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The effect of aeration and water intake on the water quality in the Asahi River Dam reservoir

W. Chen*, R.Yoshida** and O. Kawara*

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The Asahi River Dam reservoir is one of the important fresh water resources in Okayama, Japan, and its eutrophication has been noted since the 1980s. Therefore, aeration has been applied to control the growth of phytoplankton. In this study, we discussed the effect of aeration and water−intake depth on the water quality distribution in the reservoir, based on numerical simulation and observation. The principal conclusions were as follows:(1) The numerical simulation models applied here reproduced observations fairly well. (2) Water intake from the surface layer reduced the concentration of chlorophyll a in the surface layers. Water intake from the middle or bottom layer improved the deficit of dissolved oxygen in the bottom layers. (3) Aeration together with water intake from the middle or bottom layer improved the deficit of dissolved oxygen in the bottom layers.

Key words: the Asahi River Dam Reservoir, numerical simulation, eutrophication, water intake depth, dissolved oxygen, chlorophyll a

1. Introduction

Dam reservoirs are constructed for the purpose of effectively using natural water for the maintenance and improvement of our quality of life. Dams offer many benefits on different sides of flood control and water use, but there are not only good aspects. The construction of a dam reservoir brings about great changes in the river and neighboring environment. In addition, as well as changes in the water quality, changes in energy, material circulation, transportation, and other direct and indirect changes in the ecosystem of the reservoir are generated. From the water management viewpoint, the problems of cold water, turbid water and eutrophication have arisen.

The Asahi River Dam reservoir is one of the important fresh water resources in Okayama, Japan, and its eutrophication has been noted since the 1980s. Judging from the nutrient concentrations, the trophic state of the Asahi River Dam reservoir is eutrophic; the main problems result from the increase in phytoplankton. Usually, the increase of phytoplankton occurs in summer when the retention time becomes longer. Therefore, aeration has been applied to control the growth of phytoplankton.

The Asahi River Dam reservoir is located in the middle reaches of the Asahi River, whose total pondage is about 57 million cubic meters. The water level of the reservoir is kept lower from June to October for flood prevention; the water volume is then reduced to about 34 million cubic meters.

In this study, we focused on discharge management. We performed simulations of the water quality in the Asahi River Dam reservoir with changes in the discharge method (water intake

* Graduate School of Environmental Science, Okayama University, Tsushima-Naka 3-1-1, Okayama 700-8530, Japan
**Nimi Branch Office of Okayama Prefecture, Takao 2400, Nimi 718-0003, Japan

position and quantity of discharge) and examined ways to improve the water quality through discharge management. Since the growth of phytoplankton in the lower reach of the dam has been reported, and it is said that stream velocity is a factor in the eutrophication, we also simulated the hydraulic conditions in the lower reach of the dam and examined the possibility of phytoplankton growth.

2. Observation results for the Asahi River Dam reservoir

Observations were carried out during 2003 and 2004. The observed points were shown in Figure 1. We observed the water quality at depth of 0.5 meter, 1 meter, 3 meters, and intervals of 2 meters under 3m on every point from the dam-site to the upper stream. The observed water quality parameters were phosphorus, nitrogen, total organic carbon, water temperature and chlorophyll *a*. Here, we show the results of the Point A at the dam-site and the upstream Point D.

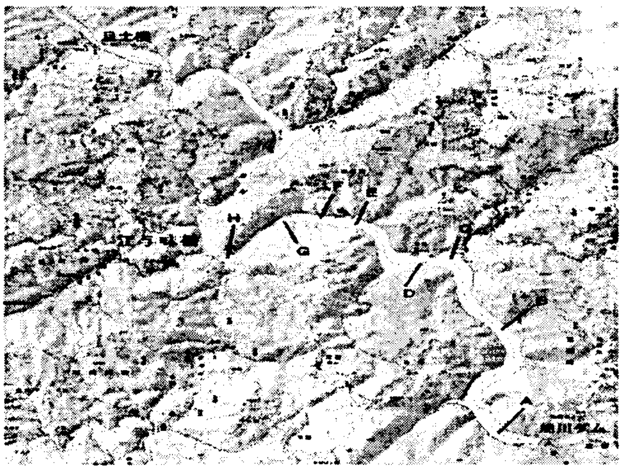

Figure 1 Observation points in the Asahi River Dam reservoir

First, we show the observation results for March 3, 2004. Those were measured when aeration devices didn't operate. We show them in Figure 2 and Figure 3.

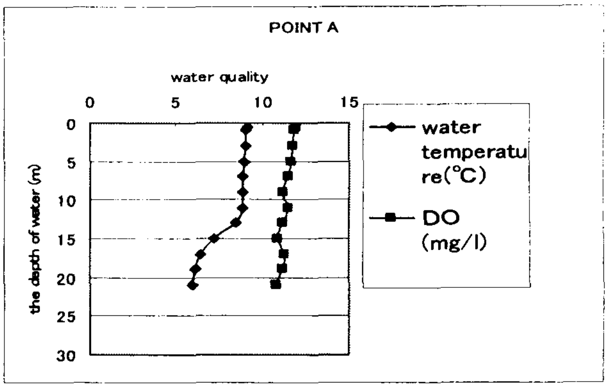

Figure 2 Water quality profiles at Point A on March 27th, 2004

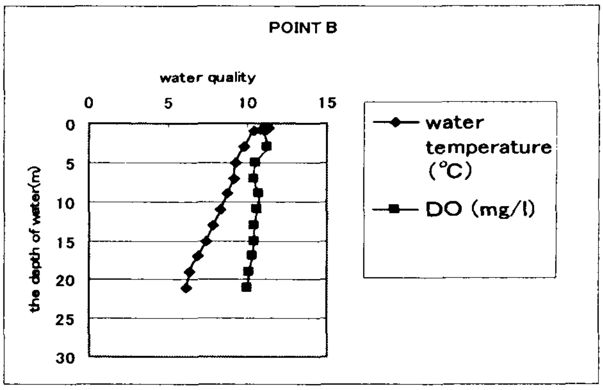

Figure 3 Water quality profiles at Point D on March 27th, 2004

The water temperature of Point A in the vicinity of the dam-site was almost uniform from the surface to about 12 meters in depth, and gradually became lower under 12 meters. On the other hand, the water temperature of Point D showed a different trend that the water temperature gradually became lower from the surface to bottom. And DO was almost similar distribution with the temperature in the reservoir. Because the oxygen deficient water was not found, the water quality in the bottom layers has not been deteriorated greatly .

In the next place, we discuss the observation results for July 18, 2004. The observation point is shown in Figure 4 and Figure 5.

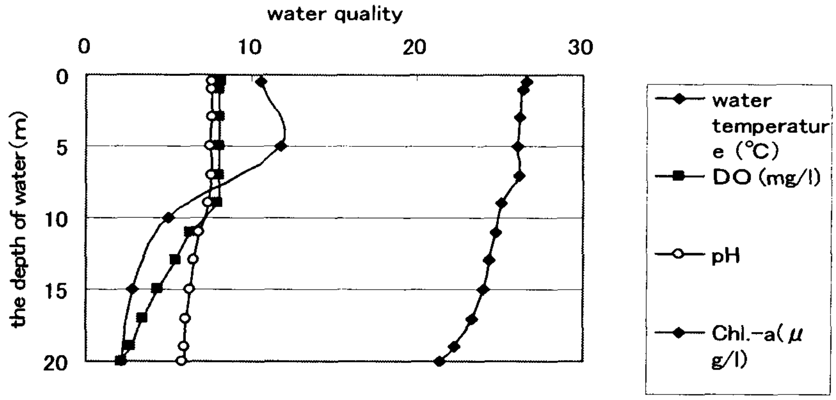

Figure 4 Water quality profiles at Point A (July 18th, 2004)

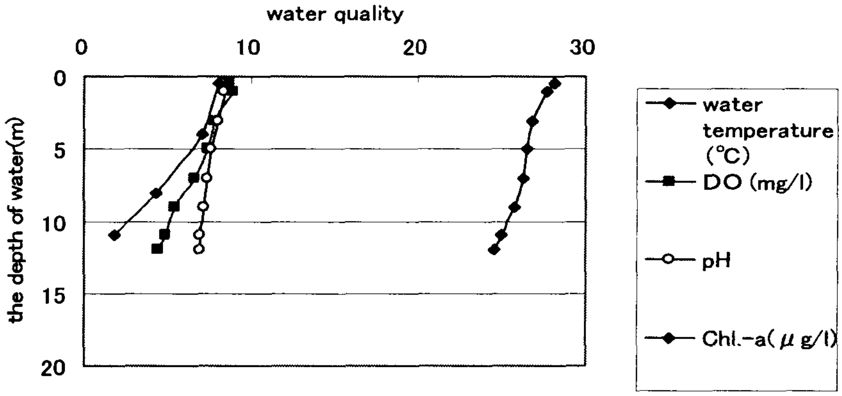

Figure 5 Water quality profiles at Point D (July 18th, 2004)

As the thermal stratification formed in summer plays an important role in the vertical distribution of water quality, the vertical distribution of water temperature is important. Though the thermo-cline is formed easily in summer in reservoirs, but the thermo-cline was not found in the Asahi River Dam reservoir. The vertical circulation caused by the aeration suppresses the formation of the thermo-cline.

The water quality distribution for the surface at Point A in the neighborhood of the dam site tended to be different from that at Point D at the headwaters. This trend was especially evident in the vicinity of the dam site on other observation days as well. This is thought to be due to the influence of the surface water intake. In addition, a fall in DO was observed in the neighborhood of the dam-site upper layers. This was likely to contribute to the increase in phytoplankton, since nutrients are dissolved from the bottom mud.

3. Numerical analysis of the dam reservoir

We investigated the characteristics of water quality distribution according with the change of discharge in the Asahi River Dam reservoir. So we used two simulation models in this study: a box model and a three-dimensional multi-level model. Because the density flow is predominant by the water temperature distribution and the waterside line in the reservoir is complex, a multi-level model by Cartesian coordinate was used to obtain the flow condition and water temperature distribution. This is a semi-three dimension model.

The box was then used to predict the water quality. The ecological water quality model was applied. The compartments included were phytoplankton, total phosphate, total nitrogen and total organic carbon. Because the time scale of ecological water change is far longer than the time scale of flow, we applied the box model to solve the ecological water quality change using the Runge-Kutta method. As the water temperature and the flow were not able to be solved by the box model, we compulsorily used the results obtained by the multi-level model. Because the thermo-cline was found once at the depth of about 8m in the Asahi River Dam reservoir, the maximum thickness of surface layer of the box model was 8m, the middle layer was set until 18m, and the bottom layer was set until the bottom. And we divided the reservoir in the horizontal distribution. The number written in each segment in Figure 7 represents the number of layers in the vertical direction.

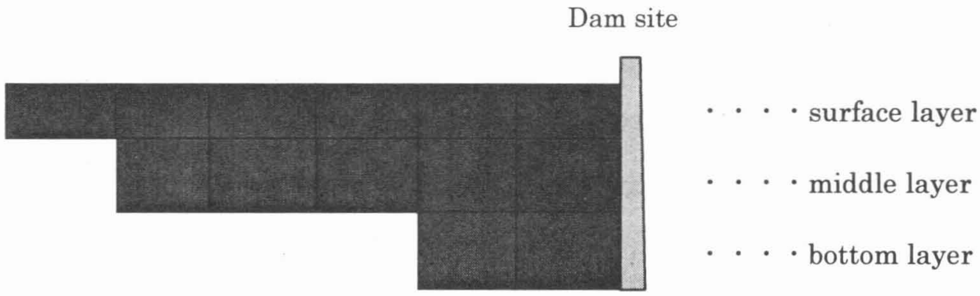

Figure 6 The layout of boxes in the vertical direction

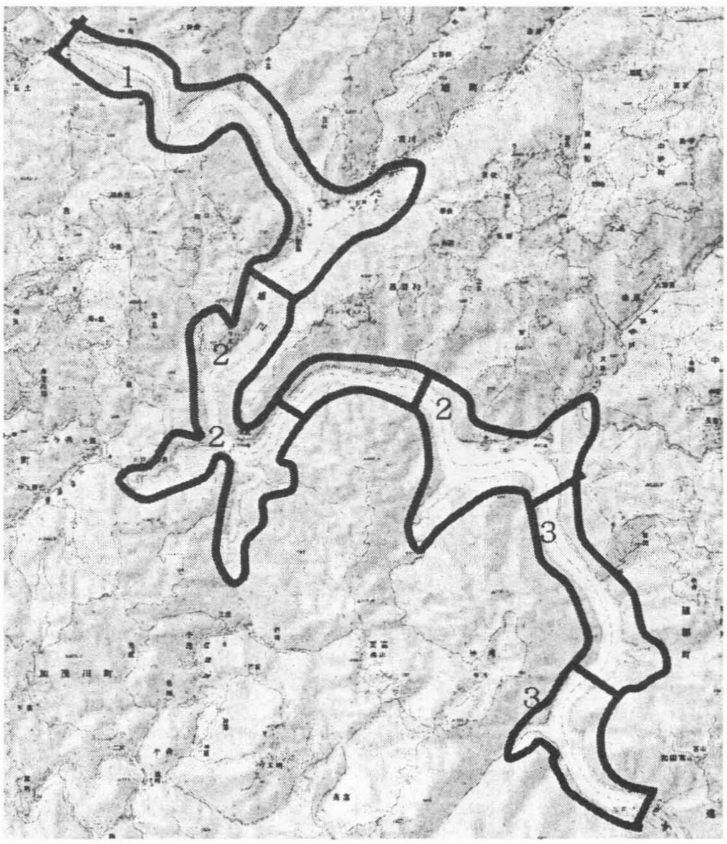

Figure 7 The horizontal layout of boxes

We investigated the flow distributions and the water quality distributions that depended on the the discharge method from the dam by using the models above mentioned.

4. Calculation results and discussion of the Asahi River Dam reservoir

Before we predicted the water quality in the reservoir under various conditions, both models were verified using the observations. Both models were found to reproduce observations fairly well.

Two sets of calculation results are shown in Figures 8 and 9. The influence of conditions such as aeration, depth of water intake and inflow rate on the dissolved oxygen and chlorophyll *a* were investigated. The depth of water intake affected the dissolved oxygen and chlorophyll *a*. Intake from the surface layer reduced the concentration of chlorophyll *a* in the upper layers because the hydraulic retention time

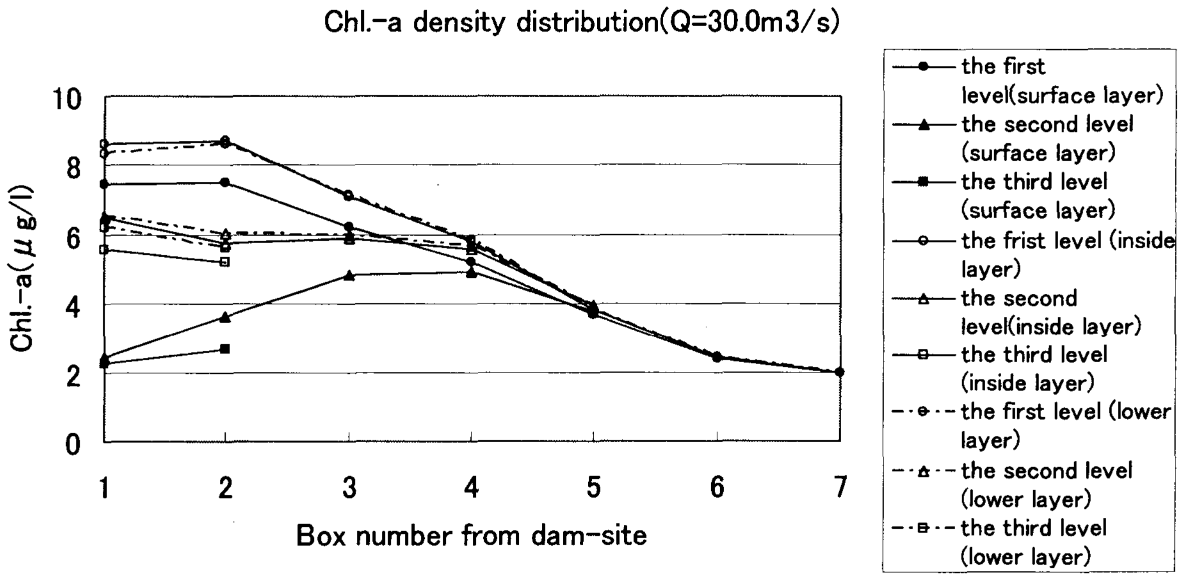

Figure 8 Calculation results for chlorophyll a

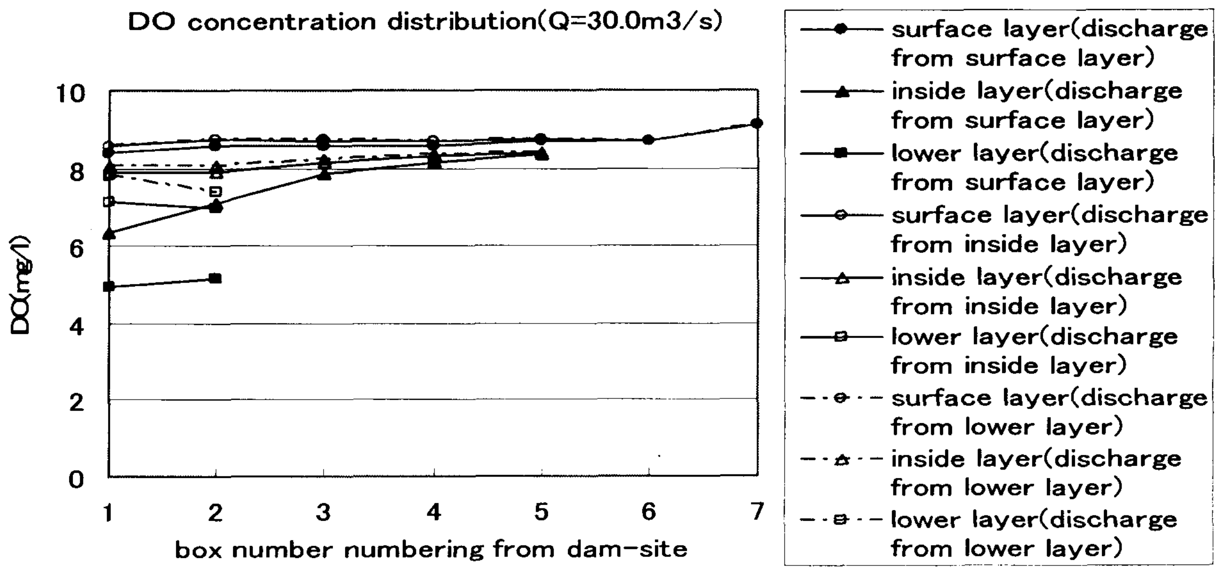

Figure 9 Calculation results for DO

was shortened. And the water intake from the surface layer reduced the dissolved oxygen in the bottom layers near the dam because the vertical mixing of the bottom water with the water in surface layers was suppressed by the surface intake. As the surface water is being discharged from the Asahi River Dam, a decrease in oxygen in the bottom layers is promoted Water intake from the middle or bottom layer improved the dissolved oxygen in the bottom layers, as compared with the water intake from the surface layer

Aeration reduced the concentration of chlorophyll *a* regardless of the depth of water intake. Aeration together with water intake from the middle or bottom layer improved the deficit of dissolved oxygen in the bottom layers. When the inflow rates were low, the concentration of chlorophyll *a* increased and the water quality difference between the upper and bottom layers became greater.

5. Conclusions

In this study, we discussed the effect of aeration and water-intake depth on the water quality distribution in the Asahi River Dam reservoir, based on numerical simulations and observations. The principal conclusions were as follows:

(1) The models applied here were verified by observations, and the models reproduced observations fairly well.

(2) The depth of water intake affected the concentrations of dissolved oxygen and chlorophyll *a*. Intake from the surface layer reduced the concentrations of chlorophyll *a* in the surface layers. Water intake from the middle or bottom layer improved the deficit of dissolved oxygen in the bottom layers, as compared with the water-intake from the surface layer.

(3) Aeration together with water intake from the middle or bottom layer improved the deficit of dissolved oxygen in the bottom layers.

References

KAWARA,O., E. YURA, S. FUJII and T. MATSUMOTO: A Study on the Role of Hydraulic Retention Time in Eutrophication of the Asahi River Dam Reservoir, Water Science & Technology, Vo l. 37, No. 2, pp. 245-252, 1998.

KAWARA, O., R. YOSHIDA and Y. KAWAI: Observations and Numerical Simulations of Water Quality Distributions in reservoirs, Journal of Faculty Of Environmental Science and Technology, Okayama University (Special Edition), pp. 105-109, 2004.