ECOHYDROLOGY
ASIA – PACIFIC
REGION

Proceedings of
Asia-Pacific Workshop
on Ecohydrology,
Indonesia, 2001

SEASONAL CHANGES OF POLLUTANTS ALONG THE UPPER CITARUM RIVER

Ami A. Meutia, Y. Sudarso, Gunawan P. Yoga, T. Suryono, and S. Sunanisari
Research and Development Center for Limnology,
Indonesian Institute of Sciences,
Cibinong 16911, Indonesia

ABSTRACT

Seasonal changes in the concentration of several pollutants along the length of the upper Citarum River in West Java are reported. The upper Citarum is the most polluted area in Citarum Basin. Measurements of the water quality parameters in the upper Citarum indicate that the majority of the pollutants were high in the dry season and decrease in concentration at the beginning and peak of the rainy season. The concentrations are the lowest at the peak, however some of pollutants are still above the standard water quality criterion. During the dry season river in an anaerobic condition, the DO concentration was found to below 1 mg/l, so degradation of carbon compounds and nitrification was not occurred. Besides that the Pb and Cd were found remain high, at this time. Tendencies of water quality parameters contribution were calculated against sampling sites by means of principal component analysis (PCA). Cluster analysis was used in calculating sampling site similarities. The results of analysis using PCA have proved that although there is correlation between sampling sites and pollutants, however is still difficult to identify the source of the pollutants. In the dry season sites 4 and 6 have similarities, while in the rainy season sites 8 and 9. Environmental education for inhabitant in the Citarum catchment area is important to protect water quality.

Key words: River; seasonal changes; dry season; rainy season; water quality; statistical analysis

1. INTRODUCTION

Citarum River is one of the five biggest rivers in West Java, Indonesia. It is about 315 km long and has a catchment area of approximately 6,600 square kilometers. Since 1989, the government of Indonesia have conducted a campaign called Prokasih to clean and protect the rivers against pollution. With the Citarum several efforts have been made such as the routine monitoring of wastewater discharge from industries. Centralized wastewater treatment plants were build in the Western and Southern part of Bandung city to treat municipal and industrial wastewater respectively. Also the rehabilitation of the riverbank such as straighting the curved parts of the river and concreting some section of the riverbank. However it has been very inadequate. At the present, the water quality of the river is still very poor. Even, if we look at the data of 1982 (Badruddin, 1987), and that of 1991 (Bukit, 1995), it seems to have become worse. The problem is there is no Citarum River action plan, that include several institutions concerning the river, to clean up the pollution and protect the Citarum water. Depending on the Prokasih alone, is not enough, because it is a big programme which includes another 24 big rivers in Indonesia. After 10 years programme obvious there has been no improvement in the quality of Citarum River water. The most polluted catchment area along the river is the upper Citarum which has nearly four million people living, working , and playing in this area. In 1991, Bukit (1995) found that municipal pollution was major contributor, rather than industrial discharge, and the contaminant loading was higher during the dry season. Based on mapping of distribution of industries, Harsono (1995) showed that in 1994 the majority of pollutant in the upper Citarum has come from the industries, especially textile industries. The concentration of pollutants are different during the dry and rainy season because they are diluted by rain. The rainfall intensity is different in each season, in the dry season about 60-90 mm/month and in the rainy season more than 200 mm/month. Below the upper Citarum Basin there are three big dams used for irrigation, agriculture, fisheries, bathing and washing for inhabitant around the dams, and hydroelectric power and public water supply (drinking water) for the capital city of Indonesia, Jakarta. Therefore, to maintain water quality in this catchment area is a major priority.

From monitoring results, beside of high concentrations of several pollutants such as biological oxygen demand (BOD) or ammonium, there are slightly concentrations of heavy metals. Most of the BOD came from domestic wastewater and ammonium came from agricultural waste, but other pollutant sources are difficult to identify because the varied activities along the upper Citarum catchment area. By characterizing pollutants in a certain section of the river, we can examine correlation between pollutant and the catchment for identify the source of the pollutant. These results could contribute to protect the river from the pollution.

The aims of this study are to investigate and compare seasonal changes of some pollutants in the upper Citarum River and to examine relationship between identify pollutants with the river sections using a statistical analysis.

2. MATERIAL AND METHODS

2.1 Description of sampling sites

Field surveys were performed at the end of the dry season in August 1995, at the beginning of the rainy season in November 1995, and at the peak of the rainy season in January 1996. Measurements were conducted in eleven sampling sites along the length of the upper Citarum (Figure 1). Sampling site number 1 in the Majalaya area is free from industrial pollution, but effected by erosion. Sampling sites 2 and 3 are rural areas which are dominated by small scale industries. Sampling sites 4 to 8 are urban area with dense of population and polluted by municipal and industrial waste discharge from hundreds of medium and large textile industries. Sampling sites 9 and 10 are rural areas which is dominated by agricultural waste and discharge of domestic wastewater. Sampling site 11 is near the inlet of Saguling reservoir and is dominated by agricultural area and effected by erosion.

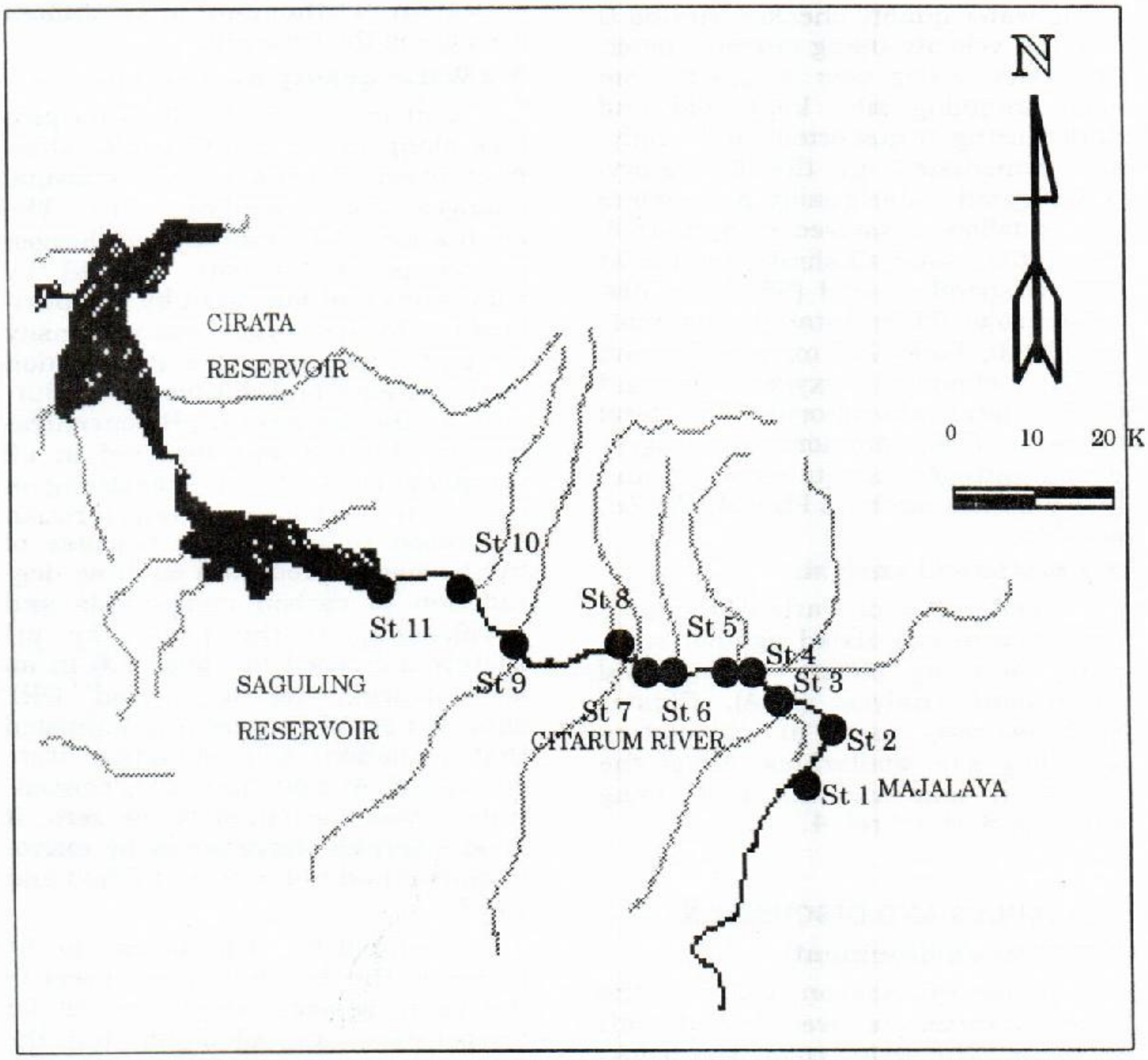

Figure1. Location of sampling sites along the upper Citarum.

2.2 Sampling and analytical methods

The water quality investigation in fields surveys where physical and chemical parameters are analyzed by means of the standard method (1993). On each visit, the following measurements were made directly at each site: pH, water temperature, oxidation reduction potential (ORP), and electrical conductivity were measured using water quality checker (Horiba U 10) and velocity using current meter. The river water was sampled from each sampling site, kept cold and dark during transported, and analyses immediately in the laboratory. Investigated water quality parameters are as follow: dissolved oxygen (DO), CO_2, HCO_3, total alkalinity, total solid (TS), suspended solid (SS), total dissolved solid (TDS), total organic matter (TOM), biological oxygen demand (BOD), chemical oxygen demand (COD), total phosphorus (TP), total nitrogen (TN), ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen, and heavy metals such as Pb, Cd, Cr, Zn, and Mn.

2.3 Statistical analysis

Tendencies of variables contribution were calculated against sampling sites by means of principal component analysis (PCA). Cluster analysis was used in calculating sampling site similarities. All of the statistical analysis was run using software Stat-itcf rel. 4.

3. RESULTS AND DISCUSSION

3.1 River environment

In the dry season, water in the upper Citarum is over loaded with pollution. The water color was black, smelt bad, and it was in an anaerobic condition. A lot of rubbish was floating in the river water and deposited on the riverbank. Wastewater from urban, rural, and industrial areas was still flowing directly into the river without treatment. In the rainy season, the water in the several parts of the river was still black and brown in color. For maintaining the river, we suggest to carry out an environment education to inhabitant in catchment area along the Citarum.

3.2 Water quality parameters

Concentration of pollutants profiles along the upper Citarum, show fluctuation depending on seasonal changes and sampling sites. The fluctuation is caused by discharged pollutants at the site, diluted by tributaries and improved by self purification. In the rainy season intensity of rainfall promotes the degradation in the stream and dilutes the pollutants. In the dry season pH concentration of about 8 was detected in all sampling sites. At the beginning of the rainy season pH concentration decreased to about 7.3, because of the biological processes such as degradation of carbon compounds and nitrification. At the peak, the pH slightly increased to about 7.6 in all sites. During the dry period, ORP showed negative values and indicated that oxidation and reduction were decreased. At that time, CO_2 concentration was measured to be zero, it means aerobic degradation by microorganism had not occurred (Thomann, 1987).

Conductivity was found to be higher in the dry season and lower in the rainy season. The same as for temperature and alkalinity, but the fluctuation pattern is different.

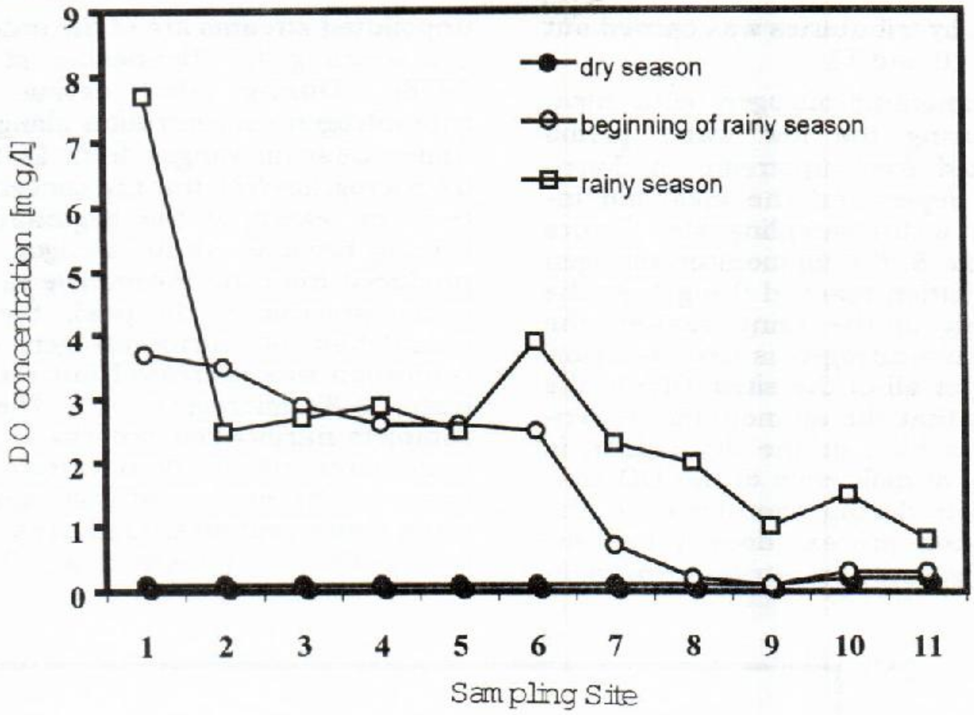

Figure 2 Dissolved oxygen concentration along the upper Citarum river.

In the dry season COD and BOD concentrations decreased from upstream to downstream. COD concentration in all sampling sites were found to be 115 to 229 mg/l (Figure 2) and BOD concentration from about 50 to 185 mg/l. The high carbon organic content indicated by COD and BOD have generated a DO concentration during this period is below 1 mg/l in all sites (Figure 3). The high carbon organic loading caused by municipal and industrial wastewater discharge which was still flowing directly into the river. At the beginning and peak of raining, the DO concentration increased but still was below 4 mg/l until site 6, from site 7 the concentration back to below 1 mg/l. At site 1 highest DO concentration was reached. Increase DO promotes biological process of carbon degradation, thus the COD and BOD concentration decrease to about 32 to 85 mg/l and 3.5 to 31 mg/l, respectively. The COD and BOD concentration was found in this study is to be higher than previous years. Between years 1979-1982 maximum COD and BOD concentration was 21 mg/l and 32.5 mg/l, respectively (Badruddin, 1987). In year 1991, maximum BOD concentration was reported to be 162 mg/l around the city of Bandung (Bukit, 1995). It indicated that the upper Citarum River water had not yet improved. Both the COD and BOD was decreased near the inlet of Saguling dam in a high water flow period, because of self purification and dilution by tributaries was carried out at sites 10 and 11.

Ammonium-nitrogen concentration during the low water period fluctuated from upstream to downstream depend on the area and inhabitant at the sampling sites (Figure 4). In site 8, the ammonium-nitrogen concentration reached 9 mg/l. At the beginning of the rainy season, the ammonium-nitrogen is usually below 2 mg/l for all of the sites. One of the reasons that the ammonium concentration is high in the dry season is because of deficiency of the DO concentration during that time, so the nitrification process does not occur. Typical values for nitrite-nitrogen in unpolluted streams are of the order of 1-3 micro g-N/l (Bennekom *et al.*, 1978). During the drying nitrite-nitrogen concentration along the upper Citarum ranges from 26.5 to 52 microgram N/l, but the concentrations increased at the beginning of raining because nitrite-nitrogen was produced from the incomplete nitrification process. At the peak, the accumulation of nitrite-nitrogen concentration was decreased but remain high (53-82 microgram N/l). The incomplete nitrification process is generate more nitrite than nitrate because of the present of high ammonium concentration's, high pH's, and low DO's (Anthonisen *et al.*, 1976;

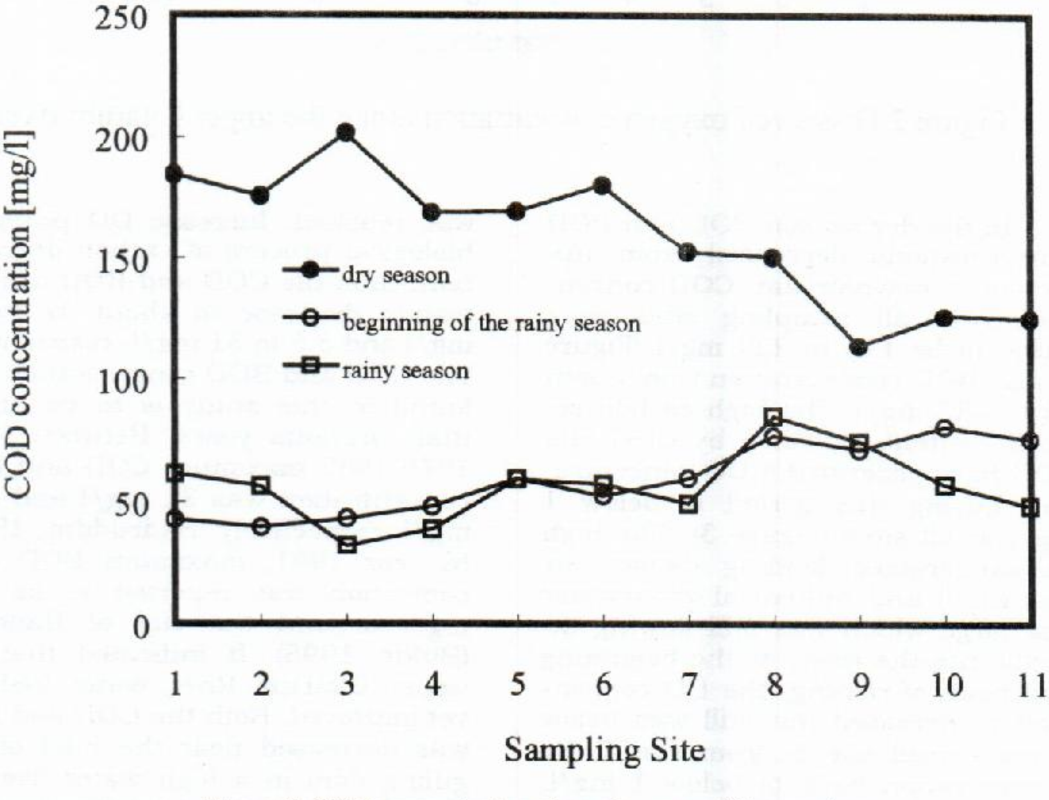

Figure 3 COD concentration along the upper Citarum river.

Balmelle *et al.*, 1992). Total phosphorous concentration were determined to be below 0.27 mg/l in the dry season. This indicates that industrial and municipal wastewater does not increase the TP concentration. At the dry and the peak of rainy season, TP flustuated between site 1 and 11. Maximum of 1.46 mg/l TP was detected in the wet season caused by erosion and agricultural waste.

In the dry season, SS concentrations were found to be ranging from 9-52 mg/l. The highest SS concentration is near the inlet of Saguling reservoir. Because of erosion, at the beginning of the rainy season it was found that generate more nitrite than nitrate because of the present of high ammonium concentration's, high pH's, and low DO's (Anthonisen *et al.*, 1976; Balmelle *et al.*, 1992). Total phosphorus concentrations were determined to be below 0.27 mg/l in the dry season. This indicates that industrial and municipal wastewater does not increase the TP concentration. At the dry and the peak of the rainy season TP fluctuated between site 1 and 11. Maximum of 1.46 mg/l TP was detected in the wet season caused by erosion and agricultural waste.

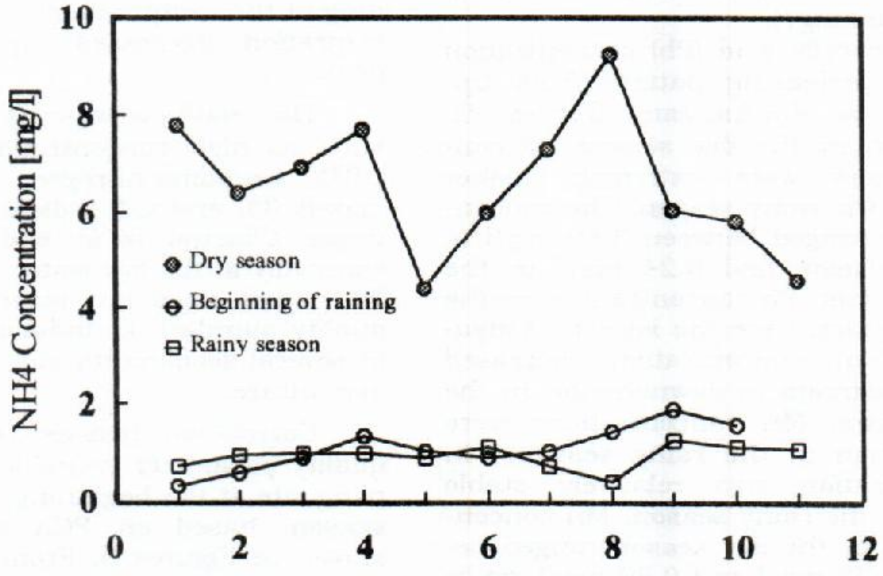

Figure 4 NH4-N concentration along the upper Citarum river.

SS concentration increased up to 292 mg/l (site 2). The concentrations were lower than was reported previously (400-450 mg/l) in 1982 (Badruddin, 1987), because concrete was used in some section of the riverbank to protect it from erosion and run-off. TDS concentration was found to be about 1000 mg/l during the dry season for all of the sampling sites, except site 11 which was 600 mg/l. The TDS was diluted by rain so in the rainy season for all of the sites the concentration decreased to 200 mg/l. In the dry season total organic matter was detected from 300 to 700 mg/l and at the beginning of the rainy season TOM concentration increased up to 750 mg/l for all the sites. At the peak of the rainy season the TOM decreased to below 360 mg/l.

Generally lead (Pb) concentration had a decreasing pattern from upstream to downstream (Figure 5). However, in the dry season Pb concentrations were extremely higher than in the rainy season. The concentrations ranged between 3.89 mg/l in the upstream and 0.24 mg/l in the downstream. Pb concentrations in the rainy season were the lowest. Manganese (Mn) concentration increased from upstream to downstream. In the dry season Mn concentrations were lower than in the rainy season. Mn concentration was relatively stable through the rainy season. Mn concentrations in the dry season ranged between 0.22 mg/l and 0.39 mg/l, while in the rainy season it ranged between 0.36 mg/l and 1.109 mg/l. It ranged from 0.04 to 0.10 mg/l. The pattern of Zinc (Zn) concentration from upstream to downstream was fluctuating between the dry season and the rainy season. Zn concentration decreased from site 1 to 4, then increased to site 9 and finally decreased again at site 11. Zn concentrations in the dry season was lower than in the rainy season. At the beginning of the rainy season, the concentration increased and it remained through the rainy season. Zn concentration in the wet season ranged between 0.044 mg/l and 0.226 mg/l. Cadmium (Cd) concentration was relatively constant from site 1 to site 9, and then increased at sites 10 and 11. Cd concentration in the dry season was slightly higher than in the rainy season. Chromium (Cr) concentration was slightly increased from upstream to downstream. Cr concentrations in the dry season ranged from 0.024 to 0.076 mg/l. Cr concentration increased at the beginning of the rainy season, but the concentration decreased again at the peak.

The results of water quality above such as high concentration of BOD, COD, ammonia-nitrogen, and heavy metals (Pb and Cd) indicated that the upper Citarum is in bad condition, especially in the low water flow period. The water does not meet the water quality standard in Indonesia. Except in several sections its still suitable for agriculture.

Correlation between each water quality parameter (variable) and sampling site at the beginning of the rainy season, based on PCA analysis, is shown in Figures 6. From the length the variable arrow in this figure, the greater its influence at the site. Thus, sites near to or beyond the tip of an arrow will be strongly positive correlated with and influenced by the variable represented by that arrow. The site at the opposite end will be less strongly affected. Sites 1 and 3 show the tendency of greater contributions of Cd and conductivity, which have a posi- tive correlation with Cd and a negative correlation with conductivity. Site 2 is characterized by positive correlation with DO and negative correlation with Mn and TDS. Sites 4, 5, and 6, in opposite to site 7, are determined by positive correlation of variable pH and alkalinity, and have negative correlation with Zn. Site 8 is strongly affected by variable conductivity and nitrite which have positive correlation, while with DO and Cd have less affected. Site 9 and 11 are characterized by variables TDS and Mn in positive correlation and DO in negative correlation. At site 10, positive correlation of HCO_3, pH and alkalinity have significantly contribution and Cd has negative correlation. In all season, DO, TDS, Mn, conductivity, and alkalinity have a greater contribution. Site 9 is characterized in positive correlation by Mn, in all season.

In the dry season, sampling sites 1, 4, 5, and 6 were characterized by variable Pb and conductivity. A positive correlation of variables alkalinity and conductivity were characterized at site 2. Besides that a negative correlation with DO was appeared. At site 3 temperature, Pb, DO, and Cd appeared to have greater influence. Temperature and Pb have positive correlation, while DO and Cd show negative correlation. The opposite condition of site 3 is occur at sites 10 and 11. Sites 7, 8, and 9 tend to be characterize by variable TOM and Mn which have positive correlation and negative correlation of alkalinity.

The results of analysis using PCA have proved that although there is correlation between sampling sites and pollutants, however is still difficult to identify the source of the pollutants.

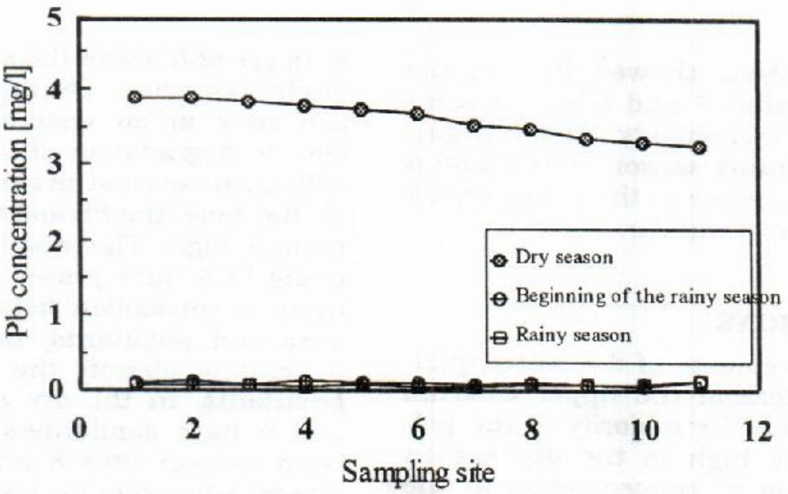

Figure 5 Pb concentration along the upper Citarum river.

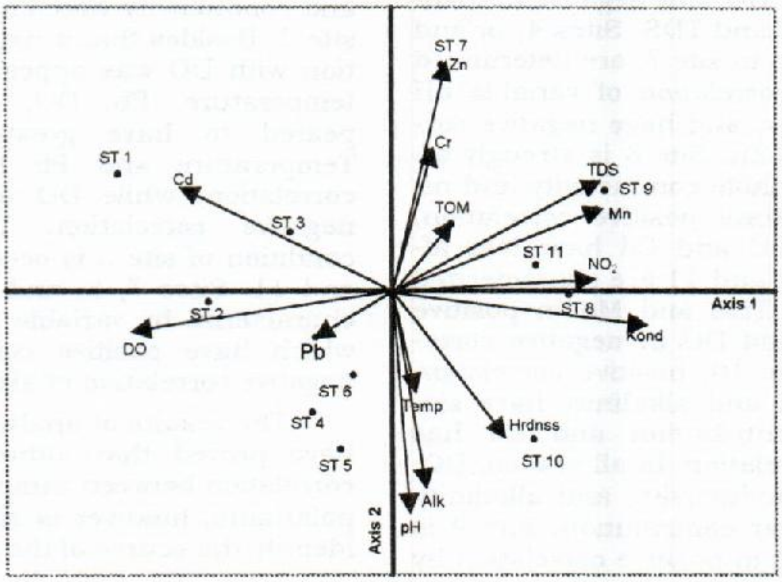

Fig. 6. Result of PCA analysis.

Cluster analysis showed that in the dry season sites 4 and 6 have a similarities in water quality. At the beginning of the rainy season sites 5 and 6 were similar, while at the peak, sites 8 and 9 were very similar.

4. CONLUSIONS

Measurements of the water quality parameters in the upper Citarum indicates that the majority of the pollutants were high in the dry season and decrease in concentration at the beginning and peak of the rainy season. The concentrations are the lowest at the peak, however some of pollutants are still above the standard water quality criterion. During the dry season river in an anaerobic condition, lead to degradation of carbon and nitrification was not occurred. Moreover at that time, the Pb and Cd were found remain high. The results of analysis using PCA have proved that although there is correlation between sampling sites and pollutants, however is still difficult to identify the source of the pollutants. In the dry season sites 4 and 6 have similarities, while in the rainy season sites 8 and 9. Environmental education for inhabitant in the Citarum catchment area is important to protect water quality.

Acknowlegement

This project was supported by Indonesian Institute of Sciences Environmental Protection Technology Grant. The authors would like to thank Siti Aisyah for assistance with the chemical analysis and Chyntia Henny, Eko Harsono, and Endang Mulyana for helping at field survey.

REFERENCES

Anthonisen A. C., Loehr R. C., Prakasam T. B. S. and Srinarh E. G., 1976, Inhibition of nitrification by ammonia and nitrous acid, *J. Wat. Pollut. Control Fed.*, 48 (5), 835-852.

Badruddin M., 1987, The correlation of biotic and abiotic indicators of polluted water in Citarum and Jatiluhur Reservoir, *JLP*, 2 (6), 77-85.

Balmelle B., Nguyen K. M., Capdeville B., Cornier J. C. and Deguin A., 1992, Study of factors controlling nitrite build-up in biological process for water nitrification, *Water Sci. Tech.*, 26 (5- 6), 1017-1025.

Van Bennekom A. J., Berger G. W., Helder W. and De Vries R. T., 1978, Nutrient distribution in the Zaire estuary and River Plume, *Neth. J. Sea Res.*, 12, 296-323.

Bukit N. T., 1995, Water quality conservation for the Citarum River in West Java, *Wat. Sci. Tech.*, 31 (9), 1-10.

Harsono E., 1995, *Identifikasi Pencemaran dan Pemetaan Penyebaran Industri Petensial pencemar Material Organik Karbon di Sungai Citarum Hulu,* Laporan teknik 1995/1996, Puslitbang Limnologi-LIPI, Indonesia.

Thomann R. V., 1987, *Principles of Surface Water Quality Modeling and Control.* Harper & Row, Inc.

Standard Methods for the Examination of Water and Wastewater, 1993, 18th edn, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC, USA.