Heavy metal concentrations in Threadfin fish (*Eleutheronema tetradactylum*) from Dumai Waters: size dependence and safe human consumption analysis

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Abstract. The coastal waters of Dumai, which are directly facing Rupat Island and the Strait of Malacca, are influenced by various coastal activities that are likely to provide inputs for pollutants such as heavy metals that can eventually accumulate in biota, including fish. This condition not only threatens the balance of the ecosystem and the life of aquatic biota, but can also affect the health of people who consume fish from these waters. This study aims to analyze the concentration of heavy metals in threadfin fish (*Eleutheronema tetradactylum*) collected from Dumai coastal waters and to determine the safe limit of weekly consumption by the community without harmful effects to health. Threadfin fish were taken with a variation in size between 19 to 34 cm, then they were analyzed for heavy metal concentrations (Pb and Cu) in the flesh by referring to the SNI 6989-84:2019 procedure. The results showed that fish with larger sizes accumulated more Pb and Cu metals (2.220 and 0.028 µg/g) compared to medium-sized fish (1.207 and 0.026 µg/g) and small-sized fish (0.811 and 0.015 µg/g). The metal concentration differed significantly ($p<0.05$) between the three sizes. The longer the size of the fish, the concentration of Pb and Cu will increase. Likewise with the fish weight, the heavier the fish, the concentration of Pb and Cu will also increase. The PTWI value that has been determined by WHO will be achieved if adults with a body weight of 60 kg consume Threadfin fish as much as 1,061 kg/week and 9,130.43 kg/week, while children with a body weight of 15 kg consume the fish as much as 0.265 kg/week and 2,282.6 kg/week, for Pb and Cu.

1 Introduction

The sea waters of Dumai City are located in the Malacca Strait area which is one of the busiest international shipping routes in the world, so of course there are various supporting

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activities such as ports, industries, and development occurring around its coastal waters. This is suspected to result in a decline in water quality that will cause pollution that will pose a serious threat to the balance of the ecosystem and the life of aquatic biota [1]. In addition to being used as a port, industrial and shipping lane area, Dumai coastal waters are also used as fishing areas by fishermen.

Heavy metals are one of the pollutants that affect the life of aquatic organisms. The existence of heavy metals in marine waters may come from various sources, including industrial, mining, household and agricultural activities. Given that Dumai City, which is experiencing rapid regional development and industrial activities, has resulted in a large number of pollutants such as heavy metals entering the waters. Metal pollution in these waters can be accumulated by biota including fish and accumulate until the concentration is extinguished which affects and causes toxic in humans as consumers. Aquatic biota living in waters contaminated with heavy metals can accumulate those metals in their body tissues and will increase over time. Heavy metals that enter the organisms then undergo absorption and will be distributed throughout the body. If humans consume aquatic organisms that contain heavy metals, it will have a detrimental impact on health.

The threadfin fish (*Eleutheronema tetradactylum*) is one of the various types of fish that are widely found in the waters of Dumai sea. This fish has important economic value because besides being an export commodity, this fish is also very popular with the public to be consumed. According to [2-4] this fish is mostly found not far from the coastal area (between 1 - 5 miles), so the influence of pollutants from the mainland in the form of waste discharge on the fish becomes greater. Threadfin fish also belong to the group of carnivorous fish and can accumulate heavy metals in their body tissues through biomagnification processes.

Dumai is an industrial area that is growing very rapidly and is suspected of having a negative impact and causing pollution to coastal waters [1]. One of the pollutants that is often discussed is heavy metals, such as Pb and Cu. These metals are very widely used in anthropogenic activities and has a negative impact on health, so that it is important to be studied further. Dumai coastal waters is also used as a fishing area, including the threadfin fish which is very popular within the community. If these fish are contaminated by heavy metals, it will endanger the health of the people who consume them. The ability of heavy metals to accumulate in fish differs based on their size. Therefore, it is necessary to conduct research on the content of heavy metals in the tissues of threadfin fish (*E. tetradactylum*) in Dumai waters so that the public would understands the side effects of consuming fish exposed to heavy metals. This study was also conducted to find out the safe limit or the maximum amount of Pb and Cu metals that can be consumed in a week without causing adverse effects on health.

2 Materials and methods

The research was carried out in March 2024 by taking fish samples from Dumai coastal waters with the help of fishermen. Fish samples caught by fishermen were selected to represent the size of the fish caught, namely small (19-21 cm), medium (23-26 cm), and large (32-34 cm). Next, the fish samples are put into plastic bags that have been labeled based on size, put into ice boxes and taken to the laboratory for further handling. In the laboratory, the fish is immediately put into the freezer with the aim of preventing changes and damage to the fish sample. Fish sample digestion was done at the Marine Chemistry Laboratory, Department of Marine Sciences, Faculty of Fisheries and Marine Science, and heavy metal content analysis was done at the Public Works Laboratory of Riau Province. The SNI 6989-84:2019 technique was utilized to conduct an examination of the heavy metal concentration found in fish.

In order to ascertain the correlation between fish length and weight, as well as the relationship between the content of Pb and Cu and the size of the fish sample, a straightforward linear regression test was conducted using the mathematical model Y = a + bx. The WHO (World Health Organization) and the JECFA (Joint FAO/WHO Expert Committee on Food Additives) have published threshold figures that can be used to determine the maximum limit of fish consumption. This information is then used to determine the level of safety associated with fish consumption. The Maximum Weekly Intake is the maximum concentration limit of concentrated heavy metal in food ingredients that can be consumed each week. The formula for calculating Maximum Weekly Intake is MWI (g) = Weight (kg) x PTWI. The maximum weekly intake, or MWI, is distinguished from the provisional tolerable weekly intake, or PTWI, which is the weekly maximum limit tolerance number. In this study, it was assumed that the average weight of adults was 60 kg and that of children was 15 kg.

The maximum weight limit of fish that can be tolerated for consumption within a week can be computed after knowing the value of the Maximum Weekly Intake and the concentration of heavy metals in fish. The weight limit can be calculated using a formula developed by [5], namely MTI = $\frac{MWI\ (g)}{Ct\ (mg/g)}$, where MTI is the Maximum Tolerable Intake, while MWI is the Maximum Weekly Intake, while Ct is the concentration of heavy metals found in fish.

3 Results

The fish obtained from fishermen who were used as samples in this study are considered to be able to represent the size of the threadfin fish (*E. tetradactylum*) from Dumai waters as can be seen in Table 1.

Table 1. Morphometric size of threadfin fish (*E. tetradactylum*) from Dumai coastal water

Fish Size	Morphometric size	
	Total length (cm)	Body weight (g)
Small	19	60
	20	70
	21	75
Medium	23	130
	25	140
	26	150
Large	32	240
	33	250
	34	280

From the data of fish grouping based on their morphometric size, it can be seen that the relationship between fish weight and total length uses a simple linear regression equation as shown in Figure 1.

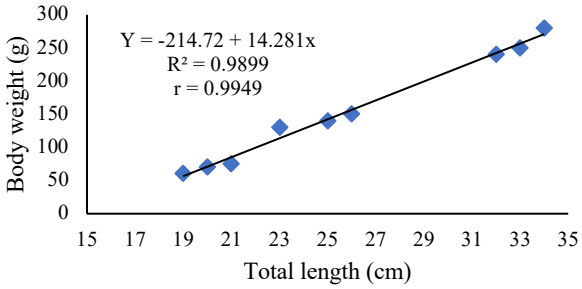

Fig.1. Relationship of length with the weight of the sample fish

From the results of the linear regression test, it was found that the total length and body weight of the fish had a positive relationship with the equation Y = 14.281x – 214.72. The determination coefficient value (R2) in the linear regression analysis is 0.9899 and the the correlation coefficient value (r) is around 0.9949 which shows a strong relationship, where the longer the fish body length, the more weight the fish's body will increase.

3.1 Heavy Metal Content Based on the Size of Threadfin Fish

The results of the analysis of Pb and Cu content carried out on the flesh tissue of threadfin fish (*E. tetradactylum*) can be seen in Table 2.

Table 2. Heavy metal content in threadfin fish (*E. tetradactylum*)

Fish size	**Mean concentration (mg/kg)**	
	Pb	**Cu**
Small	0.811±0.184	0.015±0.003
Medium	1.207±0.031	0.026±0.004
Large	2.220±0.045	0.028±0.005

Based on Table 2, small fish have smaller Pb and Cu metal content (0.811 and 0.015 mg/kg) compared to medium size (1.207 and 0.026 mg/kg) and large size (2.220 and 0.028 mg/kg) for Pb and Cu metals, respectively.

3.1.1 The Relationship between Heavy Metal Content and Fish Length

The results of a simple linear regression analysis between the metal content of Pb and Cu with the total length of the Threadfin fish (*E. tetradactylum*) showed a positive relationship with the linear regression equation Y = -1.3898 + 0.1082x (Pb) and Y = 0.0016 + 0.0008x as can be seen in Figure 3.

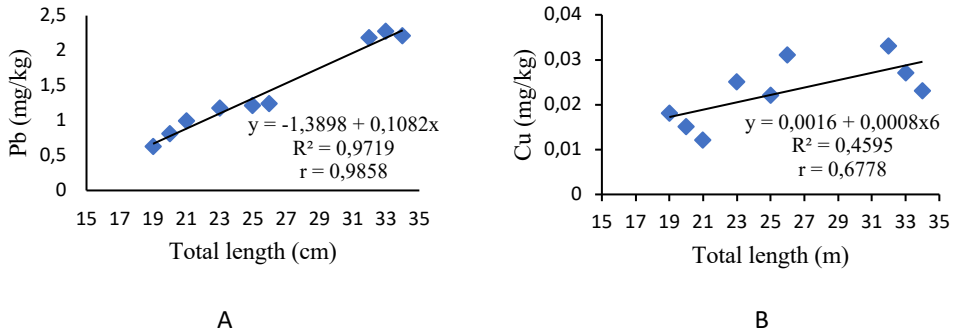

Fig.3. Relationship between heavy metal content Pb (A) and Cu (B) with the total length of the threadfin fish (*E. tetradactylum*)

Based on Figure 3, the correlation value (r) of 0.9858 for Pb and 0.6778 for Cu shows a very strong and positive relationship between the content of Pb and Cu and the total length of the fish. This means that as the total length of the fish increases, the Pb and Cu content also tends to increase. The values of the determination coefficient (R2) = 0.9719 (Pb) and 0.4595 (Cu) showed that about 97.19% and 45.95% of the total length of the threadfin fish affected the Pb and Cu metal content in the fish tissues.

3.1.2 Relationship between Heavy Metal Content and Fish Weight Size

The results of a simple linear regression analysis between the metal content of Pb and Cu and the weight of the threadfin fish (*E. tetradactylum*) have a positive relationship with the linear regression equation of Y = 0.2504 + 0.0075x for Pb and Y = 0.014 + 0.00006x for Cu which can be seen in Figure 4.

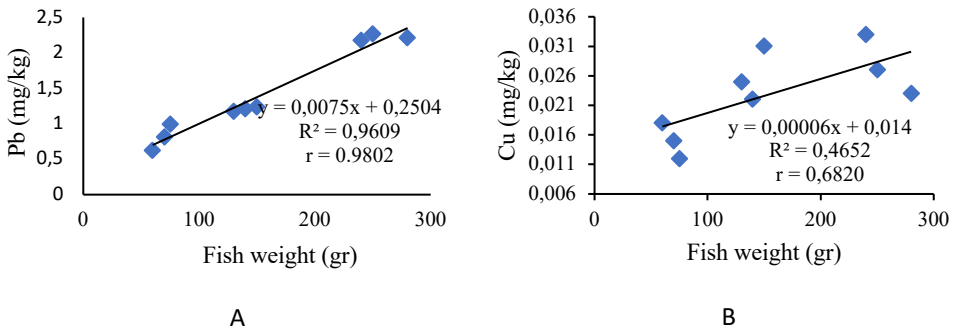

Fig.4. Relationship between Pb heavy metal content and weight of threadfin fish (*E. tetradactylum*)

Based on Figure 5, the correlation values (r) = 0.9802 (Pb) and 0.6820 (Cu) show a very strong and positive relationship between the content of Pb and Cu and the weight of the threadfin fish. This means that if the weight of the fish increases, the Pb and Cu metal content also tends to increase. The value of the determination coefficient (R2) of 0.9609 for Pb and 0.4652 for Cu shows that this linear regression model is very good in explaining the relationship between Pb content and the weight of the threadfin fish. Increasing weight of the threadfin fish would be followed by increasing Pb and Cu content in the tissues of the fish. A positive correlation between fish size and heavy metal content has been widely reported,

while a negative association has also been found in some cases. As per reference [6], variances in the correlation between concentrations of heavy metals and fish size were linked to variations in their ecological requirements, swimming patterns, and metabolic processes. For instance, the concentration of heavy metals in fish tissues is directly related with fish weight, and fish that are carnivorous in Malaysian waters [7] have greater concentrations of Pb. The study's findings indicate that the level of heavy metals in fish tissue is within WHO standards.

A positive relationship between the content of heavy metal in fish tissue and the length and weight of fish was also reported by [8]. Some studies on the accumulation of heavy metals in fish also show that the level of accumulation can varies based on the fish's weight and length. It is generally known that heavy metals accumulation in living organisms including fish is controlled by absorption, detoxification, elimination mechanisms and is also highly dependent on the specific metabolic rate of the organism size [9-11].

It was explained that small fish have less lipid content, which leads to low accumulation of heavy metals in the fish body. This is inline with the statement from [12], which states that the concentration of heavy metals in large fish is higher because the lipid content in large fish is more than in small fish. As is well known that heavy metals have a tendency to bind to fat in the body, the more fat is present in the body, the more likely it is that heavy metals will accumulate in the body of fish.

The process of fish being contaminated with heavy metals and accumulate in the fish body is affected by sensitivity according to the trophic level of the fish itself. This is in accordance with the opinion of [13], there will be a process of biomagnification, a state in which heavy metals will move from one trophic level to another and show an increase in concentration in living things according to the trophic level. Therefore, larger fish with higher trophic levels have more heavy metal levels compared to small fish. This is in accordance with the results of this study that Threadfin fish with a weight of >200 g has more Pb and Cu content compared to fish with a weight of < 200 g.

However, the results of this study are not the same as other studies on other types of fish. As a study that has been conducted by [14] found that, the content of Pb, Cu, Cd, and Zn is generally higher found in small size Croaker fish compared to large fish. The explanation given to these differences is related to the metabolic process which is one of the factors that plays an important role in the accumulation of heavy metals in marine organisms. Metabolic activity in younger (small) organisms is usually higher than in older (large) organisms so the heavy metal content in younger fish is generally higher than in larger and older fish.

In general, the low metal content in large fish is caused by an increase in body size from the growth rate. This is in accordance with [15-16], which stated that the lower content of heavy metals accumulated in a large organism is caused by several factors, namely differences in growth rate, metabolic rate, level of sensitivity of the body to the intake of certain heavy metals and physiological needs for heavy metals. This is supported by the opinion of [17] which suggests that metal content will decrease slightly with the increase in fish size. However, in this study, the analyzed threadfin fish showed that higher content of Pb and Cu was found in larger sizes whilst lower heavy metal content was found in smaller fish. Of course, the difference in the results of the study still needs to be further researched by involving the measurement of physical, chemical and biological factors of the waters and the type of fish.

3.2 Safety consumption

The risk of fish consumption is assessed using the Provisional Tolerable Weekly Intake (PTWI) formula in order to assess the consumption's safety of threadfin fish from Dumai waters. According to [11], the Provisional Tolerable Weekly Intake (PTWI) depends on the amount, duration of consumption and the level of food contamination consumed by humans. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) determines the PTWI tolerance for Pb and Cu of 0.025 mg/kg and 3.5 mg/kg body weight, respectively. Table 3 shows the maximum acceptable weight limit of fish that can be tolerated for consumption within a week (Maximum Tolerable Intake/MTI) per weight of 60 kg for adults and 15 kg for children, based on calculations using data on the Pb and Cu content of threadfin fish from Dumai coastal waters.

Tabel 3. Maximum Tolerable Intake (MTI) for Pb and Cu

Fish	Maximum Tolerable Intake (MTI)			
	MTI for Pb (kg/week)		MTI for Cu (kg/week)	
	Adult	Children	Adult	Children
Threadfin fish	1.061	0.265	9,130.43	2,282.6

The MTI value of heavy metal Pb for adults weighing 60 kg is 1.061 kg/week and for children of 15 kg is 0.265 kg/week. If the heavy metal Pb entering the body exceeds the MTI value, it is suspected that it will cause toxic effects. According to [19], acute Pb poisoning can result in growth, liver and renal problems, reproductive issues, and reduced brain function. The dose that causes human lethal (death) is estimated to occur if 500 mg or 0.5 grams of Pb is absorbed into the body. Meanwhile, the MTI value of Cu heavy metal for adults weighing 60 kg is 9,130.43 kg/week and for children weighing 15 kg is 2,282.6 kg/week.

According to [13], the The smallest value is used to establish the maximum amount of fish meat that can be consumed each day, since fish meat contaminated with heavy metals, even if it is consumed in small concentrations, will accumulate in the human body and will become harmful. The accumulation of Pb and Cu in the human body can have negative impact on health. Some of the impacts caused include damage to the lungs, kidneys, liver, and bones, neurological behaviour, such as visual impairment, ataxia, paresthesia, neurasthenia, hearing loss, dysentery, mental deterioration, tremors, motor disorders, paralysis, and death [20]. Meanwhile, according to [21] it is stated that human health problems can be caused by heavy metals, depending on the exposure dose and the part of the metal that is bonded to the body. The harmful effects of heavy metals can disrupt the function of enzymes, causing allergies, mutagenicity, teratogens, and carcinogenesis in both people and animals.

Although it is often known that fish are an excellent source of nutrients, the habitat in which they are caught can have an impact on the fish's nutritional value. Because heavy metals are not biodegradable, they pose a greater hazard to the ecosystem than other contaminants. This is in addition to its capacity for bioaccumulation and biomagnification. Fish are unable to flee or avoid the negative impacts of pollutants in the waters. It is well known that eating metal-contaminated fish can cause heavy metal toxicity, which can harm or impair the central nervous system, lungs, kidneys, bones, liver, and other important organs. Multiple sclerosis, Parkinson's disease, muscular dystrophy, and Alzheimer's disease can all develop slowly as a result of prolonged exposure. In addition, Allergies are also common, and prolonged exposure to certain metals or their compounds might even result in cancer.

Heavy metal poisoning is a chemically significant disorder that can cause serious sickness, worse quality of life, and even death if it is not recognized or treated appropriately. For this reason, caution and vigilance in consuming fish as a source of nutrients must also pay attention to where the fish is obtained from and if possible, must be aware of the amount of heavy metals present in fish meat.

4 Conclusion

Threadfin fish from Dumai sea waters with a larger size accumulate more Pb and Cu metals compared to smaller fish. Based on the Pb and Cu metal content standards, the PTWI value that has been set by WHO will be achieved if adults with a body weight of 60 kg consume threadfin fish meat as much as 1,061 kg/week and 9,130.43 kg/week, while children weighing 15 kg consume threadfin fish meat at a rate of 0.265 kg/week and 2,282.6 kg/week. Thus, it can be concluded that threadfin fish from Dumai waters can still be consumed provided that they fall below the predetermined level. Additional research is required to fully understand the findings, including assessing the fish species' and the waters' physical, chemical, and biological traits.

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