II -391 Interactions of Solar Radiation and Nutrients Concentration on formation of Algal Bloom in Lake : A Numerical Study

Dept. of Civil & Environmental Engg., Saitama Univ. Monzur Alam Imteaz
Dept. of Civil & Environmental Engg., Saitama Univ. Takashi Asaeda

ABSTRACT : To predict the magnitude and period of probable water quality deterioration of algal blooming, interactions of solar radiation and nutrients concentration which are the major factors contributing algal bloom in lake are presented. As inflow nutrient is the main source of epilimniotic nutrients it is considered as the factor of lake nutrients concentration. An earlier validated model of lake water quality which includes modelling of one dimensional lake water temperature, phytoplankton and nutrients concentration was simulated for several conditions of input solar radiation and inflow nutrients concentration. From the presented results it is clear that above mentioned factors show some regular trend.

1. INTRODUCTION

The growth rate of phytoplankton depends on many environmental factors such as nutrient concentration, light intensity, light period, temperature and zooplankton grazing. Most influencial meteorological factor to govern phytoplankton bloom is solar radiation as it is directly involved for the photosynthesis of phytoplankton cell. Solar radiation also indirectly affects the phytoplankton bloom as changes in solar radiation causes to change the water temperature which affects the phytoplankton growth. Another well known factor which is coming from inflow water and sewage or generated from sediment is the nutrients which is required for cell metabolism. Interactions of these two factors mainly decides the peak of algal bloom which is usually at summer for high solar radiation.

2. MODEL DESCRIPTION

An one dimensional reservoir simulation model, DYRESM which can simulate for water temperature and salinity was modified and coupled with a biological model to get daily variations of biological and chemical quantities. And the coupled model was validated for Lake Calhoun (USA) and Uokiri lake (Japan) by Imteaz & Asaeda (1996a,b). Equations for biological model are described below.

The equation for the phytoplankton which is represented by chlorophyll-a concentration is given by,

$$\frac{\partial Chla_i}{\partial t} = G_{\max}\theta^{T-20} Chla_i \min\{f(I_i), f(IP_i), f(IN_i)\} - k_r\theta^{T-20} Chla_i - k_m\theta^{T-20} Chla_i - k_z Z\theta_z^{T-20} P\frac{Chla_i}{K_z + Chla_i}$$

Where, $Chla_i$ is concentration of chlorophyll-a in layer i, θ is a non-dimensional temperature multiplier for growth, respiration and mortality, T is the temperature in layer i, k_r, k_m and k_z are rate coefficients for respiration, mortality and zooplankton grazing, Z is the zooplankton biomass, P is a grazing preference factor for specific phytoplankton groups, θ_z is a non-dimensional temperature multiplier for zooplankton grazing and K_z is the half saturation constant for grazing, G_{max} is maximum growth rate of phytoplankton, $f(I_i)$ is the light limitation function, $f(IP_i)$ is the internal phosphorus limitation function, $f(IN_i)$ is the internal nitrogen limitation function. Expression of light limitation function is given by,

$$f(I_i) = \frac{I_i}{I_s}\exp[1 - \frac{I_i}{I_s}] \quad \text{and} \quad I_i = \frac{I[1-\exp(-\eta\Delta h)]}{\eta\Delta h}$$

Where, I_i is the mean photosynthetically active radiation at layer i, I_S is the saturation light intensity for phytoplankton, I is the incident photosynthetically active radiation at the surface of layer i, Δh is the thickness of a layer, η is the light extinction coefficient. Internal nitrogen and phosphorus limitation functions are given by,

$$f(IP_i) = \frac{IP_i - IP_{\min}}{IP_i} \quad \text{and} \quad f(IN_i) = \frac{IN_i - IN_{\min}}{IN_i}$$

Where, IN is the internal nitrogen of phytoplankton cell, IP is the internal phosphorus of phytoplankton cell, IN_{min} is the minimum internal nitrogen, IP_{min} is the minimum internal phosphorus.

The biological model considered eight state variables as conservation of Chlorophyll-a, Phosphate phosphorus, Ammonia nitrogen, Nitrate nitrogen, Internal Phosphorus, Internal Nitrogen, Dissolved Oxygen and BOD. Conservation equation of those state variables are well described in Imteaz & Asaeda (1996b).

3. MODEL RESULTS AND DISCUSSION

For an imaginary lake considering sinusoidal variation of solar radiation, air temperature, wind speed and inflow temperature model was simulated for different conditions. Figure 1 shows the effect of solar radiation on total chlorophyll-a. It is found that as solar radiation increases magnitude of total chlorophyll-a increases also peak shifts

Keywords : *Phytoplankton, Algal bloom, Water quality*
Address : 255, Shimo Okubo, Urawa Shi, Saitama, 338. Tel. : 048-854 0824, Fax : 048-855 9361

towards the early summer from late summer. Increase of total chlorophyll-a is obvious as concentration of chl-a is directly related with the solar radiation and chl-a will increase if solar radiation is increase until a limit where photoinhibition occurs and after that chl-a decreases as solar radiation increases. As solar radiation increases chl-a increases and nutrients become limiting earlier causing a reduction of chl-a and formation of a peak in earlier. Figure 2 shows the relationship between % change of solar radiation and shift of peak. Figure 3 shows the effect of inflow nutrients on total chl-a. It is found that effect of inflow nutrients is significant after May, because before May nutrients concentration was enough and solar radiation was only limiting factor for phytoplankton growth. After May nutrients become limiting and total chl-a increases as inflow nutrients increases. But rate of increase of total chl-a become slower as inflow nutrient concentration increases beyond a certain level as in this case nutrient again become sufficient for the phytoplankton. From the figure it is found that peak of bloom shifts towards spring as inflow nutrients concentration decreases. This is because if inflow nutrient decreases amount of nutrients in the epilimnion will also decrease and nutrient for phytoplankton will become limiting earlier causing an earlier reduction of chl-a and formation of a peak. To show the combined effect solar radiation and inflow nutrient, peak value of total chl-a for different solar radiation were shown against change in inflow nutrient concentration in figure4.

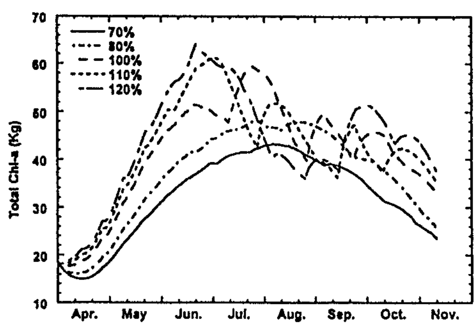

Figure 1 Effect of solar radiation

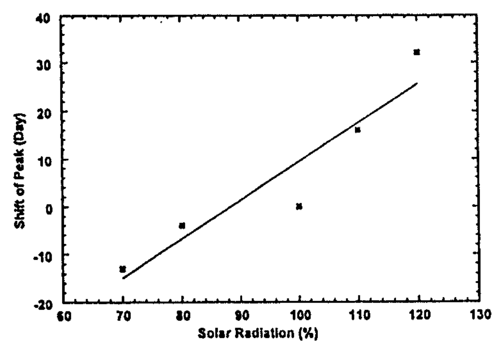

Figure 2 Shift of peak with solar radiation

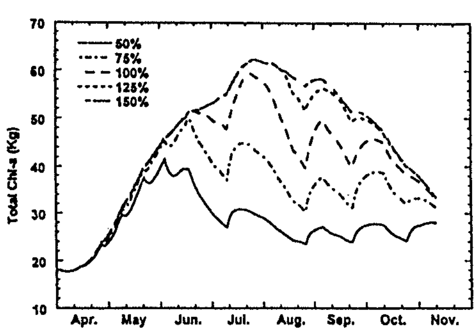

Figure 3 Effect of Inflow nutrients concentration

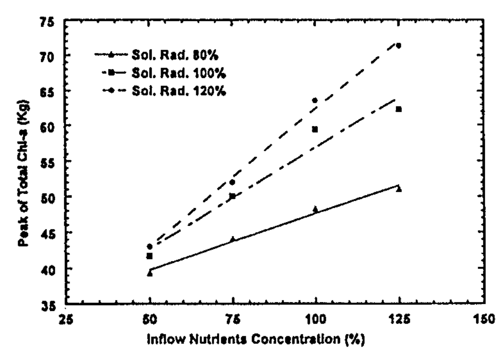

Figure 4 Combined effect of solar radiation and inflow

4. CONCLUSION

All the above trends explained above are valid within a certain range. Although for other lakes the above trends may not be exactly same but it will be nearly similar for all eutrophic lakes.

5. REFERENCES

1. Imteaz, M.A. and Asaeda, T. (1996a), Effects of bubbling operations on algal bloom in lake, Proceedings of Environmental Systems Research, JSCE, Vol. 24, pp.104-109.
2. Imteaz, M.A. and Asaeda, T. (1996b), Modelling of lake eutrophication including artificial mixing, Proceedings, Annual conference of Japan Society of Hydrology and Water Resources'96, pp. 16-17.