Heavy metal concentration in water, sediment, and *Pterygoplichthys pardalis* in the Ciliwung River, Indonesia

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Abstract. Ciliwung River is one of the most polluted freshwaters in Indonesia, shown by its color, smell, and the wastes. Generally, the presence of heavy metals is an indicator of pollution in any river. Furthermore, the survival of waters biota is determined by the pollution levels of the water and sediment, including the *Pterygoplichthys pardalis* fish dominating the river. The purpose of this study therefore was to record the concentration of heavy metals in water, sediment, and *P. pardalis* in the Ciliwung River from upstream in Bogor to its downstream in Jakarta. The X-Ray Fluorescence (XRF) spectrometer was used to analyze the metals. The results showed that the concentrations of heavy metals such as Cd, Hg, and Pb were relatively high in the water and sediment of the river, exceeding the threshold of Indonesian Government Regulation. The highest concentration of these metals was found in the samples from Ciliwung River Jakarta area. The concentrations of these metals were quite high in the *P. pardalis* flesh exceeding the threshold set through the provisions of National Agency of Drug and Food Control (BPOM) and Indonesia National Standard (SNI). On analysis, there was a strong correlation between the metal content of fish flesh and sediment. This shows that the metals in the flesh were influenced by the accumulation of metals in the river sediments.
Key Words: armoured catfish, contamination, indicator, pollution, watershed.

Introduction. Ciliwung River is one of the river in Indonesia with main flow length of over 120 km, crosses the cities of Bogor, Depok, and Jakarta, as well as in Bogor Regency (Hadiaty 2011; Yudo & Said 2018). This river has many important functions, such as a raw water sources for drinking water, fisheries, livestock, agriculture and urban businesses. Increasing population and industrialization development commonly give rise to river water pollution. Due to the domestic and industrial activities in these regions, the river is highly polluted from the upstream in Bogor Regency, to the downstream in Jakarta. One of the indicators of its pollution is the presence of heavy metals in the watersheds. The contaminants found in the river are mainly heavy metals such as lead (Pb), mercury (Hg), cadmium (Cd), iron (Fe), manganese (Mn), zinc (Zn), chromium (Cr), copper (Cu), and nickel (Ni), originating from industrial and household wastes (Yudo 2010; Yudi & Said 2018; Mulyaningsih et al 2020).

The development of food, printing, timber, motorcycle, iron, fishery, livestock, and other industries along the Ciliwung River, is the sources of these heavy metals. Additionally, community activities along the banks impacted its level of pollution. The domestic wastes are dominated by high concentrations of BOD-COD, ammonia, phosphate, detergents, and *Escherichia coli* bacteria. This high level of pollution affects the ecosystems and biota such as the fish species found in this river (Yudo 2010; Yudo & Said 2018; Ratnaningsih et al 2019; Mulyaningsih et al 2020).

Based on some previous studies, one of the fish species found in Ciliwung River is the *Pterygoplichthys pardalis* (Hadiaty 2011; Elfidasari et al 2016; Rosnaeni et al 207). It originates from the Amazon river and introduced from Central and Southern America. This fish species dominated the river and is widely used by food sellers. Previous studies shown that the flesh could be used as raw materials for processing food products such as *siomay* (dumplings), *otak-otak* (grilled fish cake), *empek-empek* (savory fish cake), and fish chips (Mahdiah 2010). The existence of *P. pardalis* in this polluted water is major a concern due to the presence of heavy metals which enter the fish through bioaccumulation. The result of research conducted by a number of researchers reported the presence of Cd, Hg and Pb in the fish. Considering this fact, most stakeholders are concerned about the potential increase of the metals in the fish which is commonly eaten by most people (Dhika 2013; Hardi 2013; Alfisyahrin 2013; Ismi et al 2019). Foods with heavy metals have the potential of causing poisoning when consumed. Heavy metals can play a role in the development of carcinogenic and non-carcinogenic diseases (Jaishankar el al 2014; Baghaie & Fereydoni 2019; Shen el al 2019; Ghosh 2020).

With the nature of the Ciliwung Watershed, there is a high tendency that the water and sediment in the downstream, which is Jakarta region, are more contaminated. Based on the background, it is therefore important to conduct a research which aims to show the concentration of heavy metals in the water, sediment, as well as the flesh of *P. pardalis* fish from three watersheds such as Bogor, Depok, and Jakarta. Additionally, it also aims at proving that the highest concentrations of the metals are at in Jakarta Ciliwung River.

Material and Method

The research objects. The research objects include water, sediment and *P. pardalis* from three locations along the Ciliwung River, such as in Jakarta, Depok, and Bogor. The number of fish used was 30, selecting 10 samples from each location. The size of each fish ranged from 280 to 500 cm and weight from 250 to 450 g.

Description of the study sites. There were three sampling locations representing upstream to downstream of the river. The first (A) is the Ciliwung watershed in MT. Haryono street, Ciliwung, Cawang, Central Jakarta with longitude coordinates of 6°14'36.50" S and latitude of 106°51'45.03" E. The second location (B) is in Poncol street, Depok with longitude coordinates of 6°21'41.9" S and latitude of 106°50'18.3" E. The third one (C) is in Otto Iskandardinata street, Bogor with longitude coordinates of 6°36'08.8" S and latitude of 106°48'08.7" E (Figure 1).

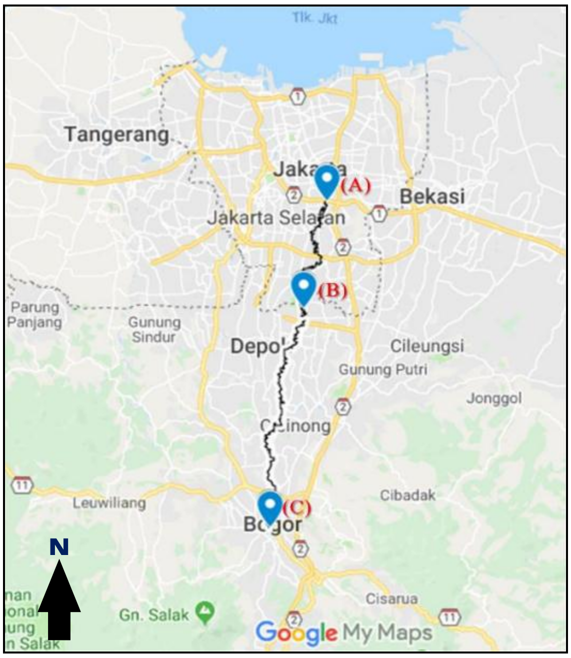

Figure 1. The sampling location of *Pterygoplichthys pardalis* in Ciliwung Watershed. (Source: Google Maps).

Sampling technique. The purposive sampling technique was used to select the study objects. Samples were taken from the original population of *P. pardalis* in the Ciliwung River at three main locations namely the upstream, middle and downstream using the SNI 6989.57.2008 method (BSN 2009). In addition, the water and sediment sampling was conducted on the area or habitat of the fish at the time of collection. The sampling was comparatively conducted starting from the surface, middle and bottom of the water. The fish were placed inside labeled plastic bags and bottles.

Preparation of P. pardalis samples. The fish samples were dissected with the fleshy parts being separated from the bones and skin through the filet technique. The flesh was weighed on an analytical balance with an accuracy of 0.0001 g and then placed in crucibles and dried in an oven at 60°C for five days. The dried flesh samples were weighed using a digital balance, crushed and placed in a plastic ziplock bags. Furthermore, the dried samples were filtered on a 200 mesh sieve and then placed in the oven at 105°C for 2 hours.

Preparation of sediment and water samples. The water and sediment samples were placed into glass beakers, each measuring 1,000 mL. The water sample was heated for 12 hours, then placed in the oven at 105°C for 4 days, while the sediment, with the beaker, was directly placed in the oven at the same temperature for 5 days allowing it to properly dry. Subsequently, it was analyzed with X-Ray Fluorescence (XRF).

Metal content analysis. The metal analysis was performed using the XRF spectrometer based method (Ene el al 2010).

Data analysis. Both qualitative and quantitative data were used in this study. Parameters analyzed included environmental factors, metal contents in water, sediment and flesh at each sampling location. This was performed using PCA analysis with the Past3 program (Hammer 2019).

Results and Discussion

Physical condition of Ciliwung River. The Ciliwung River is acidic with a pH in the range of 6.96 and 7.26. The ANOVA showed a p value of 0.065, which means there was no significant difference in the average sediment pH based on the sampling locations. The water in the river has a pH in the range of 6.65 and 6.79. Similarly, the ANOVA showed that there was no significant difference in the average pH based on the sampling locations, with a p-value of 0.508. According to (Soewandita & Sudiana 2010), this is due to the rise in the level of domestic waste on getting closer to the downstream river in Jakarta, especially alkaline wastes such as soap. In general, the pH range in the study is normal and included in the safe category (Diyanti et al 2018; Yudo & Said 2018; Ratnaningsih et al 2019). The pH of the Ciliwung river water and sediment was still normal in accordance with the standards of the Government Regulation number 82/2001 concerning the Management of Water Quality and Water Pollution Control (Ministry of Environment of the Republic of Indonesia 2001).

The water temperatures at the three locations ranged from 25 to 26ºC (Table 1). Then, a p-value of 0.161 was obtained through ANOVA, indicating there was no significant difference in the average water temperature based on the sampling locations. The temperature changes can occur directly and indirectly caused by changes in land uses system, backflow of agricultural irrigation, flow modification, water transfer between basin, changes in vegetation to riparian, global warming an closure factors in riparian (Al-Badaii et al 2013; Yudo & Said 2018; Ratnaningsih et al 2019).

Generally, dissolved oxygen (DO) is an important water quality parameter because its value determines the level of pollution in water. It is very influential on aquatic life and biochemical processes. DO also determine the resistance level of aquatic organisms toward contaminants and necessary for aquatic biota to survive. DO in the Ciliwung watershed ranged from 3.4 to 5 mg L^{-1} (Table 1). These values exceed the water quality standard limits in class III based on Government Regulation No. 82/2001. DO in waters vary and it is influenced by temperature, salinity, water turbulence, atmospheric pressure and the presence of organic waste entering the river (Al-Badaii et al 2013; Ling et al 2017; Ratnaningsih et al 2019). Based on the results, there was a decrease in the DO in Ciliwung River starting from upstream to downstream as Bogor had 5 mg L^{-1}, Depok 4 mg L^{-1}, and Jakarta 3.5 mg L^{-1}. This is consistent with the research conducted by Yudo & Said (2018), who showed a decrease in the DO of the Jakarta Ciliwung River from the upstream at the Kelapa Dua to downstream at the Istiqlal sampling location, with values from 3.5 to 2 mg L^{-1}. This decrement was caused by pollutant loads entering the waters (Ling et al 2017; Wang et al 2020). This affirms the fact that the pollution level in the downstream is higher than in the upstream. Furthermore, the DO from the three sampling locations exceeded the threshold set by the government in GR No. 82/2001 (Ministry of Environment of the Republic of Indonesia 2001).

Table 1

Chemical and physical conditions of the Ciliwung Watershed

Parameter	*Average values*			
	Jakarta	*Depok*	*Bogor*	*Water quality standards class III according to GR No. 82/2001*
pH of sediments	6.96±0.17[a]	7.23±0.28[a]	7.26±0.55[a]	6-9
pH of water	6.73±0.5[a]	6.79±0.13[a]	6.65±0.15[a]	6-9
Temperature (ºC)	26.13±0.83[a]	25.53±0.83[a]	25.80±0.86[a]	-
DO (mg L^{-1})	3.4	4	5	3

Concentration of heavy metals in the water and sediments of the Ciliwung River. The analysis results of the water and sediment samples showed the presence of heavy metals such as Cd, Hg and Pb (Table 2). This is due to household wastes, pesticides, natural weathering of rocks, traffic activities, as well as waste water disposal into the river (Gafur et al 2018; El-Metwally et al 2019; Fatima et al 2020; Kumar et al 2020). The highest concentration of Cd was found in Jakarta, with concentrations of 6.3±0.3 mg L^{-1} in water and 1.6±0.2 mg L^{-1} in the sediments. Also, the Cd concentration exceeded the quality standard, as shown in Table 2. This is caused by the high amount of domestic waste. The secondary data obtained also reported the presence of cigarettes, textiles and electronics industries around the Ciliwung River flow in Jakarta and Bogor regions. Cd metal is widely used in various industries in the processing of food, beverages, paper, textiles and electronics (Mensoor & Said 2018; Bhuyan & Anandhan 2018; Abdel-Kader & Mourad 2019). The source of Cd pollution in the Ciliwung River watershed is suspected to be from industrial wastes dumped into the river.

Table 2

Heavy metal concentrations (mg L^{-1}) in the water and sediments in the Ciliwung River

Category	*Metals*	*Location*			*Quality standards**
		Bogor	*Depok*	*Jakarta*	
Water	Cd	<0.3±0	1.3±0.1	6.3±0.3	0.01
	Hg	2±1.4	<0.7±0	<0.7±0	0.002
	Pb	59.9±0	4.2±0.4	73.8±1.5	0.03
Sediments	Cd	1±0.1	0.9±0.1	1.6±0.2	0.1-2
	Hg	<0.7±0	<0.7±0	1.8±0.9	0.02-0.035
	Pb	26.1±0.9	32.7±0	58.6±1.1	−20

* - Quality standards: water class III GR No. 82/2001 (Ministry of Environment of the Republic of Indonesia 2001).

The highest Hg concentration was found in Bogor at 2±1.4 mg L^{-1}, while Depok and Jakarta had the lowest concentration at <0.7±0 mg L^{-1} (Table 2). This value also exceeded the quality standard of the metal in water in accordance with Government Regulation, which is set at 0.002 mg L^{-1}. In addition, the sediment with the highest Hg content was found in Jakarta, at 1.8±0.9 mg L^{-1}. This also exceeded the quality standard value of 0.02-0.035 mg L^{-1}. The high concentration of this metal in Bogor is as a result of industrial and hospitals wastes being disposed without prior processing. The data from the Central Statistics Agency in Bogor showed that the area is dominated by machinery, metals, textiles and electronics industries (BPS 2019). These industries are suspected to be the main cause of this high level of metal. The secondary data also showed the presence of industries and hospitals in this region. A high concentration of Hg is caused by wastes from electronic, chemical plants, metal mining, textile, and paper (Angelovicova & Fazekasova 2014; Ernawati 2014; Gafur et al 2018; Tariq et al 2019; Abdel-Kader & Mourad 2019).

The highest Pb in water samples were found in Jakarta and Bogor at 73.8±1.5 mg L^{-1} and 59.9±0 mg L^{-1} respectively, while the lowest was in the Depok at 4.2±0.4 mg L^{-1} (Table 2). However, the highest Pb in the sediment was found in Jakarta at 58.6±1.1 mg L^{-1}, which exceeded the quality standard of 10-20 mg L^{-1} (Ministry of Environment of the Republic of Indonesia 2001). The amount of Pb in the water also exceeded the threshold set by the government at 0.03 mg L^{-1}. The high level of Pb in both water and sediments is attributed to the presence of industries along the Ciliwung River. Pb pollutants come from wastes disposed by batteries, telephone cables, paint coloring, ceramics and pipe industries (Gunther 2019; Sharma & Bhattacharya 2017; (Gunther 2019; Sharma & Bhattacharya 2017; Tchounwou et al 2012). The secondary data obtained from BBWS (River Basin Center) of Bogor also showed that (local water company (PDAM) takes water from the river through pipes, which contain Pb. This could be another reason why the level of this metal is high in both water and sediments of Ciliwung River.

Wastes from industrial activities could pollute both the water and biota in the river (Sharma & Bhattacharya 2017; Islam et al 2018; Tariq et al 2019; El-Metwally et al 2019; Fatima et al 2020). In addition, some of the industrial wastes flow with the river from Bogor and Depok to Jakarta, thereby raising the level of pollution in the region. Furthermore, the water analysis reported higher pH in Jakarta compared with the remaining two regions, which is an indication that the downstream of the river experiences higher pollution. According to Yudo & Said (2018), the high metal content could be observed based on the low DO in Jakarta of the river and low DO is an indication of high metal contamination in waters.

The water and sediment conditions of the Ciliwung River in Jakarta in 2015 were still below the quality standard threshold (Ibad 2015). However, the current research shows some level of increment in the concentration of heavy metals in Jakarta watershed. This is due to accumulation experienced at the downstream part of the river. The heavy metals dissolve in water to undergo sedimentation, which is then carried by river currents from upstream to downstream. The level of heavy metals increases moving closer to the downstream regions in Ciliwung River as shown in Table 2 (Mohiuddin et al 2010; Shanbehzadeh et al 2014; Hua et al 2016; Gabrielyan et al 2018; Dra et al 2019).

Moreover, the high concentration of heavy metals in Ciliwung River is due to developmental activities along the watershed. These activities carried out by the government are classified as very intensive, both in the upstream and downstream of the river along with very high population growth. The use of land for industrial and residential purposes contributes to the rise of pollutants in the river (Khatri & Tyagi 2015; Haseena et al 2017; Chamara & Yamada 2017; Camara et al 2019). Pollution in Jakarta region is as a result of various residential and industrial activities (Yudo & Said 2018; Ratnaningsih et al 2019; Mulyaningsih et al 2020). This is consistent with what was observed during this study as there were various human activities such as disposing of wastes, washing of clothes and dishes, and bathing around the river banks. Also, industrial wastes are directly dumped into the river without prior processing.

Heavy metal concentrations in P. pardalis flesh. The concentrations of heavy metals in the fish flesh are different based on the sampling locations. The highest concentration of Cd was found in Bogor at 0.4 mg g^{-1}, followed by Depok at 0.3 mg g^{-1} and then Jakarta at 0.2 mg g^{-1} (Figure 2). These results showed that the concentration of Cd from the three sampling locations exceeded the safe consumption threshold set by the government at 0.10 mg g^{-1} (BPOM RI 2017; BSN 2009) as shown in Table 3.

Table 3

Standard quality of metal content (mg g^{-1}) in fish flesh

Metal	*BSN (2009)*	*BPOM (2017)*
Cd	0.10	0.10
Hg	0.50	0.06
Pb	0.30	0.20

The concentration of Cd in *P. pardalis* flesh from Ciliwung River in 2009 was 0.003 ppm (Ratmini 2009). In 2013 and 2014, the concentration of Cd in *P. pardalis* flesh from the same river was less than 0.005 ppm four years later (Dhika 2013; Ernawati 2014). Similarly, the concentration of Cd in the fish flesh was less than 0.005 ppm within the period, which was still below the standard limit. However, in this study, the concentration of Cd is relatively higher in the flesh (Figure 2). The concentration is above the maximum standard declared by the National Standardization Agency (BSN 2009) and National Agency of Drug and Food Control Indonesia (BPOM RI 2017). The high content of Cd in fish is due to accumulation of Cd in the organs and body of fish. Bioaccumulation is the net result of the interaction of uptake, storage and elimination of a chemical. Cd that enters into the aquatic ecosystem may not directly impart toxicity to the organisms at low concentrations. Nevertheless, it can be accumulated in aquatic organisms including *P. pardalis*, via the food chain process and eventually threaten human health as they consume fish. Accumulation of metal in the tissues organism depends mainly on water concentrations, bioavailability and fish trophic position (Perera et al 2015; Rodriguez et al 2015; Sauliutė & Svecevičius 2015).

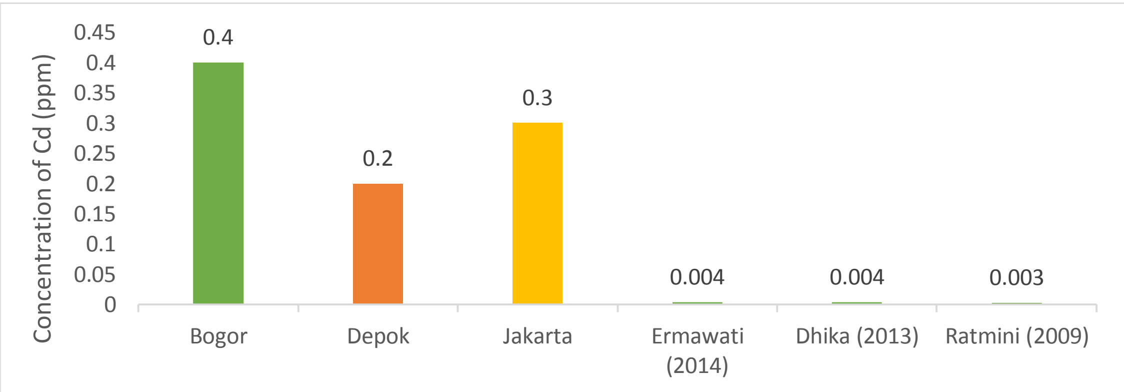

Figure 2. Concentration of Cd (ppm) in *Pterygoplichthys pardalis* flesh.

The highest concentration of Hg was found in the *P. pardalis* from Jakarta at 1.3 ppm, followed by Depok at 0.6 ppm, before Bogor at 0.5 ppm (Figure 3). Based on these sampling locations, Hg in the fish exceeded government threshold set between 0.50 ppm (BSN 2009) and 0.06 ppm (BPOM RI 2017). In addition, research in 2009, 2013 and 2014 showed that the concentration of Hg in *P. pardalis* flesh from Ciliwung River was less than 0.001 ppm, meaning it was below the government standard (Ratmini 2009; Hardi 2013; Ernawati 2014). However, this could lead to poisoning when consumed for a long period because Hg is bioaccumulative (Marusczak et al 2011; His et al 2016; Bradley et al 2017). The results obtained in 2018 also showed an increase in Hg concentration compared to previous years and exceeded the safe threshold limit. In this study, the Hg pollution in Ciliwung River water comes from anthropogenic sources, similarly with the previous study in several waters (His et al 2016; Bradley et al 2017; Gafur et al 2018; Abdel-Kader & Mourad 2019). The distribution and accumulation of heavy metals varied among aquatic organisms. It depends on the species, the concentration of the heavy metals in the water, the pH, the organism's growth phase, the organism's ability to change locations, size of ecosystem, feeding habitat and trophic position of fish (Hardi 2013; Ernawati 2014; His et al 2016; Bradley et al 2017). The highest Hg concentration in *P. pardalis* was found from Ciliwung River Jakarta Region, which is lowland compared to Depok and Bogor. Jakarta bay is downstream of the Ciliwung River. According to Marusczak et al (2011), the high Hg concentration in fish population can be explain by the fact that Jakarta region are situated in latitude, and this region are located so close with anthropogenic sources of pollution.

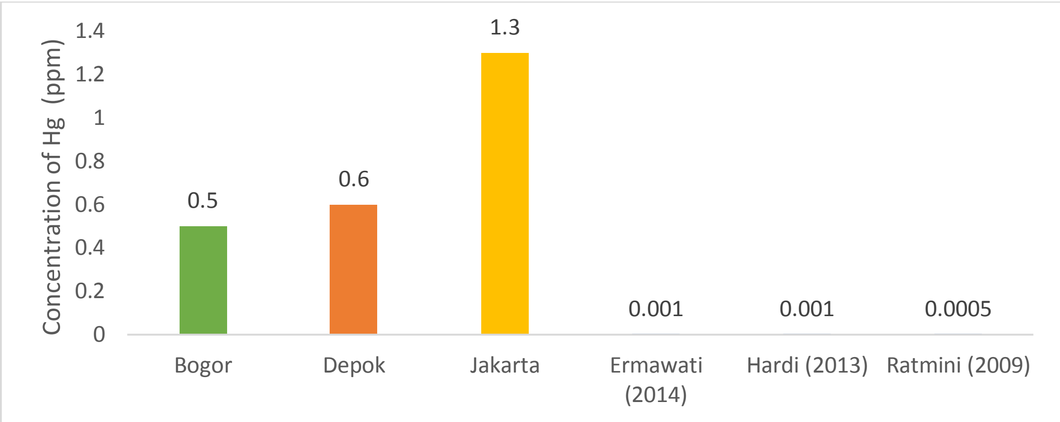

Figure 3. Concentration of Hg (ppm) in *Pterygoplichthys pardalis* flesh.

The highest concentration of Pb in flesh was found in the fish flesh from Jakarta (2.25 ppm), and the lowest was from Bogor 1.90 ppm (Figure 4). These values exceeded the safe consumption limit of fishery products set between 0.30 ppm (National Standardization Agency - BSN 2009) and 0.20 ppm (BPOM RI 2017). This means that *P. pardalis* flesh is unsuitable for consumption. According to Ratmini (2009), *P. pardalis* in Ciliwung River contained Pb at a concentration of 0.02 ppm, which was less than the set threshold. However, Alfisyahrin (2013) and Ermawati (2014) showed that the metal concentration was 2.88±1.93 ppm, which had increased and exceeded the threshold limit. In addition, this value was higher than the concentration in 2009 and 2018.

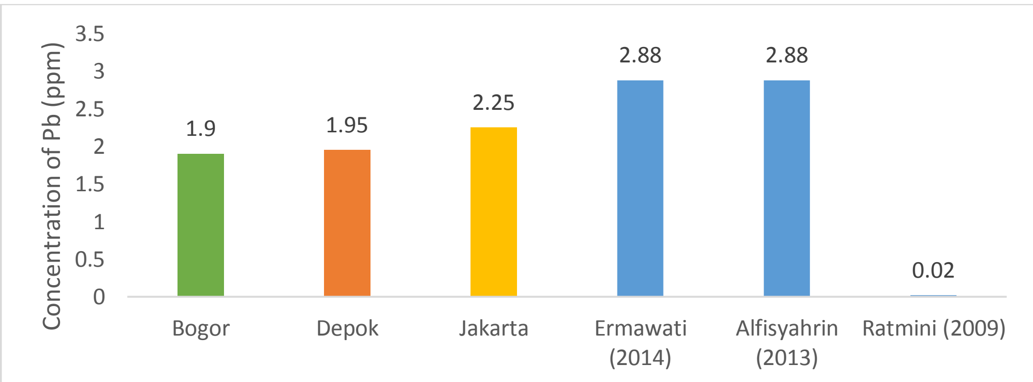

Figure 4. Concentration of Pb (ppm) in *Pterygoplichthys pardalis* flesh.

The increase in Pb concentration of *P. pardalis* flesh from Ciliwung River is influenced by the increase in the Pb content of Ciliwung river water. The Pb degree contamination in fish is determined by their habitat (depending on the degree of water pollution), duration of exposure to pollution and the eating habits of the fish (Winiarska-Mieczan et al 2018). This accumulation of metals may occur through contamination of water bodies which serve as habitat to the fish as well as from elemental heavy metals, which is mainly caused by anthropogenic activities and processing methods (Egbeja et al 2019).

Pb enters the body of a fish through the food chain, gills or diffusion through the surface of the skin (Suprapto et al 2019). The degree of Pb contamination in fish is determined by their habitat (depending on the degree of water pollution), duration of exposure to pollution and the eating habits of the fish. It is a known fact that predators accumulate much more toxic metals in their tissues since the metals are capable of accumulating in the organism and are thus transmitted to a higher level of the food chain (Winiarska-Mieczan et al 2018). The presence of heavy metals in the environment is consequently accumulated in fish tissues due to metabolic activities and bio-absorption process. Rashed (2001) found that elevated Pb level in fishes obtained from freshwater ecosystem is affected by extended agriculture, poultry farms, textile, industrial and other activities. However, the sediments could be the major sources of Pb contamination and the bottom feeders may be directly affected with this deposited element in consequence to their feeding habitat (Sarkar et al 2016).

The pollution of the river with Pb is mainly from the lead pipes used in industrial and household sewage system. According to Widowati et al (2018), waste or liquid flow through pipes results in pollutants such as Pb metal. However, the normalization process reduced the Pb in water, sediment and fish in 2018. Normalization of Ciliwung River between 2013 and 2015 led to a reduction in Pb concentration observed in 2018. This was conducted to control the increasingly high pollution in the river (Ministry of Public Works and Human Settlements 2015; TNI AD 2015). It was achieved through the collaborative efforts of several agencies and stakeholders in the society. Government institutions involved include Jakarta Regional Government, *Kodam* (Regional Military Command) Jaya, the Ministry of Public Works and the Ministry of Environment. Some activities carried out included cleaning up of garbage dredging, and planting of trees along the river banks. In addition, *Dankodiklat* (Indonesian Army Doctrine, Education and Training Development Command) and Commander of *Kodam* Jaya at the time, Maj. Gen. Agus Sutomo mobilized some Indonesian Army troops to conduct labor-intensive activities involving *Kodim* (Military District Commander) 0504 (South Jakarta) and 0505 (East Jakarta). Other activities conducted include cleaning up of rubbish along the riverbank from 4 km, cutting and closing pipes through which industrial wastes enter the river in South Jakarta, as well as socialization with the local community in building septic tanks for collecting human wastes.

Another factor responsible for the change in Pb content of the river biota is the seasonal difference. Sampling conducted in 2013 was during the rainy season (Alfisyahrin 2013), and Darmaga Climatology data reported the average rainfall to be approximately 300 millimeters that year. However, the sampling in 2018 was conducted in June-July when the average rainfall was around 97.33 millimeters. A previous study also reported higher concentrations of heavy metals in water during the rainy season. This is because larger amount of heavy metals on the land flow with the rain into the river (Puspasari 2006).

Correlation of heavy metal in water, sediment and P. pardalis. The correlation results of these heavy metals in water, sediment and fish flesh showed a moderate correlation between flesh and water with $r = 0.520$. There was however a strong correlation between flesh and sediment with $r = 0.792$. This indicates that the metal in the flesh is strongly influenced the metals in the sediment. Based on ANOVA, the interaction between water and sediment resulted in a p value of 0.010, which is a significant value since it is less than 0.05. This means that the metallic content of the flesh is influenced by the available metals in both sediment and water. However, the coefficients analysis results showed no significant interaction between water and metals contents of the fish flesh, indicated by a p-value of 0.991 (Table 4). The p-value of the analysis between the sediment and flesh was 0.039, indicating that the metallic content of the fish is determined by the metals in the sediment.

Heavy metals in the fish flesh were purely from water and sediments. The dissolved heavy metals in the water settle in the sediment thereby enter and accumulate in the fish due to contact between them (Cahyani et al 2016). This is in consistence with the previous research which stated that the accumulation of heavy metals in the fish occurs due to direct contact with chemicals in the environment and the high concentration of heavy metals in sea biota is influenced by its concentration in the water and sediment (Bhuyan & Anandhan 2018; Egbeja et al 2019; Hua et al 2016; Wang et al 2020).

Table 4

Coefficients test results on water, sediment and *Pterygoplichthys pardalis* flesh

Coefficients[a]

Model	*Unstandardized coefficients*		*Standardized coefficients*	*t*	*Sig.*	*95% Confidence interval for B*		*Correlations*			*Collinearity statistics*	
	B	*Std.Error*	*Beta*			*Lower Bound*	*Upper Bound*	*Zero order*	*Partial*	*Part*	*Tolerance*	*VIF*
1 (Constant)	.571	.176			.018	.139	1.003					
Water	.000	.010	-.004		.991	-.023	.023	.734	-.005	.002	.312	3.205
Sediment	.034	.013	.889	2.625	.039	.002	.067	.886	.731	.497	.312	3.205

Relationship between environmental parameters and metal content. The Principal Component Analysis (PCA) with biplot chart showed that the environmental parameters in each location played significant roles in the presence of heavy metals in water, sediment and fish flesh (Figure 5). The river in Jakarta contains a high amount of Pb in water, sediment and flesh, Cd in water and sediment, and Hg in sediment and flesh. This is due to the influence of high temperatures in the region. High temperatures in water results in the formation of heavy metal ions, thereby increasing the rate of deposition in the sediment. High water temperatures aid the dissolution of heavy metals due to the decrease in adsorption rates into particulates (Li et al 2013; Akpomie et al 2015; Yang et al 2019). The presence of Hg in water and Cd in the fish flesh in Bogor region are in quadrant II due to the relatively high DO (Figure 5). The DO in general determines the solubility of metals in water.

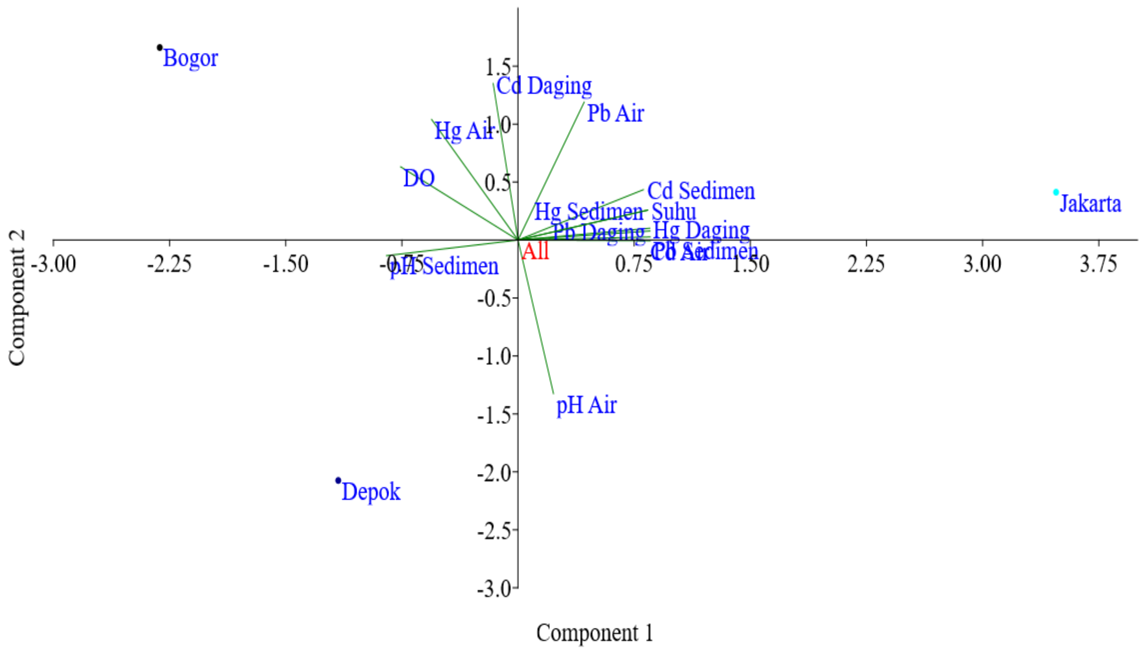

Figure 5. The results of Principal Component Analysis (PCA) analysis of the distribution of metal content in water, sediments and *Pterygoplichthys pardalis* flesh.

Based on the Factorial axes formed from the pH values, there was no relationship between the water and sediment with the content of Cd, Hg and Pb in the samples. This shows that the pH is normal. There is a relationship between pH and solubility of metals, which then determines the concentration. Low pH conditions enhance heavy metals to dissolve more in water.

In general, the river in Bogor has a high concentration of Hg in water samples, but there were no high concentrations of the metal in the water, sediment and flesh from Depok. This is because the dissolved metals upstream are continuously carried by river currents, which then accumulate downstream. This is consistent with the research by Yudo & Said (2018) that the concentration of heavy metals in Jakarta water is much higher due to the flow from the upstream downstream.

The entry mechanism of heavy metals into P. pardalis. Heavy metals enter the fish body through two mechanisms known as direct and indirect. Direct mechanism occurs through the absorption of dissolved metals and nutrients in the fish body. These are absorbed during respiration through the gills, and Pb specifically binds to the blood in the gills before circulating throughout the body (Tchounwou et al 2012; Authman et al 2015). Once absorbed in the body, they need a long time to be eliminated, thereby accumulating in the tissues or organs. The accumulation of heavy metals is usually through the gills, liver, kidneys, and flesh. Some of the metallic excreta are also reabsorbed by the biota which leads to continuous metallic rotation in the aquatic environment (Ayotunde et al 2012; Glencross et al 2020).

However, the indirect mechanism is usually through the food chain. Heavy metals enter the tissues of aquatic biota through the food chain. *P. pardalis* is a bottom feeder and also the first consumer in the food chain (Ayotunde et al 2012; Rajeshkumar & Li 2018; Ali et al 2019). During the feeding process, there is a transfer of nutrients from the preys to the predators and specifically for this food chain, plankton are the producers. These are eaten in the next stage by level 1 consumers (small fish), level 1 consumers are eaten by level 2 consumers (*P. pardalis*) and so on (Figure 6).

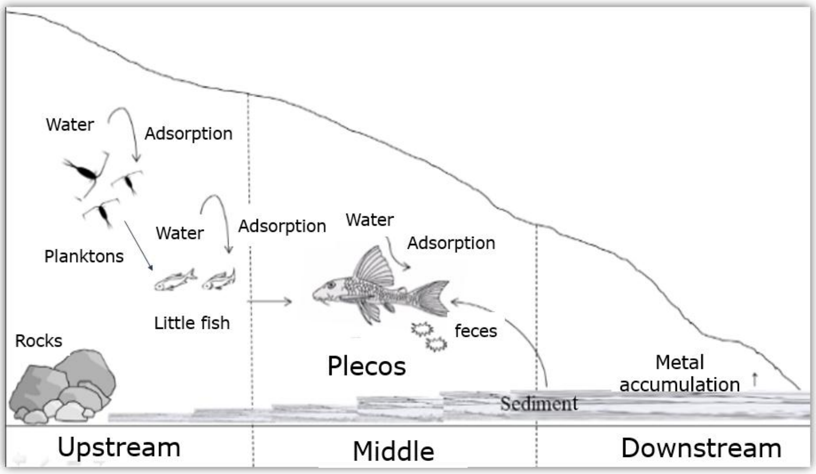

Figure 6. The entry process of heavy metals such as Cd, Hg and Pb in *Pterygoplichthys pardalis* in Ciliwung River.

The producers naturally absorb and accumulate heavy metals in their cells and when are devoured by consumers at the next trophic level, these metals are transferred to the next trophic level. This continues till it gets to the highest trophic level and the higher the trophic level, the more the metallic accumulation in the body (Mann et al 2011; Hashim et al 2014; Rajeshkumar & Li 2018).

P. pardalis, which are bottom feeders search for food by sticking to rocks, punching holes in river walls and using its suction mouth at the river bottom. Fish in the Loricariidae Order, which *P. pardalis* belongs*,* have the capacity to survive in waters with low oxygen levels, thereby accumulating heavy metals in its system (Rao & Sunchu 2017).

Conclusions. The concentrations of heavy metals such as Cd, Hg and Pb in water and sediment from Ciliwung River are quite high, exceeding the threshold set by Government Regulation No. 82 of 2001 on Class III Water for fish farming. The highest concentrations of heavy metals were found in samples from Jakarta in the downstream region. The concentrations of these metals were quite high in the *P. pardalis* flesh exceeding the threshold set through the provisions of National Agency of Drug and Food Control (BPOM) and Indonesia National Standard (SNI).

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