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WATERPLANT PURIFICATION OF EUTROPHICATED WATER IN MESOCOSM SYSTEM WITH LONG-TERM OBSERVATION

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ABSTRACT: To compare the ability of water purification as N, P, COD and Chl.a removal, 8 mesocosm systems were observed for 4 years. As results, 1) In all treated mesocosm system, Aoko did not appear, 2) CaO sprinkling treatment showed the most effect for water purification with P-elution controlling in long-term observation, but bio-diversity of phytoplankton and zooplankton became poor because of surplus purification, 3) MgO sprinkling treatment showed long-term effective P-elution control, and phytoplankton flora was not so poor as that in CaO sprinkling treatment, 4) Large size zooplankton were observed in water glass purification system with the structure of water plant roots for rich niche construction, 5) The diversity index of phytoplankton flora was higher under complicated community structure such as phytoplankton, zooplankton and water plants, 6) Water plant purification system was disturbed by immigration birds that ate water plants and supply their excrement to water, so positive maintenance is important to keep this system in order, and 7) Hybrid treatment system did not show the hybrid effect on water purification, so it considered important that environmental improvement level should be optimized.

Keywords: Waterplant, Chemical remediation materials, Mesocosm, Phytoplankton, Waterbloom

1. INTRODUCTION

The Hasunuma seaside park is locating in Kujyukurihama Coastal Line in Chiba prefecture, Japan where is the very famous long beach crowded with many attendance person/tourists, especially in summer season. However, as an eutrophication has been progressed in recent years in this park pond, Aoko, the water bloom of harmful cyanophyceae, such as *Microcystis aeruginosa* and *Anabaena spiroides*, became observed in every summer. It is important that the basic information about the succession of phytoplankton community for prevention the eutrophication of water environment [1][2].

In this study, water quality improvement by waterplant was investigated using experimental mesocosm system. Waterplant purification technology is expected as one of the most efficient method from the viewpoint of cost and the impact to natural ecosystem [3]. Four years experiment and observation was conducted to compare the waterplant purification and chemical remediation materials for their ability of water purification.

2. MATERIALS AND METHODS

2.1 Outline of Kujyukurihama Coastal Line

Kujyukurihama coastal line (about 55km length) is one of the most famous beach resort zone in Japan, facing to the Pacific Ocean. The climate is calm through a year, and it's cool in summer and warm in winter. Fishery and farming is prosperous. Thousands of people visit to this beach resort especially in summer, because of its closeness from Tokyo metropolitan and Narita International Airport.

2.2 Outline of Hasunuma Seaside Park Pond

Outline of Hasunuma seaside park pond is shown in Fig.1. The surface area of this pond is about 10,380m^2, and the pond capacity is about 7,000m^3. Hasunuma village is so influenced on the Kuroshio current (the Japanese current) that the climate is warm and much rain with an average air temperature is about 14.7℃ and a rainfall is about 1,224mm. The park area is 38.3ha, pond volume is 6,747m^3, and water depth is 0.65m in average. As for in the water of this boat pond excessive the collection water and the phosphor acid from the surroundings/the spring water from the Pacific Ocean that contains 1.0-1.5 mg/l of PO_4-P, the eco-balance which can be indicated as N/P mass ratio in this pond is under P surplus condition [4]. Phytoplankton requires N and P as their nutrient salts for its growth, and it is enough for water bloom forming cyanophyceae, that is Aoko, to grow massive in this pond.

2.3 Design of Experimental Mesocosm

To investigate waterplant purification possibility to eutrophicated water bodies, experimental mesocosm system (2m×2m×0.5m) were set up in eutrophicated brackish park pond locating Kujyukuruhama coastal line, Japan. The outline of mesocosm system was shown in Fig.2. This park pond is so much eutrophicated that massive Aoko formed by Microcystis aeruginosa and Anabaena spiroides appear every summer. This phenomena leads many problems to citizen as water use [5]. To compare the ability of water purification as N, P, COD and Chl.a removal, eight mesocosm systems were established. Those are; Run 1: control (water only), Run 2: control (water and sediment), Run 3: chemical remediation materials (MgO) sprinkled, Run 4: chemical remediation materials (CaO) sprinkled, Run5: waterplant treatment (*Eichhornia crassipes*), Run6: waterplant treatment (*Nasturium officinale*), Run7: hybrid treatment (MgO + *Eichhornia crassipes*), and Run8: hybrid treatment (MgO + *Nasturium officinale*). These experimental series were shown in Table 1. Experimental culture was started in Aug.2003, and continued to FY2007 (4 years long). Sampling was conducted once a month, and water quality analysis was conducted in laboratory as soon as possible. Parameters for analysis were pH, DO, Cl^-, T-N, NO_3-N, NO_2-N, NH_4-N, T-P, PO_4-P, COD, Chl.a, phytoplankton flora and zooplankton fauna.

2.4 Restraint Mechanism

2.4.1 Waterplant purification

Waterplant purification technology is considered as one of the bio-environmental engineering technology [3]. There has been much experiment and discussion about this technology, and the characteristics for water purification of waterplant species were made clear [6]. *Eichhornia crassipes* is widely known as one of the harmful waterplant as its irregular growth in eutrophicated water bodies against navigation of fishery and so on. On the other hand, its ability for adsorption of nutrient salts is very high, and it expected to be very essential for water purification under optimum treatment. *Nasturium officinale* is known as one of the famous plant for food. It is also utilized in biotope (for example, Lake Kasumigaura, Japan) to purify lake water. These two waterplant are shown in Fig.3. The mechanism for water purification of these waterplant is considered as i) adsorption of nutrient salts, ii) shade of sun light and iii) allelopathy effect.

The quantity of waterplant was adjusted as $0.25kg/m^2$ of *Eichhornia crassipes* and $0.5kg/m^2$ of *Nasturium officinale*, respectively.

2.4.2 Chemical remediation materials

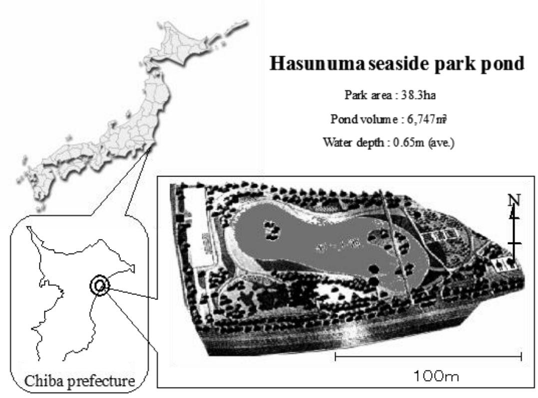

Fig.1 Outline and location of Hasunuma seaside park pond

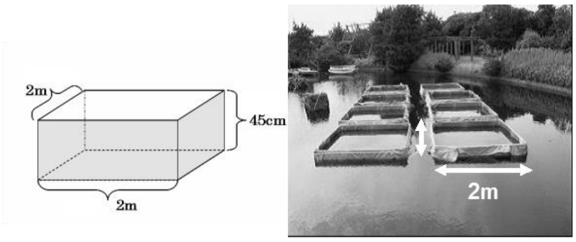

Fig.2 Outline of experimental mesocosm system

Table 1 Experimental series in this study

Run 1	control (water only)
Run 2	control (water + sediment)
Run 3	chemical treatment (MgO)
Run 4	chemical treatment (CaO)
Run 5	waterplant treatment (*Eichhornia crassipes*)
Run 6	waterplant treatment (*Nasturium officinale*)
Run 7	hybrid treatment (MgO + *Eichhornia crassipes*)
Run 8	hybrid treatment (MgO + *Nasturium officinale*)

a) *Eichhornia crassipes* b) *Nasturium officinale*

Fig.3 Waterplant applied to water purification

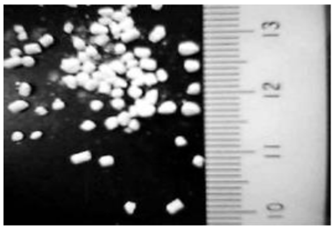

Fig.4 Chemical remediation material

Chemical remediation means the purification technology for eutrophicated sediment using some chemicals such as MgO, CaO and so on [7]. The most efficient merit of this technology is in maintenance-free and low cost. On the other hand, this method has demerit as large impact to ecosystem. For example, CaO fixes PO_4-P effectively, but washes out NH_4-N from sediment layer at the same time. In addition, it makes pH higher, and not only microorganisms but also fish, waterplant, macrobenthos and so on are damaged. The optimum pH for MgO and CaO reaction is 7 and 9, respectively. The quantity of chemical remediation materials in this study was adjusted as $1kg/m^2$ of MgO and $0.5kg/m^2$ of CaO, respectively. The quantity of these chemicals was determined with consideration of the optimum quantity to obtain most effective restraint of nutrient elution from sediment layer. The chemical remediation materials were shown in Fig.4. The chemical reaction of these chemical remediation materials are described below.

$$Mg^{2+} + HPO_4^{2-} + 3H_2O \Leftrightarrow MgHPO_4 \cdot 3H_2O \downarrow \quad (pH\ 7) \tag{1}$$

$$Mg^{2+} + NH_4^{+} + PO_4^{3-} + 6H_2O \Leftrightarrow MgNH_4PO_4 \cdot 6H_2O\ (MAP) \downarrow \quad (pH\ 7) \tag{2}$$

$$Ca^{2+} + HPO_4^{2-} \Leftrightarrow CaHPO_4 \downarrow \quad (pH\ 9) \tag{3}$$

3. RESULTS AND DISCUSSION

3.1 Restraint Rate of Nitrogen and Phosphorus

The restraint rate (%) of T-N and T-P as results of mesocosm experiment was shown in Fig.5 and **Fig.6**, respectively. Run 5, Run 6, Run 7 and Run 8 were planted waterplant in the initial stage, but after the first year passed, waterplant was dead except for Run 4. From this fact, it was made clear that the waterplant purification technology requires proper and delicate management. From these figures, Run 3, Run 4, Run 7 and Run 8 showed effective restraint of nutrient salts.

3.2 Restraint Rate of COD and Chl.a

The restraint rate (%) of COD and Chl.a as results of mesocosm experiment was shown in Fig.7 and Fig.8, respectively. From these figures, Run 8 showed negative-effective restraint of COD in the initial period. Chl.a restraint rate was negative in all mesocosms in the middle period. Both COD and Chl.a restraint rate recovered in the last period in all mesocosms. This phenomena is due to the eutrophication of water quality in Run 2, that is, control. Though the restraint of COD and that of Chl.a showed almost same succession pattern, this means COD is depending on Chl.a which indicates phytoplankton quantity. That is, the organic matter existing in water in mesocosm system is considered to be mainly phytoplankton.

3.3 Succession of Biota in Mesocosm

In all treated mesocosm system, Aoko (*Microcystis aeruginosa* and *Anabaena spiroides*) did not appear, the other hand, non-treated mesocosm system (Run 1 and Run 2) was dominated by cyanophyceae, that is, *Microcystis aeruginosa* and *Anabaena spiroides*. In other words, every treatment technology in this study indicated the restraint effect against the irregular growth of phytoplankton. CaO sprinkling treatment (Run 4) showed the most effect for water purification with P-elution controlling in long-term observation, but bio-diversity for phytoplankton and zooplankton became poor because of its too purificated water body. MgO sprinkling treatment (Run 3) showed long-term effective P-elution control, and phytoplankton flora was not so poor as that in CaO sprinkling treatment. Large size zooplankton such as *Philodina erythrophthalma* and *Brachionus angularis*, were observed in case of water glass purification system (Run 5, Run 6, Run 7 and Run 8), because of the structure of waterplant roots for rich niche construction. The diversity index (Shannon Index; H') for phytoplankton flora was higher under complicated community structure such as phytoplankton, zooplankton and waterplants. Hybrid treatment system (Run7 and Run 8) did not show the hybrid effect on water purification effect, so it considered important that environmental improvement level should be optimized. Actual restraint mechanism of each purification technology in each mesocosm is shown in Fig.9.

3.4 Environmental Factors

Waterplant purification system (Run 5, Run 6, Run 7 and Run 8) was disturbed by birds as predator, that is, immigration birds such as Anas platyrhynchos ate waterplants and supply their excrement to water, so positive maintenance is important to keep this system in order. Furthermore, pine tree as prevent-sand wall is generally planted around seaside park pond. This tree, Pinus thunbergii, releases much pollen into the air in spring season, and these pollen are poured into the lake water to supply nutrient salts such as nitrogen and phosphorus. In fact, water surface of every mesocosm were covered by pollen and colored in yellow. So, to keep the experimental system in order, the environmental factor such as pollen of Pinus thunbergii should be considered.

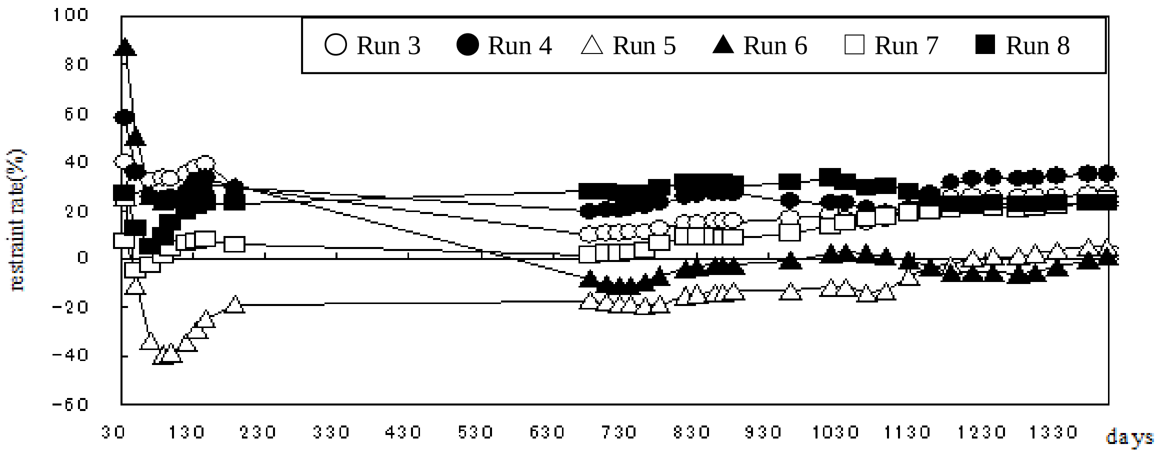

Fig.5 Succession of restraint rate of T-N in each mesocosm system

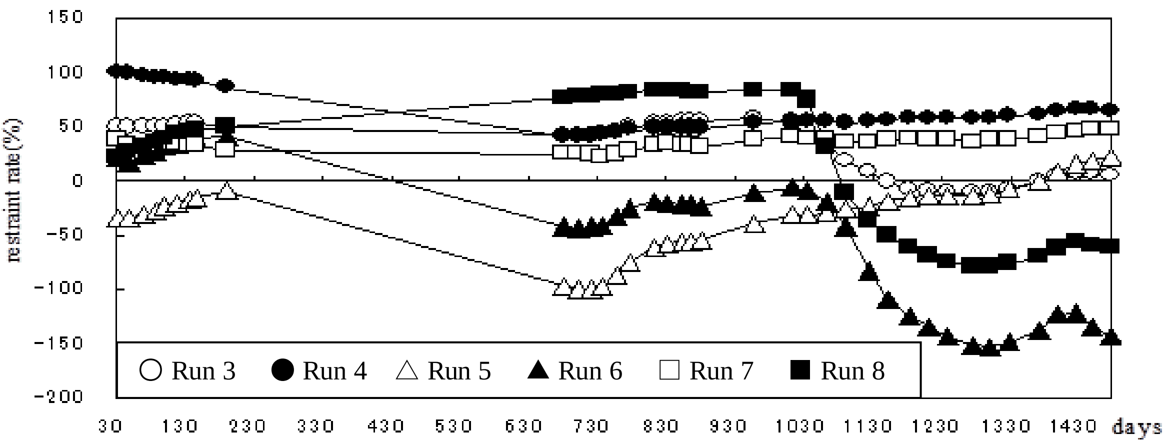

Fig.6 Succession of restraint rate of T-P in each mesocosm system

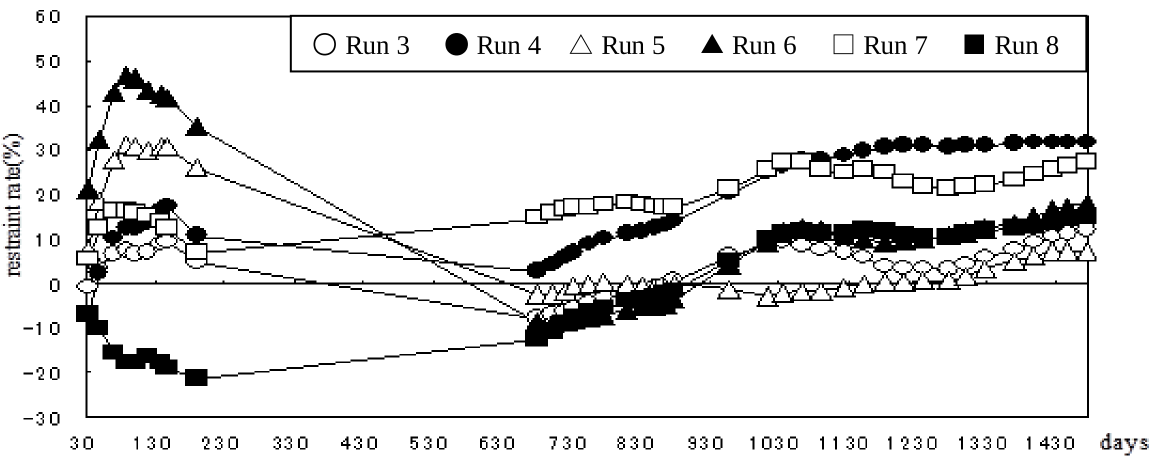

Fig.7 Succession of restraint rate of COD in each mesocosm system

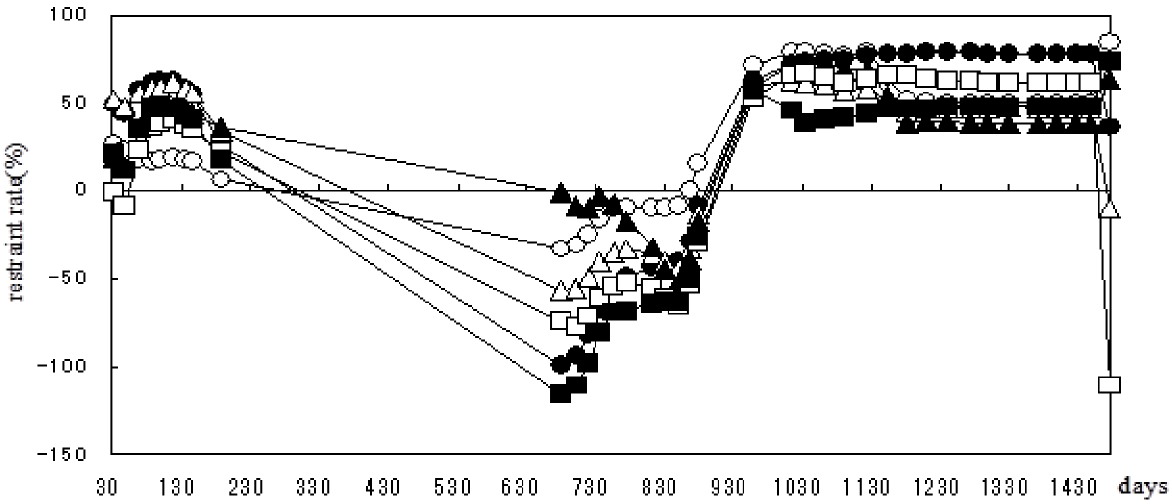

Fig.8 Succession of restraint rate of Chl.a in each mesocosm system

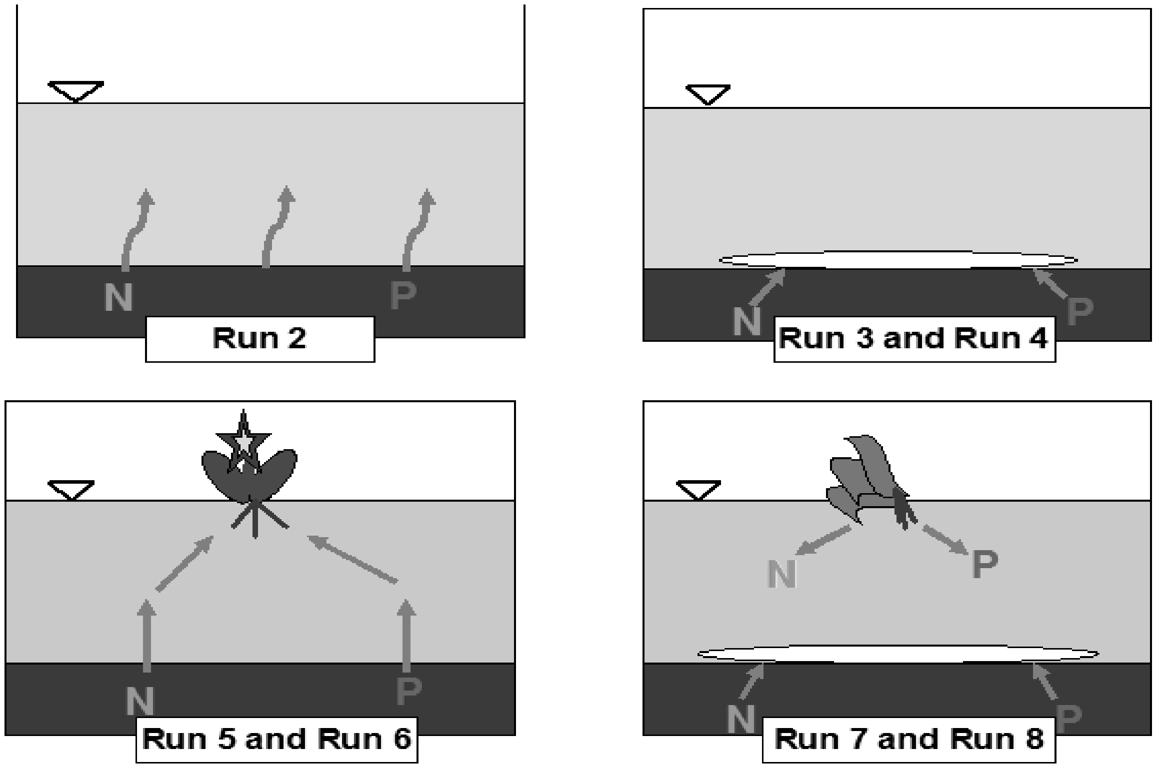

Fig.9 Actual restraint mechanism of each purification technology in each mesocosm

4. CONCLUSION

Four years experimental mesocosm experiment and observation was conducted to compare the waterplant purification and chemical remediation materials for their ability of water purification in this study. Results obtained can be concluded as follows;

1) In all treated mesocosm system, Aoko (*Microcystis aeruginosa* and *Anabaena spiroides*) did not appear.
2) CaO sprinkling treatment (Run 4) showed the most effect for water purification with P-elution controlling in long-term observation, but bio-diversity for phytoplankton and zooplankton became poor because of its too purificated water

body.
3) MgO sprinkling treatment (Run 3) showed long-term effective P-elution control, and phytoplankton flora was not so poor as that in CaO sprinkling treatment.
4) Large size zooplankton such as *Philodina erythrophthalma* and *Brachionus angularis*, were observed in case of water glass purification system (Run 5, Run 6, Run 7 and Run 8), because of the structure of waterplant roots for rich niche construction.
5) The diversity index (Shannon Index; H') for phytoplankton flora was higher under complicated community structure such as phytoplankton, zooplankton and waterplants.
6) Water plant purification system (Run 5, Run 6, Run 7 and Run 8) was disturbed by birds as predator, that is, immigration birds such as *Anas platyrhynchos* ate water plants and supply their excrement to water, so positive maintenance is important to keep this system in order.
7) Hybrid treatment system (Run7 and Run 8) did not show the hybrid effect on water purification effect, so it considered important that environmental improvement level should be optimized.

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