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The Concentration of Heavy Metals Pb, Cr, and Hg in Body of Water and Sediment, and their relationship with Plankton, Benthos, and Fish Diversity in the Ciliwung River

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Abstract

The objective of this research was to know the concentration of Pb, Cr, and Hg in the body of water and sediment, and their influence on Plankton, Benthos, and Fish diversity in The Ciliwung River. In the downstream of Ciliwung River, there were only Hg and Pb were detected in the water, while in the upstream of Ciliwung River, there were no heavy metals detected. In the rainy season, Hg and Pb were not detected in the body of water. The whole of heavy metals observed was found in the sediment of the Ciliwung River. The concentration of Pb, Cr, and Hg in sediment were significantly different at the location ($P<0.05$), while according to the replication only Hg was significantly different ($P<0.05$). The relationship between Hg concentration in River sediment with Hg concentration in water was very significant ($P<0.01$). The correlation test on the relationship between Hg concentration in water with Plankton and Fish diversity was not significant ($P>0.05$), while with Benthos Diversity, it was very significant ($P<0.01$). The correlation test on the relationship between heavy metals concentration in River sediment with Plankton, Benthos, and Fish Diversity showed that the relationship which found significant ($P<0.05$) was only between Hg concentration in sediment with Benthos Diversity, and the relationship which very significant ($P<0.01$) was only between Pb concentration in sediment with Benthos Diversity.

Keywords: Benthos, Ciliwung River, Fish Biodiversity, Heavy metals, Plankton

INTRODUCTION

The heavy metals of Lead (Pb), Chrom (Cr), and Mercury (Hg) are widely substances used in the industrial sectors including textile, manufacturing, printing, pharmacy, pesticide, painting, heavy equipment, and leathering. These industrial activities potentially contributed to the heavy metals pollution have been found located around of Ciliwung River. Generally, the wastewater coming from that industrial activities discharge to stream without treatment causing seriously River Pollution. The discharge of that industrial wastewater continuously causes the accumulation of heavy metals in the sediment and aquatic organisms such as Plankton, Benthos, and Fish. The research on Pb, Cr, and Hg concentration in the body of water and sediment and their influence on the aquatic organism are relatively rare. Due to their accumulation effects in the water environment, at the little concentration in water, there will be accumulative and increasing their concentration in the sediment and making significant effect to the Plankton, Benthos, and Fish Diversity.

The aim of this research is:

1. To know the concentration of Pb, Cr, and Hg in water and sediment at Ciliwung River;
2. To know the relationship between Pb, Cr, and Hg concentration in water and sediment with Plankton, Benthos, and Fish Diversity.

Hypothesis:

1. Concentrations of Heavy Metals Pb, Cr, and Hg in water and sediment significantly differ between sampling locations;
2. Concentrations of Heavy Metals Pb, Cr, and Hg in water and sediment significantly differ between observation time;
3. There is a significant correlation between the concentration of heavy metals Pb, Cr, and Hg in the sediment with the concentration of Pb, Cr, and Hg in the water;
4. There is a significant correlation between the concentration of heavy metals Pb, Cr, and Hg in the water and sediment with Plankton, Benthos, and Fish Diversity.

METHOD

1. Sampling Location

Research has been carried out at 11 sampling locations from upstream to estuary divided into 4 River segments (Table 1 and Picture 1).

Table 1. Location for sampling water, sediment, Plankton, Benthos, and Fish at Ciliwung River

Station	Segment	Location	Consideration
1	1 (Upstream)	Gadog-Bogor District	Control Area
2	1 (Upstream)	Warung Jambu-Bogor City	Industrial Area
3	1 (Upstream)	Panus Bridge, Depok City	Border Area between Bogor and Jakarta
4	2 (Middlestream)	Kelapa Dua, Bogor Highway	Monitoring Station of DKI Jakarta Government
5	2 (Middlestream)	Intake PAM-Condet	Monitoring Station of DKI Jakarta Government
6	2 (Middlestream)	MT Haryono Street	Monitoring Station of DKI Jakarta Government
7	3 (Middlestream)	Manggarai Floodgate	Monitoring Station of DKI Jakarta Government
8	3 (Middlestream)	Halimun Street	Monitoring Station of DKI Jakarta Government
9	3 (Middlestream)	KH Mas Mansyur Street	Monitoring Station of DKI Jakarta Government
10	4 (Estuary)	Teluk Gong Street	Monitoring Station of DKI

11	4 (Estuary)	Muara Angke	Jakarta Government Monitoring Station of DKI Jakarta Government

Sampling to represent the rainy season was carried out in December, January, February, while sampling to represent the dry season was carried out in May, June, and July.

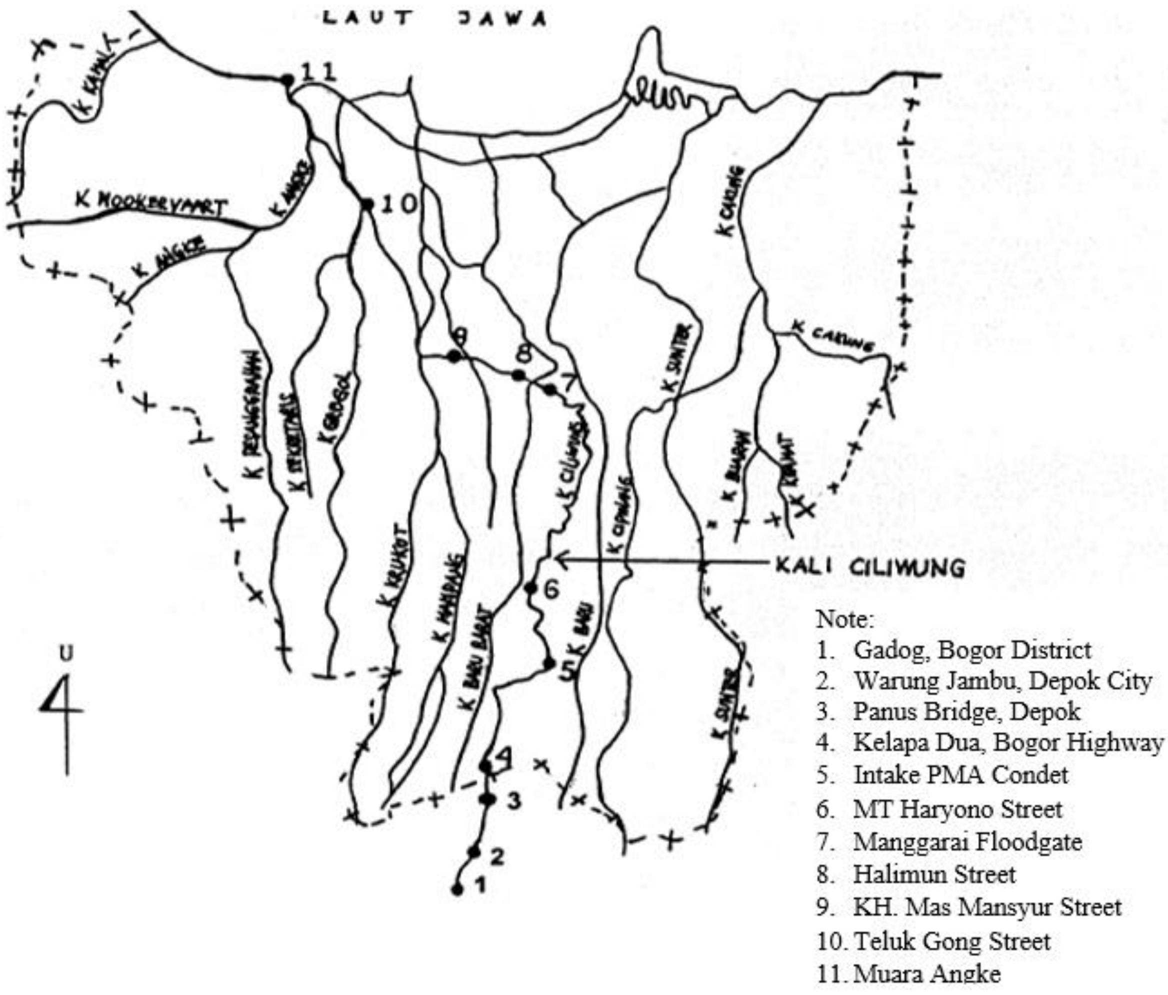

Figure 1. Sampling location at Ciliwung River

2. Research Materials

The materials used in this research include samples of water, sediment, Plankton, Benthos, and Fish from 11 sampling locations, distilled water, formalin 4 %, glacial acetic acid, methyl alcohol 70 %, plastic bags, labels, reagent for water, and heavy metal analysis such as concentrated H_2SO_4, concentrated HNO_3, $KMnO_4$, $NH_2OH.Cl$, $Kr_2Cr_2O_7$, $SnCl_2$, and filter paper.

3. Research Tools

The equipment used in this research included: Plankton net number 25, Fishing net with a diameter of 2.9 m and a net mesh of 1.5 cm, Ekman Grab 20 X 20 cm, a stratified sieve (0.5 mm in diameter), a magnifying glass, cooler box, separator funnel, vacuum pump, erlenmeyer, pipette, funnel, stereoscope type binocular microscope, oven, cooler, Van dorn bottle.

Method of Collecting Data :

(1) Water sampling

Ciliwung River water was taken using a Van dorn bottle to take water samples at the surface, middle, and bottom area. The composite water sample was collected in a white jerry can for analysis in the laboratory. To maintain the stability of heavy metals in water samples, fixation with HNO_3 was carried out.

(2) Sediment sampling

Sediment sampling was carried out at the same location as the water sampling using Ekman Grab. The sediment taken was put into a plastic bag for analysis in the laboratory.

(3) Fish sampling

The fish sample was collected using a Fishing net. Samples of fish that are still alive were brought to the laboratory for identification.

(4) Plankton sampling

At each sampling location, Plankton samples were taken with a Plankton net three times, on the left, middle, and right of the River. Samples of Plankton were filtered from 100 liters of River water, then put into a roll film and given ice to keep them alive. The Plankton samples were then identified using the books of Plankton determination by Mizuno (1990), Pentecost (1984), Prescott (1980), and Sournia (1978).

(5) Benthos sampling

At each sampling location, Benthos samples were taken with Ekman Grab 3 times on the left, middle, and right of the River. The Benthos samples were put into a plastic bag and added 4 % formalin solution + glacial acetic acid + 70 % methyl alcohol with a ratio of 2:2:1 as a preservative, then the Benthos samples were sorted using stratified filtration. The Benthos samples obtained were then identified using a binocular microscope. Identification was carried out using the Benthos determination books written by Melanby (1988) and Usinger (1971).

A Sampling of water, sediment, Plankton, Benthos, and Fish were carried out every two weeks for six months (two seasons) to know whether there is an effect of season on the level of River pollution. Identification of Plankton, Benthos, and Fish was carried out in the laboratory of the Faculty of Biology Universitas Nasional, Jakarta, while the analysis of water and sediment was carried out in the Environmental Laboratory of DKI Jakarta Government.

(6)Laboratory analysis

Analysis of heavy metal concentration in water and sediment refers to APHA, AWWA, and WPCP (1992) in the 18th edition of the Standard Method For the Examination of Water and Wastewater.

(7)Statistic analysis

To determine whether there are differences in the concentration of Heavy Metals Pb, Cr, and Hg in water and sediment at various locations and sampling times, a Randomized Block Design was used through a two-way ANOVA Test (Steel and Torrie, 1985).

(8)Diversity of Plankton, Benthos, and Fish

The species diversity of Plankton, Benthos, and Fish at each sampling location was calculated using the Shannon-Wiener species diversity index formula (Magurran, 1988) as follows:

$$H' = -\sum Pi \ln Pi$$

Note :
H' = Species diversity index
Pi = ni/N
ni = Number of individuals in species i
N = The number of individuals of all species

According to Krebs (1985), the criteria used to determine the value of species diversity index (H'), as follows:
$H' \leq 1$ = low diversity
$1 < H' < 3$ = moderate diversity
$H' > 3$ = high diversity

(9)The relationship between the concentration of heavy metals in water and sediment with the species diversity of Plankton, Benthos, and Fish

Determination of the relationship between the concentration of heavy metals in water and sediment with the species diversity of Plankton, Benthos, and Fish, firstly the relationship between variables were analyzed for significance with linear, logarithmic, quadratic, and cubic models. After that, the regression equation was determined for the models that give significant results and the highest level of correlation. Data analysis using SPSS release 7.5.1 program.

RESULT

1. Heavy Metal Concentration In Water

The results of the research on the concentration of Pb, Cr, and Hg in the waters of the Ciliwung River can be seen in Table 2.

Table 2. The average concentration of Pb, Cr, and Hg (ppm) in the waters of the Ciliwung River according to sampling locations

Heavy Metals	Sampling Locations										
	St. 1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11
Pb	Nd	nd	nd	nd	Nd	0.0003	nd	nd	nd	nd	nd
Cr	Nd	nd	nd	nd	Nd	nd	nd	Nd	nd	nd	nd
Hg	Nd	nd	nd	0.0006	0.0006	0.0017	0.0012	0.0005	0.0010	0.0015	0.0013

Note: St.1 = Gadog-Bogor District
St.2 = Warung jambu, Bogor City
St.3 = Panus bridge, Depok City
St.4 = Kelapa Dua, Bogor Street
St.5 = Intake PAM Condet
St.6 = MT Haryono Street
St.7 = Manggarai floodgate
St.8 = Halimun Street
St.9 = KH Mas Mansyur Street
St.10 = Teluk Gong Street
St. 11 = Muara Angke
nd = not detected

The results of the variance test (ANOVA) show that the concentrations of Hg and Pb in Ciliwung River water were significantly different between sampling locations ($P<0.05$). This shows the influence of the sampling location on the presence of Hg and Pb metals in Ciliwung River water. Pb was only detected at station 6 (MT Haryono Street, Cawang), while Hg was detected in water starting from station 4 (Kelapa Dua, Bogor Street) to station 11 (Muara Angke) as shown in Figure 2.

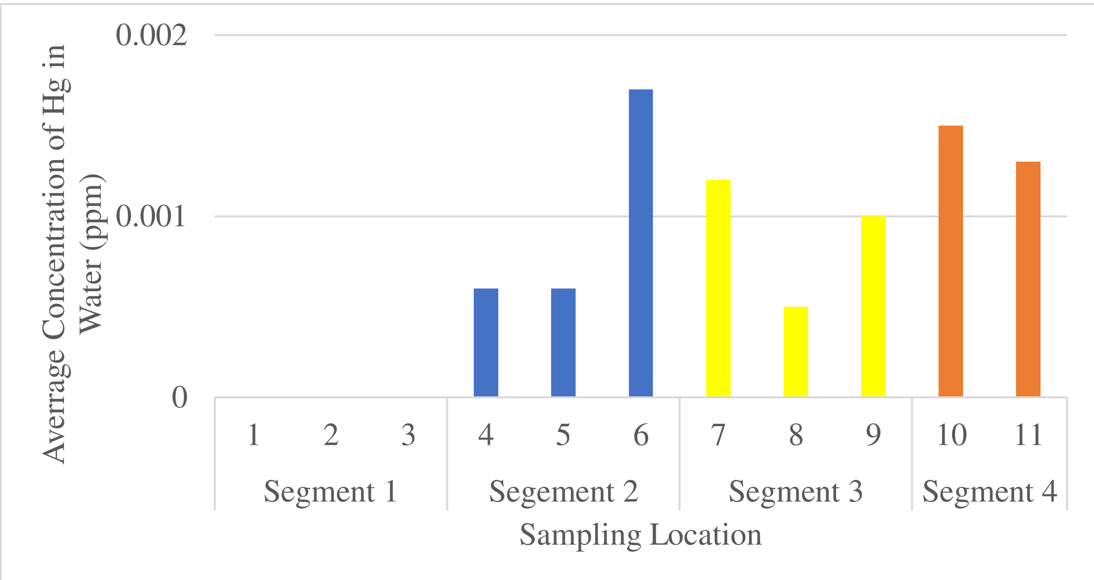

Figure 2. The average concentration of Hg in Ciliwung River water by sampling location

The results of the research on the concentrations of Pb, Cr, and Hg in the waters of the Ciliwung River according to replications can be seen in Table 3.

Table 3. The average concentration of Pb, Cr, and Hg (ppm) in the waters of the Ciliwung River according to replications

Heavy Metals	**Replications**											
	1	2	3	4	5	6	7	8	9	10	11	12
Pb	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	0.0002	0.0002
Cr	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	nd	nd
Hg	nd	nd	nd	nd	nd	nd	0.0012	0.0012	0.0013	0.0013	0.0021	0.0021

Note: nd = not detected

The results of the variance test (ANOVA) showed that the concentration of Hg in Ciliwung River water according to replication was significantly different ($P<0.05$), while for Pb it was not significantly different ($P>0.05$).
The concentration of Hg in Ciliwung River water according to replications can be seen in Figure 3.

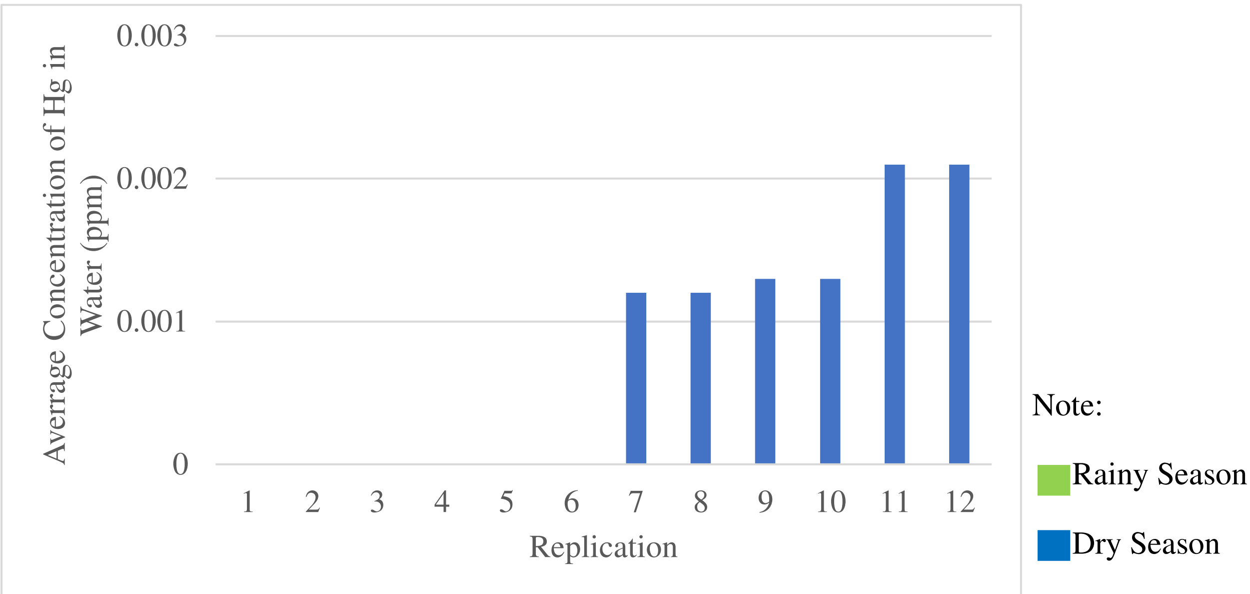

Figure 3. The average concentration of Hg in Ciliwung River water according to replications

When compared with the clean water quality standard of the Ciliwung River (stipulated in the decision of the Governor of the Jakarta Government No 582 of 1995, only Hg has exceeded the quality standard (>0.0005).

2. Heavy Metal Concentration In Ciliwung River Sediment

The results of the research on the concentrations of Pb, Cr, and Hg in Ciliwung River sediments according to the station can be seen in Table 4.

Table 4. Average concentrations of Pb, Cr, and Hg in Ciliwung River sediments according to the sampling locations

Heavy Metals	Sampling Locations										
	St. 1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11
Pb	7.4217	20.2908	7.7850	9.1730	15.8617	19.8508	27.4047	41.3737	35.9984	26.8712	32.2092
Cr	4.0117	5.5783	6.4683	8.2837	6.6335	5.4400	4.4420	4.8883	5.7652	5.8337	5.2135
Hg	0.0058	0.0061	0.0069	0.0084	0.0086	0.0124	0.0197	0.0284	0.0314	0.0314	0.0342

Note: St.1 = Gadog-Bogor District
St.2 = Warung jambu, Bogor City
St.3 = Panus bridge, Depok City
St.4 = Kelapa Dua, Bogor Street
St.5 = Intake PAM Condet
St.6 = MT Haryono Street
St.7 = Manggarai floodgate
St.8 = Halimun Street
St.9 = KH Mas Mansyur Street
St.10 = Teluk Gong Street
St. 11 = Muara Angke

Based on the data in Table 4, it can be seen that all of the heavy metals observed were detected in the sediments of the Ciliwung River, both in the Bogor, Depok, and DKI Jakarta areas. This shows the presence of all of the heavy metals that are observed in the sediments of the Ciliwung River waters naturally.

Statistical test results (ANOVA) showed that the concentrations of Pb, Cr, and Hg in the sediment of the Ciliwung River were significantly different between the sampling locations ($P<0.05$). More details can be seen in Figures 4,5 and 6.

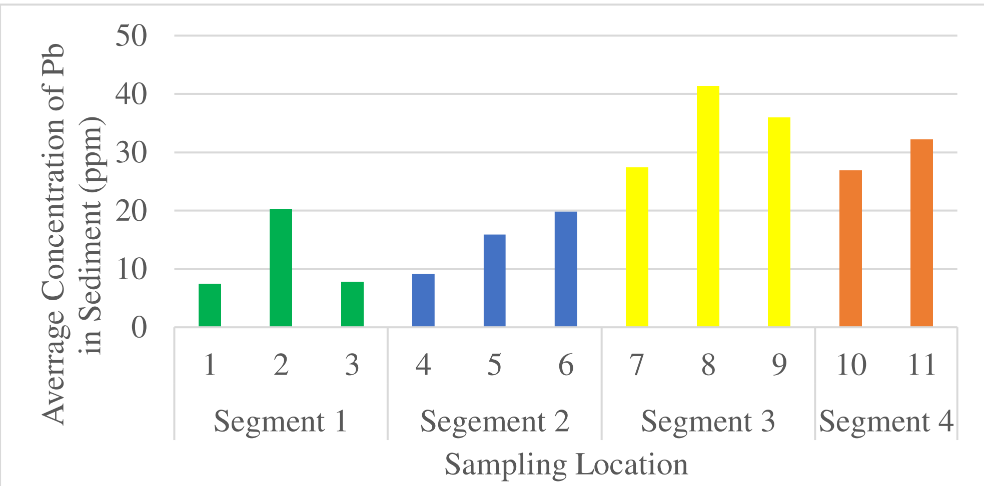

Figure 4. Concentration of Pb in Ciliwung River sediments according to sampling location

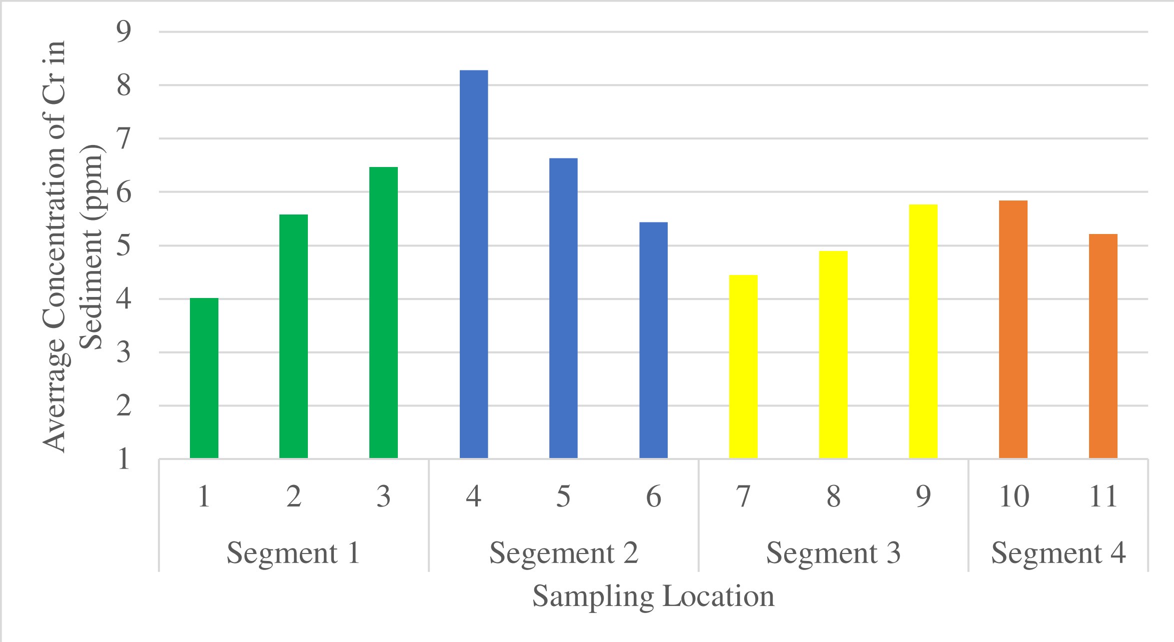

Figure 5. Concentration of Cr in Ciliwung River sediments according to sampling location

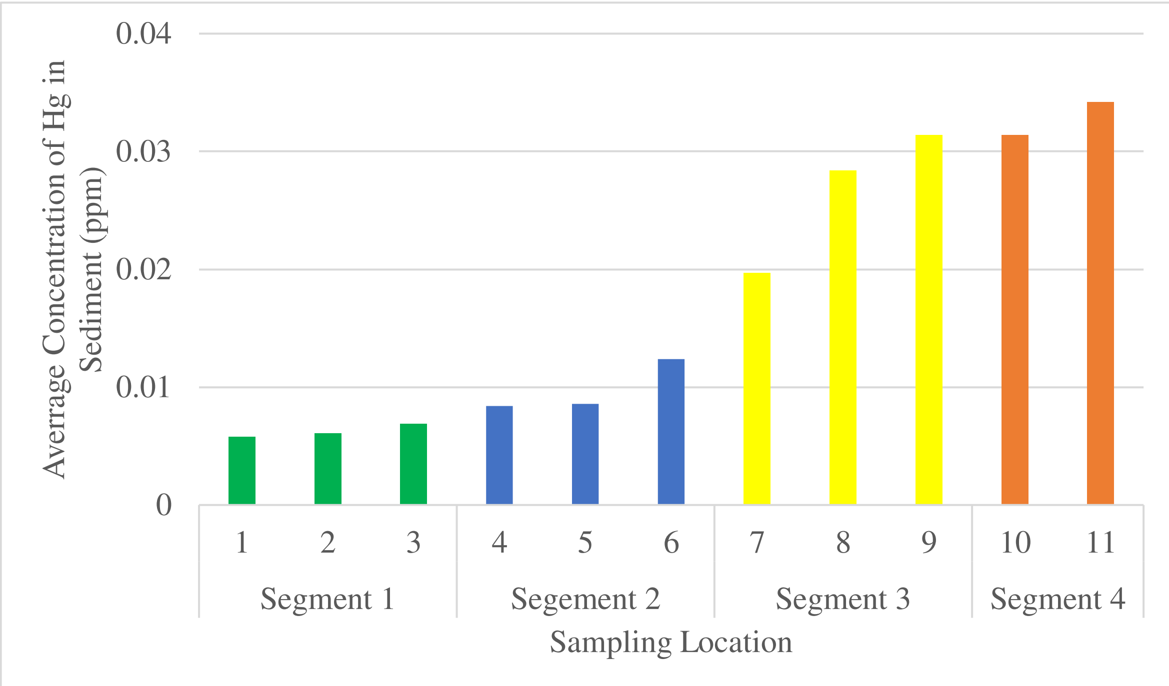

Figure 6. The concentration of Hg in Ciliwung River sediments according to sampling locations

The results of the research on the concentrations of Pb, Cr, and Hg in Ciliwung River sediments according to replications can be seen in Table 5.

Table 5. Average concentrations of Pb, Cr, and Hg (ppm) in Ciliwung River sediments according to replications

Heavy Metals	Replications											
	1	2	3	4	5	6	7	8	9	10	11	12
Pb	21.844	23.995	22.687	23.737	22.279	22.475	22.026	19.785	23.226	22.112	20.543	21.735
Cr	5.717	5.751	6.015	5.889	5.509	5.690	4.982	5.119	5.800	5.906	6.087	5.781
Hg	0.018	0.017	0.018	0.017	0.015	0.018	0.018	0.018	0.018	0.020	0.018	0.017

Based on table 5, it can be seen that during the observation, all types of heavy metals observed were detected in the sediment of the Ciliwung River. The results of the variance test (ANOVA) showed that the concentrations of Pb and Cr in the sediments of the Ciliwung River were not significantly different between replicates ($P>0.05$), while for Hg it was significantly different ($P<0.05$). More details can be seen in Figure 7.

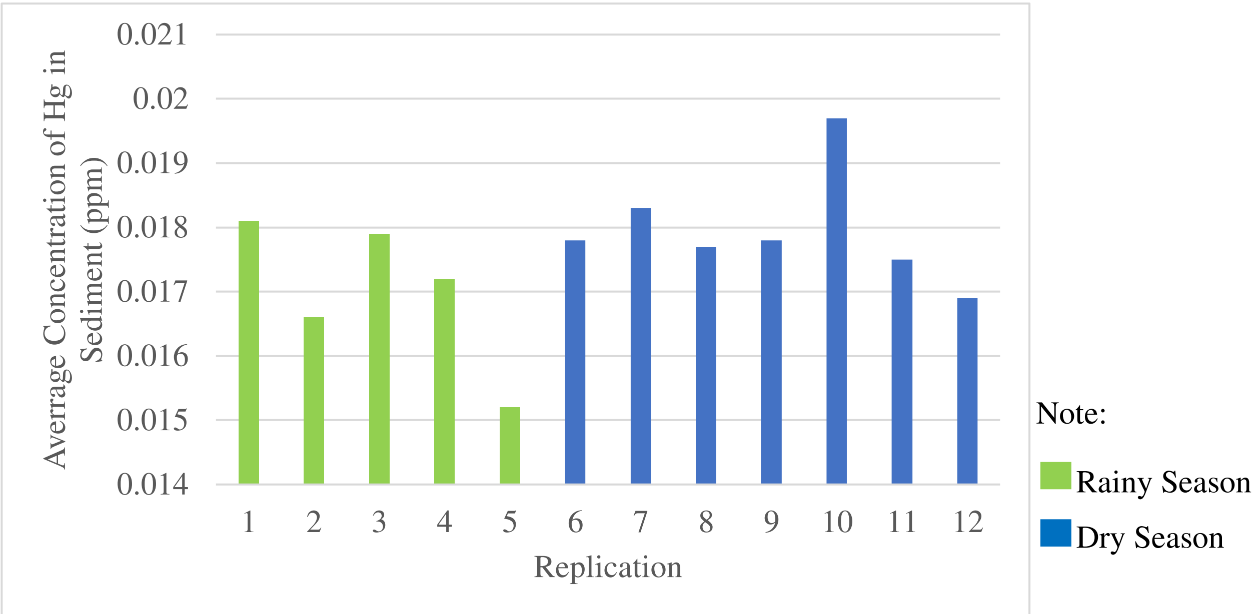

Figure 7. The concentration of Hg in Ciliwung River sediments according to replication

3. Relationship Of Heavy Metals Concentration In Sediment And Water

The results of the correlation test showed that the relationship between the concentration of Hg in the sediment and the concentration of Hg in the water was significant, with a correlation coefficient value (multiple r) of 0.55 (moderate).

The results of the analysis show a moderate cubic regression relationship with the equation: $Y=-0.0096+2.1000X-108.51X^2+1629.93X^3$ (Figure 8).

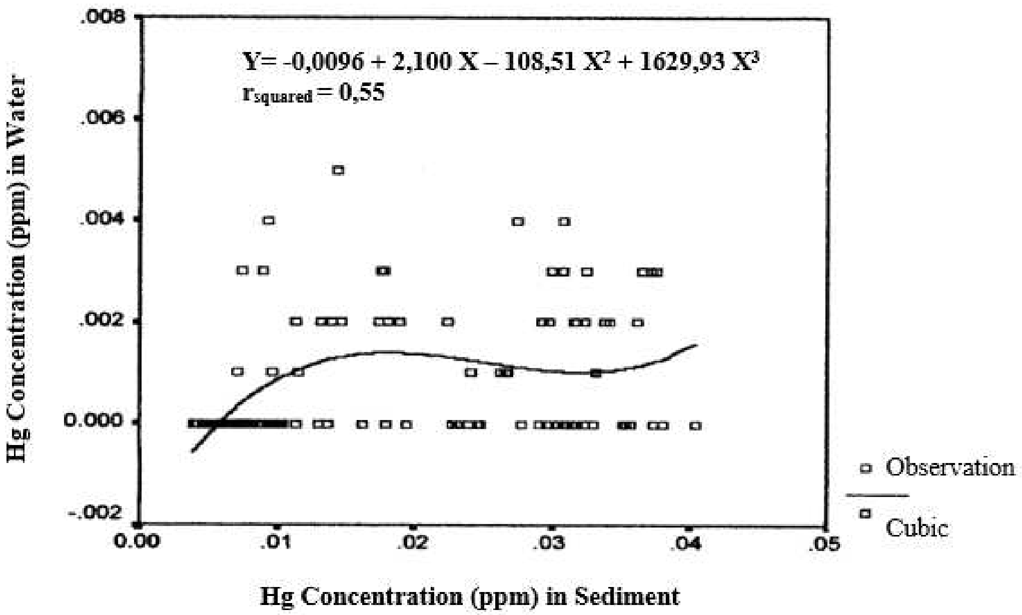

Figure 8. Relationship between Hg concentration in sediment and Hg concentration in Ciliwung
River water

4. Relationship Between Heavy Metal Concentrations In Water And Species Diversity of Plankton, Benthos, and Fish

The results of the research on the diversity of Plankton species in the Ciliwung River can be seen in Table 6.

Table 6. The index diversity of species in the Ciliwung River

Station	Sampling Location	Segment	Species Diversity Index
1	Gadog, Bogor District	1	3,15
2	Warung Jambu, Bogor City	1	4,23
3	Panus Bridge, Depok City	1	3,94
4	Kelapa Dua, Bogor Highway	2	3,99
5	Intake PAM Condet	2	4,03
6	MT Haryono Street	2	3,90
7	Manggarai Floodgate	3	3,74
8	Halimun Street	3	3,87
9	KH Mas Mansyur Street	3	3,56
10	Teluk Gong Street	4	3,15

Based on table 6, it can be seen that the Diversity Index of plankton in the Ciliwung River ranges between 3.15 and 4.23 and is classified as high.

The results of the research on the species diversity of Benthos in the Ciliwung River can be seen in Table 7.

Table 7. The Index diversity of Benthos species in the Ciliwung River

Station	Sampling Location	Segment	Species Diversity Index
1	Gadog, Bogor District	1	3.29
2	Warung Jambu, Bogor City	1	3.01
3	Panus Bridge, Depok City	1	3.43
4	Kelapa Dua, Bogor Highway	2	2.33
5	Intake PAM Condet	2	2.33
6	MT Haryono Street	2	1.42
7	Manggarai Floodgate	3	1.63
8	Halimun Street	3	1.48
9	KH Mas Mansyur Street	3	1.68
10	Teluk Gong Street	4	1.88
11	Muara Angke	4	1.49

Based on Table 7, it can be seen that the Diversity Index of Benthos in the Ciliwung River ranges between 1.42 and 3.43 and is classified as moderate until high.
The correlation test results between the concentration of Hg in the Ciliwung River water and the diversity of benthos species showed very significant results ($P<0.01$). This indicates that the presence of Hg in water has a significant effect on the diversity of Benthos species. The results of the analysis show that the relationship between the concentration of Hg in Ciliwung River water and the diversity of Benthos species is a very strong quadratic regression relationship (multiple r of 0.89) with the equation $Y=3.1738-2236.8X+813.201X^2$ (Figure 9).

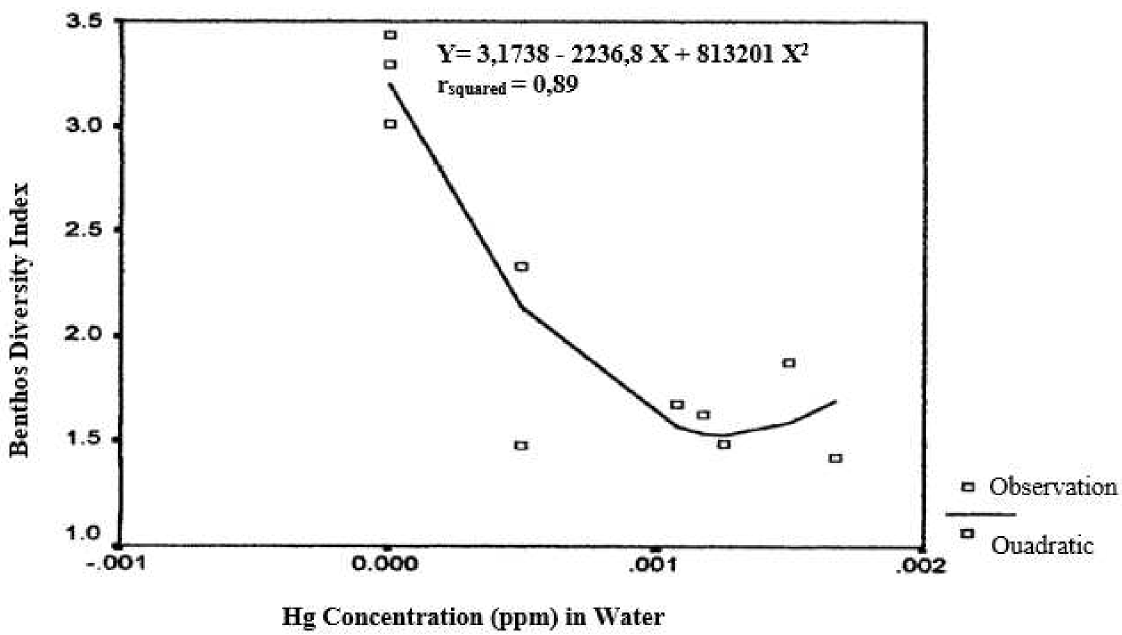

Figure 9. Relationship between Hg concentration in water and Benthos diversity in Ciliwung River

The results of the research on the diversity of Fish species in the Ciliwung River can be seen in Table 8.

Table 8. The Index diversity of Fish species in the Ciliwung River

Station	Sampling Location	Segment	Species Diversity Index
1	Gadog, Bogor District	1	0.00
2	Warung Jambu, Bogor	1	0.64
3	Panus Bridge, Depok City	1	0.79
4	Kelapa Dua, Bogor Highway	2	0.32
5	Intake PAM Condet	2	0.20
6	MT Haryono Street	2	0.04
7	Manggarai Floodgate	3	0.00
8	Halimun Street	3	0.00
9	KH Mas Mansyur Street	3	0.27
10	Teluk Gong Street	4	0.00
11	Muara Angke	4	0.37

5. Relationship Between Heavy Metal Concentrations In Sediment And Species Diversity of Plankton, Benthos And Fish

The correlation test results between the concentrations of Pb, Cr, and Hg in sediments and the diversity of Plankton, Benthos, and Fish species (Table 9) showed that a very significant relationship ($P<0.01$) was only obtained in the relationship between the concentration of Pb in the sediments and the diversity of Benthos species with multiple r values = 0.64 (strong relationship). A significant relationship was obtained in the relationship between Hg in sediments and the diversity of Benthos species with multiple r values = 0.52 (medium relationship).

Table 9. The correlation coefficient of heavy metals concentration in water and sediment of Ciliwung River and diversity of Plankton, Benthos, and Fish species

Compartment	Heavy Metal	Aquatic biota	Correlation Coefficient (Multiple r)
Water	Hg	Benthos	0.82**
		Plankton	0.25ns
		Fish	0.33ns
Sediments	Pb	Benthos	0.64**
		Plankton	0.56ns
		Fish	0.14ns
	Cr	Benthos	0.07ns
		Plankton	0.34ns
		Fish	0.31ns
	Hg	Benthos	0.52**
		Plankton	0.44ns
		Fish	0.37ns

Note : *= Significant ($P<0.05$) ns = not significant
**= Very Significant ($P<0.01$)

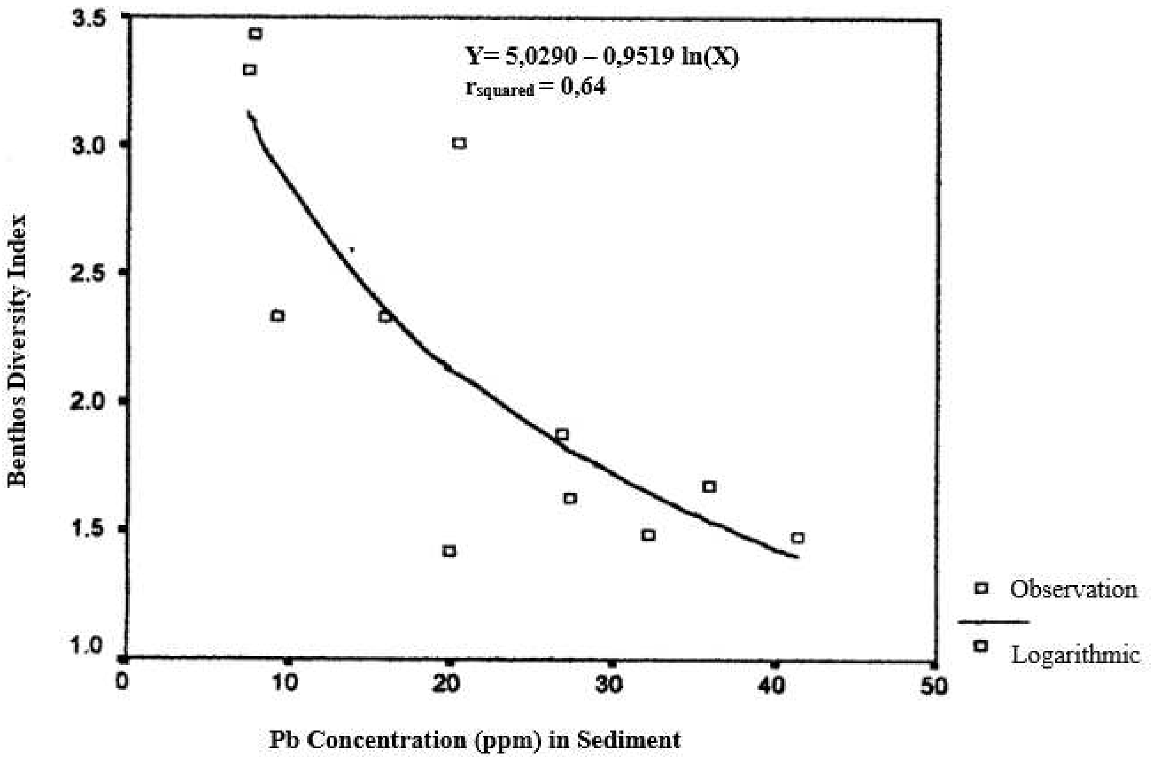

Figure 10. Relationship between Pb concentration in sediment and Benthos diversity in Ciliwung River

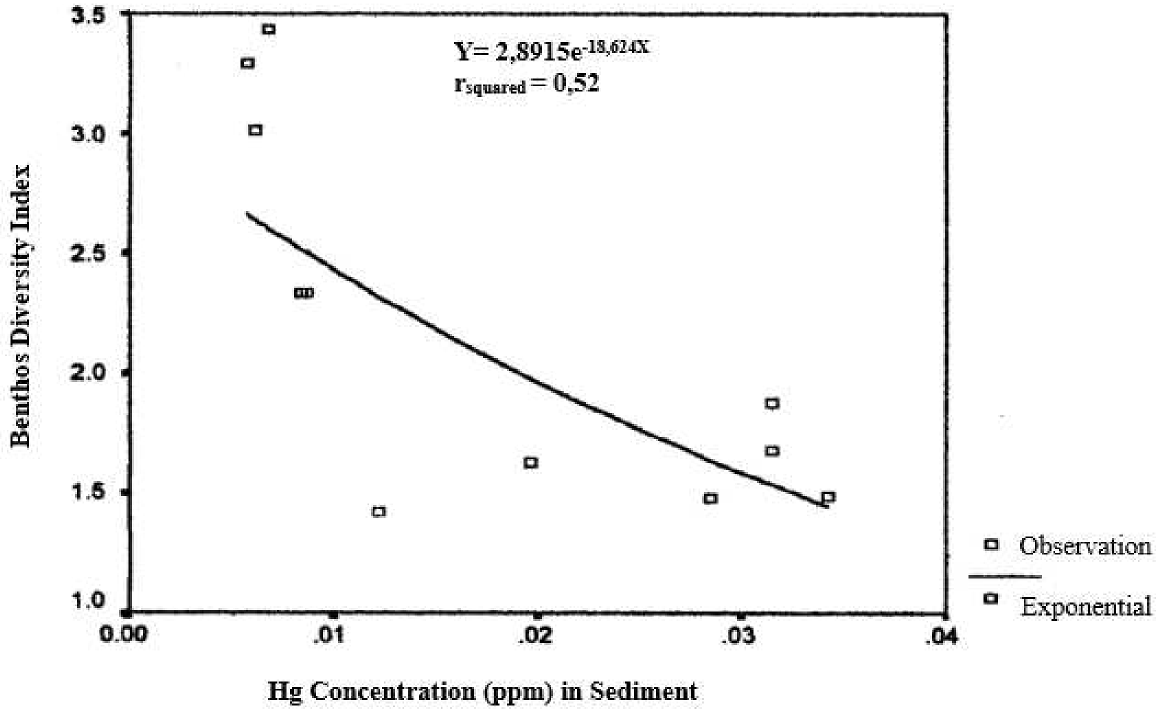

Figure 11. Relationship between Hg concentration in sediment and Benthos diversity in Ciliwung River

DISCUSSION

Based on Figure 2, it can be seen that in the upstream (segment 1), at station 1 (Gadog-Bogor District), station 2 (Warung Jambu, Bogor City), and station 3 (Panus Bridge, Depok City), the presence of Hg was not detected in the Ciliwung River water. This shows that the contribution of human activities in this segment such as industry, agriculture, and settlements to the presence of Hg in water is very small. In segment 2 starting from station 4 (Kelapa Dua, Bogor Street), station 5 (Intake PAM Condet), and station 6 (MT Haryono Street, Cawang), the presence of Hg in the water began to be detected and its concentration tended to increase in the downstream. This shows the contribution of human activities such as Industry and Settlements to the presence of Hg in water. In segment 3 starting from station 7 (Manggarai Floodgate), station 8 (Halimun Street), and station 9 (KH Mas Mansyur Street), although it fluctuated, the concentration of Hg in the water also tends to increase. Likewise in segment 4 at station 10 (Teluk Gong Street) and station 11, the concentration of Hg tends to increase due to the accumulation of Industrial and Residential activities that contribute to the presence of Hg in the water. The result of observation shows that in general, the contribution of human activities in the DKI Jakarta area to the presence of Hg and Pb in the waters of the Ciliwung River was greater than in the Bogor and Depok areas.

According to Phillips (1980), the contribution of human activities in heavy metal pollution can be in the form of urban, industrial, mining, and agricultural waste. Industrial waste generally contains more heavy metal elements. According to Bryan

(1986), the biggest source of heavy metals comes from human activities, both on land and at sea. This is because heavy metal compounds or elements are widely used in industry as raw materials, catalysts, fungicides, and additives. Pb was widely used in batteries, pigments, explosive materials, solders, cable coatings, and paints. Meanwhile, Hg was widely used in the production of chlorine alkali, electrical equipment, paints, drugs, and biocides (fungicides, herbicides, and pesticides).

Based on Table 3, it can be seen that during the rainy season (replications 1 to 6), from December to March, all of the heavy metals observed were not detected in the waters. Whereas during the dry season (replications 7 to 12), from May to July, only Pb and Hg were detected in the waters. The undetected presence of Pb and Hg during the rainy season was probably caused by the river water discharge which was much larger than during the dry season resulting in water dilution.

In general, it is seen that the concentration of Pb and Hg downstream is higher than upstream. The presence of Pb and Hg although fluctuating tends to increase in the downstream and estuary due to the accumulation of industrial, trading, services, and residential activities along the Ciliwung River.

The results of this research also showed that the concentration of Hg in the sediment during the rainy season was lower than during the dry season. This is due during the rainy season, there is flushing so that Hg from sediment will be released. The concentrations of Pb, Cr, and Hg in sediments were much higher than in the waters. The high level of heavy metals in the sediments is caused by the deposition on the bottom of the waters. In addition, sediments can accumulate heavy metals along streams (Sylvester, 1978). Law (1981) states that heavy metals have the property of being easily bound to dissolve organic matter. Household waste containing organic matter will react and bind heavy metal cations so that it settles to the bottom of the water and unite with sediment. This resulted in the concentration of heavy metals in the sediment being much higher than in the water. Under the right conditions, heavy metals in the sediment will be released again, so that a balance is achieved. Thus, the examination of heavy metals in water and sediment can provide more complete information regarding heavy metal pollution.

According to Suharno (1993) in river water, there are colloidal particles from eroded rock and suspended fine soil. These particles have a great ability to adsorb heavy metal ions. Heavy metals contained in river water together with solid particles will settle to form sediments (Mathur *et al*., 1987)

This research was indicated that the presence of Hg in sediment has a significant effect on the presence of Hg in water. The metal content in the Ciliwung River water affects the metals present in the sediment and vice versa. However, because metals are easily dissolved in water to form deposits, the metal content in the sediment becomes higher (Benes *et al*., 1985). Setyawati (1998) reported that the correlation coefficient values of Pb, Cr, and Fe in Ciliwung River water with Pb, Cr, and Fe in sediments are 0.235, 0.151, and 0.311, respectively, so it was a weak correlation value (Walpole,1993).

The results of the correlation test between the concentration of Hg in the water of the Ciliwung River and the diversity of Plankton species showed no significant results ($P>0.05$), so it could not be used to estimate the relationship between the concentration of Hg in river water and the diversity of Plankton species (Spiegel, 1988). This indicates that the presence of Hg in the water does not affect the diversity of Plankton species.

In general, the diversity of Benthos species in the Ciliwung River tends to be lower towards the downstream and estuaries. This is due to the deteriorating water quality of the Ciliwung River downstream and estuary. The measurement results show that the dissolved oxygen content was generally very low at less than 3 ppm, BOD >10 ppm, and COD >20 ppm.

Based on table 8, it can be seen that the Index of Fish species diversity in the Ciliwung River ranges between 0.00 and 0.79. In general, it can be seen that the diversity of Fish species in the upstream (segment 1) is higher than in the middle, downstream, and estuary areas (segments 2, 3, and 4). This is due to the worsening water quality of the Ciliwung River in the downstream and estuary. The results of the correlation test between the concentration of Hg in the water of the Ciliwung River and the diversity of Fish species showed no significant results ($P>0.05$), so it could not be used to estimate the relationship between the concentration of Hg in river water and the diversity of Fish species (Spiegel, 1988). This indicates that the presence of Hg in the water does not affect the diversity of Fish species.

Relationship between heavy metal concentrations in sediment and species diversity of Plankton, Benthos, and Fish showed that only relationship between the concentration of Pb and the diversity of Benthos species has a strong relationship with multiple r values = 0.64, and the relationship between the concentration of Hg and the diversity of Benthos species with multiple r values = 0.52 (medium relationship). Therefore, Benthos species can be used as Bioindicator for Pb and Hg pollutions in the river sediment.

CONCLUSION

Based on the results of the research that has been done, it can be concluded as follows:

1. The concentration of Pb and Hg in water and sediment in the Ciliwung River were significantly different between sampling locations (stations 1 to 11). The concentration of Cr in the sediments of the Ciliwung River between sampling locations (stations 1 to 11) was significantly different.
2. Concentrations of Pb and Cr in sediments between research times (rainy season and dry season) were significantly different.
3. The relationship between Hg concentration in sediment and Hg concentration in water was significant.
4. The relationship between the concentration of Hg in water and the diversity of plankton and Fish species was not significant, whereas with the diversity of Benthos species it was very significant. The relationship between the concentration of Hg in the sediment and the diversity of Plankton and Fish species were not significant,

while the diversity of Benthos species was significant. The relationship between the concentration of Pb in sediments and the diversity of Plankton and Fish species was not significant, while the diversity of Benthos species was very significant. The relationship between Cr concentration in sediments and the diversity of Plankton, Benthos, and Fish species were not significant.

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