Korean J. Ecology 5(1) : 7~13, 1982

Comparison of Water Qualities and Biotic Effects of Three River Waters in Taegu Area

Lyu, Seung-Won and Seung-Dal Song
(Dept. of Biology, College of Natural Sciences, Kyungpook National University)

大邱지방 河川의 水質特性과 水生物에 미치는 影響 比較

柳 勝 元 · 宋 承 達
(慶北大學校 自然科學大學 生物學科)

ABSTRACT

The water environmental characters of the Nakdong River, Geumho River and Sin Stream, both before-flood (Aug. 24) and after-flood (Sept. 8), have been compared, and their effects on the growth of *Spirodela polyrhiza* Shleiden have been examined. Before the flood, the concentrations of most of the chemical components of the Geumho River were similar to those of the Sin Stream; (COD, 19.6~21.4; alkalinity, 177~183; NH_4^+, 20.7~21.4; NO_3^-, 3.9~4.3; PO_4^{3-}, 3.4~3.7; Mg^{2+}, 42; Ca^{2+}, 68.5~69.7; Cl^-, 90~92; SiO_2, 10.4~11.2; SO_4^{2-}, 11~32; LAS, 3.0~3.8; $Cr^{3+,6+}$, 0.007~0.010ppm) but much higher than those of the Nakdong River (30~40 fold for NH_4^+, SO_4^{2-}, PO_4^{3-} and LAS, and 2~5 fold for COD, alkalinity, NO_3^-, Mg^{2+}, Cl^- and $Cr^{3+,6+}$). Especially in the Geumho River. Secchi disk transparency was very low (17cm) and DO was not detected. The flood caused significant increases in some chemical components: NH_4^+, 1.0; NO_3^-, 9.6; SiO_2, 12.8 and SO_4^{2-}, 5.4ppm in the Nakdong River; DO, 1.0; NO_2^-, 0.92; NO_3^-, 22.2 and SiO_2, 17.6ppm in the Geumho River; DO, 3.0; NO_2^-, 1.4; NO_3^-, 22.2; SiO_2, 19.2 and SO_4^{2-}, 25.0ppm in the Sin Stream. General species diversity index ($\bar{H}$) of phytoplankton community in the Nakdong River, Geumho River and Sin Stream before flood was 3.1, 2.7 and 1.6, respectively. After the flood, the phytoplankton growth was highly sparse in each river water, hence indices have no significance. The growth of *S. polyrhiza* was enhanced in Geumho River water (max. RGR=26%/day), while it ceased within 7days in Nakdong River water. Total chlorophyll content of *S. polyrhiza* in Nakdong River water, Geumho River water and Sin Stream water was 1.04, 1.88 and 1.25 chl. mg/g frond, respectively after 11days incubation. The concentration gradients of LAS (0.1~3.8ppm), Cd^{2+}(0~0.02ppm) and Cr^{6+}(0.004~0.010ppm) by the gradients of the field showed no significant inhibitions on the plant growth.

INTRODUCTION

The Nakdong River, the longest river(524km) consisting of many tributaries in South Korea, flows southward through the drainage area of Kyungpook and Kyungnam provinces into the Korean Strait. The two important tributaries, the Sin Stream and the Geumho River, which flow through Taegu city and the periphery drainage area, have been extremely polluted by municipal sewage, but are still important sources of water supply to crop fields, industries and domestic uses.

Recently many good investigations with respect to stream water quality have been carried out: the effect of land use pattern on stream water quality(Hirose et al., 1981), the establishment of model on production and transport of pollutants produced by land use(Couilard et al., 1980), the seasonal changes of physico-chemical factors and the comparison of pollution levels according to diversity indices of phytoplankton community(Eloranta, 1976; Hong et al., 1979; Lee, 1980; Song et al., 1978; Wetzel, 1975; Yang et al., 1981).

The present study was carried out to elucidate the differences of water quality among the Nakdong River, Geumho River and Sin Stream, the effect of flood on these water qualities, and the effect of these river waters on the growth of duckweed, *Spirodela polyrhiza* Shleiden, which is very sensitive to environmental changes.

MATERIALS AND METHODS

Study sites were selected to include different water sources in the respective drainage areas(Fig. 1). Site 1 on the Nakdong River was considered to be unaffected by Taegu city, site 2 on the Geumho River

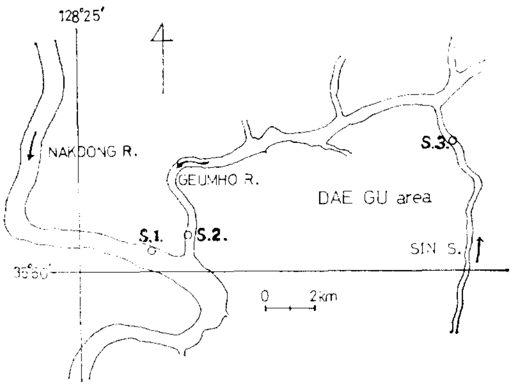


Fig. 1. Map showing locations of sampling sites 1, 2 and 3 on the Nakdong River, Geumho River and Sin Stream.

was a dumping place of wastes from the city, and site 3 on the Sin Stream was the midtown area. Water sample for each site was collected in 1*l* polyethylene bottles from below the surface within 50cm depth on August 24 (before flood) and September 8 (after flood), 1981.

On each sampling occasion, water temperature, turbidity(Secchi disk transparency), and flow-velocity were recorded. Flow rate was calculated by multiplying flow-velocity by cross area of the river. Chemical analyses were conducted with following methods: DO, Winkler method; COD, $KMnO_4$ method; pH, Fisher pH meter; NH_4^+, Nesslerization method; NO_2^-, Griess Romijn method; NO_3^-, UV-Spectrophotometer; PO_4^{3-}, Vanadomolybdophosphoric acid colorimetric method; SO_4^{2-}, Turbidimetric method; Ca^{2+} and Mg^{2+}, EDTA titrimetric method; Cl^-, Mohr method; SiO_2, Molybdosilicate method; Alkalinity, Standard method; Cd^{2+} Dithizon method; $Cr^{3+,6+}$, Colorimetric method; and Surfactants, Methylene blue method(APHA, 1976; Mizuno, 1972; Rai & Hill, 1980; Sodergaarden, 1979).

In order to measure the number of phytoplankton individuals, 250～500m*l* of sample water was filtered with Whatman No. 1 paper and then washed off the planktons attached on the paper in 10～20m*l* of distilled water, and then counted under microscope using haemacytometer(welch, 1948). The analyses of the biotic or species diversities were calculated according to following formulas:

1) Index of dominance (c)

$$c = \sum(ni/N)^2 \text{ (Simpson, 1949)}$$

2) Indices of species diversity

a. Species richness index (d)

$$d = S - 1/ln\ N \text{ (Margalef, 1958)}$$

b. Shannon index of general diversity ($\bar{H}$)

$$\bar{H} = -\sum(ni/N)ln(ni/N) \text{ (Shannon and Weaver, 1949; Margalef, 1968)}$$

c. Evenness index (e)

$$e = \bar{H}/lnS \text{ (Pielou, 1966)}$$

where ni = number of individual for each species

N = total number of individual

S = number of species

The growth responses of *S. polyrhiza* were investigated through sampled river waters and Yoshimura culture solutions treated with environmental pollutants of heavy metals and surfactants. These results were compared and interpreted in respect to the prevailing concentrations in the sampled waters. The changes in the number of fronds were counted on every alternate days. The total chlorophyll amount was measured with DMSO method.

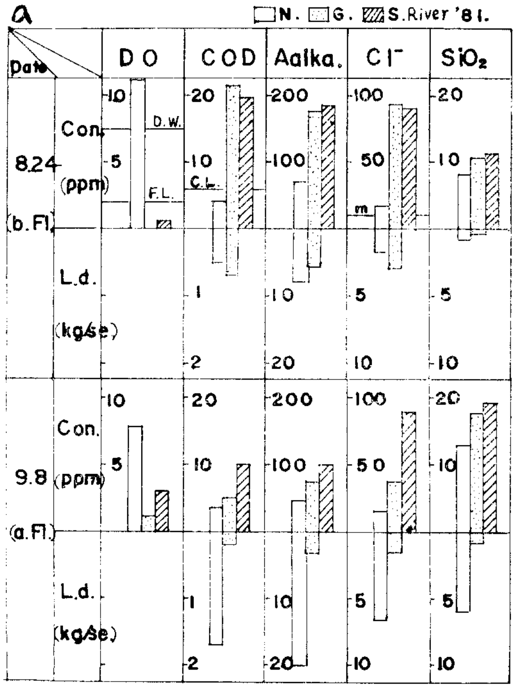
RESULTS AND DISCUSSION

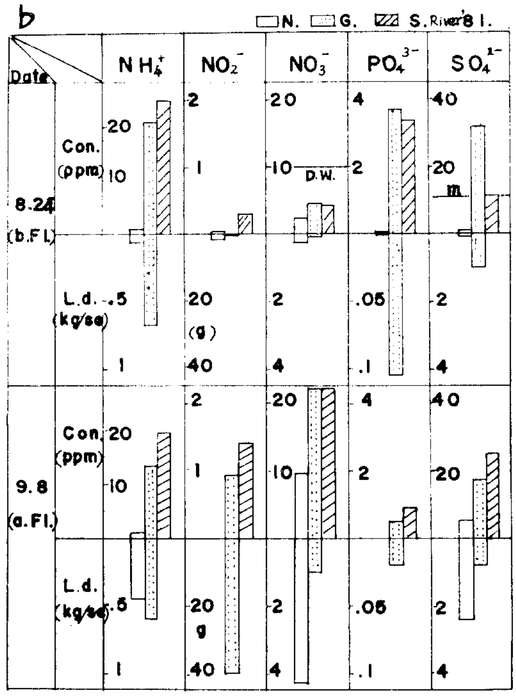
1, Comparison of physico-chemical characters in river waters before flood

The flow rate of each river before flood was similar to that of dry season (Nakdong River, 111.6m^3/sec; Geumho River, 32.6m^3/sec). The pH in the Nakdong River indicated more or less a basic state, 8.7, while the others neutral state, 7.0~7.1(Table 1).

Table 1. Some physical characteristics at 3 sites on Nakdong River (N), Geumho River (G) and Sin Stream (S) before (b.F.) and after flood (a.F.): W.T., water temp.; F.V., flow velocity; F.R., flow rate; Turb., turbidity. '81.

Date	River	W.T. (°C)	F.V. (m/sec)	F.R. (m^3/sec)	Turb. (cm)	pH
8. 24 (b.F.)	N	28	0.4	111.6	55	8.7
	G	28	0.1	32.6	17	7.0
	S	—	—	—	—	7.1
9. 8 (a.F.)	N	23	0.6	452.6	28	7.5
	G	24	0.1	44.8	95	7.1
	S	—	—	—	—	7.2





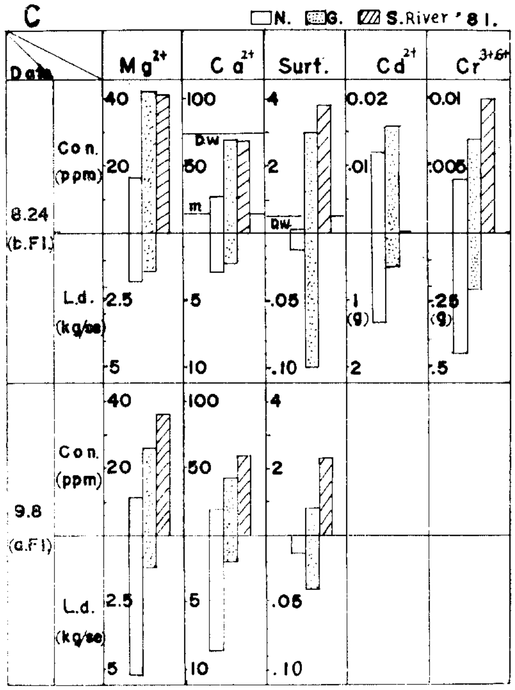


Fig. 2. Concentrations(Con. ppm) and loading rates (Ld. kg/sec)of chemical factors in 3 sites on Nakdong River, Geumho River and Sin Stream, before (b.Fl.) and after flood(a.Fl.): (a); DO, COD, alkalinity, Cl$^-$ and SiO$_2$: (b);

NH_4^+, NO_2^-, NO_3^-, PO_4^{3-} and SO_4^{2-}: (c); Mg^{2+}, Ca^{2+}, Surf., Cd^{2+} and $Cr^{3+,6+}$: DW, FL and CL; upper limit for drinking water, industrial uses and cultural uses, respectively. m; mean concentration of world rivers.

Especially in the Geumho River, the Secchi disk transparency was very low, 17cm, because of lots of suspended organic particles, and the concentration of DO was near zero (Table 1 & Fig. 2a).

As shown in Fig. 2-a,b and c, the concentrations of most of the chemical factors in the Geumho River were similar to those in the Sin Stream (COD, 10.6 ~21.4; alkalinity, 177~183; NH_4^+, 20.7~24.4; NO_3^-, 3.9~4.3; PO_4^{3+}, 3.4~3.7; Mg^{2+}, 42; Ca^{2+}, 68.5~69.7; Cl^-, 90~92; SiO_2, 10.4~11.2; SO_4^{2+}, 11~32; LAS, 3.0~3.8 and $Cr^{3+,6+}$, 0.007~0.010ppm) but 30~40 times higher for NH_4^+, SO_4^{2-}, PO_4^{3-} and LAS, and 2~5 times higher for COD, alkalinity, NO_3^-, Mg^{2+}, Cl^- and $Cr^{3+,6+}$ than those in the Nakdong River. It is notable that the concentrations of NH_4^+, SO_4^{2-}, PO_4^{3-} and LAS in the Geumho River and Sin Stream were extremely higher then those in the Nakdong River. This may suggest that a good deal of these components are generated by Taegu city life(Hirose & Kuramoto, 1981).

2. Effect of the flood on physico-chemical factors

There was heavy precipitation of 345mm in Taegu area between August 24 and September 3, 1981, which caused a flood in the drainage areas. From Table 1, it is evident that the flow rate in the Geumho River came to a steady state (44.8m^3/sec) more rapidly than that in the Nakdong River. The Secchi disk transparency in the Geumho River was much increased (95cm) as the flood washed off the suspended organic particles, while that in the Nakdong River was much decreased (28cm) because of suspended clay particles. The pH of the Nakdong River was changed from basic (8.7) to neutral(7.5) state after flood, but very little changes were observed in the Geumho River and Sin Stream(7.1~7.2). It is notable that the concentrations of some chemical factors after the flood showed significantly increased values: NH_4^+, 1.0; NO_3^-, 9.6; SiO_2, 12.8, and SO_4^{2-}, 5.4ppm in the Nakdong River; DO, 1.0; NO_2^-, 0.92; NO_3^-, 22.2 and SiO_2, 17.6ppm in the Geumhto River; DO, 3.0;No_2^-, 1.4;NO_3^-, 22.2; SiO_2, 19.2 and SO_4^{2-}, 25.0ppm in the Sin Stream (Fig. 2-a, b and c). Fig.2-a, b and c also demonstrate that the loading rate of most of the chemical factors was increased in the Nakdong River, but more or less decreased in Geumho River except for SiO_2, NO_2^- and NO_3^-.

Table 2a. Number of species and importance probability for each species (ni/N) at site 1 on Nakdong River.

a. '81.8.24.

Sp.No.	Species	Phylum	$\frac{ni}{N}$
1	*Chlorella* sp.	Chloro.	0.18
2	*Cyclotella* sp.	Chryso.	0.14
3	*Merismopedia elegans*	Cyano.	0.08
4	*Cyclotella* sp.	Chryso.	0.08
5	*Dactlococcopsis* sp.	Cyano.	0.06
6	*Nitzschia palea*	Chryso.	0.06
7	*Dactrylococcopsis* sp.	Cyano.	0.06
8	*Cyclotella meneghiniana*	Chryso.	0.03
9	*Senedesmus* sp.	Chloro.	0.02
10	*Ankistrodesmus falkalus*	Chloro.	0.02
⋮			
51			

Table 2b. Number of species and importance probability for each species (ni/N) at site 2 on GeumhoRiver.

b. '81.8.24.

Sp.No.	Species	Phylum	$\frac{ni}{N}$
1	*Chlorella vulgaris*	Chloro.	0.17
2	*Chlorella ellipsoedae*	Chloro.	0.15
3	*Dactylococcopsis rupestris*	Cyano.	0.12
4	*Chlorella* sp.	Chloro.	0.10
5	*Nitzschia palea*	Chryso.	0.10
6	*Senedesmus bicaudatus*	Chloro.	0.06
7	*Merismopedia elegans*	Cyano.	0.05
8	*Chlorococcum humicola*	Chloro.	0.05
9	*Merismopedia* sp.	Cyano.	0.04
10	*Palmella* sp.	Chloro.	0.02
⋮			
21			

Table 2c. Number of species and importance probability for each species (ni/N) at site 3 on Sin Stream.

c. '81. 8. 24.

Sp. No.	Species	Phylum	$\frac{ni}{N}$
1	*Lyngbya* sp.	Cyano.	0.39
2	*Nitzschia* sp.	Chryso.	0.29
3	*Phormidium* sp.	Cyano.	0.10
4	*Chlorella ellipsoedae*	Chloro.	0.10
5	*Phacus* sp.	Eugleno.	0.05
6	*Trachelomona* sp.	Eugleno.	0.04
7	*Cymbella affinis*	Chryso.	0.01
8	*Melosira* sp.	Chryso.	0.01
9	*Synedra* sp.	Chryso.	0.01

3. **Comparison of indices of species composition in phytoplankton community**

Table 2-a, b and c represent dominant species and number of species in each river water before flood (August 24). In the Nakdong River, Geumho River and Sin Stream, total individual density of these phytoplankton community was 26.4, 8.8 and 9.4No /mm^3; dominance index (c), 0.05, 0.10, and 0.26; species richness index (d), 10.3, 6.5 and 2.5; evenness index (e), 0.8, 0.9 and 0.7; and general diversity index ($\overline{H}$), 3.1, 2.7 and 1.6, respectively. It is said that in most of the cases, e and $\overline{H}$ indicate a low concentration of dominance(Odum, 1971), and higher diversity is related with higher stability, which also reflect favorable condition for the community(Wilhm, 1967; Nakanishi & Monsi, 1976). Therefore, the Nakdong River has still favorable environment to phytoplankton community. On the contrary the environmental stress of the Sin Stream was most intensive and most extremly polluted.

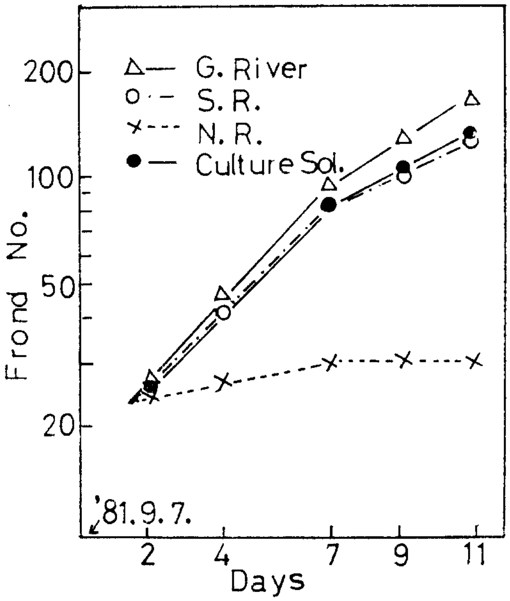


Fig. 3. Growth of duckweed population in waters of Nakdong River (N), Geumho River (G) and Sin Stream (S).

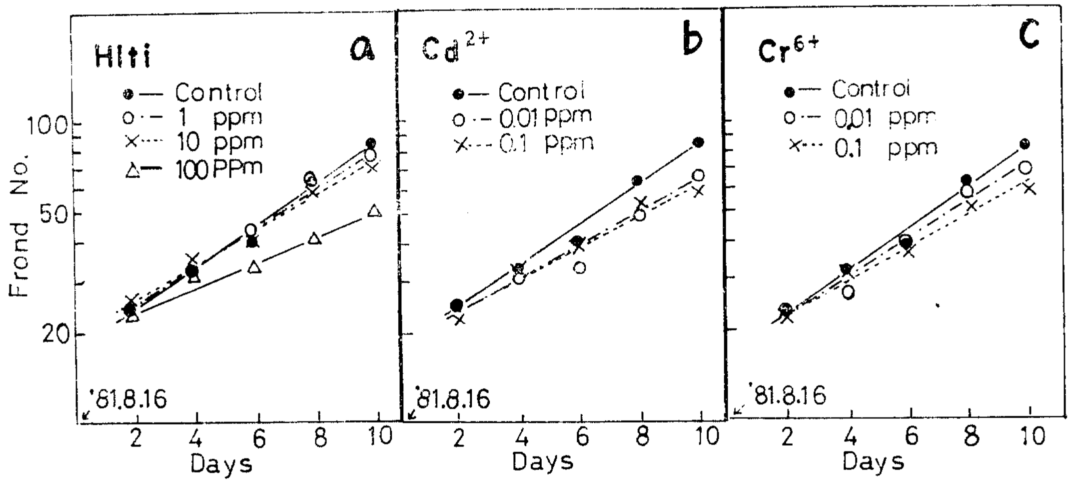


Fig. 4. Growth of duckweed population treated with environmental gradients of Hiti(a), Cd^{2+}(b) and Cr^{6+}(c). *Hiti used for this culture contained 20% of surfactants (LAS).

On the other hand, phytoplankton was rarely observed in these rivers excepting the detritus after heavy precipitation, owing to the transitory nature of stream plankton(Odum, 1971). Therefore, indices of phytoplankton species composition in flowing water were considered to be significant only when flow rate is in a stable state, excluding abrupt increase or decrease of flow rate.

4. Effects of river water quality on the growth of duckweed

Duckweed, *Spirodela polyrhiza* is known to be very sensitive to environmental change, and proliferate very rapidly in appropriate condition. As shown in Fig. 3 the number of frond in Geumho River water increased very rapidly (max. RGR = 26%/day), while that of Nakdong River water ceased by 7th day. On the other hand, the content of total chlorophyll of *S. polyrhiza* in the Nakdong River, Geumho River and Sin Stream after 11 days of culturing was 1.04, 1.88 and 1.25mg/g frond, respectively. According to these facts, it is assumed that intensive eutrophication occured by the influx of sewage from Taegu area, which enhanced the growth of duckweed but suppressed the growth of phytoplankton community.

According to Fig. 4, the concentrations of surfactants, Cd^{2+} and $Cr^{3+,6+}$ of the Geumho River (Hiti, 10; Cd^{2+}, 0.016; $Cr^{3+,6+}$, 0.007ppm) and of Sin Stream (Hiti, 18; Cr, 0.01ppm) inhibited the growth of *S. polyrhiza* but not so remarkably. Then it may be considered that such inhibition, though it was not great, was compensated by high concentration of nutritions in case of the Geumho River and the Sin Stream(Seto & Takahashi, 1979).

摘　要

大邱 지방의 중요 河川인 洛東江, 琴湖江 및 新川을 대상으로 이들間의 水質 차이와 홍수 前(8月24日)과 後(9月8日)의 水質 차이를 比較하는 한편, 各 河川水가 *Spirodela polyhiza* Shleiden의 生育에 미치는 영향을 調査하였다. 홍수 前의 화학 성분 농도는 대부분 琴湖江과 新川이 서로 유사하며(COD, 19.6~21.4; alkalinity, 177~183; NH_4^+, 20.7~24.4; NO_3^-, 39~4.3; PO_4^{3-}, 3.4~3.7; Ca^{2+}, 68.5~69.7; Mg^{2+}, 42; Cl^-, 90~92; SiO_2, 10.4~11.2; SO_4^{2-}, 11~32; LAS, 3.0~3.8; $Cr^{3+,6+}$, 0.007~0.010ppm), 洛東江에 비해 훨씬 높았다(NH_4^+, SO_4^{2-}, PO_4^{3-} 및 LAS는 30~40배 : COD, alkalinity, NO_3^-, Mg^{2+}, Cl^- 및 $Cr^{3+,6+}$은 2~5배). 특히 琴湖江은 다른 河川과는 달리 Secchi disk transparency가 극히 낮고(17cm), DO가 검출되지 않았다. Phytoplankton 群集의 general diversity index ($\overline{H}$)는 洛東江, 琴湖江 및 新川이 各各 3.1, 2.7 및 1.6으로 新川의 汚染度가 가장 높았다. 홍수기 후에는 특히 다음과 같은 成分이 증가하였다(洛東江—NH_4^+, 1.0; NO_3^-, 9.6; SiO_2, 12.8; SO_4^{2-} 5.4ppm; 琴湖江 DO, 1.0; NO_2^-, 0.92; NO_3^-, 22.2; SiO_2, 17.6ppm; 新川— DO, 3.0; NO_2^-, 1.4; NO_3^-, 22.2; SiO_2, 19.2; SO_4^{2-} 25ppm). *S. polyrhiza*의 生育은 琴湖江水에서 가장 왕성한 반면(최대 RGR, 26%/day), 洛東江水에서는 培養 7日째 生長이 중지되었고, 培養 11日째의 total chlorophyll함량은 洛東, 琴湖 및 新川水에서 各各 1.04, 1.88 및 1.25mg/g frond였다. 이들 河川水에 함유된 LAS(0.1~3.8ppm), Cd^{2+}(0~0.02ppm) 및 Cr^{6+}(0.004~0.010ppm)은 이 植物의 生育을 크게 沮害하지 않았다.

REFERENCES

APHA, AWWA, WPCR, 1976. Standard methods for the examination of water and wastewater. 14th ed.

Couillard D. and D.A. Ceuis, 1979. Generation of pollution loads within river basins. Water Research, **14** : 1621~1630.

Eloranta, p., 1976. Species diversity in the phytoplankton of some Finnish Lakes. Ann. Bot. Fennici. **13** : 42~47.

Hirose, T. and N. Kuramoto, 1981. Stream water quality as influenced by land use patterns in the Kakioka Basin. Japan. J. Environ. Qual., **10** : 184~187.

Hong, S.W., H.S. Kim and M.K. Park, 1979. On the water quality of Han River down stream. Kor. J. Lim., **12** : 19~47.

Lee, H.D., 1980. A study on the water pollution level according to the diversity of algae in Moosim Stream, Cheongjoo, Korea. Kor. J. Lim., **13** : 1~8.

Mizuno, N., 1972. Ecology of river(in Japanese). Tchikuji Publ., 94~103.

Nakanishi, M. and M. Monsi, 1976. Factors that control the species composition of fresh water phytoplankton, with special attention to nutrient concentrations. Int.

Revue Ges. Hydrobiol., **61** : 439~470.

Odum, E.P., 1971. Fundamentals of ecology. W.B. Saunders, Philadelphia, 140~161.

Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. J. Theoret. Biol., **13** : 131~144.

Rai, H. and G. Hill, 1980. Classification of central Amazon Lakes on the basis of their microbiological and physicochemical characteristics. Hydrobiol., **72** : 85~99.

Seto, M. and Y. Takahashi, 1979. Chlorotic death of *Lemna gibba* by cadmium in different concentration of nutritional minerals. Jap. J. Limnol., **40** : 61~65.

Shannon. C.E. and W. Weaver, 1963. The mathematical theory of communication. University of Illinois Press, Urbana. 117.

Simpson, E.H., 1949. Measurement of diversity. Nature, **163** : 688.

Søndergaard, M. and K. Sand-Jensen, 1979. Physico-chemical environment, phytoplankton biomass and production in oligotrophic, soft-water lake Kalgaard, Denmark. Hydrobiol., **63** : 241~253.

Song, S.D. and J.K. Koh, 1978. Limnological studies on the Sin Stream in Taegu. Kor. J. Lim., **11** : 41~47.

Welch, P.S., 1948. Limnological methods. The Blakiston Company., 231~298.

Wetzel, R., 1975. Limnology. W.B. Saunders, Philadelphia, 215~354.

Wilhm, J.L., 1967. Comparison of some diversity indices applied to population of benthic macroinvertebrates in a stream receiving organic wastes. J. Water Poll. Red. **39** : 1673~1683.

Yang, H.J., J. Chung and S.D. Song, 1981. Limnological studies of the Nakdong River in Korea. Verh. Int. Verein. Lim., **21** : 894~907.

(*Received January 18, 1982*)