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The analysis of the concentration of heavy metals cadmium, mercury and lead in the flesh of suckermouth catfish (*Pterygoplichthys pardalis*) in Ciliwung River, Indonesia

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Abstract. Ciliwung River, especially the parts flowing through the cities of Bogor, Depok, and Jakarta, is categorized as a heavy-metal contaminated river. The suckermouth catfish (*Pterygoplichthys pardalis*) caught from this river is used as food products such as *otak-otak* (a cake made of fish meat and spices), fish balls, *shu may* (a dimsum-like made of fish meat and spices), and fish crackers. This could be hazardous if the heavy metal concentration in the fish flesh exceeds the level of tolerable values, thus becoming harmful to humans. This research aims to assess the concentration of the heavy metals cadmium (Cd), mercury (Hg), and lead (Pb) in the flesh of the suckermouth fish caught from the Ciliwung River basin. The fish samples were taken between September and December 2012 from three locations, i.e. Bogor, Depok, and Jakarta. The heavy metals such as mercury, cadmium, and lead were analyzed using the Atomic Absorption Spectrophotometry (AAS). The concentrations of the cadmium and mercury in the flesh of the suckermouth catfish were still below the standards set by the National Standardization Agency, i.e. < 0.005 ppm and < 0.001 mg kg^{-1}, respectively. On the other hand, the concentration of lead exceeds that of the standard, 2.63 ± 1.43 mg kg^{-1} in Bogor, 3.45 ± 2.42 mg kg^{-1} in Depok, and 2.64 ± 1.88 mg kg^{-1} in Jakarta. The suckermouth catfish caught from the Ciliwung River Basin in Bogor, Depok and Jakarta are not recommended for human consumption due to the lead concentration.
Key Words: suckermouth catfish, Ciliwung river, heavy metal concentration, pollution.

Introduction. Ciliwung River is one of the major rivers flowing through Bogor, Depok, and Jakarta. The river flows from its source in the Tugu Puncak area to the Jakarta Bay with a length of approximately 117 km and covers an area of 387 km^2 (Hendrayanto 2008). This river is utilized for domestic, industrial, animal husbandry, and agricultural needs (KLH 2011). The water of the upstream and mid-stream Ciliwung River is categorized as class IV (to be used for irrigating parks and other usages with similar water quality requirements) in the water quality standards mentioned in Government Regulation number 82 (2001); whereas the downstream has exceeded the maximum standards for any class (Moersidik & Widhiasari 2011). Heavy metals are one of the contaminants found in Ciliwung River. The heavy metals such as cadmium (Cd), mercury (Hg), and lead (Pb) were detected in this river (BPLHD DKI Jakarta 2011; KLH 2011). The sediments of this river from upstream to sea contain the heavy metals lead (between 3.8–49 mg kg^{-1}) and mercury 0.1–0.78 mg kg^{-1} (KLH 2011).

The contaminated water will affect the lives of the organisms living in it. One of the organisms susceptible to heavy metal contamination is fish. Hadiaty (2011) reported that in 2009 there were 20 species of fish found in the Ciliwung River. Five of those were non-native species and one of them was the suckermouth catfish (*Pterygoplichthys pardalis).* The suckermouth catfish has an excellent ability in adapting to poor environmental level and thus has the potential of becoming the dominant fish in tropical areas (Ploeg 2008). Some of the ability comes from the fact that this fish is large, it is equipped with hard scales, it has the habit of rearing its young until they reach adulthood

(Wu et al 2011), it has extra breathing apparatus (Fernandes-Castillo et al 2007), and there is a lack of predators which can feed on adult suckermouth catfish (Armbruster (1998) and Liang et al (2005) in Wu et al (2011)).

The abundant number of suckermouth catfish in the Ciliwung River is utilized for various food products such as *shu mai* (a dimsum-like cake), fish balls (Aziz 2010), fish crackers (Istanti 2005), and *otak-otak* (fish cake) (Mahdiah 2002). Due to the fact that the suckermouth catfish inhabit contaminated waters, concern about the contamination of heavy metals in the flesh of this fish as a result of bio-accumulation has arisen.

A study of the concentration of the heavy metals such as cadmium, mercury, and lead in the flesh of suckermouth catfish from Ciliwung River conducted by Ratmini (2009) stated that the concentrations of the three heavy metals in the suckermouth catfish's flesh were still below the maximum levels. After three years, a concern about the increase in the levels of mercury in the suckermouth catfish's flesh due to the ever-increasing pollution of Ciliwung River has again arisen. Consuming foods containing cadmium, mercury, and lead is dangerous because it may lead to acute and chronic diseases. In addition, those heavy metals tend to accumulate in tissues. Therefore, a study about the concentrations of cadmium, mercury, and lead of the flesh of the suckermouth catfish caught from the Ciliwung River needs to be conducted

This study aims to assess the current concentration of the heavy metals cadmium, mercury, and lead in the flesh of the suckermouth catfish in Ciliwung River. The information is expected to be beneficial in evaluating whether the flesh of the suckermouth catfish is fit for human consumption based on its concentration of heavy metals.

Material and Method

Sampling time and location. This study was conducted for four months in 2012, from September to December, with in the intervals of one month in three locations such as Bogor (upstream), Depok (mid-stream), and Jakarta (downstream). Figure 1 shows study location. The sampling location in Bogor was the Bogor Botanical Gardens which is at the coordinates 106º48'5.41'' E and 6º36'3.86" S; in Depok the location was on Ir. H. Juanda Street, 106º50'19.5"E and 6º22'33.27"S; in Jakarta the location was on Gunuk Street, Pasar Minggu, 106º51'0.77"E and 6º17'33.15"S. These locations were selected based on the assumption that the levels of contamination were different between upstream and downstream.

In November, no sample was taken from Jakarta because the river had flooded due to the heavy rain. Samples were there taken in December. Sediment samples were also taken along with fish samples. Sediment samples from Ciliwung River in all three locations were only taken in October 2012.

Procedures. Fish samples were taken from Ciliwung River using a cast net with 2 inch mesh. The fish that were caught were then measured and weighed.The fish were there categorized into three sizes of length, i.e., small (10.8–27.7 cm), medium (27.8–447 cm), and large (44.8–61.7 cm). Every month, two fish were selected randomly from each size group and sampling station to be dissected and 5-10 g of the flesh was taken to be analyzed for heavy metal concentration. This procedure was done at the Macro Biological Laboratory I, Faculty of Fisheries and Marine Science, Bogor Agricultural University, Bogor, Indonesia.

The fish size-groups were classified using length frequency distribution. Three fish samples taken from the large, medium, and small size groups; from each sampling were analyzed for their cadmium, mercury, and lead concentration. The body part taken was the flesh from the dorsal part of the fish. The flesh was then placed in a labeled bottle and stored in a freezer before being analyzed for its heavy metal concentration.

The sediments from Ciliwung River were taken manually by hand. The sediments taken were those found around the fish sampling points. They were then stored in plastic bags to be analyzed in the laboratory for their cadmium, mercury, and lead content.

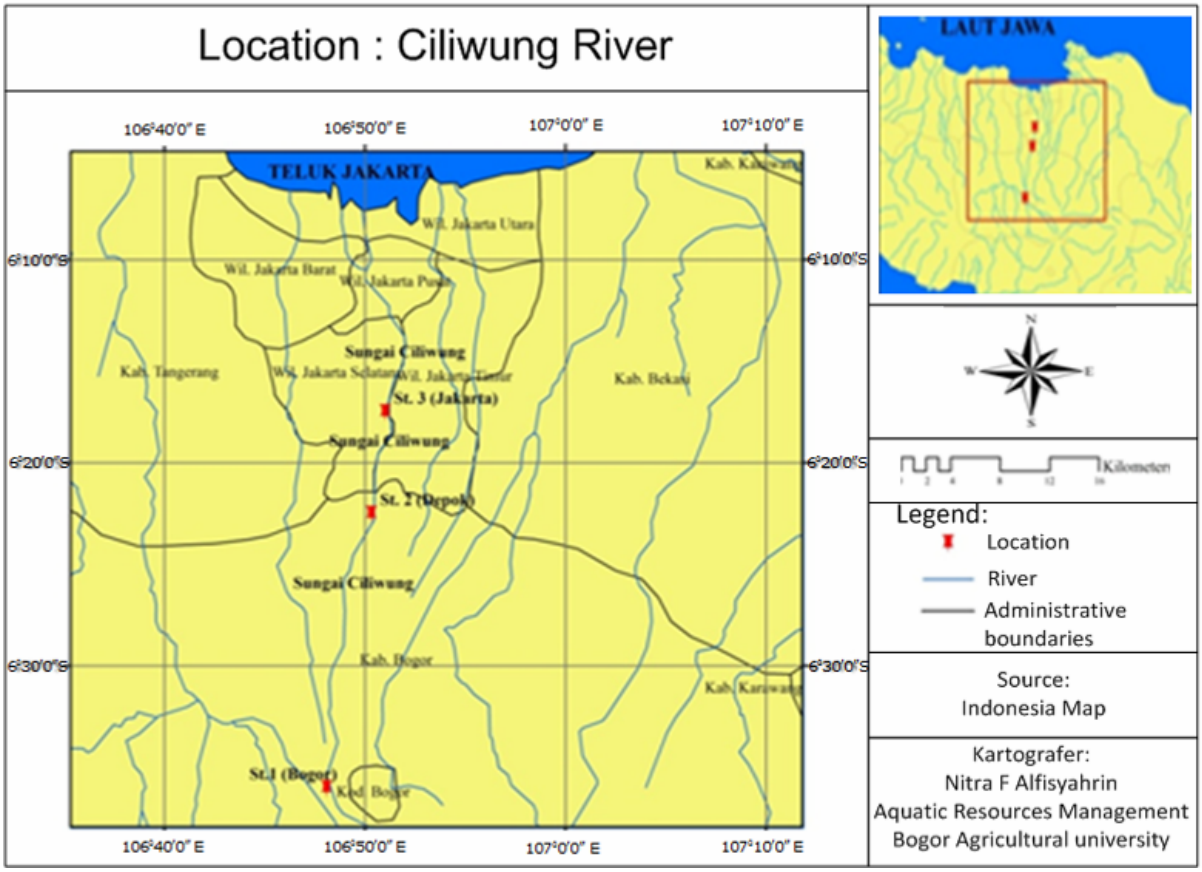

Figure 1. Study locations (Source: Alfisyahrin (2013)).

Heavy metal analysis. The method employed for analyzing the heavy metal content was using the Atomic Absorption Spectrophotometer (AAS) according to the Lambert-Beer Law. This law explains that the amount of light absorbed is proportional to the amount of heavy metals in the material. The real concentration of heavy metal can be discovered using this formula:

$$\text{Real concentration} = \frac{(D-E) \times Fp \times V}{W\,(g)}$$

Where: D: sample concentration µg L^{-1} from the AAS reading;
E: blank sample concentration µg L^{-1} from the AAS reading;
Fp: dilution factor;
V: final volume of the prepared sample solution (mL);
W: sample weight (g).

The heavy metal analysis in September was conducted in Integrated Laboratory of the Faculty of Natural Sciences and the Aquatic Environment Productivity Laboratory using the analysis procedures according to SNI 2354.5.2 (2011) (cadmium and lead) and SNI 01-2354.6 (2006) (mercury); as for the following months, the analysis was conducted in the Agricultural Industry Technology Laboratory using the APHA ed. 21th 3111B (2005) procedure analysis for the three heavy metals. The results of the heavy metal analysis of the suckermouth catfish caught in Ciliwung River were compared to the government regulations.

The average heavy metal concentration data from Bogor, Depok, and Jakarta were analyzed statistically using the two-way ANOVA with observation time as the first factor and the observation location as the second factor with the Least Significant Difference test. Statistical analysis was carried out using SPSS 18.00 software.

Results and Discussion

General condition of the sampling locations. Pollution of Ciliwung River does not only result from industrial waste, but also from domestic and household waste from housing areas and other activities such as agriculture and animal husbandry (Kusmana 2003). Based on the observation results from the three sampling stations, domestic waste and garbage thrown into and around the river have the potential to be the biggest polluters. Besides, numerous industries around Ciliwung River also have a large contribution to the pollution of Ciliwung River.

Bogor. The suckermouth catfish samples in Bogor were taken from the part of Ciliwung River which traversed Bogor Botanical Gardens. The river passed a highly populated area before entering the Botanical Garden. The river at this sampling point was relatively shallow and the water looked quite clear. A lot of human activity was observed both in and around the river.

Human activity in the river is usually fishing activities. The highly populated area alongside the river could pollute the river with domestic waste and garbage. In addition, the river is located near busy highways which could also pollute the river. The river bed of Ciliwung River where it passes through Bogor Botanical Gardens is dominated by large and small stones. The river banks are also fortified with concrete. In the river, there were piles of refuse which collected near the riverside. According to the locals, suckermouth catfish are caught only when there are orders. The size of the fish caught in Bogor was between 32 and 54 cm.

Depok. The sampling of suckermouth catfishin Depok was done in the part of Ciliwung River which is near Ir. H. Juanda. The sampling point was in a highly populated area and was surrounded by busy roads. In contrast to the observation station in Bogor, the river banks were not fortified with concrete, making it possible for soil to be washed into the river, tinting the water a brownish color. The river sediment was dominated by mud and some large rocks and the riverside was still populated by large, shady trees. Around the observation location, household waste was found; garbage on the river banks or caught on the rocks. According to direct observation, at the sides of the river, the current was slow, but towards the center, it was quite rapid.

According to the locals living around the station, there are fishermen who often catch suckermouth catfish, selling them in the form of flesh fillets. The size of the fish caught in Depok was between 26 and 41.5 cm.

Jakarta. The suckermouth catfish samples from Jakarta were taken from the part of Ciliwung River which passed Gunuk Street, Pasar Minggu. The sampling point was in a highly populated area. The water passing through this station was brownish. The current was not so fast during observation. The river's sediment was dominated by mud and garbage.

Based on the results of interviews with the locals, suckermouth catfish fishing is done quite frequently. These were done either by locals or by outsiders. These fishermen fished for twice a month, always using a *getek* (a self-constructed raft) which travels upstream to Depok. The size of the fish caught in Jakarta was between 10.8 and 38.5 cm.

Heavy metals in the sediment. The concentration of heavy metals depends on the amount of heavy metal waste entering the waters. The more waste entering the waters, the higher the concentration found in the waters. The heavy metals which enter water body will undergo sedimentation, dilution, dispersion, and then they will be absorbed by the organisms living in the waters (Hutagalung 1984). The heavy metals which settle at the bottom will be stored in the sediment. The sediment type of sampling point in Bogor was sandy, whereas the sampling points in Depok and Jakarta were muddy. There was no difference in the concentration of cadmium and mercury found in the three locations. The concentration of heavy metals found in the sediment was insignificant that the exact

amount could not be determined. The concentration of heavy metals in the sediments in this study is presented in Table 1.

Table1

The concentration of the cadmium, mercury and lead in the sediments of Ciliwung River

Heavy metal	*Sampling location*		
(mg kg^{-1})	*Bogor*	*Depok*	*Jakarta*
Cadmium	<0.005	<0.005	<0.005
Mercury	<0.001	<0.001	<0.001
Lead	7.23	7.97	8.9

The concentration of lead found in the sediment of upstream, midstream, and downstream Ciliwungriver increases as the river progresses downstream. The concentration of lead in the sediments from every station exceeds the EPA (United States Enviromental Protection Agency) (1973) standard, 5 mg kg^{-1}. This is in line with Sjafri's (1988) statement that in general, the concentration of heavy metals increases midstream and downstream. This is because the river flow carries sediments containing heavy metals from upstream to downstream.

Heavy metals in suckermouth catfish's flesh. The fish caught from Bogor were mostly large, at the size of 32 and 54 cm and weighing 945.8 g in average with a standard deviation of 336.99. The fish caught from Depok were mostly medium, at the size ranged from 26 and 41.5 cm and weighing 285.88 g in average with a standard deviation of 129.74. The fish caught from Jakarta were mostly small, within the length range of 10.8 and 38.5 cm and weighing 183.22 g in average with a standard deviation of 112.50.

The heavy metals enter the suckermouth catfish's body not only through the food chain but also through respiratory system. According to Taylor (1995), when the fish breathes, the water will pass through the gills and an exchange of O_2 thus CO_2 is be located in the gill's filaments. The gill filaments which are very thin are potential pathaway of metal ions passing through the gills and bound by hemoglobin. Hemoglobin is aranged for transporting oxygen from the gills to all parts of the body; therefore, if there are any heavy metal ions bound by the hemoglobin, they will be distributed to all of the body tissues (Klaassen 2008).

Cadmium. The concentration of cadmium in the suckermouth catfish's flesh caught from Ciliwung River was very low, that is <0.005 mg L^{-1}. This was comparable to the results of a study conducted by Ratmini (2009), who stated that the concentration of cadmium in the suckermouth catfish's flesh caught from Ciliwung River was <0.003 mg L^{-1}. This result was relevant to cadmium concentration in the water body, while Arief et al (2012) reported that cadmium concentration was relatively 0.02–0.06 mg L^{-1}.

Cadmium enters the human body through ingestion of contaminated food and drink (Sudarwin 2008). The National Standardization Agency (Badan Standarisasi Nasional) has set the maximum level of cadmium tolerable in foods in SNI 7387 2009. According to this regulation, fish and fish products may contain no more than 0.1 mg kg^{-1} cadmium. The concentration of dissolved cadmium lethal to crustaceans in 24 to 504 hours is 0.005-0.15 ppm (Tarigan & dan Rozak 2003). In fish given a dose of 0.002 mg L^{-1} of cadmium, a widening of the gap between secondary lamellae can be found, reducing the gill filtration rate. In addition, hypertrophy of gill filaments can be found in the fish *Fundulus heteroclitus* given a dose of 50 mg L^{-1} cadmium for 20 h (Hughes et al (1979) in Darmono (2006)).

The concentration of cadmium in the suckermouth catfish's flesh is still safe to consume according to the cadmium heavy metal parameters because it is still below the maximum standard declared by the National Standardization Agency. In addition, according to EC (2006), the allowed concentration of cadmium in the flesh of fish is no more than 0.050 mg kg^{-1} wet weight. Malaysia has determined standard in 1999, 1.0 mg

kg^{-1} (SNI 2009). However, it is not advisable to consume this fish considering the content of other heavy metals in its flesh.

Mercury. The concentration of mercury found in the flesh of suckermouth catfish caught in September which was analyzed using the AAS method showed a result of <0.001 ppb (parts per billion). The analyses in October and November using the APHA ed. 21th 3111B method (2005) showed results of <0.001 ppm. When compared to the standards, i.e., 0.5 mg kg^{-1} (SNI 2009), 0.3 mg kg^{-1} (BPOM RI 2007), 0.5 mg kg^{-1} (EC 2006), 0.5 mg kg^{-1} (Codex 1995), and 0.5 mg kg^{-1} (Gazette Food Standards 2011), the results shown by this study were still below the maximum concentration set by the standards. Even though the concentration of mercury discovered by this study is below the standard, consumption of suckermouth catfish caught from Ciliwung River is not recommended. Fish containing mercury, even in minute amounts, are still health hazards because the mercury that enters the body will be accumulated by the organism and it will stay in the organism's tissues.

The low concentration of mercury in the suckermouth catfishis suspected because the amount of mercury that enters Ciliwung River is very small. The analyses of mercury concentration in fish flesh and sediments both show results of <0.001 mg kg^{-1}. This was supported by the results of the monitoring done by BPLHD DKI Jakarta which did mercury concentration measurements in Ciliwung River in July, September, October, and December 2011. The results showed that the concentration of mercury was <0.001 mgL^{-1}. In addition, 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, and the organism's ability to change locations (Darmono 1995). This was supported by several studies pertaining to mercury accumulation in fish, among others the study conducted by Paterson et al (2006) who did research in several lakes in Canada. The results of this study showed that the accumulation of mercury is very different in each of the organisms living in these lakes.

Lead. The concentration of lead found by this study was <0.03–7.90 mg kg^{-1}. The concentration of lead in the suckermouth catfish's flesh during the study at the observation stations in Bogor, Depok, and Jakarta were 2.63±1.43, 3.45±2.42, and 2.64±1.68 mg kg^{-1} in average, respectively, resulting in a total average of 2.88±1.93 mg kg^{-1}. This concentration exceeds the standard established by SNI, 0.30 mg kg^{-1} (Figure 2).

The differences in observation stations and the interaction between different observation stations and different sampling months did not show any significant difference in the concentration of lead in the fish flesh ($p > 0.05$). The difference in months showed a significant difference in lead concentration ($p > 0.05$). The significant difference was found in September based on the LCD test ($p > 0.01$).

The highest average lead concentration in fish flesh was found in Depok. The high concentration was due to the heavy pollution in the vicinity of the observation station. The station was located near a heavily travelled road. According to Ling et al (2012), the rainy season could increase the concentration of heavy metals in the water, and the increase in lead could be affected by the number of vehicles passing the location in a day (Sorensen 1991).

The low concentration of lead in September was because the low precipitation level affected the amount of lead entering the river from trash and vehicle exhaust. According to Olojo et al (2012), an increase in lead concentration in fish happens during the rainy season. Some heavy metals can be found in the fish during the rainy season or the concentration of some heavy metals is higher in the rainy season compared to the concentration in the dry season (Chavez et al 2006).

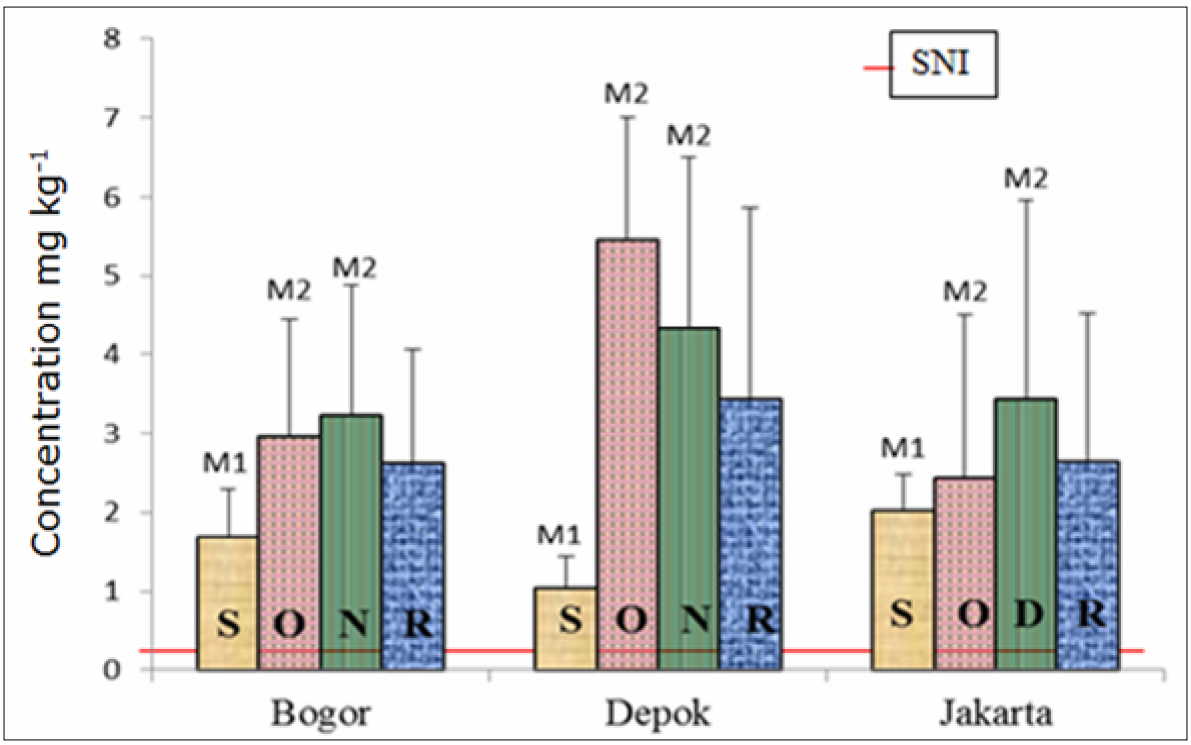

Figure 2. The average lead concentration in suckermouth catfishflesh during the study (S = September, O = October, N = November, D = December, R = Three month average, M1 = SNI SNI 2354.5 method, M2 = APHA ed. 21th 3111 B method).

The correlation coefficient value between the fish's length and the concentration of heavy metal is categorized as low, as with between the fish's weight and the concentration. However, these values are categorized as positive correlations (Table 2). Sorensen (1991) stated that the concentration of lead in the fish's entire body has no correlation to the size of the fish in some fish in Fox River, Illinois, USA. In contrast, Authman (2008) showed in the case of Nile tilapia (*Oreochromis niloticus*) that there is a positive correlation and a close connection between the length, weight, and age of the fish and the concentration of heavy metals in the fish's flesh. The conditions in the fish's habitat were very different, the value of condition factor (K) in Bogor was positive, whereas in Depok and Jakarta they had a negative correlation (Table 2). A negative correlation with the conditions and heavy metal concentration can be based on the size of the fish containing the heavy metal. Smaller fish have less fat in their tissues (Authman 2008).

Table 2

The matrix for the correlation between the total length (cm), weight (g), and condition factor (K) in the suckermouth catfish's flesh

Location	*Total length*	*Fish weight*	*K*
Bogor	0.0241	0.1790	0.3445
Depok	0.1268	0.0663	-0.0037
Jakarta	0.2558	0.0911	-0.4000

Based on the National Standardization Agency (SNI 7387 2009) standard for the maximum heavy metal contamination in food, the maximum allowable concentration for lead is 0.3 mg kg^{-1} for fish and its products. Therefore, the concentration of lead found in the flesh of the suckermouth catfish from Ciliwung River, that is 2.88±1.93 mg kg^{-1}, has exceeded the concentration allowed in food. The provisional tolerated weekly intake (PTWI) value for lead is 0.025 mg kg^{-1} body weight weekly, so the maximum limit for suckermouth catfish flesh consumption is 8.68 g kg^{-1} body weight per week. However, the concentration of lead has exceeded the maximum standard set by the government by

almost ten times. Therefore, consumption of the suckermouth catfishflesh is no longer permitted.

Conclusions. The concentration of the heavy metals cadmium and mercury in the flesh of the suckermouth catfish caught from the three observation locations were <0.005 ppm and <0.001 mg kg^{-1}, respectively. The lead concentration was 2.63±1.43 mg kg^{-1} in Bogor, 3.45±2.42 mg kg^{-1} in Depok, and 2.64±1.68 mg kg^{-1} in Jakarta. The concentrations of cadmium and mercury were still below the allowable standards for food, while the concentration of lead has exceeded the maximum standard. The consumption of the flesh of the suckermouth catfish caught in Ciliwung River and its products are not recommended.

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