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METHOD TO SUPRESS OR REMOVE BLUE-GREEN ALGAE IN THE POND OF LARGE AREA BY MICRO BUBBLES

TAKESHI NAKASHIMA[1], YUTAKA HIRATA[2]

1 T. Nakashima, United Graduate School of Agricultural Science, Tokyo University of Agriculture & Technology, Fuchu, Tokyo 183-8509, Japan, t.nakashima@dntgreen.co.jp
[2] Y. Hirata, Department of International Environment & Agricultural Science, Graduate School of Agriculture, Tokyo University of Agriculture & Technology, Fuchu, Tokyo 183-8509, Japan, peaton@cc.tuat.ac.jp

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ABSTRACT Serious pollution caused by much propagated blue-green algae kills useful aqueous organisms and causes undesirable and intolerable bad smell and the other effects. Those negative effects further raise the environmental pollution in beautiful and safe nature resulting in inevitable loss of clean environments familiar to us. Until now, small scale evaluation tests for the restoration of clean environment from such kind of serious pollution have been done, however, large scale of the experiment and evaluation tests have not been done with low electric power consumption and without chemical applications. In our present study, we describe the machine (named "Nanomizer") that generate the water flow containing ionized micro-nano bubbles and a successful example that show the restoration of clean water by applying the ionized water to the water polluted by the blooms of blue-green algae, that is, the removal of bad smell and the improvement of water quality by suppressing the growth of blue-green algae in early stage of their blooming in the ash disposal pond of 140 ha and 6 m deep on the site of South Korea – East Power Co. by using two 750 W Nanomizer.

Keywords: Micro-nano bubbles, blue green algae, ash disposal pond, growth suppression, removal of blue green algae

INTRODUCTION In recent years, the methods of water purification using micro bubbles have been developed and recognized as useful for various applications. Two basic methods are known of the generation of micro bubbles (MB) or micro-nano bubbles (MNB). One is the hydrodynamic shearing and crushing of the cavity formed in swirling flow of liquid. Another is the mechanical shearing of the mixture of liquid and gas. The first practical method for the generation of the bubbles in a large amount belongs to the former (Ohnari, 2002). Our method to be described in the following section belongs to the latter and it is additionally provided with electro-magnetic effect in order to ionize the water that carries MNB. (Nakashima, 2007). Thus, effective method to generate a large volume of negatively ionized water flow which contains ionized MNB of the diameter in the range between 200 nm to 3 μm was realized. We first developed the machine named Nanomizer based on this method. It is known that only bubbles are ionized in the previous methods. However, both the water and bubbles are ionized in our method. From the tests carried out at more than 50 sites of rather small area of 200 m in diameter, it has been proved that the combined ionization of water and bubbles is much more effective for the sterilization and purification of polluted aquatic environments than the previous ionization of only bubbles. We describe the principle of our bubble generation, the structure of the machine and finally the recent results of the purification carried out by two units of 0.75 kW Nanomizer applied to an ash disposal pond of much larger area of 140 ha. It was the first finding that the growth of blue green algae could be well suppressed with the operation of much fewer units if the operation starts as early as possible.

The authors should like to abbreviate the words "the flow of ionized water containing ionized micro-nano bubbles" to "the flow of activated MNB/W" in the following sections.

NANOMIZER AND THE GENERATION OF THE FLOW OF ACTIVATED MNB/W

The mechanism for the generation of the flow of activated MNB/W Fig. 1 (a) shows a 0.75 kW Nanomizer mounted on a support of metal frame. One of air inlets is connected with a plastic tube at its one end. Another end is connected with the air valve which is supported at a position well above the water surface. The water inlets are connected with plastic tubes to the filter cage which blocks out harmful or dangerous objects for the safe operation of Nanomizer which is immersed together with the cage in the water to be cleaned. Fig. 1 (b) shows an axial section of whole body of Nanomizer, and (c) an enlarged horizontal section of its main parts in (b). The portion indicated by dotted rectangle in (b) is the basic portion to generate the flow of activated MNB/W. The core parts of Naomizer are a stator and a rotor as shown in (b) and (c). The rotor is

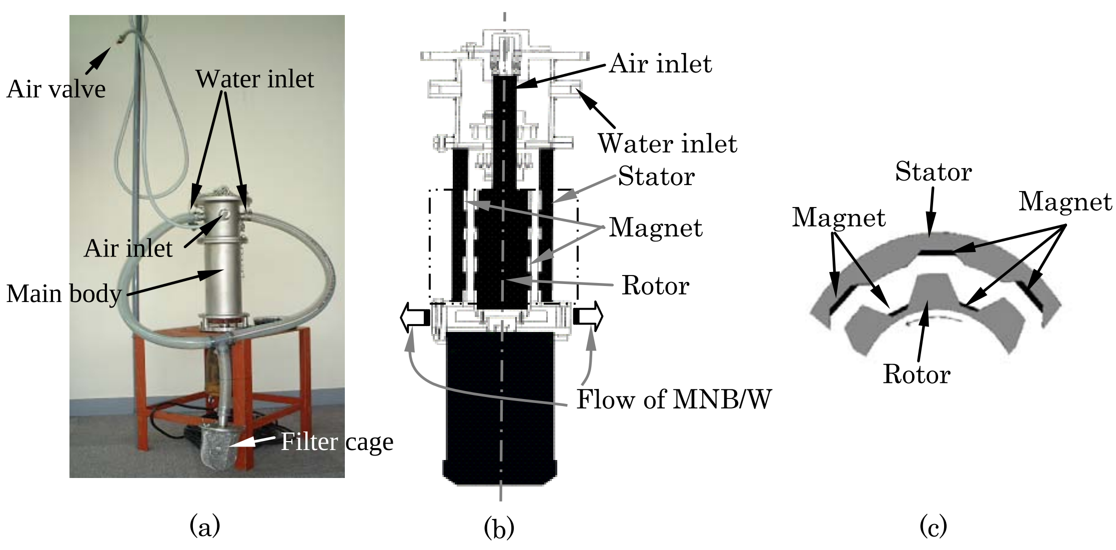


Fig. 1 The basic structure of Nanomizer

rotated at a high speed around the fixed axis of the stator by a submersible motor mounted at the bottom of the stator. Trapezoidal grooves are engraved along the axial direction on the inner surface of the stator and also on the outer surface of the rotor. Permanent magnets are mounted at the bottom of each groove. Water pump is connected with the shaft of the motor at the space between the main parts and the motor. It pumps out the flow of activated MNB/W in all horizontal directions in water at the site to be cleaned.

Generation of MNB/W When Nanomizer is operated after it is set up in water site to be cleaned, water and air at the site are pumped into main parts of bubble generation through liquid and gas inlets respectively and the mixture of water and air flows down the gap formed between the stator and the rotor. At the same time, the mixture which flows down along the each groove of the rotor is rotated at the same speed as that of the rotor. Because the axial speed of the flow is negligibly small comparing with the rotation speed, the contribution of the axial flow to the generation of bubbles can be neglected. The mixture filling each groove of the rotor is pressurized due to centrifugal force caused by its rotation. The pressure is transferred to the rest of the flow facing to each groove of the rotor. It is kept high when the grove is not facing to any groove of the stator. It changes to low when the groove faces to that of the stator. In other words, the pressure of the mixture of air and water in the grooves of stator and rotor is repeatedly compressed or decompressed depending on the periodical change in gap distance. As the solubility of air into water is proportional to the pressure, air is dissolved in water during the compression. Then minute bubbles are effectively generated when the water is decompressed. In addition, at the moment when the gap abruptly changes, the mixture flow of air and water is mechanically sheared and a large number of much smaller bubbles are generated. Because of such compression, decompression and shearing, bubbles are continuously subdivided and mixed with water. As the mixture always undergoes the same process while it moves down, bubble size becomes smaller and smaller, thus a large number of MNB is generated.

Activation of water and MNB Permanent magnets are embedded in each groove on the surface of both stator and rotor. When magnetic field of each magnet moves relatively to water, electrolysis takes place due to well known Faraday's law. This results in the ionization of water and the generation of hydroxyl ion. In this way, the air and water taken into Nanomizer are converted into a large volume of the flow of activated MNB/W through powerful action of mixing, shearing and ionization. It has been known that micro bubbles are negatively charged due to the property of water molecules and frictional charging to the surface of the bubbles. Although theoretical interpretation of the process of ionization is very difficult to analyze in case of Nanomizer because of the mutual motion of water and bubbles are made random in the process of the generation of MNB, activated water that is negatively ionized is proved to be very effective for sterilization and providing useful microbes with good environment.

The properties of the bubbles generated with Nanomizer The important factors for the purification of aquatic environment and the extermination of blue-green algae by MNB are the concentration, diameter and stability of the bubbles. Fig. 2 shows an example of the distribution of the diameter of bubbles which are contained in the water sampled after 24 hours operation of a unit of 0.75 kW Nanomizer in a tank of 1.5 cubic meters filled with city water. The data was taken with a flow type particle analyzer developed by Sysmecs Inc. (2007). Diameter is distributed within 0.2 μm to 2.2 μm so that all the bubbles belong to MNB. Peak value is approximately 6 M/mL and located at 1.3 μm. The total number of the bubbles was about 60M/mL. As 0.2 μm is the resolution limit of the optics of the analyzer, the distribution less than 0.2 μm can not be measured.

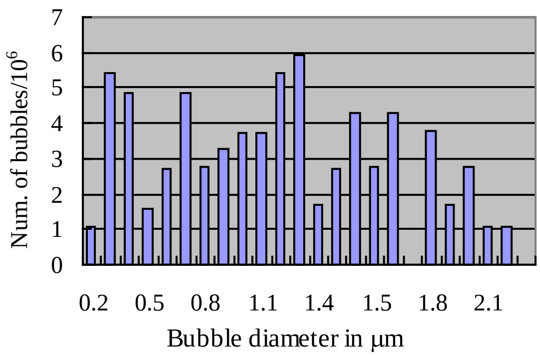


Fig. 2 Distribution of bubble diameter

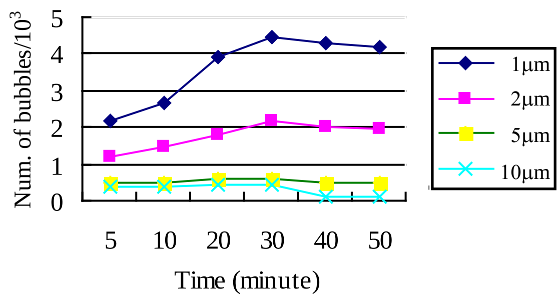


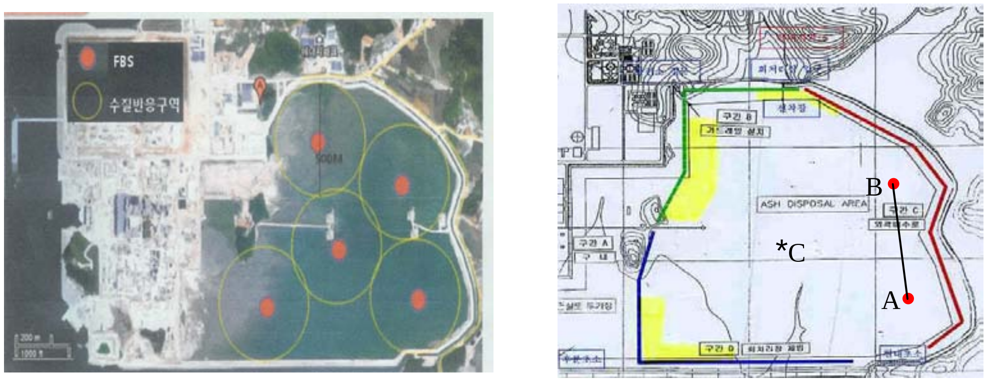
Fig. 3 Variation in bubble population

Fig. 3 shows the dependence on temporal variation of the number of bubbles for each diameter of 1, 2, 5 and 10 μm during and after the operation of Nanomizer. A smaller type of Nanomizer with controllable rotational speed was used for this purpose. It was operated for 30 minutes and then stopped. The variation of the number of bubbles was recorded for 20 minutes after the stop of operation together with the first 30 minutes during the operation. The number is kept almost constant in case of 5 and 10 μm within the first 30 minutes, while it continues to increase in case of 1 and 2 μm. It is because large bubbles are always converted into smaller ones by means of the mechanical shear as already mentioned. It deceases during the next 20 minutes in case of 10 μm in diameter. This means that larger bubbles are more instable. In case of smaller diameters it keeps almost constant value. This supports the well known property of MNB that can stay stable in water. The large amount of stable MNB and water, both of them are activated, are powerful means for the improvement of BOD and COD or the restoration of good aquatic environment from the pollution caused by eutrophication.

SUPRESSION AND PURIFICATION TEST IN THE ASH DISPOSAL POND The pond to be purified has been used for the disposal of the ash i.e. the waste discharged out of Yughug Power Plant, Korea South-East Power Co. It is an isolated man-made fresh water pond of 140 ha in area and 6 m in depth. The resident nearby the pond has complained of the discomfort caused by the outbreak of blue-green algae in every early summer resulted from the ash disposal. The company had been trying to work out how to deal with the complaints without finding effective solution and finally asked us to exterminate the algae and suppress their outbreak.

The site to be purified and test plans Fig. 4 (a) shows an aerial photograph and (b) the plan view of the site. The early bloom of the algae was clearly recognized as slight cloudy area on the left side of the pond in (a). Its area and location change by the blow of salt breeze. Each of red disks shows the location where a unit of Nanomizer was initially scheduled to be set up. Each yellow circle shows the area to be covered by a unit of 0.75 kW Nanomizer. However, it was decided in real plan to set up only two units at the locations A and B separated by 200 m and 30 m away from the east shore of the pond on

May 2nd in 2009 when the algae just started to bloom. Two types of the analysis were carried out during the continuous operation of the units for 65 days. One was chemical analysis and another visual and olfactory inspection.



(a) (b)

Fig. 4 (a) Aerial photograph and (b) Plan figure of the site

Chemical analysis For the chemical analysis, stirred surface water at the center C of the pond was sampled in the Power Plant Co. The measurement and analysis were carried out by the Korean Institute of Chemical Analysis by the request of the Yughug Power Plant. Data on COD, BOD, T-P, T-N, SS (suspended solid) and pH are shown in Table 1. The data collected on July 2nd in 2008 are those of reference showing the state when the pond was covered by the bloom of blue-green algae. Very high value 31.6 of COD and that 22.9 of BOD mean that the algae dominate over other useful creatures. It may be too time-consuming and high-costing to recover clean state existent before the outbreak of the algae. Therefore, the operation at the time when the algae just begin to bloom could be much more effective to suppress the blooming of the algae with the least number of the Nanomizers or the least cost to maintain the pond clean. It is actually found that COD, BOD, T-P, T-N and SS can be reduced to considerably low values. The temporal increase of the value of T-P and also T-N on June 15th could be attributed to their elution from bottom sediment judging from our experience in various types of purification. Both T-P and T-N decreased on August 19th to nearly a half of the values on June 15th as shown in the Table 1. SS decreased from 27.5 on May 15th to 7.4 on June 15th. When SSs meet with a bubble, they attach to and float up together with the bubble. If the solids are exposed to air at water surface, they are usually decomposed. This is the reason why SS value decreases. The value of pH increased from 8.1 to 8.9. It should decrease in ordinary purification test. In order to identify the reason further investigation is necessary.

Table 1. Results of chemical analysis

Date	COD (mg/L)	BOD (mg/L)	T-P (mg/L)	T-N (mg/L)	SS (mg/L)	pH
08/07/02	31.6	22.9	0.25	4.5	17.2	8.9
09/05/15	3.7	6.1	0.00	1.1	27.5	8.1
09/06/15	12.4	4.0	0.12	2.9	7.4	8.4
09/08/19	8.9	3.4	0.06	1.6	9.2	8.9

Visual and olfactory evaluation The water surface was visually observed and photographically recorded. Fig. 6 (a) shows the bloom of green algae in 2008 that covered the water surface on the left shore of the pond. It caused irritating and intolerable smell. Fig. 6 (b) shows those aggregated into the form of scum after their death floated to the surface. They were decomposed and disappeared within test period days. The algae killed by active NMB/W were observed on water surface within 4 days after the operation of the units of Nanomizer. Bad smell disappeared at the same time. Fig. 6 (c) shows the water picked up on the same day as that when the photograph in (b) was taken. The water in PET bottle B1 was sampled near the water surface. Dark portion in the bottle shows dead algae and green portion live algae. Water sampled 30 cm below the surface in the same area is shown in the bottle B2. Clean water in the bottle proves that the pond was already purified.

(a) (b) (c)

Fig. 6 (a) Blooms of blue-green algae seen in August in the previous year of 2008
(b) The scum of dead algae floating on water surface on August 6th 2009
(c) Algae sampled near surface in right bottle and below 30 cm on 9th 2009

CONCLUSION It is proved that the blooming of blue-green algae in an ash disposal pond of very wide area of 140 ha can be suppressed and the algae can be exterminated and water quality can be improved by means of the flow of activated MNB/W generated by only two units of 0.75 kW Nanomizer. Accordingly, it is also proved that bad smell intolerable to nearby residents can be removed and comfortable environment restored.

It is much more effective to apply Nanomizer when or before algae start to grow for the successful suppression of the blooming of the algae than when the bloom of the algae covers water surface.

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