Heavy metal contamination (Cd, Cu) in the gills and flesh of mullet (*Planiliza subviridis*) in Cilincing Coastal Waters, Jakarta Bay

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Abstract. The Cilincing coastal waters, part of Jakarta Bay, are significantly affected by waste inputs resulting from various community activities both nearby and further upstream. This situation is anticipated to impact the local biota, particularly mullet fish (*Planiliza subviridis*). This study aimed to evaluate the concentrations of heavy metals, specifically cadmium (Cd) and copper (Cu), in the gills and flesh of mullets. Sampling was conducted over a six-month period from February to July 2023 in the Cilincing coastal waters. The heavy metal concentrations were analyzed using the Atomic Absorption Spectrophotometer (AAS) method. The findings indicate that the concentrations of cadmium in the gills and flesh ranged from 0.19 ppm to 0.25 ppm and 0.07 ppm to 0.25 ppm, respectively. For copper, the concentrations in the gills and flesh varied from 0.62 ppm to 2.195 ppm and from 0.12 ppm to 1.62 ppm, respectively. Histopathological examinations revealed signs of hyperplasia, infiltration inflammatory cells, hemorrhage in the basal cells of the gills, and inflammatory cell infiltration in the flesh. Despite the observed heavy metal concentrations, the mullet captured in the Cilincing coastal waters of Jakarta Bay is deemed safe for consumption.

1 Introduction

Jakarta Bay Jakarta Bay is a region with a dense population and is significantly impacted by urban activities in DKI Jakarta. The bay serves as the end point for 13 rivers, including Angke, Mookervaart, Grogol, Pesanggrahan, Krukut, West Kalibaru, Ciliwung, East Kalibaru, Cipinang, Sunter, Buaran, Jatikramat, and Cakung [1]. Pollutants in the bay largely originate from anthropogenic activities, such as industrial by-products, port operations, fishing, and waste disposal. These pollutants often contain hazardous and toxic substances that pose serious threats to ecosystems and human health [2]. Consequently, the water quality in Jakarta Bay has likely deteriorated over time [3].

Anthropogenic influences contribute significantly to the accumulation of heavy metals in aquatic sediments [4]. Heavy metals, classified as hazardous pollutants with densities

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exceeding 5 g/cm³, tend to settle in the sediments [5]. Environmental changes, especially physicochemical shifts, can mobilize these metals from sediment into water, increasing their bioavailability and associated risks to organisms and ecosystems [6]. At high concentrations, heavy metals can cause mortality in aquatic organisms, whereas even at low concentrations, they may bioaccumulate in aquatic species [7].

Handayani et al. [8] highlighted that industrial discharges are a major source of heavy metal contamination, including cadmium (Cd) and copper (Cu). Cd enters aquatic environments through industrial, domestic, and agricultural activities [9], whereas Cu is introduced through sources such as air emissions, shipyards, and the metal plating industry [10]. These metals are highly soluble in water, resistant to degradation, and accumulate easily in sediments and aquatic organisms, including fish [11]. One fish species commonly found in Cilincing Beach is mullet, which is known for its ability to adapt to varying salinity levels and its wide distribution in tropical and subtropical waters [12].

Mullet plays an important economic role in Indonesia, with *Planiliza subviridis* is a popular species owing to its high nutritional value [13]. However, high market demand often leads to overexploitation. Heavy metal accumulation in fish tissues poses a significant health risk to humans who consume contaminated fish, potentially causing adverse health effects [14]. Several studies have been conducted on heavy metal contamination in Jakarta Bay, including research on sediment pollution [15], mercury (Hg) contamination in fish [16], and the effects of heavy metals on crabs [17] and mussels [18]. However, there is limited information on the accumulation of heavy metals such as cadmium (Cd) and copper (Cu) in the gills and flesh of mullets. Therefore, this study aimed to investigate the levels of Cd and Cu in mullet from Cilincing Coastal Waters, Jakarta Bay, providing valuable insights for public health considerations and sustainable management of Jakarta Bay.

2 RESEARCH METHODS

2.1 Time and location of research

Sampling of mullet was carried out in the period from February to Juli 2023 in the Cilincing coastal waters, Jakarta Bay. This research involved five observation stations, namely Station 1, Station 2, Station 3, Station 4, and station 5 which is part of the sea waters receiving waste flows from rivers and estuaries. The selection of locations for these stations was based on the results of the fishing ground of the fish which is around the Cilincing coastal waters, Jakarta Bay. Map illustration that show geographical research locations are presented in Figure 1.

Mullet dissection process was carried out at the Macro Biology Laboratory I, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences. Analysis of heavy metals in water was carried out in the Aquaculture Environment Laboratory, while analysis of heavy metals in flesh and gills was carried out in the Integrated Laboratory, IPB Baranangsiang Campus. Analysis histopathology in aquatic organism health laboratory, aquaculture, FPIK IPB.

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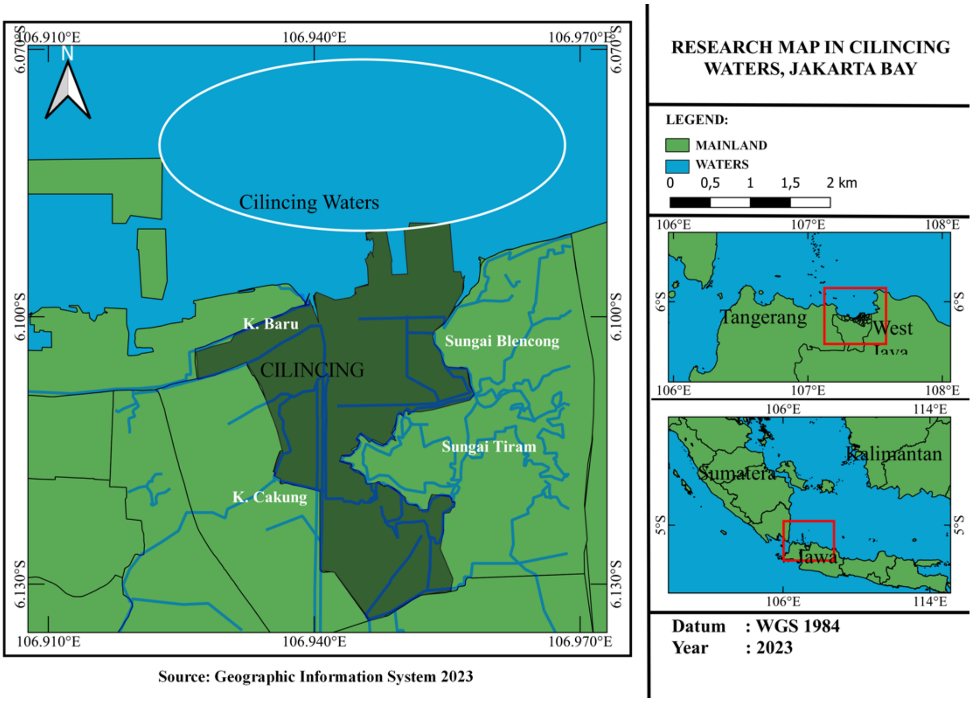

Fig. 1. Map of locations and research sampling points in Cilincing coastal waters, Jakarta Bay.

2.2 Data collection

This research This study used primary data collected from field observations and laboratory analyses. The primary data included the concentrations of heavy metals, specifically cadmium (Cd) and copper (Cu), in the gills and flesh of mullet, as well as mercury (Hg) and lead (Pb) in water samples. Additional data on the water quality parameters were also gathered. Mullet specimens were collected using a purposive sampling method based on fishing activities in the coastal waters of Cilincing, Jakarta Bay.

2.2.1 Sampling of mullet

Mullet (*Planiliza subviridis*) were caught using gill nets, with monthly samples ranging from 30 to 40 individuals. To ensure freshness, captured fish were immediately stored in a cooler box containing ice and transported to the laboratory. Sampling was conducted three times across different months, and the obtained fish were combined. The length of each mullet was measured using a ruler, whereas its weight was recorded using an analytical balance. Gills and flesh samples were extracted by dissecting each fish. Flesh samples, ranging between 50 and 100 g, were homogenized, wrapped in aluminum foil, and stored in a refrigerator to preserve sample integrity for subsequent analysis.

2.2.2 Analysis of mullet fish samples

The gills and flesh of the mullet were analyzed to determine the concentrations of heavy metals (Cd and Cu). Cadmium was measured at a wavelength of 228.8 nm, while copper was measured at 324.7 nm. Prior to analysis, the samples were processed using the Nitric Acid-

Perchloric Acid digestion method, as described by [19]. Levels of heavy metals in the gills and flesh were quantified using an Atomic Absorption Spectrophotometer (AAS).

2.2.3 Observation of fish tissue histopathology

A histopathological analysis of the gills and flesh of the mullet was conducted. Prior to analysis, the gills and flesh were separated and preserved in Davidson's solution to prevent tissue degradation. Histopathological samples were prepared following the procedure outlined in [20].

2.3 Data analysis

2.3.1 Bioconcentration factor (BCF)

The bioconcentration factor is an aspect that reflects the capacity of mullet to absorb and store polluting substances present in the surrounding environment. Estimation of the bioconcentration factors is carried out by comparing the concentration of heavy metals contained in the water moderate and the concentration of heavy metals accumulated in the organism's tissue. This step is intended to evaluate the ability of mullet to accumulate heavy metals from environmental water into their bodies. Calculation of the bioconcentration factor can be carried out using this formula [21].

BCF = Ct / Cw Where:

BCF = Bioconcentration factor
Ct = Heavy metal concentrations in the organism's body (ppm)
Cw = Heavy metal concentration in water (ppm)

Furthermore, the resulting *bioconcentration factor* (BCF) values were grouped into three categories based on the assessment carried out by [22], which indicates the level of heavy metal accumulation as follows:

Low accumulation = BCF less than 100
Moderate accumulation = BCF 100-1000 High accumulation
= BCF more than 1000

2.3.2 Maximum limit of consumption per week (*Maximum Weekly Intake*/MWI)

The maximum threshold for the amount of heavy metals in food that can be consumed per week (*Maximum Weekly Intake*) can be analyzed by referring to the *Provisional Tolerable Weekly Intake* (PTWI) value available in Table 1. PTWI is a value that indicates the maximum limit for intake of heavy metal contaminants in one week is considered safe for human health [23]. In calculating *Maximum Weekly Intake* (MWI), as explained by [24] the body weight used is 50 kg for adult individuals and 15 kg for children. The MWI calculation is carried out as follows:

MWI = Weight x PTWI

Where:

MWI = *Maximum Weekly Intake* (mg)
PTWI = *Provisional Tolerable Weekly Intake* (mg/kg BB)

Table 1. Maximum tolerance value for consumption per week

Heavy Metal	PTWI (mg/kg BB)
Cd	0.0070
Cu	3.5000

2.3.3 Maximum tolerance limit of consumption per week (Maximum Tolerable Intake/MTI)

Mullet is one of the biota that is a favorite in people's consumption patterns. However, it is important to determine the level of consumption of mullet that is still acceptable to the human body if the fish contains heavy metals. Determining the threshold for consumption of mullet within one week that the body can still tolerate, known as Maximum Tolerable Intake (MTI), can be calculated using the following formula [26]:

MTI = MWI / Ct

Where:

MWI = *Maximum Weekly Intake* (mg for adult body weight Indonesia 50 kg and children 15 kg per week)
Ct = Concentration of heavy metals found in the flesh of biota (ppm)

3 RESULT AND DISCUSSION

3.1 Cd and Cu content in gills and flesh of mullet

The results of the analysis of Cd heavy metal content exceeded the quality standard in gills and flesh, while Cu in gills and flesh was below the specified quality standard. The standards for heavy metal content Cd and Cu in gills and flesh are adjusted to the quality standards according to [27], [28], and [29]. The content of heavy metals Cd and Cu in mullet is presented in Figure 2.

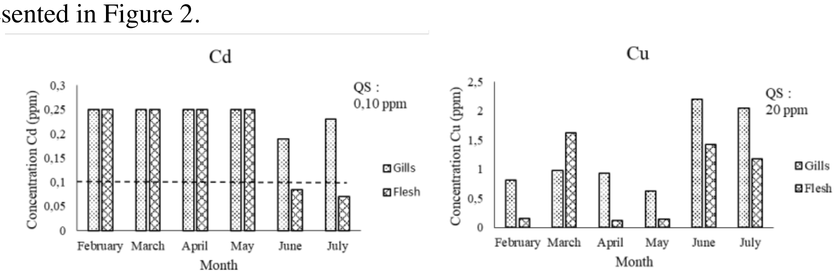

Fig.2. Content of heavy metals (Cd and Cu) in the gills and flesh of mullet

Mullet fish collected from the waters of Cilincing Beach, Jakarta Bay, exhibited a relatively uniform length distribution, ranging from 15 to 24 cm. The gills were dissected for analysis because heavy metals primarily enter the aquatic biota through this organ. Gills play a key role in osmoregulation, respiration, and excretion of metabolic waste and are highly sensitive to metal toxicity. Additionally, the flesh was analyzed because it is the part consumed by humans, making it important for assessing safe consumption limits and examining heavy metal accumulation. The concentrations of cadmium (Cd) and copper (Cu) in the gills and flesh of mullet fish from Cilincing Beach waters are shown in Figure 2.

Cadmium (Cd) is a non-essential heavy metal with no biological function in humans, and its presence is highly toxic, potentially causing poisoning. In contrast, copper (Cu) is an essential heavy metal required in small quantities for physiological and metabolic processes in aquatic organisms; however, it becomes toxic at elevated concentrations in their bodies [30]. Based on the analysis, the highest concentration of cadmium (Cd) in mullet gills and flesh was recorded between February and May 2023, reaching 0.25 ppm. In June 2023, cadmium (Cd) levels in the gills and flesh were 0.19 ppm and 0.085 ppm, respectively, while in July 2023, the concentrations were 0.23 ppm in the gills and 0.07 ppm in the flesh. The cadmium (Cd) content in the gills and flesh consistently exceeded the quality standard of 0.10 ppm set by [27] and [28], except for the flesh in June and July 2023. This discrepancy is likely due to cadmium (Cd) being more readily deposited in the gills. According to [31], cadmium (Cd) contamination originates from various sources, including air pollution, agricultural runoff from fertilizers and pesticides, industrial activities, and paint residue.

The concentration of cadmium (Cd) in fish is influenced by three main factors: the regulatory mechanisms within the fish body, the concentration of cadmium (Cd) in the surrounding water and sediment, and the duration of exposure to cadmium (Cd) in the environment. Additionally, elevated cadmium (Cd) levels may be linked to the use of cadmium-containing paints, fuel leaks, and ship welding activities. As noted in [32], the accumulation of heavy metals in aquatic biota is affected by environmental conditions, the biota's growth and metabolic rates, physiological requirements for metals, sensitivity to metal intake, exposure duration, metal concentrations in water, and sources of metal input.

The concentration of copper (Cu) in the gills and flesh of mullet fish from Cilincing Coastal Waters, Jakarta Bay, between February and July 2023, is also illustrated in Figure 2. The highest copper (Cu) concentration in mullet gills was recorded in June 2023 at 2.20 ppm, while the lowest was in May 2023 at 0.62 ppm. For mullet flesh, the highest copper (Cu) concentration was observed in March 2023 at 1.62 ppm, whereas the lowest was in April 2023 at 0.12 ppm. Notably, the copper (Cu) levels in both gills and flesh did not exceed the quality standard of 20 ppm, as outlined by [29]. According to [33], copper (Cu) contamination in aquatic environments may stem from volcanic activity, dock operations, fishing vessel transportation, and the use of anti-rust paints on ship hulls.

3.2 Histopathology of mullet

The results of histopathological observations of the gills and flesh of mullet fish in the Cilincing Coastal Waters, Jakarta Bay during the study are presented in Figures 3 and 4.

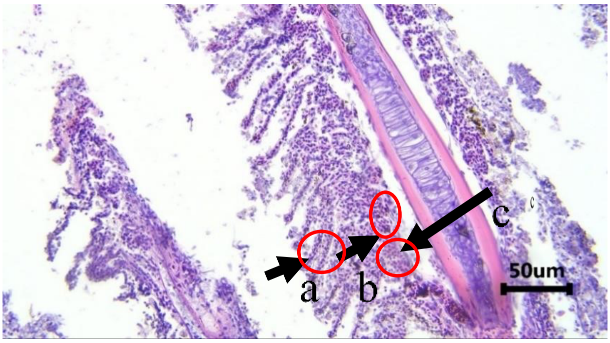

Fig. 3. Histopathology of mullet gill samples in Cilincing Coastal Waters, Jakarta Bay a). hyperplasia, b). inflammatory cell infiltration, c). basal cell hemorrhage (magnification 400).

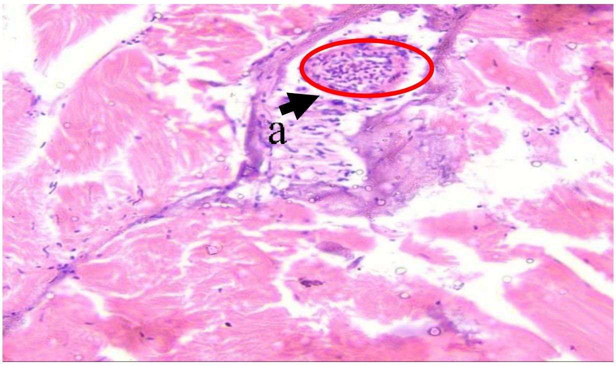

Fig. 4. Histopathology of mullet flesh samples in the waters of Cilincing Beach, Jakarta Bay a) inflammatory cell infiltration (magnification 400)

The findings of this study indicate that the concentration of heavy metals in the gills of mullet fish is higher than that in their flesh. This is because the gills are the primary organs exposed to substances entering the biota during respiration, with some of these substances being transported to other organs via the bloodstream. Heavy metal levels in aquatic organisms can be reduced through excretion, which allows the biota to eliminate toxic substances from their bodies. Additionally, aquatic organisms can naturally detoxify harmful compounds through the skin surface in significant amounts. According to [34], heavy metal concentrations in fish flesh are generally lower than those in other organs, such as the gills, liver, and kidneys.

Histological observations of the gills of mullet fish from Cilincing Coastal Waters, Jakarta Bay, revealed signs of hyperplasia, infiltration of inflammatory cells, and basal cell hemorrhage. Hyperplasia, as described in [35], refers to excessive tissue growth caused by an increase in cell numbers. In the gills, hyperplasia can lead to thickening of the epithelial tissue, either at the ends of the filaments or near the base of the lamellae. This condition is often triggered by exposure to heavy metals, such as lead (Pb), which irritates gill tissues and stimulates mucus secretion as a protective response. However, the mucus produced can coat the gill lamellae and obstruct the exchange of oxygen and carbon dioxide. This disruption

effectively prevents oxygen from binding to hemoglobin in the blood, thereby impairing oxygen transport throughout the fish's body.

Hemorrhage refers to blood loss caused by damage to blood vessels. It occurs when blood vessels rupture, resulting in blood leaking into tissues or outside the body. The hemorrhage observed in the histopathological analysis can be identified as dark red or black spots. According to [36], hemorrhage involves bleeding within cells due to severely damaged blood vessels, often caused by extreme congestion in the affected organs. This damage leads to blood pooling in areas where it should not occur, thereby compromising normal physiological functions. As noted by [37], hemorrhage can manifest as blood spots in body tissues, caused by excessive pressure or congestion that damages blood vessels.

Inflammatory cell infiltration in the gills and flesh of mullets represents an inflammatory response to pollutants. Inflammation is a defensive reaction of blood vessels and tissues to injury or exposure to harmful substances and is considered a vital response mechanism. When toxic materials enter the fish body, the primary response involves the accumulation of fluids from the blood vessel system and the migration of immune cells, such as lymphocytes, neutrophils, macrophages, and other blood components, to the affected area. Inflammation can be triggered by various factors, including viruses, bacteria, parasites, radiation, heat, or toxic substances, such as heavy metals [38].

3.3 Bioconcentration factor in mullet

The ability of aquatic organisms, such as mullets, to accumulate and retain water-borne pollutants is measured using bioconcentration factors. These factors are determined by comparing the concentration of heavy metals in the organisms to that in the surrounding water. Table 2 illustrates the bioconcentration factors of heavy metals in the gills and flesh of mullets sampled from the Cilincing Coastal Waters in Jakarta Bay.

Table 2. Bioconcentration factor of mullet in Cilincing waters, Jakarta Bay

Month	Gills of Mullet		Flesh of Mullet	
	Cd	Cu	Cd	Cu
February	150.00	45.85	150.00	8.49
March	39.47	108.89	39.47	180.00
April	250.00	348.75	250.00	45.00
May	438.60	885.71	438.60	200.00
June	791.67	365.83	354.17	238.33
July	367.02	341.67	111.70	196.67

Cadmium (Cd) is categorized as having a moderate level of accumulation, characterized by a bioconcentration factor (BCF) ranging from 100 to 1000. However, in March, Cd accumulation was considered low, with the BCF falling below 100. In contrast, copper (Cu) exhibits variable accumulation patterns across different months: it is classified as low accumulation (BCF < 100) in February and April, whereas from March to July, it transitions to a moderate accumulation status (BCF 100-1000). This fluctuation underscores the significant impact of seasonal changes and environmental conditions on the bioavailability and accumulation of these metals in aquatic ecosystems.

The investigation of mullet fish (Planiliza subviridis) in the Cilincing Coastal Waters of Jakarta Bay revealed that the accumulation of the heavy metals Cd and Cu varied from low to high levels. Supporting research conducted in the Bojonegara Coastal Waters of Banten Bay demonstrated similar findings regarding the accumulation of heavy metals, including mercury (Hg), cadmium (Cd), lead (Pb), and copper (Cu), in green mussels, which also exhibited accumulation levels ranging from low to high. Both mullet fish and green mussels are classified as demersal organisms, inhabiting the seabed and foraging for food. Factors influencing the degree of metal accumulation include the species of biota, type of heavy metal, duration of exposure, concentrations of heavy metals in the surrounding water, and overall water quality.

3.4 Safe limit of consumption of mullet

The coastal waters of Cilincing in Jakarta Bay have established consumption limits for mullet fish based on the maximum tolerable intake (MTI) for both adults (50 kg) and children (15 kg). These limits are determined by the heavy metal with the lowest MTI value, ensuring safe consumption levels to mitigate health risks. This approach highlights the importance of monitoring heavy metal concentrations in fish to protect public health, particularly for vulnerable populations such as children. The study shows that the weekly MTI for mullet flesh in this region is 1.400 kg for adults (50 kg) and 0.420 kg for children (15 kg). These results suggest that mullet fish can be consumed safely as long as individuals adhere to these weekly limits. Compliance with these consumption guidelines is essential for safeguarding public health, especially for children who are more vulnerable to heavy metal exposure.

Table 3. Maximum tolerance limits for consuming mullet fish per adult weight (50kg) and child weight (15 kg)

	Safety Level for adults per week (kg meat/week)		Safety Level for children per week (kg meat/week)	
	Cd	Cu	Cd	Cu
MWI*	0.350	175.000	0.105	52.500
Flesh Of Mullet	1.400	108.020	0.420	32.410

**Maximum weekly intake* in mg/week

The consumption of aquatic organisms contaminated with heavy metals poses significant health risks to humans, potentially leading to toxic effects and long-term illnesses. The severity and duration of these health effects depend on factors such as the concentration of heavy metals in the fish and the health condition of the individuals consuming them. Vulnerable groups, including children and pregnant women, are particularly susceptible to adverse effects that may manifest more quickly. To mitigate these risks, regular monitoring of heavy metal levels in aquatic organisms and public health education are essential to ensure the safe consumption of seafood [41].

Research has determined that the safe consumption limits for mullet fish meat from the Cilincing waters in Jakarta Bay are 0.420 kg per week for children and 1.400 kg per week for adults. Mullet fish from this region can be safely consumed if these limits are not exceeded. Adhering to these guidelines is critical to reducing

the risks associated with heavy metal contamination and protecting public health. Continuous monitoring of heavy metal concentrations in fish is necessary to ensure consumer safety. According to [42], the safe consumption limit is calculated based on the smallest Maximum Tolerable Intake (MTI) value for heavy metals such as cadmium (Cd) and copper (Cu).

Exceeding the safe consumption limits for mullet fish from Cilincing Beach, Jakarta Bay, can lead to health complications. Cadmium (Cd) contamination in fish has been linked to physiological damage, including damage to the circulatory system, kidneys, heart, and bones, potentially causing fibrotic bone damage. Copper (Cu) contamination, on the other hand, can result in liver damage, elevated blood pressure (hypertension), respiratory issues, seizures, vomiting, and, in severe cases, death [43].

4 CONCLUSION

The evaluation of heavy metal contamination in mullet fish from the Cilincing coastal waters of Jakarta Bay highlights several critical findings. Cadmium (Cd) concentrations in both gills (0.19 mg/kg – 0.25 mg/kg) and flesh (0.07 mg/kg – 0.25 mg/kg) generally exceed the established quality standards, raising significant health concerns. In contrast, copper (Cu) concentrations in gills (0.62 mg/kg – 2.195 mg/kg) and flesh (0.12 mg/kg – 1.62 mg/kg) remain within acceptable limits. The accumulation of these metals is classified as low to moderate. Histopathological analysis revealed notable damage to the gills, including hyperplasia, inflammatory cell infiltration, and basal cell hemorrhage, whereas similar inflammatory changes were observed in the flesh. To ensure safe consumption, the recommended limits are 0.420 kg of mullet meat per week for children and 1.400 kg per week for adults. As long as these limits are met, mullet fish from these waters can be safely consumed. However, ongoing monitoring and assessment of heavy metal levels are essential to safeguard public health and ensure the safety of fish harvested from this region.

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