measure to alleviate the problem in dam reservoirs. However, occurrences of cyanobacteria blooms in reservoirs are frequently observed despite the implementation of this measure, mainly in the upstream ends and inlet areas of dam reservoirs that are not so effected by aeration.

In seeking new measures to fight blooms occurring in the upstream ends and inlet areas of dam reservoirs, the authors took a new look at cyanobacteria's advantages in growth and investigated ways of suppressing these advantages, as well as methods of turning these advantages against them. The result was the development of the Bloom Control Fence System, which exploits the horizontally migrating characteristics of water blooms carried by wind-induced currents, the Jet-Shock System, which destroys cyanobacteria colonies that store nutrients and protect the cyanobacteria from predators, and which inactivates the vertical mobility that helps them photosynthesize and acquire nutrients, and the UV Radiation System, which inactivates Peridinium's vertical migration and proliferation. The bloom suppressing effects of these systems were verified through applications in dam reservoirs affected by occurrences of blooms. Furthermore, in order to promote the benefits of these systems and improve secondary negative impact on the surrounding water environment, we conducted laboratory and field experiments using the Ecological Dam, which utilizes microorganisms that feed on the blooms, and the LED Radiation Method, which mitigates negative impact on the bottom layer of the reservoir by facilitating water purification with photosynthetic microorganisms, and confirmed the enhanced benefits and reduced negative impact. It is expected that the coordinated application of these measures will activate the dam's inherent water purifying functions and result in the more efficient suppression of blooms.

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