INTRODUCTION

Eutrophication in the closed water body, such as lake or reservoir, is attracting more and more attention (JONES R. A. and LEE G. F. (1982); NAKANISHI H., et al. (1991); UEDA N., et al. (2000); NOMURA R. and SETO K. (2002)). To prevent the eutrophication, nowadays much effort is put on diminishing the nutrition resource from the wastewater treatment plants. For the water bodies that are already eutrophicated, reducing the anaerobic bottom sediment comes to be very important. In this study, the method of using high concentrated oxygen water to depurate the bottom sediment was confirmed to be effective. The high concentrated oxygen dissolver was developed and the lab scale experiment was performed. High rate, high efficiency oxygen dissolver was developed, the optimum running condition of the equipment and the method of making high concentrated oxygen water was discussed in this study. In addition, the inhibition of phosphorus release was also studied. On the basis of the fundamental knowledge from the lab scale study, pilot scale apparatus was set up and the pilot study was carried out.

High rate, high efficiency equipment of high concentrated oxygen water is shown in Fig.1. To improve the contact efficiency between gas (oxygen) and water, pressure gas is applied to contact the water film. The oxygen-water mixture is ejected into the high concentrated oxygen dissolver at a tangent so a great deal of air bubbles is produced. As a result, the DO content in the water can achieve a very high value immediately. The surplus oxygen is recycled at the bottom part of the high concentrated oxygen dissolver, so it is possible to use 100% of the oxygen under the proper running condition, that is, oxygen loss can be avoided if no gas is released from the high concentrated oxygen dissolver.

Fig.1 Experimental apparatus of high concentrated oxygen dissolver

2 HIGH CONCENTRATED OXYGEN DISSOLVER

2.1 The Development of High Concentrated Oxygen Dissolver

Key words: Closed Water Body, Eutrophication, High Concentrated Oxygen Water, Bottom Sediment
2.2 Running Condition
DO content depends on the pressure in the high concentrated oxygen dissolver. A valve is set at the outlet of the lab scale high concentrated oxygen dissolver. By adjusting this valve, the pressure in the high concentrated oxygen dissolver can be increased. However, increasing the pressure also means decreasing the water flow rate, so it is necessary to find the optimum condition to keep both of them at a proper amount. Additionally, the amount of gas supply should also be considered to prevent the oxygen loss.

In the lab scale study, 2.3-liter of high concentrated oxygen water was made and the pressure in it was kept at 0.2Mpa. Pure oxygen was supplied as the oxygen resource. DO and flow rate were measured at the oxygen supply of 300, 500, 700 and 900 mL/min, respectively.

2.3 Experimental Results
Under the running condition mentioned above, the results are shown in Fig.2. To consider the importance of oxygen transfer, oxygen transfer rate was applied and calculated as follows:

\[
\text{Oxygen transfer rate (mg/min)} = \text{DO (mg/L)} \times \text{water flow rate (L/min)}
\]

From Fig.2, it was found that the oxygen supply rate at the oxygen supply of 700 mL/min was same as that of 900 mL/min. That meant the oxygen was not fully used at the supply of 900 mL/min and surplus oxygen was released from the high concentrated oxygen dissolver. Fig.2 revealed that 700 mL/Min was the optimum oxygen supply amount at the pressure of 0.2 MPa. With 700 mL/min oxygen supplied, the instant DO amount was as high as 70 mg/L and 22 m³/day of high concentrated oxygen water could be made with this high concentrated oxygen dissolver.

![Fig.2 Variations of oxygen supply rate with the changes of oxygen flow rate](image)

**Table 1** Operational conditions of Vial experiment

<table>
<thead>
<tr>
<th>Condition of experiment</th>
<th>Sampling</th>
<th>Analytical item</th>
</tr>
</thead>
<tbody>
<tr>
<td>The water of bottom layer (after the treatment by high concentrated oxygen dissolver) + soil sediment</td>
<td>0,12,24hr after passing</td>
<td>PO₄-P</td>
</tr>
<tr>
<td>The water of bottom layer + soil sediment</td>
<td>3,5,7day after passing</td>
<td>Fe²⁺,Fe³⁺</td>
</tr>
<tr>
<td>(after the treatment of N₂ aeration) + soil sediment</td>
<td>2,4week after passing</td>
<td></td>
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</tbody>
</table>

Based on these results, the pilot plant was made to produce the high concentrated oxygen water.

3 THE EFFECT OF HIGH CONCENTRATED OXYGEN WATER ON THE PHOSPHORUS RELEASE

By introducing the high concentrated oxygen water into the bottom sediment, it was expected that the phosphorus release be inhibited. Vial experiment was performed to verify it. The bottom sediment treated with high concentrated oxygen water was sealed into the 200 mL serum bottle and was put in a 20 °C dark incubator.

![Fig.3 Phosphorus release in the water of bottom layer (after the treatment of high concentrated oxygen dissolver) + bottom sediment](image)

![Fig.4 Phosphorus release in the water of bottom layer + bottom sediment](image)

![Fig.5 Phosphorus release in the water of bottom layer (after the treatment of N₂ aeration) + bottom sediment](image)
Variation of dissolved phosphorus (PO\textsubscript{4}-P), dissolved ferrous (Fe\textsuperscript{2+}) and ferric (Fe\textsuperscript{3+}) irons were measured with time course, as shown in Table.1. For comparison, same experiment was done to the bottom sediment mixed with the bottom water sampled from the same place. Results of Vial experiments are shown in Fig.3, Fig.4 and Fig.5. From these figures, obvious differences were found among the different samples. The inhibition of dissolved oxygen on the phosphorus release was confirmed.

4 PILOT STUDY IN THE ACTUAL CLOSED WATER BODY

4.1 Outline
Modeled after the lab scale high concentrated oxygen dissolver shown in Fig.1, pilot scale apparatus, shown in Fig.6, was developed, with the production capacity of 1,000 tons of high concentrated oxygen water per day. It was set in an 18,770,000 m\textsuperscript{3} (valid volume) dam reservoir. The total volume of the reservoir was 19,570,000 m\textsuperscript{3}. The high concentrated oxygen dissolver was introduction the bottom sediment.

Though it is very difficult to depurate the lake completely, the three-year pilot study focuses on the verifying the feasibility of the full-scale application.

4.2 Pilot Scale High Concentrated Oxygen Dissolver and Its Characteristics
The mechanisms of the high concentrated oxygen dissolver are just the same as the lab scale one. However, due to the different water pressure at the different water depth, it is possible to utilize the water pressure in the pilot experiment, and thus, to save the energy consumption and the running cost. For example, if the high concentrated oxygen dissolver is put at the water depth of 40 m, 0.5 MPa water pressure is exert on the high concentrated oxygen dissolver naturally. With only a small pump at the outlet, 0.2 MPa can be available in the high concentrated oxygen dissolver. For that purpose, the high water pressure-tolerant pump is necessary. Compared with those working onshore, the submerged apparatus has some advantages. First, it doesn’t need to pump, return, or transfer the substrate, so the expend on energy consumption and transferring pipelines is saved. Second, the equipment doesn’t need to be cooled down when it works, so the energy consumption and device for cooling down are also no necessary. And third, also the most important, in the submerged high concentrated oxygen dissolver the treated water (high concentrated oxygen water) keeps its temperature unchanged so it can keep in touch with the bottom sediment directly without any temperature control.

4.3 Production of High Concentrated Oxygen Water and the Improvement Method
The pilot scale apparatus was set at a place where the average water depth was about 41 m. The high concentrated oxygen dissolver was hung at the water depth of 37~38 m to avoid the bottom sediment being sucked into the high concentrated oxygen dissolver, as observed with a submerged camera. In the pilot study, oxygen production device (pressure swing adsorption) used air as resource and produced 8 L-O\textsubscript{2}/min at most, so air was also supplied to remedy the inadequacy of oxygen. In this way, the oxygen accounted for 30 % of the gas supplied to the high concentrated oxygen dissolver, therefore, DO concentration in the high concentrated oxygen water was much lower than that in lab scale experiment. In the pilot study, the high concentrated oxygen dissolver produced 1000 t/d high concentrated oxygen water that contained 10 mgO\textsubscript{2}/L.

An YSI MODEL 58 Dissolved Oxygen Meter was used to measure the DO contents and water temperature the upper stream, the down stream and close at the high concentrated oxygen dissolver, as shown in Fig. 7. Fig.8, Fig.9 and Fig.10 show the variation of DO and water temperature along with the depth at these three sites.
Fig. 8 Variations on concentration of DO and temperature every depth in the dam (sampling point is upper buoy)

Fig. 9 Variations on concentration of DO and temperature every depth in the dam (sampling point is under the machine)

Fig. 10 Variations on concentration of DO and temperature every depth in the dam (sampling point is the opposition of the buoy)

From the results, a thermocline was found at the depth of 30 m, DO concentration also decreased rapidly over the water depth of 30 m. However, at the depth of 37 m where the high concentrated oxygen dissolver was set, higher DO was found at all the three sites, which verified that the high concentrated oxygen water didn’t destroy the thermocline of the water body and surely made a layer of higher DO surroundings near the bottom.

5 CONCLUSION

1. The production of high concentrated oxygen water was available by using the high rate, high efficiency oxygen dissolver. The 2.3 L lab scale apparatus could make 0.015 m³/min (22 m³/d) of high concentrated oxygen water in which the instant DO could be as high as 70 mg/L.
2. Samples were taken and pretreated in different ways to verify the effect of high concentrated oxygen water on the phosphorus release. Compared with the sediment soaked in bottom water and in nitrogen-aerated water, the sediment contacted with high concentrated oxygen water released the least phosphorus, which confirmed that the phosphorus release was inhibited when the high concentrated oxygen water was introduced into the bottom sediment.
3. Pilot study was performed in an 18,770,000 m³ dam reservoir. The apparatus for high concentrated oxygen water production was set at a place where the average total depth was about 41 m. When the high concentrated oxygen dissolver was hung at the water depth of 37-38 m, oxygen accounted for 30 % of the gas supplied to the high concentrated oxygen dissolver, which produced 700 L/min (1,000 tons/day) of high concentrated oxygen water. DO concentration in the high concentrated oxygen water achieved 10 mgO₂/L.
4. Measurement of DO concentration and water temperature confirmed that the high concentrated oxygen water didn’t destroy the thermocline of the water body and made a layer of higher DO surroundings that might alter the anaerobic conditions near the bottom.

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REFERENCES