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Environmental Changes of the Rivers in Taegu Area after a Heavy Rain

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大邱地方 河川의 集中降雨후의 水系環境의 變化

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ABSTRACT

The changes of environmental factors with flow rates were studied quantitatively for two rivers, the Nakdong River and the Sin stream, which have different basins in ecosystem structures, during short period after a heavy rain. In the Nakdong River, transparency, DO, alkalinity and hardness were negatively correlated with the flow rate by logarithmic function, but the concentration of SiO_2 was relatively constant regardless of the flow chage. In the Sin stream, transparency, alkalinity, hardness and the concentration of NH_3-N, NO_2-N and $SO_4^=$ showed negative correlation with the flow rate by logarithmic function. The ratios of maximum to minimum values for aquatic environmental factors during the sampling period were in the ranges of 1～7 in the Nakdong River and 1～28 in the Sin stream, but these ratios were much smaller than that for flow rate in the respective rivers (28 in the Nakdong R.; 50 in the Sin S.). Immediately after the heavy rain, the concentrations of NO_2-N, NH_3-N and PO_4-P in the Sin stream were 8, 6 and 1 times as high as those in the Nakdong River, respectively, but in the stable flow state, those became 94, 25 and more than 10 times, respectively. The load for most of the dissolved environmental constituents changed similraly to the flow rate in both rivers. It is notable that, at the stable flow state, the loads for NH_3-N (59g/sec) and NO_2-N (3.3g/sec) in the Sin stream were 4.3 and 1.3 times as high as those in the Nakdong River.

INTRODUCTION

Over the centuries, deforestration and soil eroision have consistently modified the run-off patterns, and extended drainage network through the urbanization has caused an increase of the surface ground area which is made impervious. As a result, the total volume of run-off increased, giving rise to a more pronounced flood peak, and the basin lag time was reduced so that the stream responded to precipitation input more rapidly(Whitton, 1975). The relationship between stream flow and biological-chemical changes has been discussed for a few decades. And it was suggested that total dissolved solids seemed to be inversely proportional to flow rate in many cases, however in some situations, total dissolved solids increased with flow rate possibly as a result of soluble salts being washed out of organic material (J.L. Blum, 1956; Douglas, 1972; Cleaves et al., 1972).

On the other hand, river water quality is greatly influenced by ecosystem structure of river basin. For example, a result calculated from the data of Bormann and Likens (1970) revealed that a hardwood forest ecosystem has a great ability to hold and circulate nutrients, and then controls river water quality more efficiently than flow rates (Whitton, 1975). In addition to this fact, it is notable that the concentration of NO_3-N, NO_2-N, PO_4-P, K, Mg, and Cl was correlated with the fraction in settlement area, and the concentration of NH_4-N and $SO_4^=$ was correlated with the fraction in the croplands(Hirose and Kuramoto, 1981).

In this study, an attention was given to the relationship between changes in river flow and those in aquatic enviromental factors during short period after a heavy rain, and the variations of the concentration and total load for these factors were compared between two Rivers, the Nakdong River and the Sin stream, which have different basins in ecosystem structres.

STUDY AREA AND METHODS

The Nakdong River, about 524 km long, flows through Kyungpook and Kyungnam provinces into Korean Strait, and the basin of the mid-stream is characterized by a mixture of mountain forest, crop land, settlement and industrial region. On the other hand, the Sin stream, about 20 km long, originates from Mt. Biseul and flows into the Geumho river which is a tributary of the Nakdong River, and the representative environment of this basin is Taegu city. Sampling site were selected in each river as showing in Fig. 1. Site 1 was under the Waegwan bridge on the mid-stream of the Nakdong River and site 2 was under the Kyungdae bridge on the Sin stream. Water sampling and flow rate determination were made from immediately after the heavy rain (14 and 27 Aug. 1982) to the stable flow state (11 Sept. 1982). There were two heavy precipitations, 122 and 50 mm in average of Kyungpook province from August 13 to 14 and on August 27, 1982, respectively. Water samples were taken from 50cm below the water surface, and centrifuged at 11,000 G for 20minutes if necessary for spectrophotometric analysis. Physico-chemical analysis of water was carried out with the methods described by Lyu and Song(1982), APHA(1975) and Saijo Yatsuka(1963).

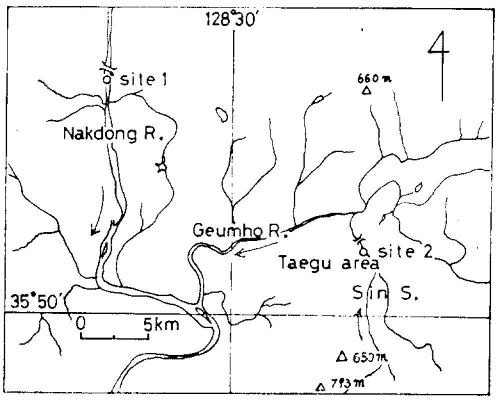


Fig. 1. Map showing positions of sampling site 1 on the Nakdong River and site 2 on the Sin stream.

RESULTS AND DISCUSSION

Changes in aquatic environmental factors

1) The Nakdong River

The change patterns of flow rate and environmental factors at site 1. the mid-stream of the Nakdong River, are shown in Fig.2-a,b,c,d. The flow rates measured immediately after the heavy rain, on August 16 and 28, 1982, were 1530 and 1700m^3/sec, and that of the stable flow state, on September 11, 1982, was 60m^3/sec, respectively. Although the Andong Dam on the upper stream controlled the flow, the ratio of maximum to minimum value was 28. Water temperature and pH varied in the ranges of 22-29°C and 7.1-8.8, respectively, showing lower values during the flood. Transparency of water, ranged between 10 and 127 cm, increased with decreasing flow rate owing to the sedimentation of

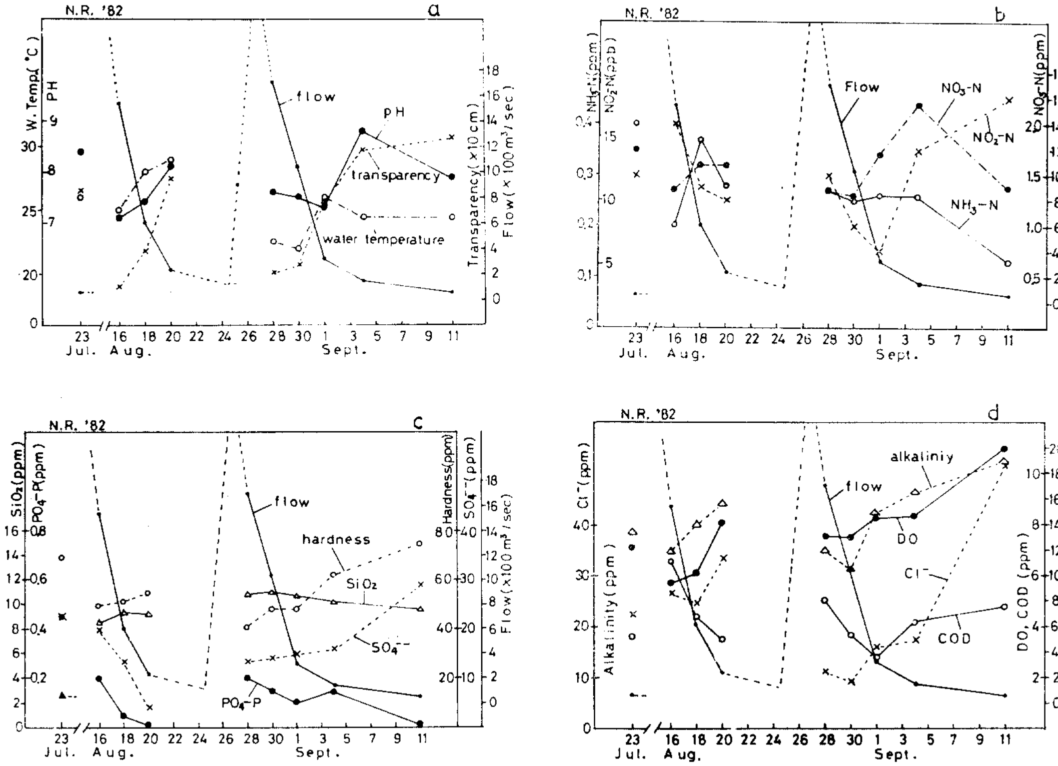


Fig. 2. Changes in environmental factors with the flow rate at site 1 on the Nakdong River.

suspended particles. The concentration of NH_3-N, ranged between 0.13 and 0.37 ppm, retained relatively higher values for a few days after the heavy rain and then decreased with flow rate. The concentration of NO_2-N, ranged between 6 and 18 ppm, decreased with flow rate during the flood but increased again as the flow became stable. The concentration of NO_3-N ranged between 1.3 and 2.2ppm, and the peak attained a week after the heavy rain. The similar result was already reported by Casey and Newton (1972), i.e. NO_3-N increased with flow and all peaks in the NO_3-N curve came a few days after the rain peaks in the South Winterbourne. In the Nakdong River, the variation of the NO_3-N concentration is probably due to leaching from basin land, and Johnson et al. (1976) suggested that NO_3-N concentration in Fall Creek is controlled by water movement through the soil profile. Hardness expressed by $CaCO_3$ concentration, ranged between 40.3 and 74.7ppm, increased gradually with decreasing flow rate. The concentration of SiO_2 showed relatively constant values rangnig between 8.5 and 11.0ppm regardless of the variation of the flow. Edward and Liss (1973) reported that SiO_2 concentration varied around 10ppm in many rivers, and according to Livingston (1963), world-wide mean value of SiO_2 concentration was 13.1 ppm. The maximum value of PO_4-P concentration during the flood was 0.2ppm, and the value became lower in the stable flow state. Golterman (1973b) calculated from Viner's (1973a) data that the ratio of SiO_2 to PO_4-P concentration was about 110 in many rivers in Uganda. This ratio is similar to that of earth crust, and strongly indicates that the PO_4-P originates from weathering of rock and can be used to estimate natural phosphate loading in contrast to that from human impact (Whitton, 1975). On the

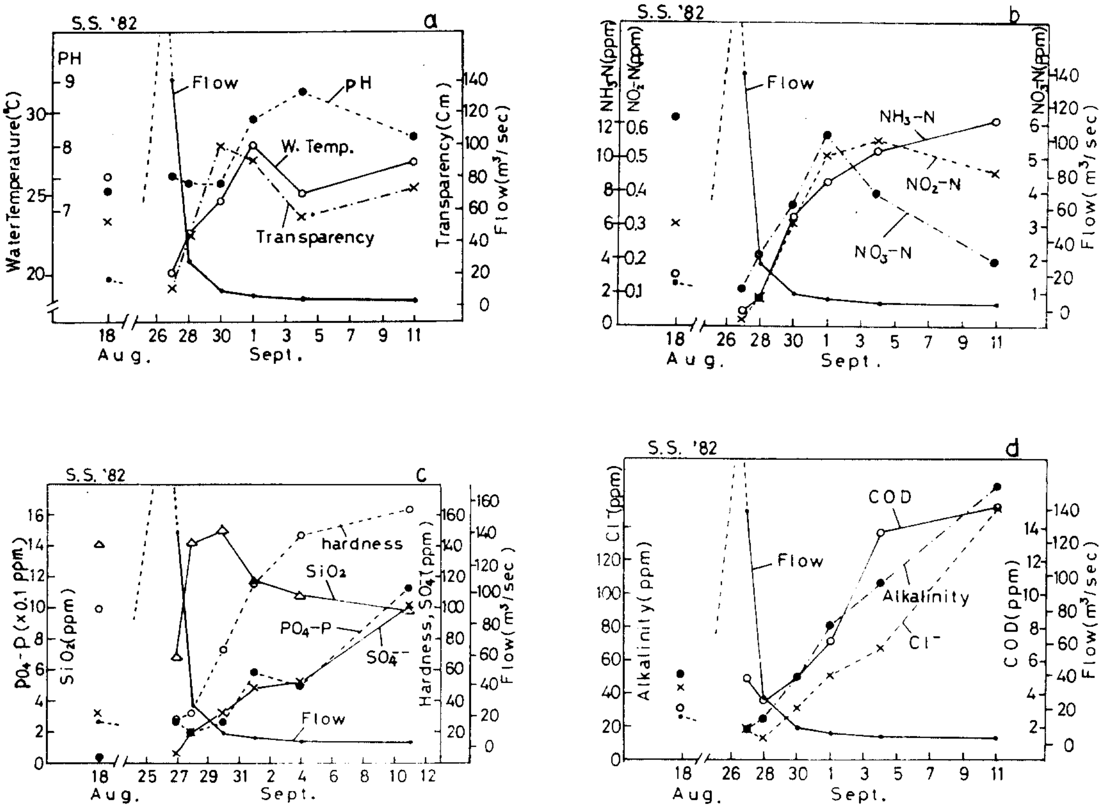
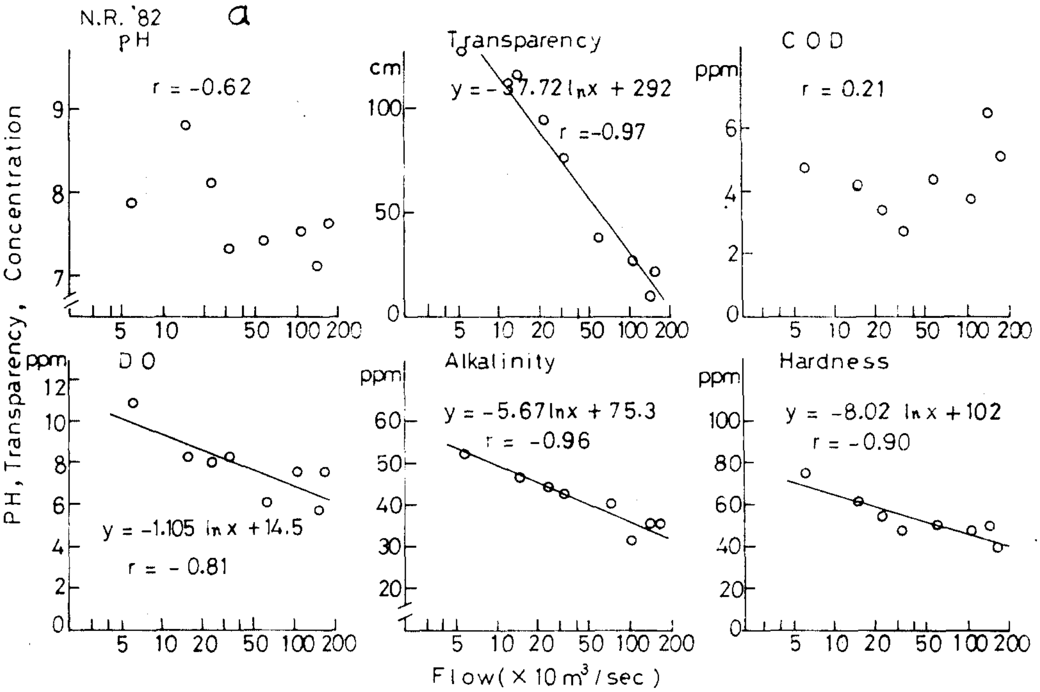


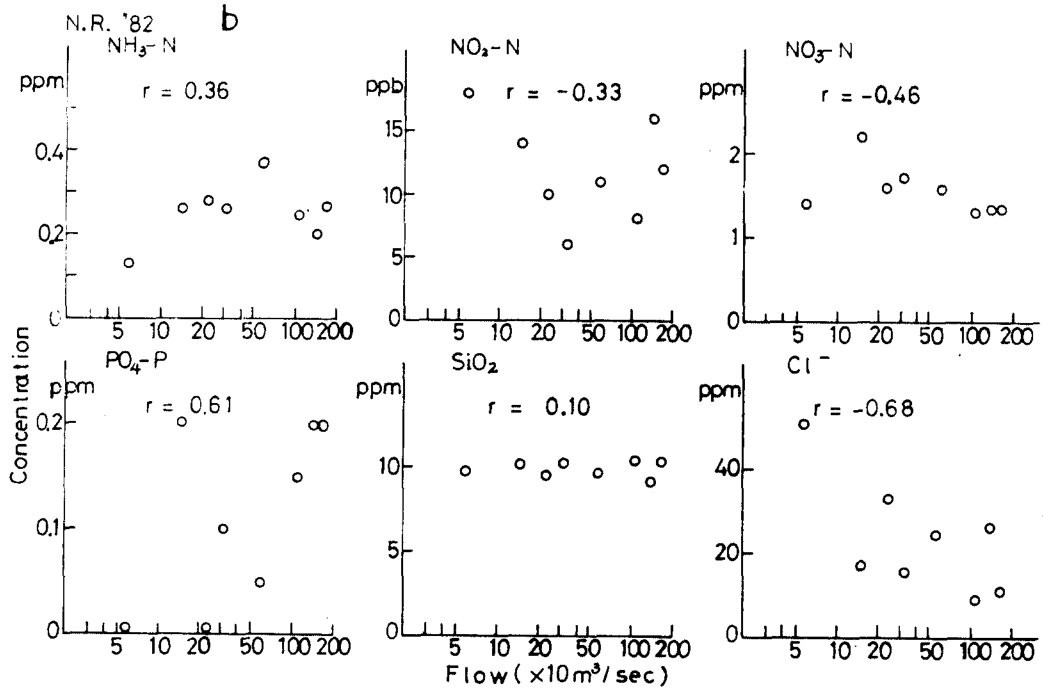
Fig. 3. Changes in environmental factors with the flow rate at site 2 on the Sin stream.

basis of this ratio, it was estimated that natural erosion contributed about 45% of the total phosphate loading during the flood in the Nakdong River, however almost all PO_4-P originated from natural ersion in completely stable flow state. The concentration of $SO_4^=$ and Cl^- increased from 4. 1 and 9. 3ppm to 29. 0 and 51. 5ppm, respectively, with decreasing flow rate. Alkalinity, the quantitative capacity to neutralize a strong acid to a designated pH, was expressed with $CaCO_3$ concentration. It increased from 31. 0 to 51. 5ppm with decreasing flow rate. This increasing tendency with decreasing flow rate is the same as the case of the R. Frome, a chalk stream in Southern England, which has an inverse relationship between flow and alkalinity (Casey and Newton, 1972). COD, ranged between 2. 8 and 6. 6 ppm, decreased with flow rate, then increased agin in the stable flow state. DO increased from 5. 7 to 11. 0ppm with decreasing flow rate. During the sampling period the ratios of maximum to minimum valus for $SO_4^=$ and Cl^- concentration were 7 and 5. 5 respectively, and that for the others was lower than 3. These values showed that variation range for chemical constituents was much smaller than that for flow rate (28 in the Nakdong River).

2) The Sin stream

The variations of environmental factors and flow rates of the Sin stream are shown in Fig.3-a,b,c,d. For two weeks after the heavy rain, the flow rate changed from 141 to 2. 8m³/sec. The ratio of maximum to minimum value for flow rate was about 50, twice as high as that of the Nakdong River. Water temperature and pH varied in the range of 20. 0~28. 0°C and 7. 3~8. 8, and the change patterns were


N.R. '82
a
pH
r = -0.62
Transparency
cm
y = -37.72 ln x + 292
r = -0.97
COD
ppm
r = 0.21
PH, Transparency, Concentration
DO
ppm
y = -1.105 ln x + 14.5
r = - 0.81
Alkalinity
ppm
y = -5.67 ln x + 75.3
r = -0.96
Hardness
ppm
y = -8.02 ln x + 102
r = -0.90
Flow (× 10 m³/sec)


N.R. '82
b
NH3-N
ppm
r = 0.36
NO2-N
ppb
r = -0.33
NO3-N
ppm
r = -0.46
Concentration
PO4-P
ppm
r = 0.61
SiO2
ppm
r = 0.10
Cl⁻
ppm
r = -0.68
Flow (×10m³/sec)

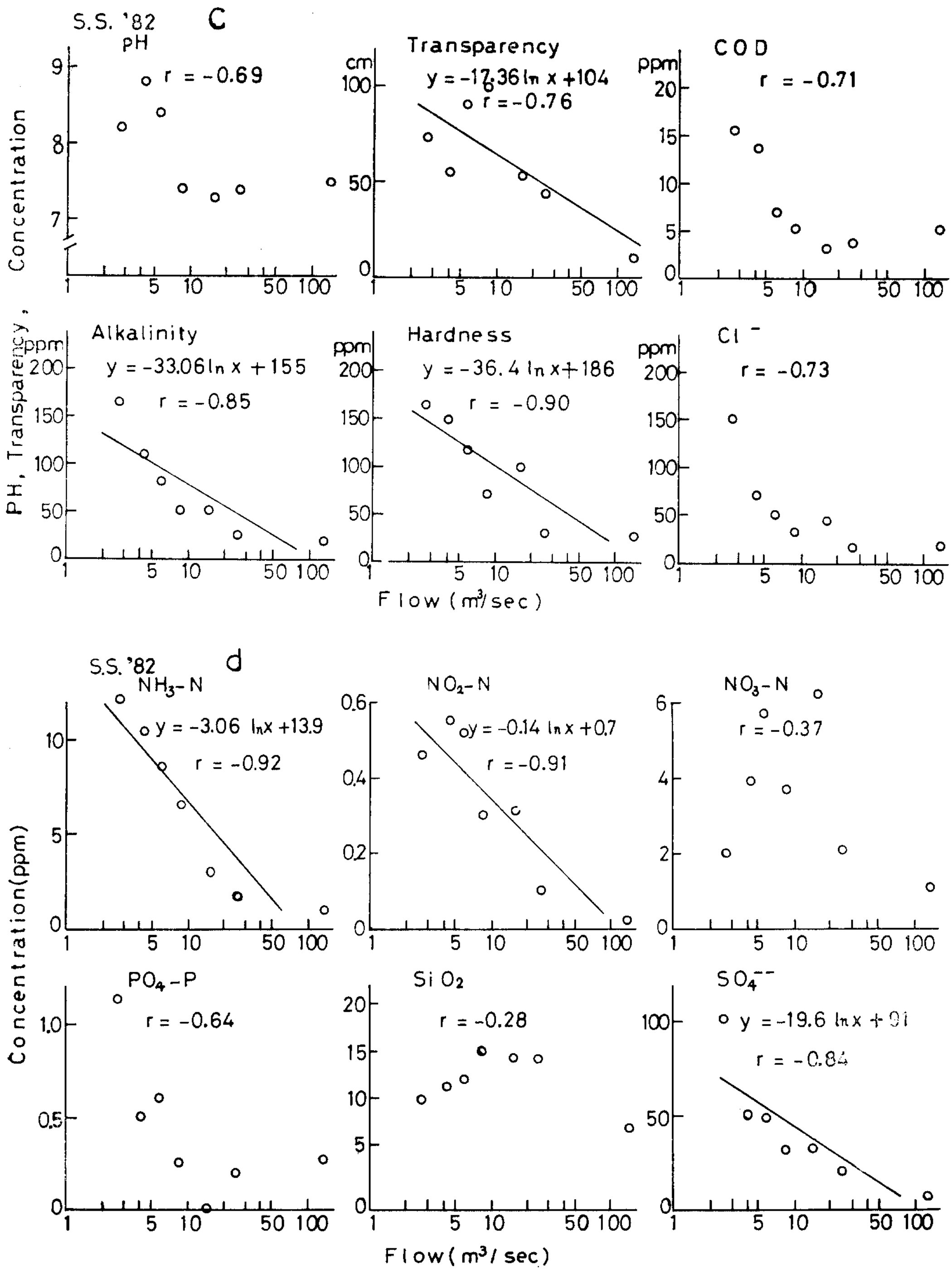


Fig. 4. Correlation of environmental factors(y) with the flow rate(x) on the Nakdong River(a,b), and on the Sin stream(c,d).

similar to those of the Nakdong River. Transparency increased from 10 to 99 cm during the flood, but decreased again in the stable flow state, which was different from that of the Nakdong River. Especially, the concentration of NH_3-N and PO_4-P, on the contrary to the Nakdong River, increased from 1.1 to 2.2 ppm and from 0.2 to 1.1 ppm respectively, with decreasing flow rate. In the stable flow state, the contribution of PO_4-P from natural erosion to total PO_4-P in this stream water was about 8%, which was calculated on the basis of the value of 110 which was the ratio of SiO_2 to PO_4-P concentration in the rivers in Uganda (Golterman, 1973b). The concentrations of NO_2-N, NO_3-N, hardness, $SO_4^{=}$, COD, alkalinity and Cl^- varied in the ranges of 0.02~0.55, 1.1~6.2, 31~164, 20~102, 3.1~15.3, 19~165 and 14~152 ppm, respectively. SiO_2 maintained the most constant concentration and ranged between 6.8 and 15.0 ppm, which was similar to that in the Nakdong River. The change pattern of these factors in the two rivers was very characteristic. By flood the concentrations of NO_2-N and NH_3-N in the Sin stream were 8 and 6 times as high as those in the Nakdong River respectively, but the other factors were not much different from theose in the Nakdong River. In the stable flow state. the concentrations of NH_3-N, NO_2-N, and PO_4-P became 94, 25 and more than 10 times as high as those of the Nakdong River, and others became 2~3 times, while the concentrations of SiO_2 and NO_3-N were similar to those in the Nakdong River.

Relationship between flow and environmental factors

During the short period after the heavy rain,

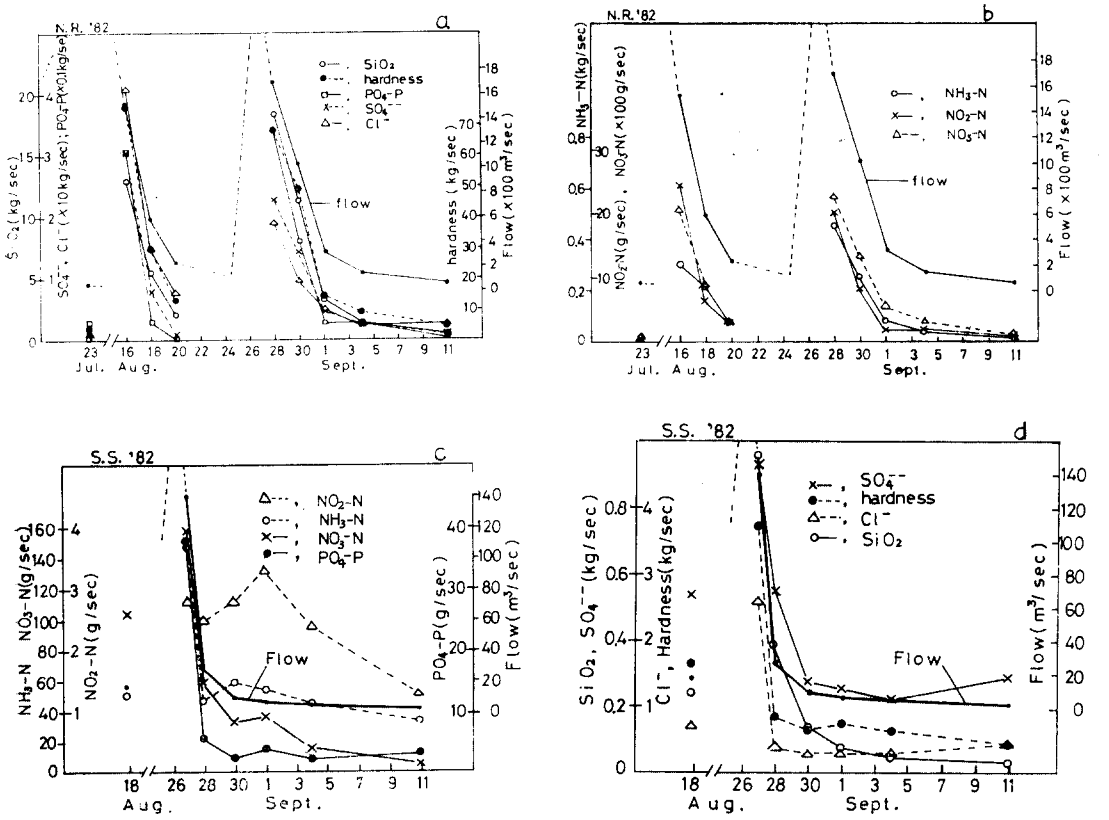


Fig. 5. Changes in loads for dissolved constituents at site 1 on the Nakdong River (a.b), and site 2 on the Sin stream (c,d).

many environmental factors (y) in the two rivers were correlated with the flow rates (x) by logarithmic functions as shown in Fig.4-a,b,c,d. The following factors showed significant correlation with the flow rate; i.e. transparency ($y=-37.721 \ln x+292$, $r^{**}=-0.97$), DO ($y=-1.105 \ln x+14.5$, $r^{*}=-0.81$), alkalinity ($y=-5.67 \ln x+75.3$, $r^{**}=-0.96$) and hardness ($y=-8.02 \ln x+102$, $r^{**}=-0.90$) in the Nakdong River, and transparency ($y=-17.36 \ln x+104$, $r^{*}=-0.76$), alkalinity ($y=-33.06 \ln x+155$, $r^{*}=-0.85$), hardness ($y=-36.4 \ln x+186$, $r^{**}=-0.90$), NH_3-N ($y=-3.06 \ln x+13.9$, $r^{**}=-0.92$), NO_2-N ($y=-0.14 \ln x+0.7$, $r^{**}=-0.91$) and $SO_4^{=}$ ($y=-19.6 \ln x+91$, $r^{*}=-0.84$) in the Sin stream. It is notable that, in both rivers, alkalinity and hardness were correlated with the flow rates negatively.

Changes in the loads

The load is usually subdivided for analytical purposes into three categories, i.e. dissolved load, suspended sediment load and bed load (Guy and Norman, 1970). In this study, only dissolved one was calculated. The change pattern of the load for most of the environmental constituents was similar to that of the flow rates in the two rivers during the period from August 28 to September 11, as shown in Fig. 5-a,b,c,d. In the Nakdong River, the loads for NH_3-N, NO_2-N, NO_3-N, PO_4-P, SiO_2, $SO_4^{=}$, Cl^- and hardness varied in the ranges of 0.008~0.459, 0.001~0.020, 0.080~2.310, 0.006~0.340, 0.6~18.4, 1.7~22.8, 2.6~19.2 and 4.5~68.5kg/sec, respectively. And in the Sin stream, they varied in the ranges of 0.034~0.059, 0.0013~0.0033, 0.006~0.059, 0.0022~0.0055, 0.027~0.389, 0.2~0.5, 0.3~0.4 and 0.5~0.8 kg/sec, respectively. On August 28, immediately after the heavy rain, the load for NH_3-N and No_2-N in the Sin stream was 10~13%; that for NO_3-N, PO_4-P, SiO_2, $SO_4^{=}$, Cl^- and hardness was 1~3% of those in the Nakdong River. However, in the stable flow state, the loads for NH_3-N and NO_2-N in the Sin stream were 430 and 130%; those for $SO_4^{=}$, Cl^- and hardness were 17, 14 and 10%; that for NO_3-N, PO_4-P and SiO_2 was 5~7% of those in the Nakdong River, respectively. This result indicates that the chemical composition of the Nakdong River is seriously influenced by the Sin strem water, and the impact of NH_3-N and NO_2-N of the Sin stream on the chemical composition of this river is most conspicuous in the stable flow state.

摘　要

流域環境이 서로 다른 洛東江中流와 그 支流인 新川을 대상으로 집중강우로 인한 범람기부터 流量안정기까지의 流量變化와 水系環境要素變化와의 관계를 조사하였다. 洛東江에서는 transparency, DO, alkalinity 및 hardness가 流量의 대수값과 負의 相關을 보였으며, SiO_2농도는 流量變化와 관계없이 일정하였다(8.5~11.0 ppm). 新川에서는 transparency, alkalinity, hardness와 NO_2-N, NH_3-N 및 $SO_4^{=}$의 농도가 流量의 대수값과 負의 相關을 보였다. 측정기간 동안 流量變化폭(낙동강, 28배 : 신천, 50배)에 비해 各 水系環境要素의 변화폭(낙동강, 1~7배 : 신천, 1~28배)은 훨씬 작았으며, 집중강우 직후의 新川의 NO_2-N, NH_3-N 및 PO_4-P의 농도가 각각 洛東江의 8, 6 및 1배였으나 流量안정기에는 94, 25 및 10배이상이 되었다. 各 溶解成分들의 負荷量은 대체로 流量감소와 더불어 감소했으며, 流量안정기에 新川의 NH_3-N (59g/sec) 및 NO_2-N (3.3g/sec)의 負荷量은 洛東江의 4.3 및 1.3배 였다.

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