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The Effect of Rainfall on the Water Quality of a Small Reservoir (Lake Wangkung, Korea)

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The dynamics of water quality with the storm events were analyzed in a small reservoir for irrigation, Lake Wangkung. Water quality of the inflowing stream fluctuated seasonally with the variation of flow rate. Thermal stratification was consistent from April to October below 2 m depths and anoxic layer was developed below 2 m depth in summer. The unique feature of temperature showed that thermal stratification was disrupted by a heavy rain event during monsoon, but hypolimnetic hypoxia were reestablished after a few days. Phosphorus and nitrogen increased immediately following storm events. The marked increase may be due to the input of P-rich storm runoff from the watershed. Internal phosphorus loading can be one of the explanations for TP increases in summer. When there was a storm, total populations of phytoplankton and zooplankton was reduced immediately following the storm, indicating possible flushing of algae and zooplankton. After a lag period of low-density the plankton population bloomed to a peak again within five days after the storm. Turbid water in lake became clear again which coincided with the time of the phytoplankton buildup. The results demonstrate that water quality is regulated greatly by rainfall intensity in Lake Wangkung.

Key words : Lake Wangkung, water quality, effect of rainfall

INTRODUCTION

The monsoon climate of East Asia is characterized by intensive storms during summer. Effluents from non-point sources during the storms carries massive loads of suspended solids and nutrients in which affects greatly water quality and ecosystem of reservoirs (Kim *et al.*, 1995; Kim *et al.*, 1997, 1998).

Large lakes and reservoirs were ancient or important for human life, and have been intensively studied on their ecosystems. According to earlier studies of water quality variations in those lakes has been showed spring and autumn bloom caused by nutrients loading from watershed and sediments. Microorganisms produce the organic matters by reusing the nutrients supplied from watershed and sediments (Wetzel, 2001).

In contrast, small lakes and ponds have not been paid great attention, though these aquatic environments are used for agricultural irrigation. Hence, eutrophication of small lakes and ponds proceeds seriously in Korea. In small and shallow lakes, there are marked influence on water quality by nutrients from sediments. The nutrients releases from the sediments were related with the hypolimnetic anoxic condition (Chapman, 1996). But the rainfall effect each

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condition on phytoplankton density and the oxygen status of under water in lake were poorly studied.

MATERIALS AND METHODS

Lake Wangkung is a small reservoir for agricultural irrigation located of central Korea. Phytoplankton blooms were observed in summer season. Hydrological and physical characteristics of Lake Wangkung were described in table 1.

Water sample were collected monthly from May. 2000 to Apr. 2001 at the front of dike which were the deepest station. Water temperature (°C), secchi disc depth (m), turbidity (NTU), and concentration of dissolved oxygen were measured *in situ*. Water quality and plankton density analysis, including chlorophyll *a*, total phosphorus (TP) and total nitrogen (TN) were followed standards methods (APHA 1992).

RESULTS AND DISCUSSION

Lake Wangkung has two inflowing streams,

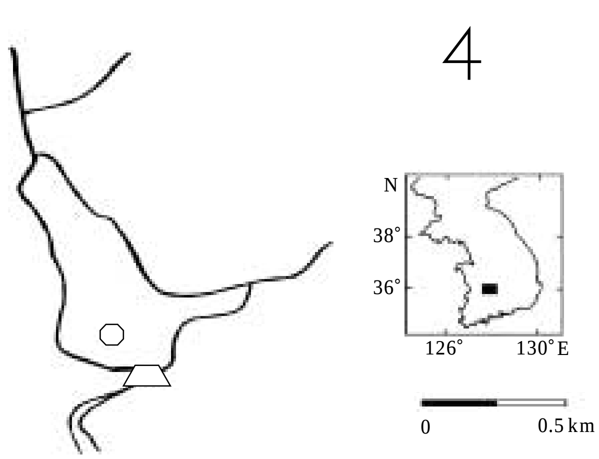

Fig. 1. Map showing the study area.

Table 1. Hydrological characteristics of Lake Wangkung.

Surface area (ha)	44.2
Water capacity (m^3)	2,061,345
Maximum depth (m)	9.65
Water surface elevation (m)	50 ~ 52
Hydraulic residence time (day)	162
Drainage area (ha)	866

and the nutrient loading from the watershed fluctuated seasonally with the variations of flow rate (Fig. 2). It was directly related with rain events. Phosphorus and nitrogen increased immediately following rainstorm events. The marked increase may be due to the flushing of phosphorus-rich topsoil from agricultural fields in the watershed.

The anoxic layer was developed below 2 m depths. Thermal stratification and anoxic hypolimnion were disrupted by heavy rainfall, but hypolimnetic hypoxia were reestablished after a few days (Fig. 3). And then after formation of anoxic zone, phytoplankton blooms were started again.

The vertical and seasonal variations of total nitrogen and total phosphorus concentration were

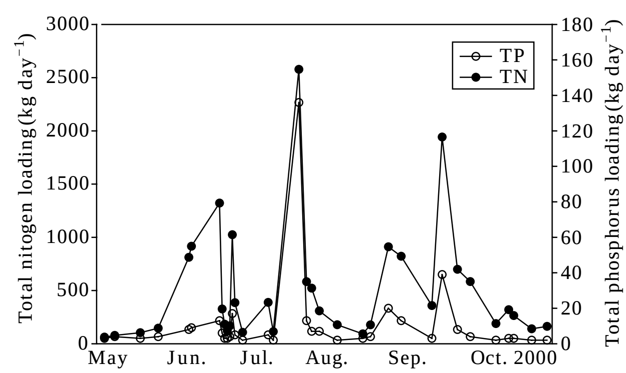

Fig. 2. Total nitrogen and phosphorus loading from inflowing water (May ~ October 2000).

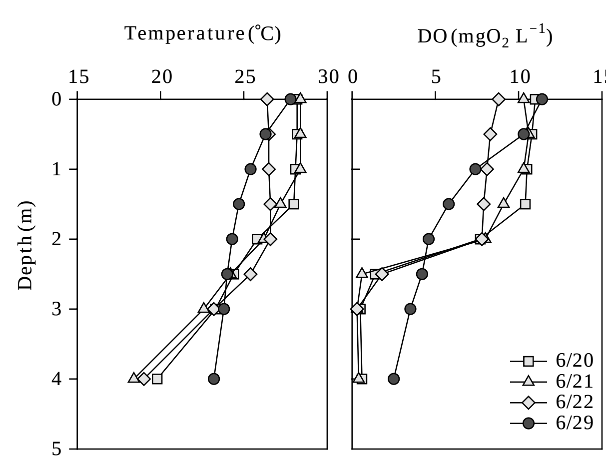

Fig. 3. The Vertical profiles of temperature and dissolved oxygen in Lake Wangkung from 20 Jun to 29 Jun, 2000.

described in Fig. 4 and Fig. 5. Total nitrogen concentration ranged 0.8～1.2 mg L^{-1} in vertical mixing periods (winter and spring), and 1.2～2.0 mg L^{-1} in stratified seasons (summer and autumn). Total phosphorus concentration ranged 0.030～0.050 mg L^{-1} in vertical mixing periods and 0.060～0.140 mg L^{-1} in stratified seasons. The maximum concentration of total phosphorus was observed at the hypolimnion just above the sediment.

Internal phosphorus loading can be one of the explanations for TP increases in summer after

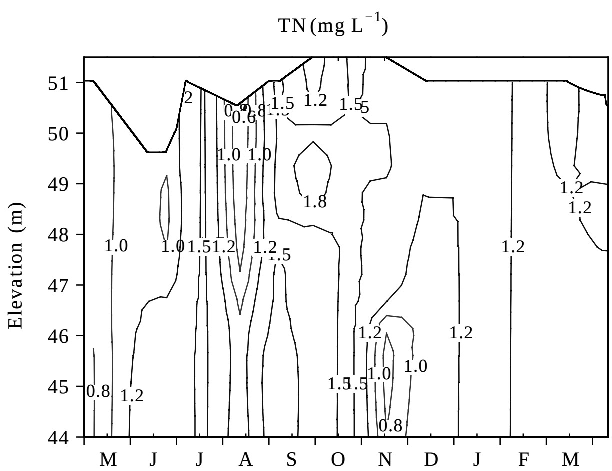

Fig. 4. The vertical and seasonal variation of TN concentrations in Lake Wangkung, May 2000 to Apr. 2001.

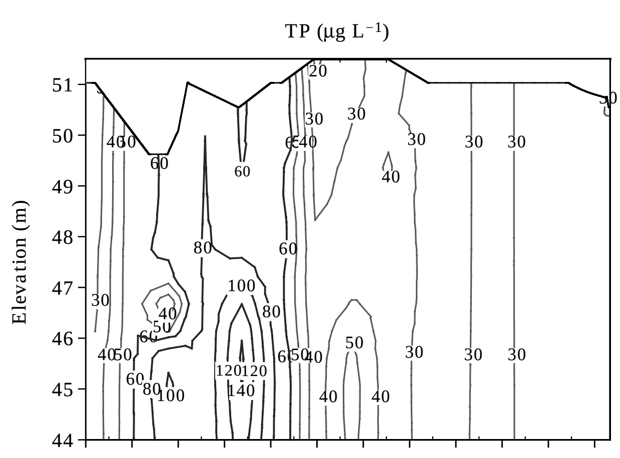

Fig. 5. The vertical and seasonal variation of TP concentrations in Lake Wangkung, from May 2000 to Apr. 2001.

the rainfall events. In other report (Lee *et al.*, 2003), rainfall effects on the sediments of Lake Wangkung were investigated. And, it was found that rainy season highly increased potential contents of the organics and phosphorus in the sediments, which was thought to be caused by the organic debris discharge from the upland and rice paddy by an intensive and long-term rainfall runoff during rainy season.

At the same time, rainy season changed types of the phosphorus in the sediments. Prior to the rainy season residual-P was predominant, while the distribution shifted to the NAl-P and Apatite-P as major components which are associated with soil particles from the crop field during rainfall events. Nutrient release rates of the sediments undergoing the rainy season were very much slowed down (Lee *et al.*, 2003). It can be concluded that the storm water is not only a supply source of fresh sediments of high organic and phosphorus content, but also affects nutrient release rates by providing an internal mixing of the bottom water and a plenty of oxygen for the sediments. But the oxygen supplies were not enough to oxidizing the whole organic sediments of Lake Wangkung.

Population of phytoplankton and zooplankton were reduced immediately following with the rainfall events, indicating possible flushing or sedimentation of algae and zooplankton. After a lag period of low density phytoplankton bloomed to a peak density in a week after the storm. The results demonstrate that water quality and plankton biomass is regulated greatly by the rainfall intensity in Lake Wangkung.

Another report of Korean reservoir showed that phytoplankton bloom and bad water quality occur after storm input (An and Jones, 2000). But this study implies that the effect of storm event is manifested through not only nutrients loading but also through flushing effect of biomass in such a small reservoir.

CONCULUSIONS

Water quality of inflowing stream fluctuated seasonally with variations of flow rate in the streams of agricultural area. Thermal stratification and hypolimnetic hypoxia that were developed in early summer were disrupted by heavy rainfall during the monsoon season, but they

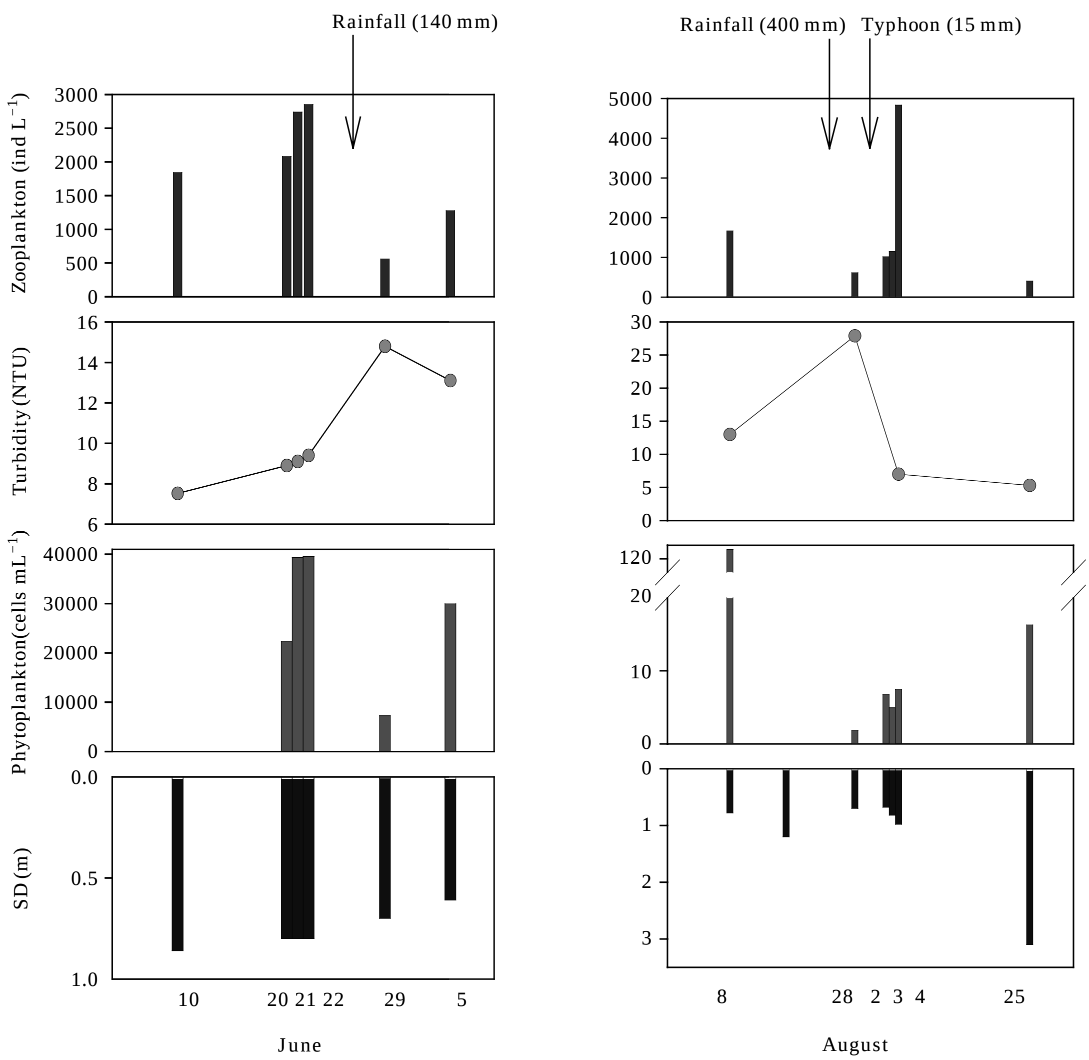

Fig. 6. Zooplankton and phytoplankton density, turbidity, and Decchi disc depth for periods immediately preceeding and following the storm events.

were reestablished after a few day. Phosphorus and nitrogen concentration of reservoir increased immediately following storm events. Total populations of phytoplankton and zooplankton were reduced immediately following the storm events and after a lag period they bloomed to a peak density within five days after the storms.

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