# Influences of Seasonal Rainfall on Physical, Chemical and Biological Conditions Near the Intake Tower of Taechung Reservoir

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**Physical, chemical, and biological parameters were measured during the period from July 1993 to August 1994 near the Munui intake tower of Taechung Reservoir to evaluate effects of nutrients and suspended solids on algal chlorophyll-*a* and water clarity. Large amounts of precipitation during summer 1993 produced minimum conductivity (88 μS/cm), minimum TN : TP (<40), and maximum total phosphorus (TP; 59 μg/L) and resulted in a chlorophyll-*a* peak (79 μg/L) and minimum transparency (<1.5 m) among the seasons. At the same time, ratios of volatile suspended solids (VSS) : non-volatile suspended solids (NVSS) were maximum (13.0), indicating that the reduced transparency was mainly attributed to biogenic turbidity in relation to phytoplankton growth. In contrast, severe drought in summer 1994 resulted in greater conductivity (>120 μS/cm), water clarity (>2 m), and lower TP and chlorophyll-*a* (<10 μg/L) relative to those of summer 1993. Total phosphorus ($R^2$ = 0.46, n = 59) accounted more variations of chlorophyll-*a* compared to total nitrogen ($R^2$ = 0.29, n = 59). The mass ratios of TN : TP ranged from 39 to 222 and were strongly correlated with TP (r = −0.80) but not with concentrations of TN (r = −0.05). Ambient nutrient concentrations and TN : TP mass ratios indicated that seasonality of chlorophyll-*a* was likely determined by concentrations of phosphorus reflected by the distribution of rainfall. It was concluded that reductions of phosphorus during heavy rainfall may provide better water quality for the drinking water in the intake tower.**

**Key words : Intake tower, Rainfall, Nutrients, Chlorophyll-*a*, Suspended solids**

## INTRODUCTION

Characteristics of water quality fluctuation in lentic systems generally are frequently determined by nutrient concentrations (Claesson and Ryding, 1977). In order to understand ecological functions and characteristics of a lake and to preserve and manage water quality that is used for drinking water, we have to examine fluctua- tions of nutrients. Two factors that control water quality are 1) inflow of nutrients which is created from another environment: one is point source (Chapra and Rovertson, 1977) that is a known incoming channel, and the other is non-point source that comes from scattered environments 2) autochthonous organic matter made by photosynthesis of primary producers such as phytoplankton within a lake.

With respect to lake eutrophication, it is well

known that increased nutrient loading frequently results in increased phytoplankton standing crop which, in turn, may lead to increased hypolimnetic oxygen deficit, decreased water clarity, and changes in species composition. Studies provided some evidence how much phytoplankton standing crop would increase with a given change in nutrient loading. Individual waterbodies, however, act differently in reponse to the nutrient loading, its morphology, and rainfall patterns.

To understand and control eutrophication in lakes and reservoirs, it is essential to determine factors that are limiting to the growth of phytoplankton. Relationships between nutrients and chlorophyll–a concentration are widely used to estimate eutrophication of lakes/reservoirs (Jones and Bachmann, 1976; Hoyer and Jones, 1983; Mineeva, 1993). Such empirical relationships or theoretical models provide appropriate management strategy for better water quality.

Although nitrogen and phosphorus are not the only nutrients required for algal growth, it is generally agreed that they are the two major nutrients involved in the process of lake eutrophication over the world. Phosphorus is often stated as the most frequent limiting nutrient in lakes (Claesson and Ryding, 1977). According to most studies for lakes and reservoirs in North America and Europe, phosphorus leads to algal production in lakes and reservoirs (Sakamoto, 1966; Chiaudani and Vighi, 1974; Schindler and Fee, 1974; Forsberg and Ryding, 1980). Thus, phosphorus has direct functional relations with chlorophyll–a concentration (Schindler *et al.*, 1971). These characteristics, however, differ with regional climate, altitude, and the watershed area.

The surface waterbodies in Korean peninsula are influenced by monsoons every year. Intensive precipitation during a summer period from June to August can result in large heterogeneity of water quality. Most Korean reservoirs served as drinking water source and often have intake tower. During monsoon season, therefore, it is important to protect the water near intake tower from the impact of intense precipitation. The objectives of this study were to evaluate how precipitation affected lake dilution and nutrient loads, nutrients are associated with algal biomass, and to determine which nutrient is a key element for algal growth in the water supplying intake tower.

## MATERIALS AND METHODS

Taechung Reservoir in Korea is located in the middle of South Korea (127° 50′E, 36° 50′N) and was constructed in December 1980 by impounding the Keum River about 150 km upstream from its estuary to provide a water resource (An, 2000a). There were two intake towers in the reservoir: Dongmyun intake tower and Munui intake tower. Munui intake tower, which included the sampling area used in the analysis, was near 127° 30′N and 36° 30′W, furthest downstream in the Taechung Reservoir. Munui intake tower provides industrial water as well as drinking water to Chongju citizens, at a rate of approximately $1.6 \times 10^6 \ m^3 \ d^{-1}$.

Water samples were collected at the surface (depth $< 0.5$ m) using 4 L polyester bottle weekly during the period from July 1993 to August 1994 between 7 am and 11 am. Such frequency of water sampling in the reservoir seems to be appropriate based on previous study (Harris, 1987). After collecting water samples, we placed them in an icebox and brought them to the laboratory.

Water temperature, dissolved oxygen, and pH were measured immediately *in situ* using oxygen meter (YSI Model 51B) and pH meter (Orion Research digital ionalyzer/501), respectively and turbidity was measured using turbidimeter (HACH Model 2100A) in the laboratory. Water transparency was determined by using a 30–cm diameter Secchi disk, and conductivity was measured by conductivity meter (YSI Model 33). Total phosphorus (TP), total nitrogen (TN), chlorophyll–a (Chl–a), total suspended solids (TSS), non–volatile suspended solids (NVSS), and volatile suspended solids (VSS) were measured in the laboratory. Total phosphorus (TP) and total nitrogen (TN) were measured using the ascorbic acid method after persulfate digestion (Menzel and Corwin, 1965; Prepas and Rigler, 1982) and second derivative method after a persulfate digestion (Crumpton *et al.*, 1992), respectively. Chlorophyll–a concentration was determined by using a spectrophotometer (Beckman Model DU–65) after extraction in ethanol (Sartory and Grobbelaar, 1984). Gravimetric analyses of total suspended solids, non–volatile suspended solids and volatile suspended solids were conducted after water samples were filtered through preweighed glass fiber filters (0.45 μm, Whatman GF/C fil-

ter). Total suspended solids were determined by filtering water through preweighed, Whatman GF/C filters, and the filters were weighed after drying at 103°C for 1 hour. Non-volatile suspended solids (NVSS) were determined after combustion (range: 450~550°C in muffle furnace, 1 hour). Volatile suspended solids (VSS) were determined by differences between total suspended solids and non-volatile suspended solids (APHA, 1985).

Linear regression and correlation analyses were used to examine relations between variables. Statistical analyses were performed using the SigmaStat 2.03 computer package.

## RESULTS

### Physico-chemical parameters

Water temperature averaged 17.1°C during the study and ranged from 3.0 to 31.2°C (Table 1), indicating a typical pattern of temperate regions. Water temperature fluctuation was widely separated into three periods: rising period (January ~June), maximum period (July~August), and falling period (September~December). The three periods were matched well with the pre-monsoon, monsoon, and post-monsoon described in An (2000b). During the water temperature maximum period of 1993 and 1994, mean water temperatures were 25.2 and 29.4°C, respectively, and the inter-annual variation was evident between the two periods (Fig. 1a).

Dissolved oxygen concentration averaged 9.8 mg/L and varied from 7.0 to 13.6 mg/L during the study (Table 1). The pattern of fluctuation indicated that dissolved oxygen concentrations were low in summer and were high in winter, and showed reverse trend of water temperature fluctuation (Fig. 1a, b). As shown in Table 2, DO concentration was negatively correlated (r = −0.87, $P < 0.05$) with water temperature, and had an inverse relation (r = −0.44, $P < 0.05$) with chlorophyll-a. Mean DO of mid-July 1993 was significantly ($P < 0.05$) greater than that of mid-July 1994.

Values of pH ranged from 6.5 to 8.9 with an average of 7.7 during the study (Table 1). In general, pH tended to increase during daytime as carbon dioxide was uptaked by phytoplankton and aquatic plants for photosynthesis. The pH fluctuation followed the seasonal trend of water temperature. During the study pH fluctuated considerably over time, but mean pH in both 1993 and 1994 were very similar (Table 1, Fig. 1c).

Conductivity averaged 107 μS/cm and varied from 88 to 127 μS/cm during the study (Table 1). Annual mean conductivity (98 μS/cm) in 1993 was low relative to 1994 (114 μS/cm). Also, summer mean conductivity in 1993 and 1994 was 102 and 119 μS/cm, respectively. Lower annual and seasonal conductivity in 1993 was mainly attributed to greater rainfall (dilution effect) (Fig. 1d, g). Actually, the amount of rainfall during the monsoon period in 1993 (659.9 mm) was high by about 3.4 fold relative to 1994 (195.6 mm), and was slightly greater than 50% of total annual

**Table 1.** Means±standard errors and ranges of physical, chemical, and biological parameters in the Munui intake tower between 1993 (July~December; n=26) and 1994 (January~August; n=33).

| Parameters | 1993 | | 1994 | |
|---|---|---|---|---|
| | Mean±S.E. | Range | Mean±S.E. | Range |
| Temperature (°C) | 19.4±1.2 | 6.9~28.0 | 15.2±1.8 | 3.0~31.2 |
| Dissolved oxygen (mg/L) | 8.9±0.1 | 7.0~10.4 | 10.5±0.3 | 7.4~13.6 |
| pH | 7.7±0.1 | 6.5~8.9 | 7.8±0.1 | 6.8~8.7 |
| Conductivity (μS/cm) | 98±1 | 88~110 | 114±1 | 104~127 |
| Secchi transparency (m) | 2.3±0.1 | 1.2~3.2 | 2.4±0.1 | 1.6~3.2 |
| Turbidity (N.T.U) | 2.7±0.7 | 1.1~18.5 | 2.1±0.2 | 1.2~5.7 |
| Chlorophyll-a (μg/L) | 15.6±2.8 | 4.5~79.1 | 5.6±0.4 | 2.6~12.2 |
| Total suspended solids (mg/L) | 3.5±0.5 | 1.5~14.1 | 3.0±0.3 | 1.4~7.3 |
| Volatile suspended solids (mg/L) | 1.7±0.5 | 0.2~13.4 | 0.8±0.1 | 0.3~1.8 |
| Non-volatile suspended solids (mg/L) | 1.8±0.1 | 0.7~3.0 | 2.1±0.2 | 0.6~6.0 |
| Total nitrogen (mg/L) | 1.46±0.06 | 1.20~2.72 | 1.24±0.03 | 0.91~1.64 |
| Total phosphorus (μg/L) | 21±2 | 6~59 | 17±1 | 10~37 |
| Ratios of TN : TP | 83±8 | 39~222 | 83±5 | 29~1378 |
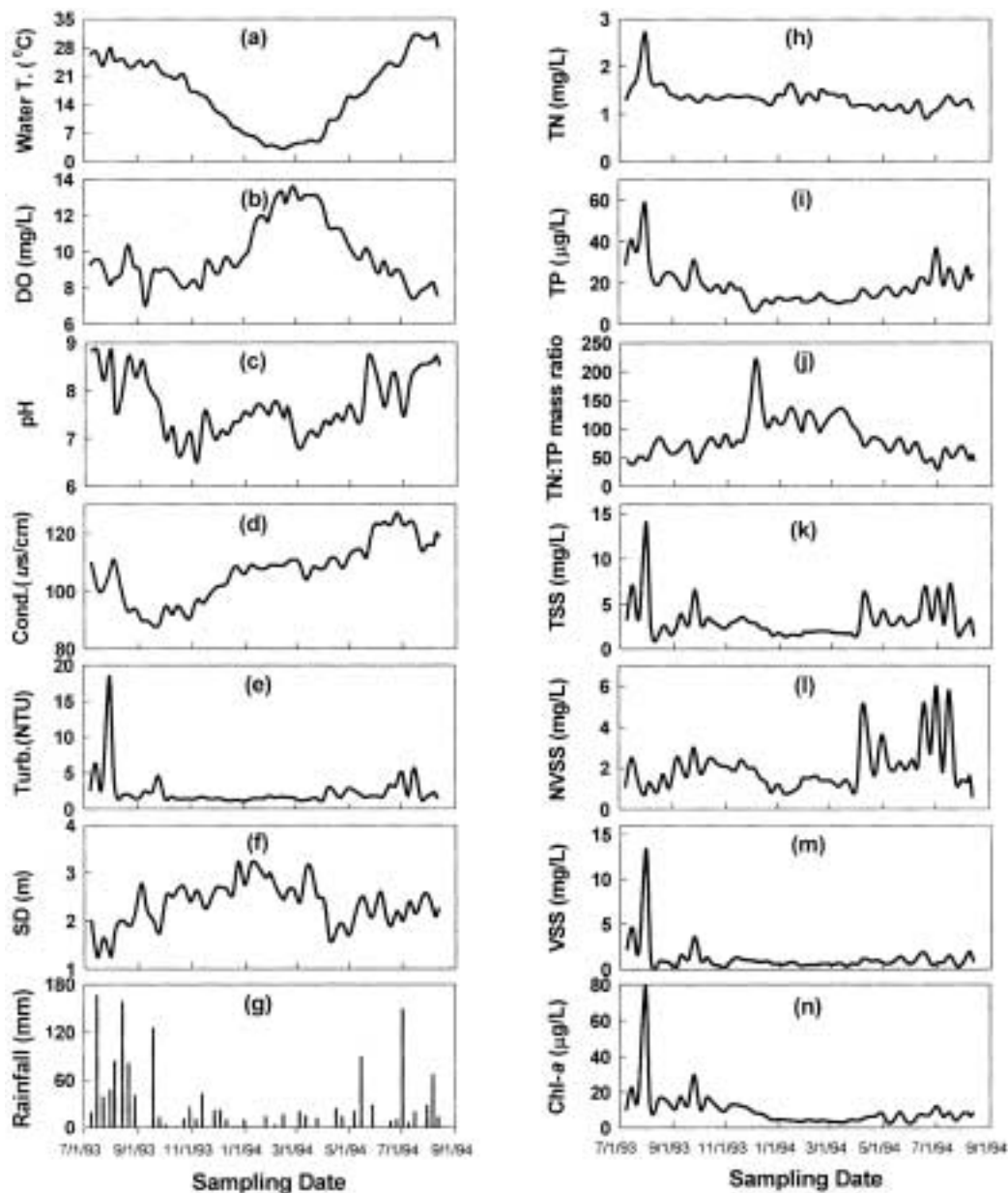
**Fig. 1.** Temporal variations of physical, chemical, and biological parameters at the Munui intake tower of Taechung Reservoir. Abbreviations are as follows: Water T. = water temperature; DO = dissolved oxygen; Cond. = conductivity; Turb. = turbidity; SD = Secchi depth.

precipitation (Fig. 1g).

Secchi transparency was minimum when turbidity values were maximum (Fig. 1e, f). Secchi depth and turbidity values were determined by the combined effect of algal biomass and inorganic solids. Turbidity of greater than 15 NTU in summer 1993 coincided with the peak of algal chlorophyll and minimum transparency in spring 1994 occurred when nonvolatile suspended solids

values were greater than 4 mg/L (Fig. 1e, f, l, n).

Concentrations of total nitrogen (TN) in 1993 averaged 1.46 mg/L and varied from 1.20 to 2.72 mg/L, while in 1994, mean TN was 1.24 mg/L and ranged from 0.91 to 1.64 mg/L (Table 1, Fig. 1h). As shown in Table 2, the minimum and maximum ranges of TN were similar between the two years but mean TN of summer 1993 was greater than that of summer 1994. Values of TN

were varied little in the intake tower area except for the period of summer 1993 as shown in Fig. 1h. This study supports the finding (An, 2000b) that this reservoir is N–rich system.

On the other hand, total phosphorus (TP) concentrations averaged 19 μg/L and varied from 6 to 59 μg/L during the study (Table 1, Fig. 1i). The peak of TP showed a marked difference between the two years. Concentration of TP increased up to 59 μg/L in summer 1993, but was less than 37 μg/L in summer 1994. Overall annual means (by sampling date), however, were slightly greater in 1993 than in 1994 (Table 1).

The mass ratios of TN : TP ranged 29 to 222 during the study and the mean values were similar between both years ($P = 0.703$) and both monsoon periods ($P = 0.564$) (Table 1). The mass ratios were low (about 50) when TP concentrations were greater than 20 μg/L (the monsoon period), while the values were high ($> 100$) when TP concentrations were about 10 μg/L (winter period) (Fig. 1i, j). The highest peak of TN : TP mass ratio (222) coincided with the lowest TP concentration (6 μg/L), indicating a severe phosphorus limitation for algal growth based on the criteria of Forsberg and Ryding (1980).

The two major sources of suspended solids in the reservoir water reflected mineral particles from the basin and particulate organic matter resulting from live plankton and detritus. Values of non–volatile suspended solids (NVSS) were less than 3 mg/L in 1993, but increased up to 6 mg/L in 1994 (Fig. 1l). In this embayment of the reservoir, NVSS did not closely associated with rainfall as shown in Fig. 1g. The maximum volatile suspended solids (VSS) in summer 1993 coincided with total suspended solids (TSS), and at this time NVSS were less than 3 mg/L, indicating that the suspended solids made up organic matter such as phytoplankton cells (Fig. 1k, l, m). This suggestion was supported by the chlorophyll–a peak of 79 μg/L as shown in Fig. 1n. In contrast, concentrations of TSS in 1994 were similar to the values of NVSS, indicating the major contribution of inorganic solids to the total solids (Fig. 1k, l).

### Biological parameters

Concentrations of chlorophyll–a (Chl–a) in 1993 averaged 15.6 μg/L and varied from 4.5 to 79.1 μg/L, while in 1994 mean Chl–a was 5.6 μg/

L and ranged from 2.6 to 12.2 μg/L (Table 1). The distinct difference between the two years was mainly attributed to difference during summer period of both years. As shown in Fig. 1i, TP were similar to seasonal patterns of Chl–a; TP values were $> 40$ μg/L in summer 1993 and were mostly above 17 μg/L in 1993, while TP values were less than 17 μg/L from January to May 1994. Ratios of TN : TP indicated that the reservoir was P–limited system, based on the conventional criteria of Forsberg and Ryding (1980), so that the level of phosphorus determined the Chl–a concentration in both years. Also, seasonality of VSS as an estimate of particular organic matter indicated the predominance of organic matter in 1993 (Fig. 1m).

### Relations among water quality parameters

Table 2 shows the relations of correlation coefficients among various parameters. Values of TN, TP, Chl–a, VSS, and turbidity were positively correlated ($r > 0.50$, $P < 0.05$) with precipitation, and TN : TP ratios and Secchi transparency were negatively correlated (absolute value of $r > 0.50$, $P < 0.05$) with precipitation (Table 2). We found that N : P ratios were direct function of TP ($r = -0.80$), but not with TN ($r = -0.05$). This result implies that TN : TP ratio was determined by P rather than N. This was attributed to high N concentrations in the water and low seasonal variability. The correlation coefficient was 0.89 between Chl–a and VSS, whereas it was $-0.09$ between Chl–a and NVSS, indicating that Chl–a was not affected by NVSS in this intake site.

### Empirical relations of nutrients to Chlorophyll–a

Regression analyses of log–transformed Chl–a against nutrients (TN, TP) showed that the variation of Chl–a was explained more by TP ($R^2 = 0.46$, $P < 0.05$, n = 59) than TN ($R^2 = 0.29$, $P < 0.05$, n = 59) (Fig. 2). In the Chl–a–TP relation, the slope and intercept were 1.05 and $-0.41$, respectively, while in the Chl–a–TN relation, they were 2.08 and $-5.61$, respectively. The equations were as follows;

$$\mathrm{Log}_{10}(\mathrm{Chl}-a) = 2.08\ \mathrm{Log}_{10}(\mathrm{TN}) - 5.61$$
$$\mathrm{Log}_{10}(\mathrm{Chl}-a) = 1.05\ \mathrm{Log}_{10}(\mathrm{TP}) - 0.41$$

The greater relation of Chl–a to phosphorus was due to lower P contents in this system as

**Table 2.** Correlation coefficients ($P < 0.05$) among the water quality parameters. Data used were monthly means (n = 12) during the study.

| | Prec. | TN | TP | TN/TP | Chl−a | TSS | NVSS | VSS | Temp | pH | DO | Cond. | Turb. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TN | 0.61 | | | | | | | | | | | | |
| TP | 0.76 | 0.58 | | | | | | | | | | | |
| TN/TP | −0.58 | −0.05 | −0.80 | | | | | | | | | | |
| Chl−a | 0.71 | 0.77 | 0.86 | −0.52 | | | | | | | | | |
| TSS | 0.47 | 0.33 | 0.81 | −0.69 | 0.76 | | | | | | | | |
| NVSS | −0.11 | −0.53 | 0.05 | −0.44 | −0.09 | 0.44 | | | | | | | |
| VSS | 0.59 | 0.68 | 0.86 | −0.50 | 0.89 | 0.84 | −0.12 | | | | | | |
| Temp | 0.60 | 0.08 | 0.79 | −0.90 | 0.53 | 0.58 | 0.33 | 0.44 | | | | | |
| pH | 0.64 | 0.22 | 0.79 | −0.76 | 0.46 | 0.54 | 0.04 | 0.58 | 0.74 | | | | |
| DO | −0.38 | 0.03 | −0.55 | 0.66 | −0.44 | −0.44 | −0.32 | −0.28 | −0.87 | −0.48 | | | |
| Cond. | −0.17 | −0.48 | −0.02 | −0.17 | −0.45 | 0.07 | 0.28 | −0.09 | 0.09 | 0.36 | 0.08 | | |
| Turb. | 0.64 | 0.65 | 0.90 | −0.58 | 0.85 | 0.89 | 0.06 | 0.95 | 0.50 | 0.65 | −0.27 | 0.02 | |
| SD | −0.72 | −0.32 | −0.80 | 0.79 | −0.67 | −0.78 | −0.28 | −0.69 | −0.65 | −0.66 | 0.37 | −0.04 | −0.74 |

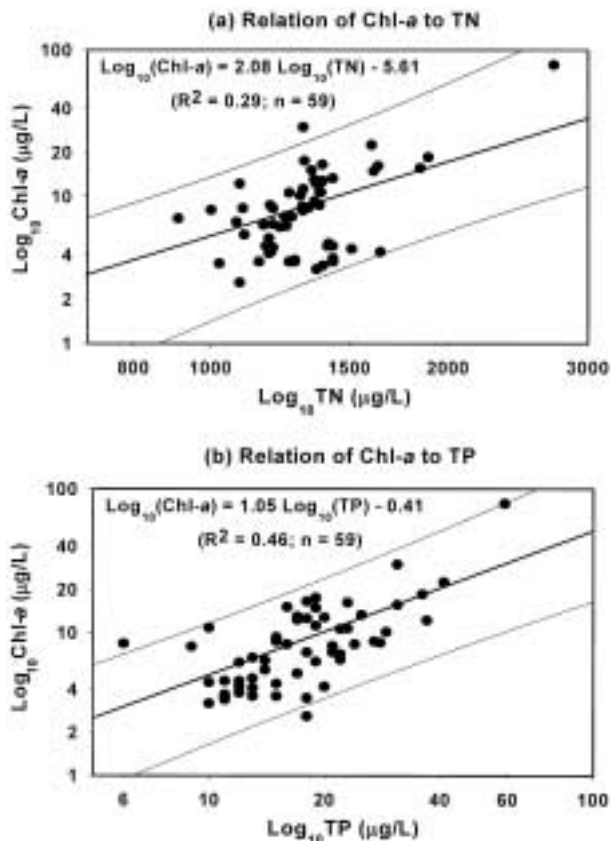*Prec. = Precipitation, Temp = Water temperature, Cond. = Conductivity, Turb. = Turbidity, SD = Secchi depth



**Fig. 2.** Regression analyses of chlorophyll−a (Chl−a) against total nitrogen (TN, upper) and total phosphorus (TP, lower). Lines indicate 95% predictive confidence interval.

mentioned in the TN : TP ratios. The relations also suggest that nitrogen was enough to support the algal growth in this system.

## DISCUSSION

Seasonality of DO showed that mean DO during monsoon (July~August) was significantly greater ($P < 0.001$) in 1993 than 1994. There might be two reasons for the difference between the monsoon periods of 1993 and 1994. During the monsoon period mean water temperature in 1994 was significantly higher than in 1993 so that higher water temperature resulted in lower DO content due to reduced solubility of oxygen in the water. The higher water temperature was mainly attributed to reduced rainfall and high air temperature. Also, mean Chl−a concentration in 1993 (23.8 µg/L) was high by 3 fold relative to 1994 (7.8 µg/L) due to greater external nutrient (especially phosphorus) loading by intensive rain. Contents of Chl−a from all samples during the 1993 monsoon were also greater than 10 µg/L, but in 1994 they were less than 10 µg/L. The greater algal biomass created more oxygen production through photosynthetic activity.

Conductivity had a positive relationship with fluctuations of total dissolved solids, cations, and anions as shown in North American lakes (Rodhe, 1949; Hutchinson, 1957). We believe that seasonal monsoon is a typical factor affecting dilution of waterbody based on conductivity values (An and Jones, 2000). Dilution effects associated with monsoon rains have been noted previously in several Indian lakes (Singh, 1981

and 1985; Banerjee *et al.*, 1983; Lohman *et al.*, 1988). The study was investigated weekly from 9 July 1993 to 12 August 1994. Fortunately, the summer of 1993 in Taechung Reservoir was one of the most intense rainfall since the construction of the dam (1980), whereas the summer of 1994 was most drought period since then (An and Jones, 2000). The climate pattern reflected the minimum conductivity in summer 1993 vs. maximum in summer 1994. This finding suggests that ionic dilution occurred in the summer 1993 due to the heavy monsoon rain, while ionic elevation occurred in summer 1994 due to the continued drought.

Previous reservoir studies (Priscu *et al.*, 1982; Knowlton and Jones, 1990) have demonstrated that the most variable reach in most reservoirs is the zone of transition between riverine areas near the headwater and the lacustrine zone near the dam. Although heavy rainfall in the upper watershed generally caused increased inorganic suspended solids of >20 mg/L (An, 2000c), non-volatile suspended solids in our study site maintained low values during the intense rainfall. These reasons were that 1) there were small tributary streams which flowed into the sampling area and the size was small, compared to the main tributaries of Keum River and Bochung streams, 2) although NVSS abruptly increased during intensive raining period in the headwaters of the reservoir, NVSS did not increase near the dam because the increased NVSS settled out from the water column by sedimentation process as upper water came to the dam (Ford, 1990; Thornton, 1990; Knowlton and Jones, 1990). Furthermore, the intake tower area is located in the embayment, so the high NVSS in the headwater did not occur in the intake tower area.

Both TN and TP concentrations showed highest peaks at the end of July 1993 when intense rainfall occurred. Thereafter, both concentrations were declined rapidly and maintained the low level. During weak–monsoon period of 1994 a few scattered rainfalls did not influence water level change and also did not lead to increase TN and TP concentrations. These results suggest that seasonal patterns of in–lake nutrients were determined by rainfall pattern and that external nutrient loads though the watershed runoff might have increased the in–lake nutrient level during the intense rainfall. Another potential cause is that high fluctuations of water level in the embayment might have increased an interface of sediment with water as shown in temperate lakes of North America (Thornton, 1990), although we could not measured in this study, resulting in greater nutrient contents.

The positive relations between phosphorus and Chl–*a* imply that phosphorus is the key element controlling algal biomass in the system as suggested in North America lakes (Jones and Bachmann, 1976). The slope of the log–log regression line was greater than 1, indicating that Chl–*a* increases at a faster rate than does the phosphorus concentrations. The phosphorus–Chl–*a* relations provide a means for understanding the differences in the algal densities of the reservoirs and should provide a mean of estimating the expected effects of changes in phosphorus levels on algal biomass.

Numerous scientists have demonstrated important roles of TN : TP ratio on lake eutrophication. Sakamoto (1966) indicated that chlorophyll–*a* concentration was influenced by N or P when TN : TP ratio was between 10 and 17, but that Chl–*a* was dependent only on TN when the TN : TP ratio was smaller than 10, and only on TP when the ratio was larger than 17. Similarly, Forsberg and Ryding (1980) classified the phosphorus–limitation as the TN : TP of >17. Based on the criteria, Taechung Reservoir is typically P–limited for algal growth because of high TN : TP ratios of >80 during the study.

We believe that high phosphorus during summer 1993 came from the soil erosion in the watershed and greater exchanges of lake water with the bottom of shallow littoral zone. Previous studies have suggested that regional chemical characteristics of lake water are closely related to the soil characteristics of their drainage basin. Surface layers of soil are relatively rich in organic phosphorus from plant detritus in various stages of decomposition by soil fungi and bacteria, thus surface drainage is often a major contributor of phosphorus to lentic systems (Wetzel, 2001). The quantities of phosphorus entering surface drainage vary with the amount of phosphorus in soils, topography, vegetative cover, quantity and duration of runoff flow, land use, and pollution. The major source of phosphorus in precipitation is from dust generated over the land from soil erosion and from urban and industrial contamination of the atmosphere, thus soil erosion by intensive rain can lead to increase

external phosphorus loading to watershed. There are no big point sources such as wastewater disposal plants and industrial area in the intake tower area because of water−resource protection for drinking water. These circumstances indicate that P was originated from the soil erosion during the rainy period. Our data support previous findings (An, 2000a, b; An and Jones, 2000; Oh and Kim, 1995) that water quality such as nutrients of nitrogen and phosphorus, ionic contents, suspended solids, and bluegreen algal bloom is determined by the duration and the magnitude of intense rainfall. To minimize external phosphorus loads during intensive monsoon period, geomorphologic approaches around the reservoir would be useful for better water quality. We suggest that a variety of designs such as soil surface covers by plants, silt fence (haybale or artificial porous silt fence), and sedimentation ponds (/basins) would be efficient for reducing external phosphorus loads (Waters, 1995).

As shown in above results, solving fundamental problems of eutrophication in the Munui intake tower is to accomplish decrease of phosphorus concentrations. The decrease of phosphorus is largely able to control increase of algal biomass in water, then water transparency would increase, and finally water quality will be get better for drinking water. If we consider that an input of phosphorus is achieved during the monsoon period (July through August), about 60% of annual precipitations occur during high inflow periods. Therefore, the control of phosphorus inflow during these periods may facilitate a recovery of the water quality and reduce nutrient levels.

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<국문적요>

# 대청호의 취수탑 주변의 이화학적·생물학적 상태에 대한 계절강우의 영향

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1993년 7월부터 1994년 8월까지 대청호 내 문의취수탑에서 조류의 엽록소 양 및 투명도에 대한 영양염류 및 현탁물의 영향을 평가하기 위해 물리적, 화학적, 생물학적 요소들이 측정되었다. 1993년 여름기간 동안 집중 강우는 수체의 희석효과 (전기전도도 = 88 μS/cm), 최소의 총질소와 총인 질량 비 (< 40), 그리고 최대의 총인 농도 (59 μg/L)를 야기시켰고, 계절들 가운데 최고점의 엽록소 (79 μg/L)와 최소의 투명도 (< 1.5 m)를 초래하였다. 이와 동시에 유기현탁물 (VSS)과 무기현탁물 (NVSS) 질량비는 최대 (13.0)였으며, 이것은 감소된 투명도가 식물성 플랑크톤 성장과 연관된 생물학적인 혼탁도로부터 주로 기인되었다는 것을 제시하였다. 반면, 1994년 여름기간동안의 극심한 가뭄은 1993년 여름보다 높은 전기전도도 (> 120 μS/cm)와 물의 투명도 (> 2 m), 그리고 낮은 총인과 엽록소 (< 10 μg/L)를 초래하였다. 영양염류에 대한 엽록소의 회귀분석에 따르면, 엽록소의 변이는 총질소 ($R^2$ = 0.29)보다는 총인 ($R^2$ = 0.46)에 의해 설명되었다. 총질소와 총인의 질량비는 조사기간동안 39~222 범위에 속하였으며, 총질소의 농도 보다는 총인의 농도에 의해 결정되었다. 조사기간동안 두 영양염류의 농도와 총질소 대 총인의 질량 비는 엽록소의 계절 주기성이 주로 강우의 분포에 반영된 인 (Phosphorus)의 농도에 의해 결정된다는 것을 의미하였다. 집중강우 기간동안의 인 유입의 저지는 취수탑에서 식수를 위한 보다 나은 수질을 제공할 것으로 사료된다.