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Relationship Between Heavy Metals Pb, Cr, and Hg in Ciliwung River Water and Sediment and Pb, Cr, and Hg Content in Plakton

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Abstract

This research aims to determine the relationship between the concentrations of the heavy metals Pb, Cr, and Hg in water and sediment with the concentrations of the heavy metals Pb, Cr, and Hg in the water, sediment, and plankton of the Ciliwung River. The concentrations of heavy metals Pb, Cr, and Hg in water, sediment, and plankton generally appear to fluctuate. As you move downstream, heavy metal concentrations tend to increase in line with increasing human activities downstream such as industrial activities, services, trade, and residential areas. The concentrations of Pb, Cr, and Hg in plankton were significantly different according to observation location ($p<0.05$), whereas according to replicates (seasons), only Pb and Hg were significantly different ($p<0.05$). The correlation test results showed that the relationship between Hg concentration in water and Hg concentration in different plankton was not significant ($p>0.05$). The relationship between the concentrations of Pb, Cr, and Hg in sediment and the concentrations of Pb, Cr, and Hg in different plankton was not significant ($p>0.05$).

Keywords: *Heavy metals Pb, Cr, Hg, Plankton, Ciliwung River*

INTRODUCTION

The Ciliwung River stretches from upstream in Bogor, covering the areas of Mount Gede, Mount Pangrango, and Cisarua, and then flows downstream to the north coast of Jakarta. The length of the Ciliwung River is 117 kilometers with a watershed area of 347 square kilometers (Said, 2018). The Ciliwung River is divided into three sub-watershed areas. Upstream Ciliwung covers an area of 15,251 hectares in Bogor Regency and Bogor City, Central Ciliwung covers an area of 16,706 hectares in Bogor Regency, Bogor City, Depok and Bekasi and Hilir Ciliwung covers an area of 6,295 hectares in DKI Jakarta Province.

Based on research by the Indonesian Institute of Sciences (LIPI), the waters of the Ciliwung River have experienced pollution and decreased environmental quality due to human activities, industrial waste, and household waste. The amount of household waste, garbage, industrial waste, livestock waste, and agricultural pollution in the Ciliwung River is 54.4 tons of BOD per day. Meanwhile, the Ciliwung River's capacity to accommodate the pollution load is only 9.29 tons of BOD (*Biochemical Oxygen Demand*) per day.

One potential source of pollution in the waters of the Ciliwung River is the presence of heavy metals due to various human activities. According to Smith et al (1980), the distribution of heavy metals in aquatic ecosystems is characterized by the presence of heavy metals in certain water areas. Different concentrations of heavy metals in aquatic ecosystems are caused by the mixture of various

forms of complex compounds. The reactions that occur will influence or change the concentration, including changes in the valence of the cation. Apart from that, there is the possibility of absorption by particulate matter, which settles to the bottom, and there is a dilution process. These conditions affect these heavy metals' chemical and physical processes in aquatic ecosystems.

According to Cross and Sunda (1978), colloidal materials have an important role because they influence flocculation and metal deposition. Colloidal materials such as metal oxides, organic metal colloids, and clay minerals tend to adsorb metal ions in water, so they can reduce the concentration of heavy metals in water. Apart from that, the activity of organisms is also able to absorb metals in water through biological processes. This is because some metals can form complexes with organic materials so that the metals will be involved in the body tissues of organisms.

Research purposes:

1. To determine the relationship between the concentrations of the heavy metals Pb, Cr, and Hg in water and sediment with the concentrations of the heavy metals Pb, Cr, and Hg in the plankton of the Ciliwung River.

Hypothesis:

1. Concentrations of heavy metals (Pb, Cr, and Hg) in plankton differ between research locations.
2. Concentrations of heavy metals (Pb, Cr, and Hg) in plankton differ between study periods (seasons).
3. There is a real correlation between the concentrations of western metals (Pb, Cr, and Hg) in water and the concentrations of Pb, Cr, and Hg in plankton.
4. There is a real correlation between the concentration of heavy metals (Pb, Cr, and Hg) in sediment and the concentration of Pb, Cr, and Hg in plankton.

METHOD

1. Sampling location

The research was carried out at 11 observation stations from upstream to estuary which were divided into 4 river segments (Table 1 and Figure 1).

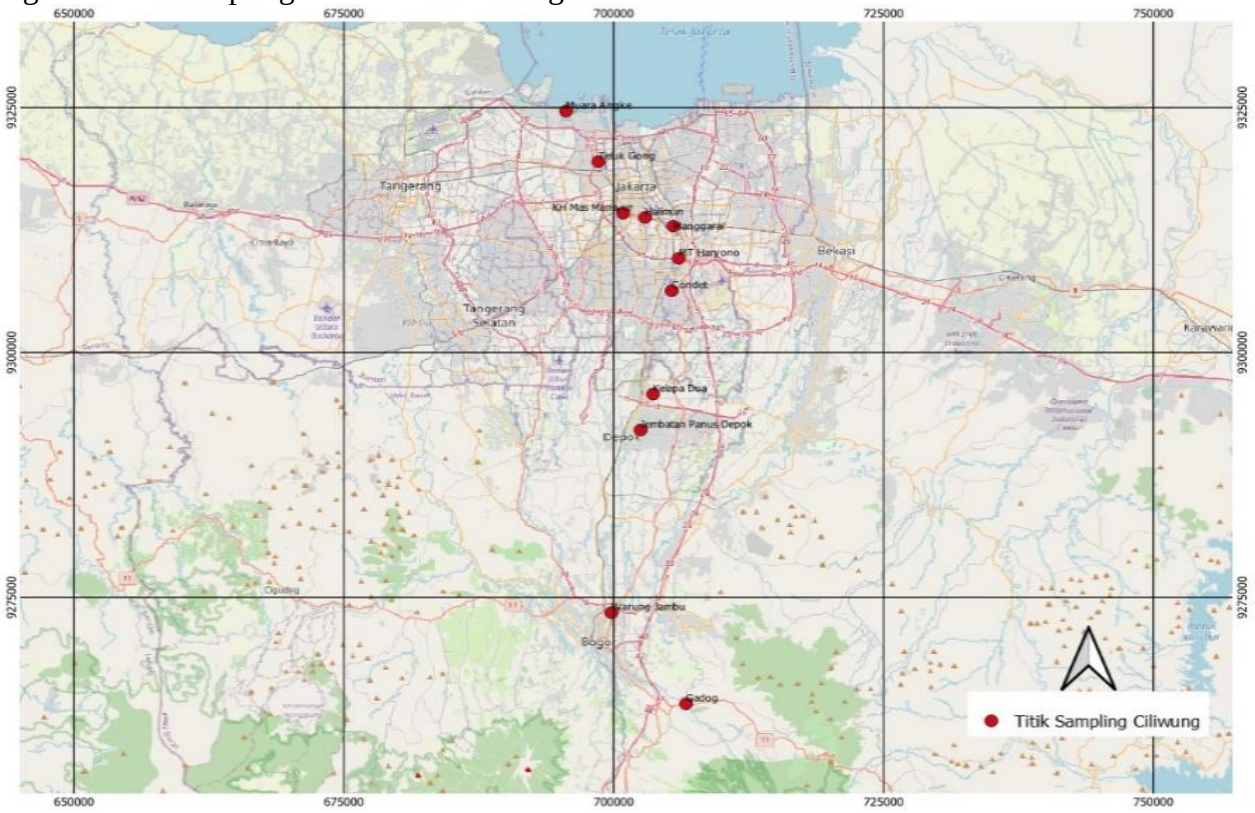
Table 1. Water, Sediment, and Plankton Sampling Locations in the Ciliwung River

Stations	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 (Estuaries)	Gong Street Bay	Monitoring Station of DKI Jakarta Government
11	4 (Estuaries)	Muara Angke	Monitoring Station of DKI Jakarta Government

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

Figure 1. The sampling location at Ciliwung River



2. Research Materials

Materials used in this research include water, sediment, and plankton samples from 11 research stations, distilled water, glacial acetic acid, 70% methyl alcohol, plastic bags, labels, reagents for water, and analysis of heavy metals such as concentrated H_2SO_4, Concentrated HNO_3, $KMnO_4$, $NH_2OH.Cl$, $K_2Cr_2O_7$, $SnCl_2$, and filter paper.

3. Research Equipment

Equipment used in this research includes plankton net number 25, Egman Grab, cooler box, separating funnel, vacuum pump, Erlenmeyer flask, beaker, measuring cup, measuring flask, pipette, glass funnel, bath, oven, cooler, bottles Van Dorn. For analysis of heavy metals found in plankton, water, and sediment, an atomic absorption spectrophotometer Shimadzu type AA-680 was used.

4. Data Collection Method

a. Water sampling

Examples for analyzing the concentration of heavy metals in water are taken using a Van Dorn bottle, namely to take water samples at the depth stratification of the surface, bottom, and

bottom. The water samples were then composited and stored in white jerry cans. The composite results are analyzed in the laboratory. To maintain the stability of heavy metals in water samples, fixation was carried out with HNO_3.

b. Sludge sampling

Mud sampling is carried out at the same station (sampling point) as water sampling. The tool used is the Ekman Grab. The sludge taken is put into a plastic container for analysis in the laboratory.

c. Taking plankton samples

At each research location, plankton samples were taken with plankton nets three times each on the left, middle, and right banks of the river. Samples of plankton were filtered from 100 liters of river water, then put into a container containing "roll film" and given ice to keep them alive.

Water, sediment, and plankton samples are taken every two weeks for six months (two seasons) to see whether there is an influence of the season on the level of pollution.

d. Laboratory Analysis

Water, sediment, and plankton samples whose heavy metal content (Pb, Cr, and Hg) will be determined through a digestion process with concentrated H_2SO_4 using methods according to APHA, AWWA, and WPCP in the Standard Method for the Examination of Water and Wastewater. The analysis was carried out at the environmental laboratory, DKI Jakarta Provincial Environmental Service.

e. Statistical analysis

a) Concentrations of heavy metals in water, sediment, and plankton. To determine whether there are differences in the concentrations of heavy metals (Pb, Cr, and Hg) in water, sediment, and plankton at various locations and research times, a randomized block design was used using a two-way ANOVA test (Hinkelman and Kempthorne, 2008). Statistical data analysis was carried out using the SPSS (Statistical Package for Social Sciences) release 7.5.1 program.

b) The relationship between heavy metal concentrations in water and sediment and heavy metal concentrations in plankton.

To determine the relationship between heavy metal concentrations in water and sediment and heavy metal concentrations in plankton, the relationship between variables is examined for significance for the models:

Linear: $Y = b_0 + bX$

Logarithmic : $Y = b_0 + b_1 . Ln(X)$

Inverse: $Y = b_0 + \frac{b_1}{X}$

Quadratic: $Y = b_0 + b_1 X + b_2 X^2$

Cubic: $Y = b_0 + b_1 X + b_2 X^2 + b_3 X^3$

Power: $Y = b_0 + X^{b1/x}$

Compound: $Y = b_0 . b_1$

Sigmoid: $Y = e^{b_0 + b_1}$

$$\text{Logistics: } Y = \frac{X}{1/\mu + b_0 . b_1^{X}}$$

Growth : $Y = e^{b0 + b1 . X}$

Exponential: $Y = b_0.e^{b1.X}$

After that, the regression equation is determined for the model that provides real results and the highest level of correlation. Data analysis used the SPSS release 7.5.1 program.

RESULT

1. Heavy Metal Concentration in Plankton

   The results of the research on the average concentrations of Pb, Cr, and Hg in plankton in the Ciliwung River according to location can be seen in Table 2.

Table 2. Average concentrations of Pb, Cr, and Hg (ppm) in plankton in the Ciliwung River according to research location

Types of Heavy Metals	Location										
	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10	St. 11
PB	0.1505	0.0817	0.0855	0.0847	0.0722	0.2194	0.1830	0.3480	0.4007	0.2935	0.1152
Cr	0.0420	0.0933	0.0653	0.0512	0.0562	0.0792	0.1522	0.1040	0.2043	0.1677	0.0808
Hg	0.0108	0.0139	0.0133	0.0081	0.0112	0.0154	0.0183	0.0153	0.0209	0.0188	0.0096

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

The results of the variance test showed that the concentrations of Pb, Cr, and Hg in plankton in the Ciliwung River between research locations were significantly different ($p<0.05$). For more details, see Figure 2, Figure 3, and Figure 4.

Figure 2. Average Pb Concentration in Plankton According to Location in the Ciliwung River

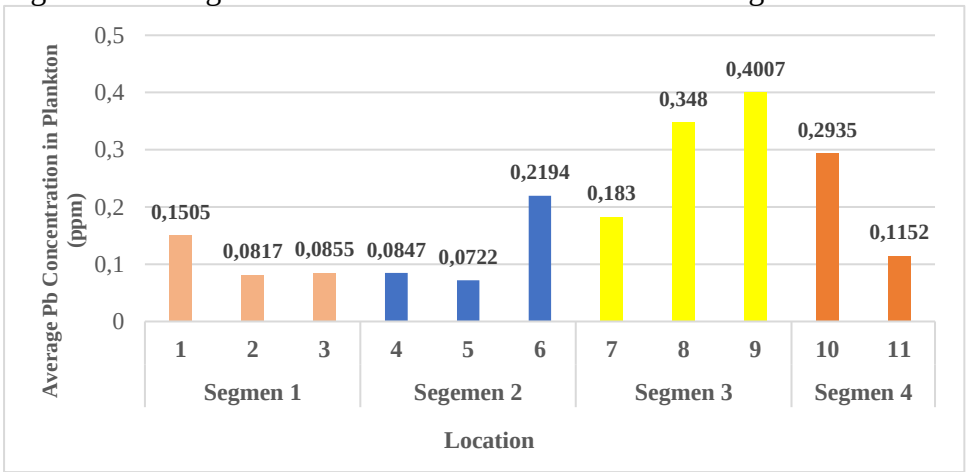


Figure 3. Average Cr Concentration in Plankton According to Location in the Ciliwung River

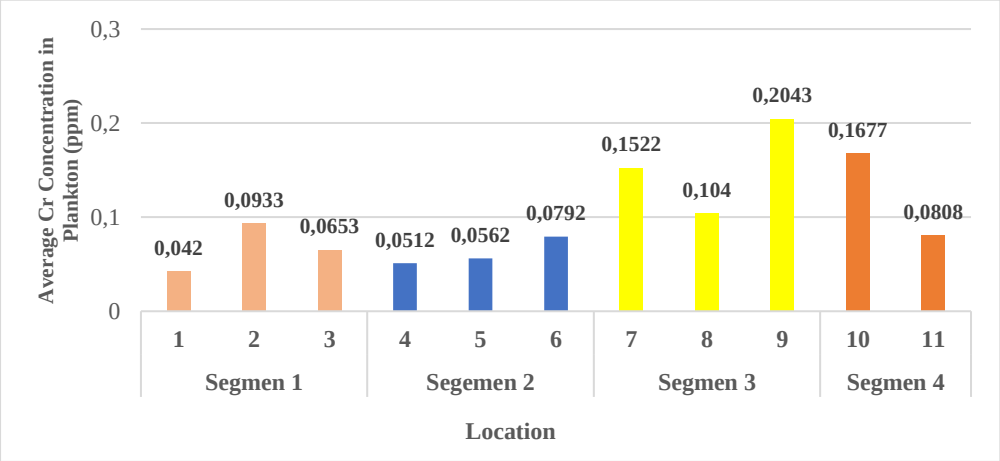
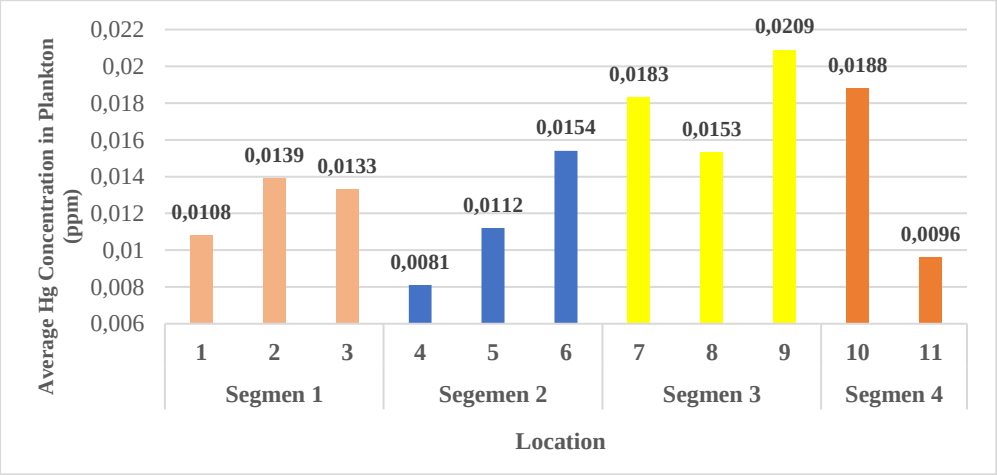


Figure 4. Average Hg Concentration in Plankton According to Location in the Ciliwung River



The results of the research on the average concentrations of Pb, Cr, and Hg in plankton in the Ciliwung River according to repetitions (seasons) can be seen in Table 3.

Table 3. Average Concentrations of Pb, Cr, and Hg (ppm) in Plankton in the Ciliwung River According to Repeats (Seasons)

Types of Heavy Metals	Test											
	1	2	3	4	5	6	7	8	9	10	11	12
PB	0.4988	0.0994	0.4567	0.0899	0.1829	0.0664	0.0975	0.0915	0.1106	0.1867	0.1870	0.1517
Cr	0.1854	0.0504	0.1452	0.0833	0.1385	0.0482	0.0465	0.0718	0.0802	0.1124	0.1186	0.1154
Hg	0.0314	0.0220	0.0289	0.0150	0.0105	0.0072	0.0049	0.0115	0.0072	0.0101	0.0106	0.0106

The results of the variance test showed that the concentrations of Pb and Hg in plankton in the Ciliwung River were significantly different between replications ($p<0.05$), while for Cr the differences were not significant ($p>0.05$). For more details, see Figure 5 and Figure 6.

Figure 5. Average Pb Concentration in Plankton According to Repeats (Seasons) in the Ciliwung River

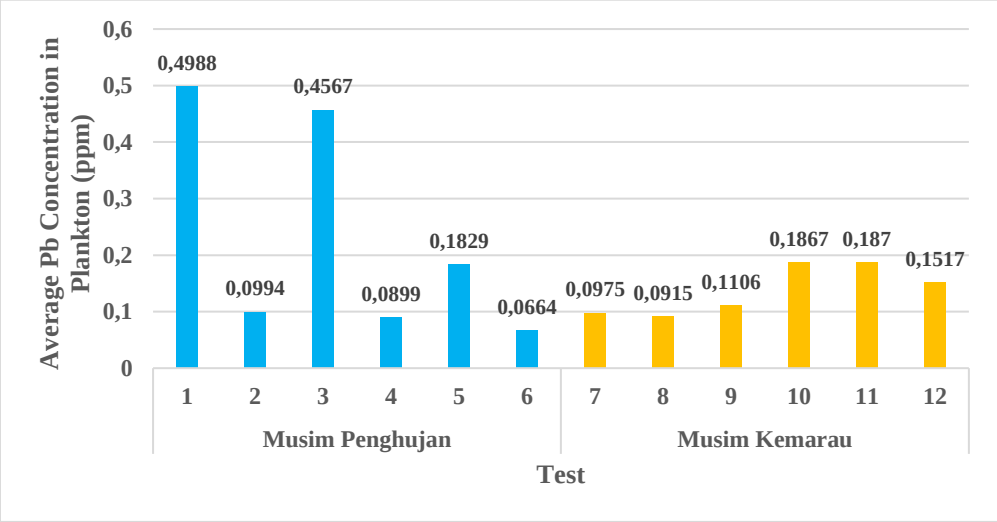
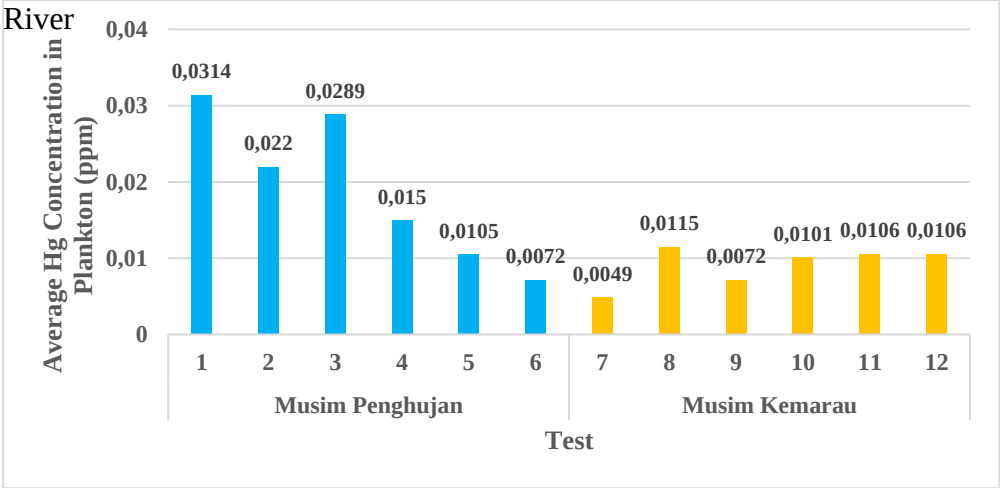


Figure 6. Average Hg Concentration in Plankton According to Repeats (Seasons) in the Ciliwung River



The average concentrations of Pb, Cr, and Hg (ppm) in sediment and plankton water in the Ciliwung River according to observation location and replication (season) can be seen in Table 4 and Table 5

Table 4. Average Concentrations of Pb, Cr, and Hg (ppm) in Water, Sediment, and Plankton in the Ciliwung River According to Observation Locations

Types of Heavy Metals	Location										
	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10	St. 11
PB											
1. Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
2. Sediment	7.4202	20.2908	7.7850	9.1730	15.8617	19.8508	27.4047	41.3737	35.9984	26.8712	32.2092
3. Plankton	0.1505	0.0817	0.0855	0.0847	0.0722	0.2194	0.1830	0.3480	0.4007	0.2935	0.1152
Cr											
1. Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2. Sediment	4.0117	5.5783	6.4683	8.2837	6.6335	5.4400	4.4420	4.8883	5.7652	5.8337	5.2135

3. Plankton	0.0420	0.0933	0.0653	0.0512	0.0562	0.0792	0.1522	0.1040	0.2043	0.1677	0.0808
Hg											
1. Water	0.0000	0.0000	0.0000	0.0006	0.0006	0.0017	0.0012	0.0005	0.0010	0.0015	0.0013
2. Sediment	0.0058	0.0061	0.0069	0.0084	0.0086	0.0124	0.0197	0.0284	0.0314	0.0314	0.0342
3. Plankton	0.0108	0.0139	0.0133	0.0081	0.0112	0.0154	0.0183	0.0153	0.0209	0.0188	0.0096

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

Table 5. Average Concentrations of Pb, Cr, and Hg (ppm) of Water, Sediment, and Plankton in the Ciliwung River According to Repeats (Seasons)

Types of Heavy Metals	**Test**											
	1	2	3	4	5	6	7	8	9	10	11	12
PB												
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002
Sediment	21.8436	23.9945	22.6874	23.7371	22.2785	22.4745	22.02664	19.7851	23.2264	22.1115	20.5428	21.7345
Plankton	0.4988	0.0994	0.4567	0.0899	0.1829	0.0664	0.0975	0.0915	0.1106	0.1867	0.1870	0.1517
Cr												
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sediment	5.7169	5.7509	6.0145	5.8891	5.5091	5.6904	4.9818	5.1185	5.8000	5.9060	6.0874	5.7805
Plankton	0.1854	0.0504	0.1452	0.0833	0.1385	0.0482	0.0465	0.0718	0.0802	0.1124	0.1186	0.1154
Hg												
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00012	0.0012	0.0013	0.0013	0.0021	0.0021
Sediment	0.0181	0.0166	0.0179	0.0172	0.0152	0.0178	0.0183	0.0177	0.0178	0.0197	0.0175	0.0169
Plankton	0.0314	0.0220	0.0289	0.0150	0.0105	0.0072	0.0049	0.0115	0.0072	0.0101	0.0106	0.0106

2. Relationship between heavy metal concentrations in water and heavy metal concentrations in plankton

Considering that the concentration of heavy metals detected in Ciliwung River water and fulfilling the requirements for correlation testing was only Hg, testing was only carried out on Hg concentrations in Ciliwung River water and Hg concentrations in plankton. The correlation test results show that the relationship between Hg concentration in water and Hg concentration in plankton is not significant ($p>0.05$), so it cannot be used to estimate the relationship between Hg in water and Hg concentration in plankton (Spiegel, 1988).

3. Relationship between heavy metal concentrations in sediment and heavy metal concentrations in plankton

The results of the correlation test showed that the relationship between the concentrations of Pb, Cr, and Hg in sediment and the concentrations of Pb, Cr, and Hg in plankton is not significant ($p> 0.05$), so it cannot be used to estimate the relationship between the concentrations of metals Pb, Cr and Hg in sediments with metal concentrations of Pb, Cr, and Hg in plankton (Spiegel, 1988)

The results of calculating the correlation coefficient for heavy metal concentrations in water, sediment, and plankton can be seen in Table 6.

Table 6. Correlation Coefficient of Heavy Metal Concentrations in Water and Sediment with Heavy Metal Concentrations in Plankton

Compartment	Metal	Aquatic Biota	(n)	Correlation coefficient
Water	Hg	Plankton	12	0.15 ns
Sediment	PB	Plankton	12	0.001 ns
	Cr	Plankton	12	0.11 ns
	Hg	Plankton	12	0.20 ns

Note: ns = not significant (p>0.05)
n = number of samples

DISCUSSION

The concentrations of heavy metals Pb, Cr, and Hg in plankton generally appear to fluctuate. As you move downstream, the concentration of heavy metals tends to increase. This is thought to be closely related to the increasing human activities such as industrial, service, and trade activities and residential areas downstream which contribute to the presence of heavy metals in the waters of the Ciliwung River. In the downstream section (segment 4) a decrease in heavy metal concentrations in plankton can be seen. This is thought to be due to tidal influences in the estuary area. A decrease in heavy metal concentrations in plankton can also be caused by a decrease in heavy metal concentrations in water and sediment due to flushing and release from sediment.

Based on Figure 5 and Figure 6, it can be seen that the concentrations of Pb and Hg in plankton in the rainy season and dry season fluctuate. The observation results also show that fluctuations in Pb and Hg concentrations in the dry season are not as large as when observed in the rainy season. This can be caused by the influence of fluctuations in rainfall intensity which are greater in the rainy season than in the dry season.

According to Moore and Ramamoorthy (1984), heavy metals in water tend to form bonds with the organic materials contained in it. Heavy metals that enter the waters will experience precipitation, dilution, and dispersion and can then be absorbed and adsorbed by organisms that live in these waters. Laws (1981) added that heavy metals in waters are more quickly adsorbed by detritus, plankton, suspended particles and combine with living organisms, thus affecting the lives of these organisms.

Phytoplankton take up heavy metals that are distributed vertically in the waters by absorption. The heavy metals that are absorbed are generally heavy metals that are in inorganic form, while the uptake of heavy metals by zooplankton is carried out in the same way as macroinvertebrates, namely through food (Setiadi and Soeprianto, 1992).

CONCLUSION

Based on the results of the research that has been carried out, the following conclusions can be drawn:

1. Pb concentrations in water, sediment, and plankton in the Ciliwung River between research locations (stations 1 to 11) were significantly different. Cr concentrations in sediment and plankton in the Ciliwung River between research locations (stations 1 to 11) were significantly different. The concentration of Hg in water, sediment, and plankton in the Ciliwung River between research locations (stations 1 to 11) was significantly different.
2. Pb concentrations in plankton in the Ciliwung River between study periods (rainy season and dry season) were significantly different, while in sediment the differences were not significant. Cr concentrations in sediment and plankton between study periods (rainy season and dry season) were not significantly different. Hg concentrations in water, sediment, and plankton between study periods (rainy season and dry season) were significantly different.

3. The relationship between Hg concentration in water and Hg concentration in plankton is not significant. The relationship between Pb and Cr concentrations in sediment and Pb and Cr concentrations in plankton is not significant.
4. The relationship between Hg concentration in sediment and Hg concentration in plankton is not significant.

ACKNOWLEDGMENT

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