Heavy Metal Contamination In Kotopanjang Dam, Indonesia

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Abstract. Heavy metal contamination has been reported in commercial fish in the Kampar River as the source of water for the Koto Panjang Reservoir. Heavy metal investigations (Pb, Cd, Zn) in water, sediment and their accumulation were carried out on 6 important commercial fish species, namely Cyprinus carpio, Oreochromis niloticus, Osphronemus gouramy, Hemibagrus nemurus, Channa micropeltes, Barbonymus schwanefeldii. Such accumulation is observed in gill, kidney and muscle tissue. The results showed that the Zn concentration was the highest in water and sediment, followed by Pb and Cd. Similar heavy metal sequence concentrations were found to be accumulated in all the analyzed tissues by means of an accumulation pattern in the kidney, followed by gills and muscle in all fish species. Metal concentrations in the muscles of all fish species meet limits for human consumption.

1. Introductions
Kampar River with a length of 413 km [1] is one of the largest rivers in Riau Province which river engineering has carried out to form a new ecosystem called the Koto Panjang Hydroelectric Dam. The main function of this reservoir was built in 1986 to function as a provider of electricity for 114 MW with an inundation area of around 12,400 ha [2, 3]. Other functions of reservoirs are irrigation, tourism and fisheries [4]. The prominent fishery activity is floating net cages (KJA) which are concentrated in the Dam Site of this reservoir. The number of cages growth recorded was 196 plots in 2003 [5] and 1,582 plots with three species. The main cultivars are: mas (Cyprinus carpio), gouramy (Osphronemus goramy) and tilapia (Oreochromis niloticus) [2]. In addition, it is also a fishing location for local fishermen with high economic value native fish commonly caught, namely baung (Hemibagrus nemurus), kapiek (Barbonymus schwanefeldii) and toman (Channa micropeltes). The demand for these six fish commodities tends to be high so that this dam plays an important role in producing freshwater fish and is a source of livelihood for the community as well as supporting regional or national food security.

Anthropogenic activities inside and outside the dam tend to increase and have an impact on increasing various organic and inorganic wastes which in turn can affect the life of fish species in this dam. Among the inorganic pollutants that must be watched out for and present in it are heavy metals such as lead (Pb) and cadmium (Cd). Both types of heavy metals were detected quite high in the upstream to downstream parts of the Kampar River as a source of dam water [6]. Lead (Pb) and cadmium (Cd) are metals that are not biologically important (also called xenobiotics or foreign substances), and their toxicity increases with increasing concentration [7] and is toxic in water [8]. In contrast, zinc (Zn) is micronutrients essential to living organisms, including fish, are found in nearly every cell and are involved in nucleic acid synthesis and occur in many enzymes [7]. Zn is also involved in more complex functions, such as the immune system, nerve transmission and cell signaling [9, 10] and toxicity occurs either in metabolic deficiency or at high concentrations [11]. Essential metal deficiency can therefore cause adverse health effects,
whereas high concentrations can also result in negative effects equivalent to or worse than those caused by non-essential metals [12].

Heavy metal contamination negatively impacts the ecological balance of the receiving environment and the diversity of aquatic organisms [13]. Therefore, fish are considered as the most significant biomonitor in aquatic systems for estimating the level of metal contamination [14, 15]. Heavy metals can be absorbed by fish either from ingestion of contaminated food through the digestive tract or through gills and skin [16, 7] and accumulate in their body tissues. Heavy metal concentrations in fish tissues reflect past exposure through water and/or food and may indicate the current situation of animals before toxicity affects the ecological balance of populations in aquatic environments [17]. Until now, research on heavy metal content (Pb, Cd and Zn) in waters, sediments and fish organs (C. carpio, O. goramy, O. niloticus, H. nemurus, B. schwanefeldii and C. micropeltes) is still limited in this dam. Therefore, this research data can reflect the current health condition of the dam ecosystem and become preliminary data before major changes occur in the future.

2. Material and Method

2.1. Sampling location

This research is located in the Koto Panjang dam, Riau, Indonesia at location I (O°17'32.755" North Latitude; 100°46'31.346" East Longitude) and II (O°17'23.375" North Latitude; 100°52'52.835" East Longitude) (Figure 1) with the survey method in September - November 2019.

![Figure 1. Map of research location](image)

2.2. Sampling of water, sediment and six species of fish organs.

Water and sediment samples were taken from three different locations at two locations using the Van Dron and Ekman grab water samplers. Each of these water and sediment samples was composited separately according to location and transferred to a container or bottle of BOD (250 ml) that had been acidified. At the same location, the pH of water (pH meter Hanna HI98107), air temperature (mercury thermometer), water brightness (secchi disk), depth (fish finder), as well as DO and CO2 with [18] analysis method.

The total sample of fish was 90, consisting of 15 for each type of fish. The mean total length and weight of each fish were baung (± 278 cm and weight ± 192.59 g), kapiek (170 - 200 mm and 73 - 109 g), toman (250-330 mm and 225-438 g), mas (± 20.22 cm and ± 57.5 g), tilapia (250 - 330 mm and 315 - 639 g) and gouramy (180-290 mm and 92-398 g) obtained from fish farmers and fisherman. The gills, kidneys and muscles were taken and collected by surgery from each individual type of fish and compiled based on the type of organ, namely: gills, kidneys and muscles (at least 5 g), then put into an acidified sample bottle.
2.3. Analysis of heavy metal.
Analysis of heavy metal content in water, sediment and fish organs is carried out through crushing (acid digestion), filtering, and making standard solutions. The Pb, Cd and Zn solutions were respectively obtained from Pb(NO$_3$)$_2$, Cd(NO$_3$)$_2$ and ZnO$_3$, then each solution was diluted into 4 concentrations (0.00; 0.05; 0.1; and 1 ppm) and checked for concentration by Atomic Absorption Spectrophotometer (Shimadzu AA– 7000 flame type) with wavelengths respectively Pb 217 nm, Cd 228.8 nm and Zn 213.9 nm).

2.4. Data analysis. The analysis was carried out descriptively by referring to the literature and compared with the value of water quality standards, sediment and heavy metal contamination in national food, each of which is [19, 20, 21, 22].

3. Results and Discussion
3.1. Results
The ranges of water quality obtained from the two research locations were temperature 28-31°C, pH 6.0-6.8, DO 5.13 - 7.12 mg/L, brightness 1.45 - 2.55 m and a depth of 20.1-57 m. The ranges for Pb, Cd and Zn in water, respectively, were: 0.0054-0.0066 mg/L; 0.0043-0.0051 mg/L and 0.0122-0.0145 mg/L, and sediment, are: 0.0146-0.0186 mg/kg; 0.0133-0.0142 mg/kg and 0.2773-0.3085 mg/kg (Figure 2). The concentrations of these three heavy metals in water and sediment are still below the water and sediment with the order of concentration from highest to lowest is Zn>Pb>Cd.

![Figure 2. Heavy metal concentrations in water (A) and sediment (B)](image)

![Figure 3. The average histogram of heavy metal content in the organs of six fish species](image)
The content of heavy metals in the organs of the six fish species from these two locations was found to be different (Figure 3). From the research, it was found that heavy metal content from the highest to the lowest in each type of fish from the two locations was Zn > Pb > Cd. The highest zinc was found in the kidneys of *H. nemurus* (0.3137-0.3412 mg/kg) and the lowest was in the gills of *O. gouramy* (0.1224-0.1232 mg/kg) below the quality standard (100 mg/kg). The highest lead content in the kidneys of *H. nemurus* (0.0199-0.0259 mg/kg) and the lowest in fish muscle of *O. niloticus* (0.0051-0.0058 mg/kg) were below the quality standard (2 mg/kg). The highest Cd was in *H. nemurus* fish kidneys (0.0071-0.0105 mg/kg) and the lowest was in *O. niloticus* fish muscles (0.00257-0.00259 mg/kg) below the quality standard (0.5 mg/kg).

The ratio of heavy metal content in six fish bodies is different, even the content in each organ in the body of one type of fish is different, but the accumulation pattern of the three heavy metals was found to be the same. Ordered from highest to lowest was kidney>gills>muscle. Comparison of heavy metal content based on fish type is as follows:

**Pb:** H. nemurus > C. micropeltes > C. carpio > B. schwanefeldii > O. gouramy > O. niloticus  
**Cd:** C. micropeltes > H. nemurus > C. carpio > O. gouramy > B. schwanefeldii > O. niloticus  
**Zn:** H. nemurus > C. carpio > C. micropeltes > O. niloticus > B. schwanefeldii > O. gouramy

3.2. Discussion

The results revealed that the heavy metal content (Pb and Cd) which were toxic and non-essential were still in natural concentrations. The levels of Pb and Cd in natural fresh water were <0.05 mg/L and 0.0001-0.0.01 mg/L respectively [6], except for Zn above the quality standard of 0.05 mgL-1 [19] or 0.12 ppm [23], even the concentration is lower than previous research, namely Pb 0.011-0.017 mg/L and Cd 0.035156-0.045573 mg/L in the Kampar River [6]. Heavy metals that enter the aquatic environment will experience deposition, dilution and dispersion, then absorbed by organisms that live in these waters [24]. This high Zn indicates that anthropogenic activities of non point sources inside and outside the reservoir produce a lot of Zn. The source of this Zn is estimated from the runoff from plantation / agricultural agrochemicals and household waste and natural sources. Zn in water as free cations and zinc complexes dissolves, or can be adsorbed on suspended matter. Zinc and its compounds are widely used in commerce and medicine. Common sources are galvanized iron, zinc chloride used in plumbing and zinc-containing paints [25]. In the water, heavy metals are generated from direct atmospheric deposition, geological weathering or through disposal of agricultural, municipal, residential or industrial waste, as well as through wastewater treatment plants [26].

From this research, the content of the three heavy metals was observed to be higher in the sediment than in water in the same order in water. This is because this heavy metal in water can be adsorbed by suspended organic particles from uneaten feed and fish metabolic waste. This occurs through the passage and transfer of heavy metal ions from water into the sediment [27] through the water-sediment partitioning process, which is the transfer of metals from dissolved forms in water into the sediment through the adsorption process, especially those rich in organic matter [28], so that it accumulates high in the sediment. Finally, the sediment in the aquatic environment serves as a pond that can hold metals or release metals into the water column by various remobilization processes [29]. Surface sediment becomes a layer that controls metal exchange between sediment and water [30] so that it can be a sensitive indicator of contaminants in water systems [31].

Zinc (Zn) is the second most abundant trace element after Fe and is an essential micronutrient in living organisms, found in almost every cell and involved in nucleic acid synthesis and occurring in many enzymes [7]. From this study, the kidneys were the target of high Zn accumulation in six types of fish and followed by the lowest accumulation in gill organs. Fish kidneys are considered to be the target organ for Zn accumulation [32], although the main targets for waterborne Zn toxicity are gills [10], because Ca2+ uptake is impaired, leading to hypocalcemia and eventual death [33]. Other toxicity end points varied between freshwater and marine fish with the most common being survival, growth, reproduction, and hatching [10],
respiratory and cardiac changes, and many additional adverse effects threatening fish survival. The gills, liver, kidneys, and skeletal muscles are damaged [34]. However, the excess Zn in the fish body will be excreted through the existing excretion system [35] so that this Zn is below the quality standard (100 mg/kg).

Pb is a naturally occurring substance, its environmental concentration is significantly increased by anthropogenic sources [36, 37] and is a dangerous persistent heavy metal [38]. Aquatic organisms accumulate Pb from water and food, although there is evidence that Pb accumulation in fish is likely to be This is mainly derived from contaminated water rather than food [39]. Accumulation of lead in different fish species has been found in several studies [40]. In this study, kidney organs accumulated higher Pb, followed by gills and muscles. This is in accordance with [6] research which found high Pb accumulated in the kidneys of H. nemurus from the Kampar River. Lead deposits in various fish organs such as the liver, kidneys and spleen, but also the digestive tract and gills. Although usually the Pb level in fish is found highest in the gills, followed by the digestive tract and fish meat. This corresponds to the physiological processes in the fish body [41].

Cadmium is a naturally occurring non-essential trace element and its tendency to accumulate biologically in living organisms is often in dangerous levels thereby increasing environmental concern [7, 32, 42]. As a cumulative pollutant that is not degraded, Cd is considered capable of changing the trophic level of waters [34]. This heavy metal has been shown to accumulate mainly (about 75%) in the kidneys, liver and gills of freshwater fish [43], but can also be deposited in the liver [44] and other tissues [45]. This research found a high accumulation of Cd in the kidneys of the six types of fish studied, followed by gills and muscles, especially in the kidneys of H. nemurus fish. The same research also found in H. nemurus fish kidneys from the Kampar River. The structure of the fish kidney cells has abnormalities such as mineralization, necrose, infection and inflammation of lymphocytes [6]. In addition, Cd inhibits calcium absorption in gills [46] and can alter the metabolism of essential trace elements by influencing the normal tissue distribution of trace elements such as Zn and Cu [47]. Cd alters carbohydrate metabolism, causing hyperglycemia in several freshwater fish species [48, 49]. It was revealed that tilapia exposed to Cd had a negative effect on growth rates, meat quality and blood physiology [50]. Exposure to low Cd levels can cause DNA damage and stress in C. carpio [51].

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