Heavy Metals (Hg, Cd, Pb, Cu) in Greenback Mullets (*Planiliza subviridis* Valenciennes, 1836) from Bojonegara coastal waters, Banten Bay, Indonesia

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Abstract

Waste from industrial activities can be a source of pollution for the waters of Banten Bay. One source of these pollutants are heavy metals. High concentrations of heavy metals in waters can pollute the aquatic environment, endangering all organisms. Heavy metals can accumulate in aquatic environments and living organisms such as fish. The greenback mullet Planiliza subviridis (Valenciennes, 1836) is known as a fish for human consumption. Heavy metals that are contained in mullets can move to a higher trophic level within the food chain and endanger the health of humans. This study aims to analyze the accumulation of heavy metals, such as Hg, Cd, Pb, and Cu, in the flesh of greenback mullets at Bojonegara Waters of Banten Bay. The research was carried out for five months (August - October 2020 and March - April 2021). Samplings were taken from Terate River and Wadas River, which are mullet fishing areas and natural habitats of these mullets. Data analysis consisted of descriptive and quantitative analyses. The results showed that the Hg, Cd, Pb, and Cu contents were below the quality standards based on Government Regulation of the Republic of Indonesia (PP RI) No. 22 of 2021. *The greenback mullets have experienced a moderate accumulation rate. The different rates of Cu metal accumulation in each month indicate a variation in catches with low to moderate accumulation rates. The water conditions in Bojonegara can still be seen as tolerable and still suitable for mullets usable for human consumption in a reasonable amount. Monitoring and evaluation activities need to be carried out periodically for the management of the aquatic environment in Bojonegara.*

Keywords: Accumulation, Bojonegara, Heavy Metals, The Greenback Mullet

Introduction

Banten Bay, with an area of ± 150 km^2, are waters to the west of Java Island in the northern part of Serang and Cilegon city. Its depths ranging from 2 to 20 m and consist of 12 large and small islands. This bay is the estuary for seven watersheds, including the Cibanten, Cikamayung, Ciujung Lama, Cikranjung, Cilengkong, Ciujung, and Ciluncing Rivers. Sediments consisting of mud-sand were carried from these rivers, forming the bottom of the waters of this bay (Rustam *et al.,* 2018). According to Wisha *et al.* (2015), these relatively shallow waters have undergone many changes due to pressure from the surrounding environment, including rapid population growth with many settlements around the beach area, several industries, and sand mining activities.

Anthropogenic activities, especially industrial activities, can be a source of pollution for waters in Banten Bay. The main sources of pollutants entering Bojonegara waters are strongly suspected from settlements and by-products of industrial activities, such as the palm oil processing industry, oil and gas industry, steel and construction industry, and the power plant industry. Waste from these activities flows through rivers that empty into Banten Bay. According to Falah *et al.* (2020), industrial activities in Banten Bay are growing rapidly, increasing the amount of solid, gas, and liquid wastes. The Bojonegara area is an industrial and port area located in the west of Banten Bay (Sugiarti *et al.,* 2016). According to Liyubayina (2018), 44 types of industrial activities have been recorded in the Bojonegara District, 30 of which are in coastal areas. One of the many wastes generated from the

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port and industrial activities such as the use of ship lubricants, which can be a potential pollutant, are heavy metal wastes.

Heavy metals are toxic to living organisms, difficult to degrade, and can accumulate in the body of organisms to cause death in high concentrations (Prastyo *et al.,* 2017). Mullets *Planiliza subviridis* (Valenciennes, 1836) are one of the fish species living in the waters of the estuary with high tolerance to changes in water conditions, and the ability to adapt to a variety of food in their habitat (Nuringtyas *et al.,* 2019). Research related to heavy metals in biota in the waters of Banten Bay has been carried out by several researchers, including the blue swimming crab (Febrianessa *et al.,* 2020) and green mussels in Cengkok coastal waters (Melinda *et al.,* 2021). These studies showed that the heavy metals that contained in the flesh of biota were still below the values of the quality standards. The bioconcentration factors were low (<100) and still suitable for consumption by the local community as long as it does not exceed the safety level. Several studies related to waters in Banten Bay have also been investigated, including on the Cengkok coastal waters showed that the heavy metal concentration in the sediment has no significant effect on the environment and it is below the threshold (Wardani *et al.,* 2020); and concentration of heavy metals in the Bojonegara coastal waters are still in a good condition for aquatic life (Surbakti *et al*., 2021).

However, research related to heavy metals in greenback mullets in Bojonegara coastal waters has never been done before. The greenback mullet can often be found in coastal waters of Bojonegara and is one of the consumption fish in that area. Mullets accumulate heavy metals which can be transferred to the human body through the food chain process, thus endangering human health. Therefore, the analysis of heavy metals in the mullets from the coastal waters needs to be carried out to determine the heavy metal pollution levels in the fish. So the conditions of Bojonegara coastal waters can be monitored for the life of mullets and to control the fish food safety and limits for mullet consumption in Bojonegara coastal waters of Banten Bay. The information can be seen as baseline data from this research concerning heavy metals and fish food safety and are expected to support the management of the respective waters and fishery activities in Banten Bay, especially in the waters of Bojonegara in future.

Materials and Methods

This research was conducted in the coastal waters of Bojonegara, Banten Bay (Figure 1). Sampling was carried out in August–October 2020 and March–April 2021. Observation stations consisted of two points close to various input sources from surrounding settlements and industries, Station 1 (Terate River) and Station 2 (Wadas River). The stations are mullet fishing area and the habitat of the mullet itself. Measurements of length and weight and dissection of mullet flesh were carried out in the Laboratory of Biomacro (Dept. of Aquatic Resources Management), analysis of heavy metals from the water samples were conducted in Laboratory of Aquatic Environment (Dept. of Aquaculture), Faculty of Fisheries and Marine Sciences, and destruction of mullet flesh and heavy metal analysis were carried out using AAS method in Laboratory of Food Technology, Faculty of Agricultural Technology of IPB University,

Water quality measurement

Physical and chemical parameters of the waters were measured as supporting data (Table 1). Monthly observation of water quality (except heavy metal) was carried out *in situ.* Meanwhile, the measurement of the heavy metal contents of water was carried out *ex-situ* (Mukarromah *et al*., 2016)

Water sampling

Water samples at the observation stations were monthly taken using a *water sampler.* The sample was put into a 100 mL polyethylene sample bottle and 0.75 mL of nitric acid (HNO_3) was added as a preservative to bind heavy metals (Hutagalung, 1997). Next, the samples were put in a cooler filled with ice and taken to the Laboratory of Food Technology of IPB University to be analyzed for heavy metal contents.

Mullet sampling

Mullets samples were caught using cast net (1.5 inches in size) in rivers and estuaries. The fish samples were then put into a cooler filled with ice to maintain the freshness of the fish until they arrived at the laboratory for analysis. Morphometric measurements of fish included total length using a ruler (with an accuracy of 0.5 mm) and fish weight using an analytical balance (with an accuracy of 0.0001 gram) were performed. Afterward, the mullets were dissected, and the fish flesh has been taken as samples for further analysis. The separated flesh was then analyzed for its heavy metal content through a digestion process.

Sample digestion

The type of digestion used in this next step is called 'wet digestion', referring to APHA (2017) with the *Nitric Acid-Perchloric Acid Digestion* method. A total of 5-10 grams of mullet flesh were weighed using an analytical balance. Next, 5 mL of $HNO_{3(p)}$

was added to release elements, such as C, H, O, N, S in the sample. The mixture was then heated on a hotplate at 105°C until the volume of the solution was reduced by half. Each sample has been added with another 10 mL of concentrated nitric acid ($HNO_{3(p)}$) and concentrated perchloric acid ($HClO_{4(p)}$), then heated again at a temperature of about 40°C until the yellow vapor disappeared and concentrated white vapor from $HClO_4$ runs out. The addition of perchloric acid is useful for vaporizing the fat contained in the sample. 10 mL of $HNO_{3(p)}$ solution can be added to complete the digestion process if necessary. Then the solution has been cooled, filtered using a hard filter (0.4 m in size), and diluted to a volume of 50 m. At the end the samples were then analyzed using an Atomic Absorption Spectrophotometer (AAS) instrument (AA-688 Shimadzu).

Heavy metal content analysis

Atomic Absorption Spectrophotometry (AAS) was used to analyze the heavy metal contents (Hg, Cd, Pb, and Cu) in the taken mullet flesh. The working principle of AAS is based on the evaporation of the sample solution. The sample has been atomized and absorbs radiation from the light source emitted by a cathode lamp containing the specified element. The amount of radiation absorption was measured at certain wavelengths according to the type of metal being analyzed (Aziz *et al.,* 2015). APHA (2017) states that Cu, Cd, and Pb can be measured using the Direct Air Acetylene Flame method, while Hg uses the Cold Vapor Atomic Absorption Spectrometry method. The wavelengths used were based on the type of the respective heavy metal, namely 253.7 (for Hg), 228.8 (for Cd), 283.3 (for Pb), and 324.7 nm (for Cu). The amount of solution injected was about 7 mL per 2 seconds using a standard solution of low concentration >1 ppm.

Descriptive analysis

The data analysis performed in this research was descriptive in the form of a single value concentration from the average value of the heavy metal content obtained. The data obtained were processed using Microsoft Excel. The analysis results of the water quality and heavy metal contents in the waters were compared with the quality standards based on Government Regulation of the Republic of Indonesia (PP RI) No. 22 (2021) Appendix VIII concerning the implementation of environmental protection and management, specifically for seawater quality standards for marine biota. The heavy metal contents in fish flesh have been compared to determine the effect of time and water conditions on the heavy metal contents in mullet flesh. The results obtained were compared with quality standards based on IFDSA (2018) and FAO/WHO (2018) for Cd, Pb, and Hg, and based on the Director-General of POM, Ministry of Health RI No. 03725/B/SK/1989 for Cu. This process aimed to find out whether the results obtained were still within the allowed range or have exceeded the limit for heavy metals in fish food.

Bioconcentration factor (BCF)

Bioconcentration is the entry of pollutants in water into the bodies of living organisms through the gills or skin directly (Hidayah *et al.,* 2014). Bioconcentration factor (BCF) displays the tendency of an aquatic organism to absorb a chemical substance from water under stable conditions. It can also be determined kinetically as the ratio between

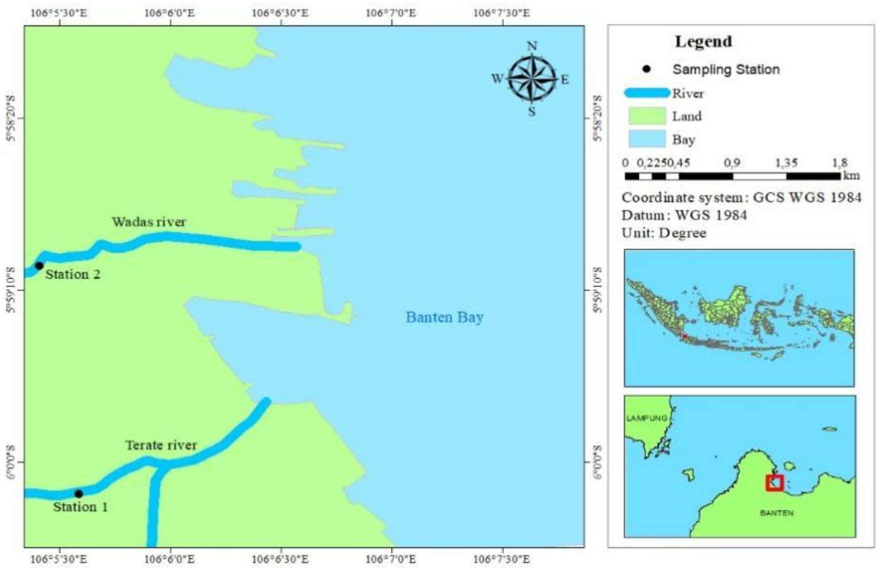

Figure 1. Map of mullet sampling locations in the Bojonegara coastal waters, Banten Bay

Table 1. Water quality parameters

Parameter	Unit	Method	Tool
Temperature	°C	Electrometric method	DO meter
pH	-	Electrometric method	PH meter
DO	mg O_2.L^{-1}	Electrometric method	DO meter
Salinity	‰	Electrometric method	refractometer
Hg	mg.L^{-1}	Cold vapor atomic absorption spectrometry	AAS
CD	mg.L^{-1}	Flame atomic absorption spectrometry	AAS
Pb	mg.L^{-1}	Flame atomic absorption spectrometry	AAS
Cu	mg.L^{-1}	Flame atomic absorption spectrometry	AAS

the stable rate of chemical absorption from water and the total release or depuration (Arnot and Gobas, 2006). Esch (1978) divided the accumulation rate of heavy metals into three groups, namely low accumulation rate (BCF value <100), moderate accumulation rate (BCF value between 100–1000), and high accumulation rate (BCF value >1000). The value of the bioconcentration factor can be calculated using the formula according to Oost *et al.* (2003).

Safety level

Mullets are a consumption fish in great demand. Therefore, its exposition to heavy metals can endanger human health if consumed. Calculation of safe consumption limits according to Sulistiono *et al.* (2018) can be used as a reference in determining the level of consumption of a material to avoid adverse effects. Foods that contain heavy metals, even in low concentrations, can accumulate in the human body and become toxic if consumed continuously. Therefore, the daily maximum limit for fish is determined by looking at the smallest value from the calculation of the safe limit for consumption (Hidayah, 2014).

Provisional Tolerable Weekly Intake (PTWI) is a temporary maximum tolerance limit for a substance that can be consumed per week. The PTWI value has been determined by the international food agency Joint FAO/WHO Expert Committee on Food Additives (JECFA) (2018) and SNI (2009). Maximum Weekly Intake (MWI) is the tolerance limit for heavy metal content in an ingredient that can be consumed within one week with the assumption that adults weigh (50 kg) and children (15 kg). The MWI value can be obtained through the formula according to Cahyani *et al.* (2016).

The safe limit for consumption can be determined by calculating the MTI value (Maximum Tolerable Intake), which is the maximum tolerance limit for fish flesh or an ingredient that is still allowed to be consumed in a week. The calculation of the MTI value needs to consider the MWI and PTWI values. The following is the MTI formula based on the EPA (2000).

Results and Discussion

Bojonegara is a coastal area in Banten Bay that is known as an industrial, port, settlement, and fishing areas. The operations of various activities that occur around the Bojonegara coast can be a source of pollution for the waters and the biota, including heavy metals. Heavy metals are non-biodegradable and can accumulate in the environment and aquatic organisms so that they are categorized as pollutants (Tarigan *et al.*, 2003). Apart from anthropogenic activities, heavy metals can also come from natural processes, such as the atmosphere, weathering of rocks, volcanic activity, sandstorms, and biological particles. The metal contents can end up in the waters either from the atmosphere that falls into the sea or from by-products of an industry that enter the sea through rivers (Hutagalung, 1984). The high presence of heavy metals in the environment can harm the biota and humans who consume them throughout the food chain. Therefore, it is necessary to analyze the content of heavy metals in fish, here especially in the commercially important mullets, to determine the level of accumulation and the safe limit of its consumption.

Water quality parameters describe the condition of the waters as a habitat for the investigated mullets. The physical and chemical conditions of the waters can affect the heavy metal contents in these waters. Characteristics of waters and heavy metal contents in Bojonegara coastal waters of Banten Bay during the observation can be seen in Table 2.

Heavy metal contents in waters can be influenced by physical and chemical conditions of waters, such as temperature, acidity (pH), dissolved oxygen (DO), and salinity (Riani, 2019). Based on observations, temperatures in October 2020 and from March to April 2021 were still within the range of seawater quality standards for marine biota in estuarine areas based on PP RI No. 22 of 2021 Attachment VIII concerning the implementation of environmental protection and management for seawater quality standards for marine biota.

Table 2. Water quality of Bojonegara coastal waters, Banten Bay.

Parameter	Month					Quality Standards*
	Aug (St.2)	Spt (St.2)	Oct (St.1 dan 2)	Mar (St.2)	Apr (St.1)	
Temperature (°C)	33,5	34	30,25	32	28,4	28-32
pH	8	8	7,75	7	7,37	7-8,5
DO (mg O_2.L^{-1})	4,7	5,4	6,15	5,6	6,4	>5
Salinity (‰)	26	19	19	23	5	34
Heavy metals in water (mg.L^{-1})						
Hg	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	0,001
Cd	<0,001	<0,001	<0,001	0,002	<0,001	0,001
Pb	<0,002	<0,002	<0,002	<0,002	<0,002	0,008
Cu	0,005	0,006	0,006	0,004	0,006	0,008
Average Cu			0,005			

*Source: Gov. Reg. RI No. 22 of 2021 Appendix VIII concerning the implementation of environmental protection and management specifically for sea water quality standards for marine biota

In August and September 2020, the water temperature was above the quality standard (>32°C). The high temperatures of the water could be caused by the time samplings were carried out (during the day), so that the high intensity of sunlight directly enters the water. This result can also be affected by the hot temperature from the *cooling water* effluent or the PLTU (coal power plant) industrial cooling water discharged into the waters. According to Nuringtyas *et al.* (2019), mullets have a fairly wide tolerance to temperatures. Mullets are still found in these waters (temperature of 39.5°C) due to the discharge of PLTU hot wastewater (Burhanuddin and Birowo, 1981).

The solubility of heavy metals will be higher along with high water temperatures (Eshmat *et al*., 2014), while at low temperatures heavy metals are easily settled into sediments (Happy *et al.,* 2012). According to Stickney (1979), temperatures above the optimum limit can cause an increase in metabolic rates and a decrease in growth rates of fish. This result has been documented in this study while measuring the size of the fish, found at the sampling location (during August and September 2020) on average fish have been classified as small fish (<13 cm). The classification was based on the size of the first mullet gonad maturity according to Fitriah *et al.* (2021), which is 13.78 cm (for male fish) and 16.39 cm (for female fish).

Water conditions with low pH can increase the toxicity of heavy metals, while at high pH heavy metals tend to settle to the bottom of the waters (Mahardika and Salami, 2012). The degree of acidity (pH) in the waters of Bojonegara during the observation was still within the quality standard range based on PP RI No. 22 of 2021. This result shows that the pH value in Bojonegara waters has still been good for the life of mullets in this estuary. High dissolved oxygen in the waters can increase the solubility of heavy metals (Li *et al.,* 2013). The DO content in Bojonegara waters was still in line with the quality standard, except in August 2020 (less than 5 mg L^{-1}). The low DO content in August 2020 was estimated to be caused by high water temperatures and organic matter decomposition. Mubarak *et al.* (2010) stated that the process of respiration and decay of organic matter at the bottom of the water body can reduce the value of dissolved oxygen.

According to Yudiati *et al.* (2009), decreased salinity can increase the toxicity of heavy metals. The salinity of the waters in Bojonegara is still within the quality standard range. The highest salinity in March 2021 (34 ‰) can be assumed to be caused by seawater intrusion. Herdyansah and Rahmawati (2013) stated that areas close to the sea have high salinity levels or high levels of seawater intrusion. The lowest salinity occurred in April 2021 (at 5 ‰) which could be due to high rainfall in that month. The detected salinity value was still safe for mullets because mullets can tolerate salinities up to 0-38 ppt (Effendie, 2002). The quality of Bojonegara waters on average was therefore still within the range of the given quality standards based on Gov. Reg RI No. 21 of 2021, which means the waters are still suitable for life and development of mullets.

Heavy metal toxicity is also influenced by the type as well as the physical and chemical properties of the heavy metal itself (Darmono, 2001). Heavy metals can be found in nature in low concentrations. In waters, they are usually found at around 10^{-3} to 10^{-2} mg.L^{-1} (Hutagalung, 1984). The Hg, Cd, Pb, and Cu contents in Bojonergara waters show that the waters are not yet polluted by these non-essential and essential metals. Because the heavy metal content in the waters is still below the quality standard, according to Gov. Reg. RI No. 82 of 2021.

The Hg, Cd, and Pb contents in Bojonegara coastal waters were very low, even below the detection limit of the AAS instrument. Meanwhile, Cu was still monthly detectable by the tool (ranging from 0.004-0.006 $mg.L^{-1}$). This result was different to that of a similar study conducted by Nirari, (2020) regarding the contents of Pb, Hg, Cu, Cd in mullet fish on Cengkok beach, Banten Bay. The contents of Hg, Cd and Pb in Bojonegara waters were smaller than those on the Cengkok coast. Meanwhile, the Cu content in Bojonegara waters was higher than that on the Cengkok coast.

Heavy metal contents in mullet flesh

The Hg, Cd, and Pb contents in mullet flesh were below the detection limit of the AAS tool (Table 3). The Hg contained in mullet flesh was below the AAS detection limit, which is <0.001 $mg.kg^{-1}$. This value is still below the quality standard based on IFDSA RI (2018) and FAO/WHO (2018) with a maximum limit of 0.5 $mg.kg^{-1}$. Cd was also below the AAS detection limit of <0.005 $mg.kg^{-1}$. This value was still below the quality standard based on IFDSA RI (2018) with a maximum limit of 0.1 $mg.kg^{-1}$. The Pb content in mullet flesh was as well below the AAS detection limit of <0.03 $mg.kg^{-1}$. This value was still below the quality standard based on IFDSA RI (2018) with a maximum limit of 0.2 $mg.kg^{-1}$ and FAO/WHO with a maximum limit of 0.3 $mg.kg^{-1}$.

The distribution of heavy metals in fish tissu was found to be high in the liver, followed by the kidneys, gills, and muscles (Darmono, 2001). This study focused more on the heavy metals in the flesh of mullets as those are the parts for human consumption. Mullets have fairly high economic value and are favored by the public. It contains complete nutrition with a composition of 20% protein, 2.5% fat, and 37% water (Hafiluddin *et al.,* 2012).

The presence of heavy metals in the body of biota is not dangerous as long as it is below the quality standard. Hg, Cd, and Pb are non-essential heavy metals whose benefits (if even existing) in the body of living organisms are unknown (Lembah *et al.,* 2014). The Hg, Cd, and Pb concentrations in mullet flesh during the observation were very low, below the tool detection limit (AAS). Therefore, the contents of the three metals were still under the quality standard based on IFDSA RI (2018), FAO/WHO (2018), leading to the conclusion that these fisheries products are safe for consumption. This result is in line with the low contents of Hg, Cd, and Pb in Bojonegara coastal waters. The contents of Hg and Pb in mullet flesh in Bojonegara were smaller than those of the results of Nirari's (2020) who studied fish from Cengkok beach. Cd in mullet flesh in Bojonegara and Cengkok waters have not been detected in that study.

The results of measurements of heavy metal content in mullet flesh during the months of observation showed different results. The Cu in mullet flesh ranged from 0.17 to 4.72 $mg.kg^{-1}$ with an average of 1.44 $mg.kg^{-1}$ (Figure 2). The highest Cu bioaccumulation was found within mullet flesh in October at 4.72 $mg.kg^{-1}$ and the lowest in April at 0.17 $mg.kg^{-1}$. The results of the measurement of Cu content in mullet flesh were still below the quality standards or the maximum limit of Cu contamination in food for fish and their processed products based on the Director-General of POM, Ministry of Health RI No. 03725/B/SK/1989, which is 20 $mg.kg^{-1}$.

Meanwhile, the Cu in the body of mullets in Bojonegara waters ranged from 0.17 to 4.72 $mg.kg^{-1}$. This value was higher than that of the results of Nirari's research (2020), in which, the Cu in mullet found on the Cengkok coast of Banten Bay was around 0.035-0.48 $mg.kg^{-1}$. This result was also higher than that of the Cu content in mullets from the Donan River estuary (Cilacap, Central Java Province) in October 2015 of 2.3032 $mg.kg^{-1}$ conducted by Prastyo *et al.* (2017). Cu is one of the essential metals and its presence in certain amounts is beneficial for living organisms as it is needed for physiological processes, especially in the formation of hemocyanin in the blood system and for enzymatic activity of aquatic animals. Essential metals can easily enter the food chain so that they accumulate in the body of living organisms (Hu *et al.,* 2019). However, high copper content in fish can damage the gills, liver, kidneys, nervous system, and can even kill the fish and damage mucous membranes at concentrations of 2.3 to 2.5 $mg.L^{-1}$ (Pratiwi, 2020).

Table 3. Heavy metal content Hg, Cd, Pb in mullet flesh

Heavy metal	Month					Quality Standards ($mg.kg^{-1}$)
	August	September	October	March	April	
Hg	<0,001	<0,001	<0,001	<0,001	<0,001	0,5[a,b]
Cd	<0,005	<0,005	<0,005	<0,005	<0,005	0,1[a]
Pb	<0,03	<0,03	<0,03	<0,03	<0,03	0,2[a]; 0,3[b]

[a]Source: IFDSA RI (2018), [b]Source: FAO/WHO (2018)

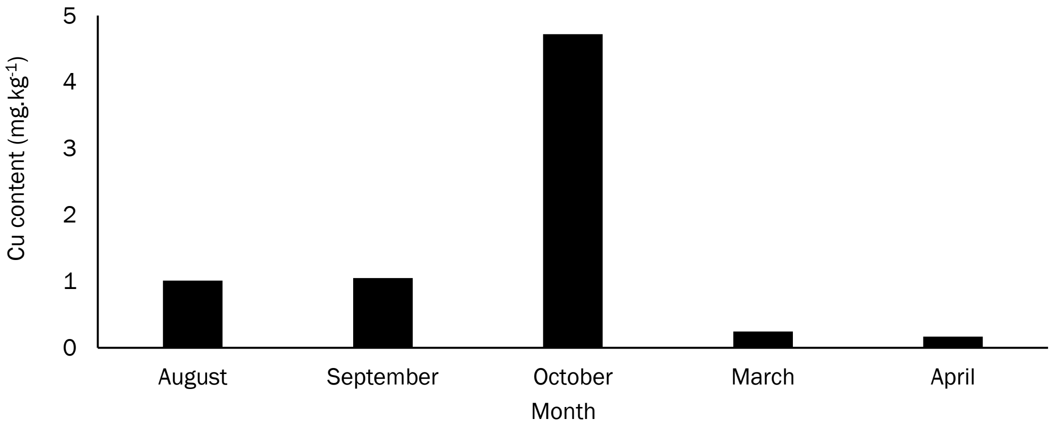

Figure 2. Heavy metal content of Cu in mullet flesh

The Cu content in mullets from Bojonegara coastal waters was still below the quality standard according to the Indonesian Ministry of Health No.03725/B/SK/1989 with a tolerance limit of Cu in content can also be influenced by the presence of heavy metals in the sediments. Mullets feed on organic matter produced or found in sediments at the bottom of the water. These fish usually eat basic organisms, macroalgae, plankton, and other organic materials, both fine particle organic matter and coarse particle organic matter (Isangedighi *et al.,* 2009).

The presence of Cu in Bojonegara coastal waters can have originated from by-products of PLTU (coal power plant) activities due to waste and coal steam entering the waters, as well as port activities. The release of heavy metals into the atmosphere due to the burning of oil (hydrocarbons) and coal can mix with rainwater and re-enter the seawaters (Yudo, 2018). According to Siaka (2008), Cu is usually used as a wood preservative and anti-rust paint on ships. It can naturally be found in waters due to erosion of mineral rocks, dust and copper particulates in the atmosphere carried by rainwater. Anthropogenic activities, such as domestic waste, agriculture, mining, and industrial waste from shipbuilding, metal plating, and wood processing can also be sources of Cu input into the seawaters (Darmono, 1995).

The concentration of heavy metals in the body of biota and waters can determine the level of accumulation of pollutants by biota. The bioaccumulation process is influenced by the direct absorption of heavy metals through breathing, the skin surface uptake, and the food chain (Nurhayati and Putri, 2019). Heavy metals can attack sulfur bonds and enzymes in living organisms so that they can inactivate related enzymes. This condition is due to the nature of heavy metals which have a high affinity for the element S (sulfur). Heavy metals can food and its products of 20 mg.kg^{-1}. Thus, mullets are still a safe food source for consumption. The high Cu content in the mullet's flesh was in line with the high content of Cu in the waters. The high heavy metal also form bonds with carboxylic groups (-COOH) and amines (-NH2). Cu, Cd, and Pb can be bound to cell membranes which inhibit the transformation process through the cell wall (Darmono, 1995).

Bioconcentration factor (BCF)

The ability of biota to accumulate pollutants from surrounding waters can be determined from the calculation of the bioconcentration factor (BCF). This value can be obtained by comparing the concentration of heavy metals or pollutants in the body of the biota with the content of heavy metals in the waters so that it can be seen that the biota has a high, medium, or low accumulation rate. The results of the calculation of the BCF value of mullets in this study (Table 4.) ranged from 28 to 787 with an average of 266, indicating that the average mullet had a moderate accumulation of pollutants (FBC between 100-1000). The BCF value for the three metals was zero because the content of these three heavy metals was very low in mullet flesh and could not even be detected using the AAS instrument. Meanwhile, in August-October 2020, Cu experienced moderate accumulation (BCF between 100-1000), in March-April 2021 it experienced low accumulation (BCF<00). The highest accumulation of Cu (copper) has been in mullets in October 2020, reaching a value of 787.

According to Hidayah *et al.* (2014), an increase of BCF value indicates a higher accumulation of heavy metals in the biota. The results showed that mullets in Bojonegara waters experienced a moderate accumulation rate (BCF value between 100-1000). The difference in the monthly values of BCF indicates a variation in the catch or sampling. Based on the results obtained in August-October 2020,

Table 4. Accumulation of heavy metals in flesh of mullets from Bojonegara waters, Banten Bay

Parameter	BCF				
	August	September	October	March	April
Hg	0	0	0	0	0
Cd	0	0	0	0	0
Pb	0	0	0	0	0
Cu	202	175	787	62	28
Average			266y		

mullet fish experienced a moderate accumulation of Cu. Meanwhile, they experienced low accumulation in March-April 2021. The accumulations of Hg, Cd and Pb in mullets were considered not have taken place or there was no accumulation. This condition was because the content of the three heavy metals was very low and was not detectable by the AAS tool either in the waters or in the flesh of mullets.

Differences in the level of accumulation of Cu can be influenced by seasonal factors at the time of sampling. The accumulation of Cu in March-April 2021 was lower because the rainfall in those months was quite high so that the heavy metals in the waters experienced dilution, decreasing the solubility of heavy metals. According to BMKG data, rainfall in April 2021 in the Banten area was generally in the medium to high category. The content of heavy metals in the rainy season would be smaller because in the dry season heavy metals would be higher concentrated (Darmono, 1995). Concentrated heavy metals would be absorbed by fish when the waters recede (Siregar and Murtini, 2008). This result was in line with Nirari (2020), the level of accumulation of heavy metals in mullets from Cengkok waters in August was higher than that in March and April.

The accumulation of Cu in mullets from Bojonegara was higher than that of other heavy metals. These results were similar to that of the research conducted by Hidayah *et al.* (2014), according to which the bioaccumulation of Cu in *Tilapia* sp was higher than those of Pb and Cd. Factors that can affect the level of accumulation of heavy metals in aquatic biota according to Asante *et al.* (2014), are namely the presence of heavy metals in waters and the metabolic ability of an organism. According to Hidayah *et al.* (2014), the accumulation of heavy metals can also be influenced by environmental conditions (temperature, pH, DO), fish species, feed, and excretion processes. It is also impacted by salt content, size, and stages of development (Grosell *et al.,* 2007).

Safety level

The safety limit for mullet consumption can be used to avoid the adverse effects that can be caused by the accumulation of heavy metals. This value is taken from the heavy metal which has the lowest MTI value. Calculation of the safe limit for consumption was not taken into account because the results of the analysis showed that the Hg, Cd, Pb, and Cu in the mullet's body were still below the quality standard. Therefore, mullets from the coastal waters of Bojonegara can be considered to be still safe for human consumption.

The accumulation of heavy metals in the bodies of living organisms will increase along with the increase in trophic levels so that it is closely related to prey biomass and food chain length (Puspitasari, 2006). Exposure to heavy metals in humans according to Siregar *et al.* (2020) can occur through the consumption of contaminated water and food. According to Sulistiono *et al.* (2018), foods with a low heavy metal content can increase the uptake of pollutants in the body if consumed continuously and have the potential to be toxic if a certain amount has been reached. Accumulation of heavy metals in aquatic biota can cause a decrease in gonadal maturity, inhibit growth due to closed gill membranes, and affect economic aspects because it can reduce the quality of fishery products leading to a decreased marketability (Suryani *et al.,* 2018).

According to Pratiwi (2020), mercury (Hg) poisoning at an acute level is characterized by symptoms of paralysis to death. Acute poisoning with cadmium (Cd) can cause emphysema or lung disorders. Other effects that can be caused are high blood pressure, liver disease, disorders of the kidneys and digestive glands, reproductive glands, respiration, and bone fragility (Setiawan 2013). Lead (Pb) in the body of living organisms can inhibit the formation of hemoglobin, and cause organ system disorders such as the kidneys, blood, reproductive system, gastrointestinal tract, and central nervous system (Laila and Shofwati, 2005). Symptoms arise in the form of decreased appetite, lethargy, seizures, vomiting, and dizziness. Acute copper poisoning can cause nausea, abdominal pain, vomiting, hemolysis, neutrophilic, seizures, and even death. Chronic poisoning causes copper to accumulate in the liver and hemolysis occurs, resulting in anemia and inhibited growth (Darmono, 1995).

The presence of heavy metals in nature that exceeds the thresholds can be a source of pollutants that can damage ecosystems, especially waters as the final estuary of by-products or waste from various natural processes and human activities. If the input of heavy metals into the waters occurs continuously, it is not noticed. This condition can disrupt and endanger the life of the surrounding biota. The existence of fish and other biotas in nature can be threatened or even extinct. Therefore, it is necessary to have an integrated system and firm action from the local government in carrying out environmental management efforts following the conditions of different seawater bodies, exemplified here at Bojonegara coastal waters. With this knowledge, the present study intended to enhance the sustainable use of resources in the waters of Bojonegara in the future.

Management can start with monitoring and evaluation of waste disposal from various sources, such as industries in the watershed (DAS) or water catchment area (DTA) of Bojonegara waters, starting from the upstream part of the river. It is necessary to ensure that there is a waste treatment planned (WWTP) that operates properly in every industry or activity that produces liquid waste. This is to ensure that the by-products or industrial waste discharged into the waters meet the quality standards and do not endanger the waters themselves.

The involvement of the local community would be very helpful in maintaining the marine environment of Bojonegara sustainably. People need to be more educated about these facts related to the consumption of biota from Bojonegara waters so that people are more aware of the dangers of heavy metals that can threaten their health. Socialization to the local community needs to be done regarding the sources and dangers of heavy metals. The public must be more vigilant in the use of materials containing heavy metals such as the use of ship anti-fouling. According to Lu (2006), lead is widely used as a pigment in the paint industry. This can be reduced by the use of anti-fouling obtained through the isolation of active materials from marine organisms. Mangrove tissue extracts, such as roots, stems, and leaves are known to contain secondary (bioactive) metabolite compounds that function as anti-fouling (Nur and Rahmawati, 2019) and do not have such negative effects on the environment.

Further research related to heavy metal contents in biota needs to be carried out at different locations and biota in the waters of Banten Bay. Besides that, research with different types of heavy metals and different organs studied, such as gills, liver, or kidneys in mullet also needs to be done as the focus of the present study was on the flesh of these fish. This study aimed to provide comparative data and to ensure the fish food safety of aquatic biota as consumption biota and fisheries products from coastal waters of Banten Bay.

Conclusion

Mullets from Bojonegara coastal waters experienced an accumulation of Cu with a moderate accumulation rate. The monthly variation in the levels of Cu accumulation indicates a difference in catches with a low to moderate accumulation level. The concentrations of Cu detected in waters and mullets flesh was still below the specified quality standards. Accumulations of Hg, Cd, and Pb were not detectable with the used methods or did not occur because their concentrations were too low and undetectable in both, waters and mullet flesh. The present study intended to enhance the sustainable use of fisheries resources and to support respective management in the waters of Bojonegara in the future.

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