II－216 CONTROL OF THE LAKE PHYTOPLANKTON BLOOM USING BUBBLE PLUME

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1. INTRODUCTION

For the management of lakes, artificial mixing such as that of aeration or using the bubble plume is usually used to improve the lake water quality. If air is injected from the bottom of a stratified lake, water with high density from hypolimnion can be brought to the surface, collides with the epilimnion water, plunges down to a neutral density layer and spread out to form an intermediate water layer. Thus the mixing between the epilimnion and epilimnetic water can be promoted.

The use of such management techniques in a lake apparently dates from many years ago. For the study of the efficiency of alteratives for the lake management, their impact on lake phytoplankton population should be carefully studied. For this purpose, numerical models have been proved of providing valuable and inexpensive information. In this study, it is attempted to couple a phytoplankton model and a bubble plume model to illuminate the influence of the destratification process by the application of bubble plume on the development of lake phytoplankton population through performing a series of numerical experiments.

2. GOVERNING EQUATIONS

The equations governing the biological processes in ambient-outer plume of the lake can be expressed as:

$$\frac{\partial(AC_i)}{\partial t}+U_{si}\frac{\partial(AC_i)}{\partial z}+\frac{\partial(QC_i)}{\partial z}+(C_{in}-C_i)\frac{\partial Q'}{\partial z}-\frac{\partial}{\partial z}AK_i\frac{\partial C_i}{\partial z}=BA \quad (1)$$

And the vertical transport of heat is described by a diffusion convection equation of the form:

$$\frac{\partial(AT)}{\partial t}+\frac{\partial(QT)}{\partial z}+(C_{in}-C_i)\frac{\partial Q'}{\partial z}-\frac{\partial}{\partial z}AK_i\frac{\partial T}{\partial z}=HA \quad (2)$$

Where Q is the vertical water discharge in the ambient at level z due to the entrainment of water from ambient to the inner and outer plume or the detraiment of water from outer plume to the ambient. Q' is the discharge of water from the bubble plume to the ambient at level z. C_{in} are the biological concentration C_i caring up by bubble plume at level z; V_{si} is the settling velocity of the biological quantity,which is set equal to zero for the nutrient components; z is vertical coordinate; K_i is the diffusion coefficient of the quantity C_i in z direction; B represents the biological processes that can locally change the concentration of C_i; A is the horizontal area of the lake at level z; T is water temperature as function of the depth z and time t, H is the internal distribution of heat sources due to radiation absorption inside the water column.

The convection of heat and mass produced by bubble plume are calculated by integral bubble plume model, the model was first developed by McDougall (1978), then it has been modified by Asaeda and Imberger (1993).

3. NUMERICAL MODELLING

The lake was divided into vertical layers, then governing equations were discretized in the vertical direction. A Crank-Nicolson implicit finite volume numerical scheme was applied to integrate the system of differential equations (1-2) to determine the values of concentration of phytoplankton, nutrient, detritus and temperature at the center of the finite volume of water. A first order upwind scheme was used for the advection terms

4. INITIAL AND BOUNDARY CONDITION

The initial conditions for the integration are the given values of biological quantity and temperature at nodal points at the beginning of the simulation. At the lake surface, the boundary conditions are that of zero values of fluxes of biological quantity, the heat fluxes at surface, simple aerodynamic bulk formulae was used to calculate surface wind shear. The heat flux at the surface is the solar radiation, net longwave radiation, sensible heat and latent heat carried from the water surface to the atmosphere by water vapour. At the lower boundary, the conditions are that of fluxes of phytoplankton and detritus equal to their sinking rates. Meteorological conditions such as daily average clound, wind velocity, temperature, humidity and solar radiation were used for water temperature computation.

5. RESULT AND DISCUSSIONS

Figures 1 shows a comparision between the computed and observed concentrations of phytoplankton for period of lake Calhoun destratification experiment from March 1 - November 1972. Figure 2 depicts numerical experiments with the gas flow rate of 100 l/s and different bubble port for lake Calhoun. As shown, increasing a number of bubble ports can reduce the lake surface phytoplankton concentration.

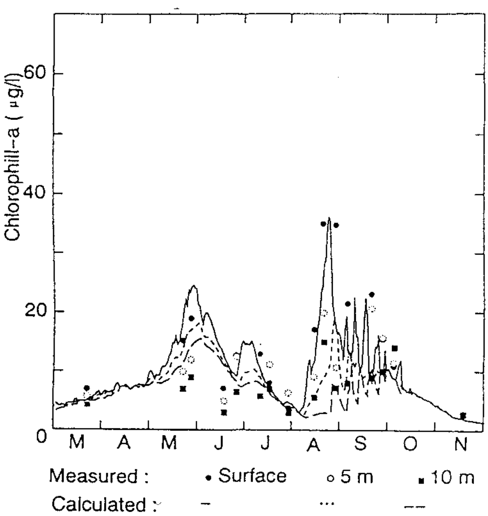

Figure 1: Comparison of Measured and Simulated of Phytoplankton Concentration at three Depth in Lake Calhoun (1972)

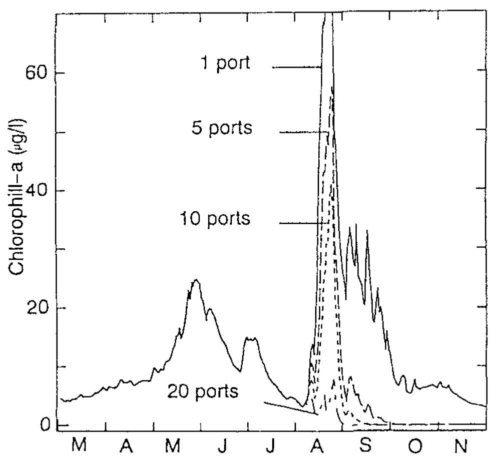

Figure 2: Sensitivity of Surface Layer Phytoplankton Concentration to Different Number of Bubble Ports Keeping Total Gas Flows Rate as Constant

6. REFERENCES

1-Takashi Asaeda and Jorg Imberger (1993), Structure of bubble plumes in linearly stratified environments, Journal of Fluid Mechanics, Vol.249, pp.35-57. Cambridge University Press.
2-Trevor J. McDougall (1978), Bubble plume in stratified environments, J. Fluid Mechanics, Vol.85, pp 655-672.