Heavy Metal Content of Lead (Pb) And Copper (Cu) in Green Mussels (*Perna Viridis*) in The Ancol Waters

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Abstract. Heavy metals represent a significant class of pollutants in marine ecosystems due to their persistence and tendency to bioaccumulate in aquatic organisms and food chains. The green mussel (*Perna viridis*), a filter-feeding bivalve species abundant in Ancol Waters, is particularly vulnerable to heavy metal accumulation. This study investigates the levels of lead (Pb) and copper (Cu) in green mussels collected from Ancol Waters between February and June 2024. Sampling included water, sediment, and mussel tissue, and heavy metal concentrations were measured using Atomic Absorption Spectrophotometry (AAS). Results showed that Cu concentrations in water remained within acceptable environmental quality standards. However, Cu concentrations in mussel tissues exceeded permissible consumption limits in all months, while Pb levels surpassed the safety threshold only in February. Bioaccumulation assessment indicated that Pb in green mussels falls under the low accumulation category (BCF <100), whereas Cu ranged from moderate (100–1000) to high (>1000). Estimated safe consumption limits for mussel meat were 6.81 kg/week for children (15 kg body weight) and 22.74 kg/week for adults (50 kg body weight). These findings highlight potential health risks from long-term consumption and underscore the importance of regular monitoring of heavy metals in seafood from urban coastal areas.

1 Introduction

Ancol waters, situated along the northern coastline of Jakarta within Jakarta Bay, represent a strategically important economic zone. However, this region is under significant environmental stress due to various human-induced activities and the influx of pollutants from the Ciliwung River. The area has experienced ongoing development, accommodating critical infrastructures such as the Jawa 2 Gas and Steam Power Plant (PLTGU), Tanjung Priok International Port, Sunda Kelapa Harbor, and two fishing ports. These industrial and maritime facilities are considered potential sources of heavy metal pollutants, particularly lead (Pb) and copper (Cu) [1].

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Heavy metals, which are not biologically required by the human body, are among the most persistent contaminants in aquatic ecosystems. Characterized by their high densities (greater than 5 g/cm³) and ability to accumulate in aquatic organisms, these elements can enter water bodies through multiple anthropogenic sources [2]. Lead and copper are of particular concern due to their toxicological impacts on aquatic organisms, originating primarily from industrial waste, maritime transport, and port activities. These metals can be absorbed by marine life through ingestion, respiration, or dermal exposure, often accumulating in sensitive tissues such as the nervous system, thereby disrupting biological and physiological processes in species such as the green mussel (*P. viridis*) [3].

P. viridis is a sessile, filter-feeding bivalve that remains anchored to substrates in its habitat, making it highly vulnerable to pollutants in its immediate environment. Through its feeding mechanism—filtering suspended particles including plankton—the species is especially prone to accumulating heavy metal. Despite this susceptibility, green mussels are still actively harvested in the Ancol area and serve as a crucial protein source for the surrounding communities.

Several investigations have previously addressed heavy metal accumulation in green mussels. For instance, Riani *et al.* [4] analyzed contaminant levels in mussels from Jakarta Bay, while examined the morphological effects of metal accumulation in mussels from Muara Kamal. Other studies have assessed metal concentrations in sediments across Jakarta Bay [1] and explored lead toxicity in green mussels under varying water quality conditions [5]. Furthermore, [6] reported heavy metal levels at the estuarine outlet of the Ciliwung River, which directly influences Ancol's marine ecosystem. Nonetheless, dedicated research focusing specifically on the accumulation of heavy metals in green mussels from Ancol waters remains limited.

Addressing this gap, the present study aims to quantify the concentrations of Pb and Cu in both the waters of Ancol and the tissues of green mussels collected from the area. It also investigates variations in metal accumulation based on mussel size, examines the relationship between water and tissue metal content, and evaluates the potential health risks by estimating safe consumption limits for both children and adults.

2 Methods

2.1 Time and location

Green mussel sampling was conducted from February to June 2024 in the Ancol Waters to compare conditions between the north-west monsoon (NWM) season from February to March and the south-east monsoon (SEM) season from April to June. Water sampling carried out at three sites: station 1, station 2, and station 3. Station 1 is located near Sunda Kelapa Harbor and the mouth of the Ciliwung River. Station 2 is close to Ancol's recreational beach, and Station 3 is situated near the Tanjung Priok international port and the Jawa 2 Gas and Steam Power Plant (PLTGU). A map of the sampling locations can be found in (Figure 1) Green mussel samples were transported to the laboratory for sample digestion at the Environmental Productivity Laboratory, Faculty of Fisheries and Marine Science, IPB University.
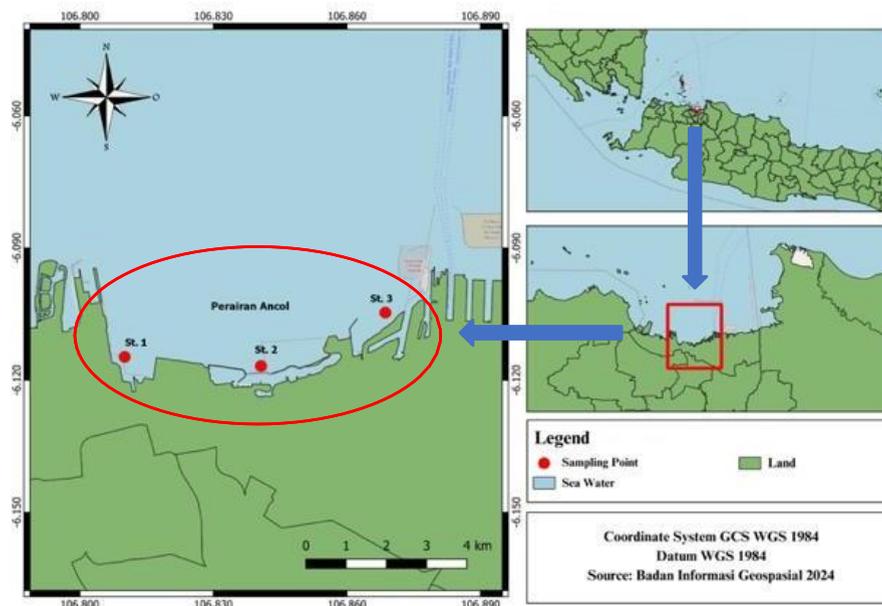
Fig. 1. Research and Sampling Location Map in Ancol Waters, Jakarta Bay.

2.2 Data collection

The data used in this study comprises both primary and secondary data. Primary data were obtained from sampling at the research site and laboratory analyses. The primary data analyzed and utilized in this study include heavy metal concentrations of Pb and Cd in the soft tissue of small and large green mussels, as well as Pb and Cu concentrations in water and sediment in the Ancol Waters. Secondary data were collected from journal articles and scientific publications on heavy metal pollution status in the Ancol Waters, serving as a comparison for this study's findings. Green mussel sampling followed a purposive sampling method based on the designated station areas.

2.2.1 Green mussels sampling procedures

Green mussels (*P. viridis*) were collected from around the Ancol Waters, Jakarta Bay, at three stations based on catchment areas. Mussels were harvested using an iron rake or traditional hand-diving methods. Live green mussels were placed in an ice box for transport to the laboratory. Sampling was repeated five times, once per month, with each sample comprising 100 mussels. Mussels were then composited and sorted into small mussels (<4 cm in width) and large mussels (>4 cm in width) [7], with 50 individuals in each size category per sampling month.

2.2.2 Separation of green mussels tissue

At the laboratory, samples in the cool box were processed to separate the soft tissue, weigh the net mass, measure tissue mass, and record mussel dimensions. Small (<4 cm) and large (>4 cm) mussels were dissected to collect the soft tissue [7]. The tissue was weighed using a digital balance with 0.0001g accuracy, wrapped in aluminum foil, labeled, and stored in a

freezer for up to 5 days. Subsequently, mussel tissue samples were digested to analyze Pb and Cu concentrations.

2.2.3 Digestion of green mussels tissue sample

Heavy metal analysis for the green mussel samples was conducted using an *Atomic Absorption Spectrophotometer* (AAS) after digestion with the *nitric acid-perchloric acid* method [7]. After digestion, 2 g sample was weighed using an analytical balance (0.0001 g accuracy), placed in a 300 mL Erlenmeyer flask, and positioned in an acid hood. Five milliliters of concentrated *nitric acid* (HNO_3) was added, and the sample was homogenized. The sample was heated on a hot plate at 100°C for 15 minutes until the mussels tissue dissolved, producing a light-yellow solution. Then, 2 mL of deionized water was added, and the sample was removed from the hot plate to cool at room temperature for 10 minutes. Afterward, 2 mL of *perchloric acid* ($HClO_4$) was added, and the sample was homogenized again. Additional *nitric acid* (HNO_3) and perchloric acid ($HClO_4$) were added to oxidize the sample, breaking down inorganic and organic compounds. The solution was reheated until white fumes of *perchloric acid* ($HClO_4$) appeared for 15 minutes. If the solution remained unsaturated, heating continued with the addition of 10 mL of concentrated *nitric acid* (HNO_3) until digestion was complete. The digestion phase was deemed complete once precipitate and white fumes were observed. The sample solution was then cooled at room temperature for 15 minutes.

2.2.4 Heavy metals analysis in green mussels

The fully digested mussel solution was filtered through a 0.45 µm filter paper into a 100 mL volumetric flask to separate any precipitates. Deionized water was added until the solution volume reached 100 mL, which was then homogenized. The solution was transferred to a labeled sample bottle, sealed, and stored at room temperature. The solution was analyzed using Flame Atomic Absorption Spectrophotometery (FAAS) to measure Pb and Cu concentrations.

The mussels tissue solution was injected into the AAS at 2 L per minute using an air-acetylene mixture to measure Pb and Cu concentrations. The Pb was measured at a wavelength of 283.3 nm, while Cu was measured at 324.7 nm. The sample solution passed through the nebulizer to the spray chamber, where aerosol mixed with fuel and oxidizing gas, then flowed to the burner head. The solution was excited using the air-acetylene flame, and the detector read its energy.

2.3 Data analysis

2.3.1 Bioconcentration factor (BCF)

This analysis was conducted to assess the level of heavy metal contamination in green mussels. The bioconcentration factor (BCF) is calculated by comparing heavy metal concentrations in water and in the mussels tissue. The BCF formula can be calculated as follows [8]:

$$BCF = Ct \,/\, Cwr \qquad (1)$$

In this formula, BCF represents the bioconcentration factor, *Ct* is the concentration of heavy metals in the organism (green mussels) in mg/kg, and *Cwr* is the concentration of heavy metals in water in mg/L. The results from the bioconcentration factor analysis are

classified into three categories based on [9]: low accumulation (BCF < 100), moderate accumulation (BCF 100-1000), and high accumulation (BCF > 1000).

2.3.2 Maximum limit consumption per week

The Maximum Weekly Intake (MWI) is the safe weekly consumption limit for green mussels by humans, ensuring health is not at risk, and is analyzed using the Provisional Tolerable Weekly Intake (PTWI) value [10] (Tabel 1). The PTWI is based on an average body weight of 15 kg for children and 50 kg for adults. The MWI can be calculated using the following formula:

$$\text{MWI} = Weight \text{ x } PTWI \qquad (2)$$

In this formula, MWI represents the maximum weekly intake, *weight* is the human body weight, and *PTWI* is the provisional tolerable weekly intake.

Table 1. Maximum tolerable value for consumption per week.

Heavy Metals	PTWI (mg/kg Bb)
Hg	0.0016
Cd	0.0070
Pb	0.0250
Cu	3.5000

2.3.3 Maximum tolerable intake (MTI)

The Maximum Tolerable Intake (MTI) is calculated after determining heavy metal concentrations and the MWI. MTI represents the tolerance limit for human consumption of green mussels with accumulated heavy metals. MTI can be calculated using the following formula:

$$\text{MTI} = MWI \text{ / } Ct \qquad (3)$$

In this formula, MTI is the maximum tolerable intake, *MWI* is the maximum weekly intake and *Ct* is the concentration of heavy metals in the organism (mg/kg).

2.3.4 Statistical analysis

Two-factor without replicaton analysis (ANOVA) with Microsoft Excel software to determine the effect of different sizes of green mussels (*P. viridis*) on Pb and Cu heavy metal contamination.

2.3.5 Descriptive analysis

The water quality data obtained are presented in tabular form, and Pb and Cu heavy metal concentration data are shown in bar charts. The data are analyzed by comparing heavy metal concentrations based on green mussel size (*P. viridis*), specifically small-sized mussels (weighing less than 4 g) and large-sized mussels (weighing 4 g or more) based on monthly catch sizes. Heavy metal concentration data for water and water quality are compared with standard quality values based on [3], which sets water quality standards for marine biota protection. Additionally, the heavy metal concentration data from this analysis are compared to the maximum permissible levels of heavy metal contaminants in processed food for

mollusks. Pb concentrations are compared according to standards in and, and Cu concentrations according to.

3 Results and discussion

3.1 Concentration of Pb and Cu in green mussels meat

The analysis results showed that Pb concentrations in large green mussels (*P. viridis*) exceeded the food safety standard (1.5 mg/kg) from February to May which shown in (Figure 2). The highest Pb contamination in large mussels was recorded in February (5.39 mg/kg), while the lowest was in May and June (below the detection limit). Pb concentrations in small green mussels also exceeded the safety standard in February and March, but in April, Pb contamination levels did not surpass the standard limit. In May and June, Pb concentrations in small mussels were undetectable, falling below the AAS detection limit of 0.23 mg/kg. The highest Pb contamination in small mussels was recorded in February (3.78 mg/kg), with the lowest in May and June (below detection limits).

Cu analysis revealed that Cu levels in both large and small green mussels were below the food safety standard of 20 mg/kg which shown in (Figure 3). The highest Cu contamination in large mussels was found in February (10.28 mg/kg), with the lowest in May (6.26 mg/kg). In small mussels, the highest Cu level occurred in February (4.73 mg/kg) and the lowest in June (2.74 mg/kg). Bivalve organisms, including green mussels, produce metallothionein compounds capable of binding heavy metals absorbed into their bodies. *Metallothioneins* are low molecular weight, *cysteine-rich cytosolic* proteins that can bind heavy metals. *Metallothioneins* bind heavy metals entering the organism with *sulfur thiolates* and convert toxic heavy metals into zinc within the organism's body.
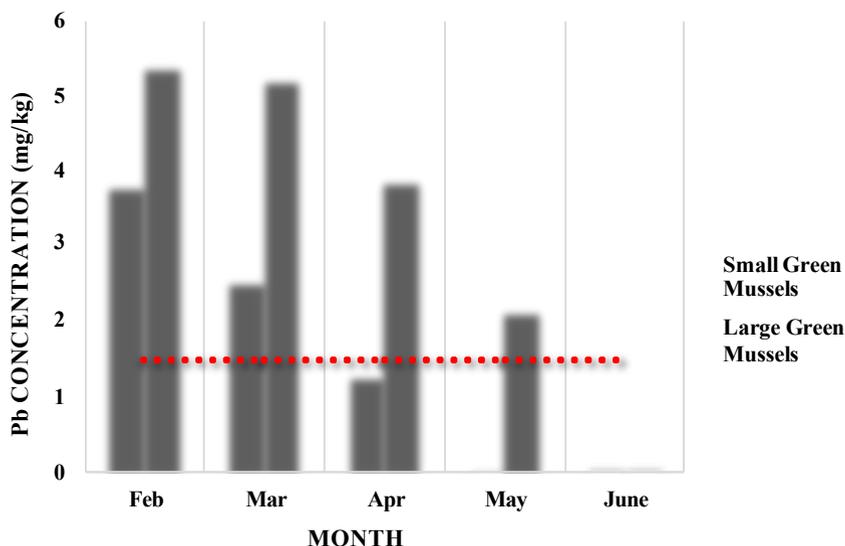

Fig. 2. Pb contamination levels in small green mussels and large green mussels. (---) indicates the Pb contamination standard limit.
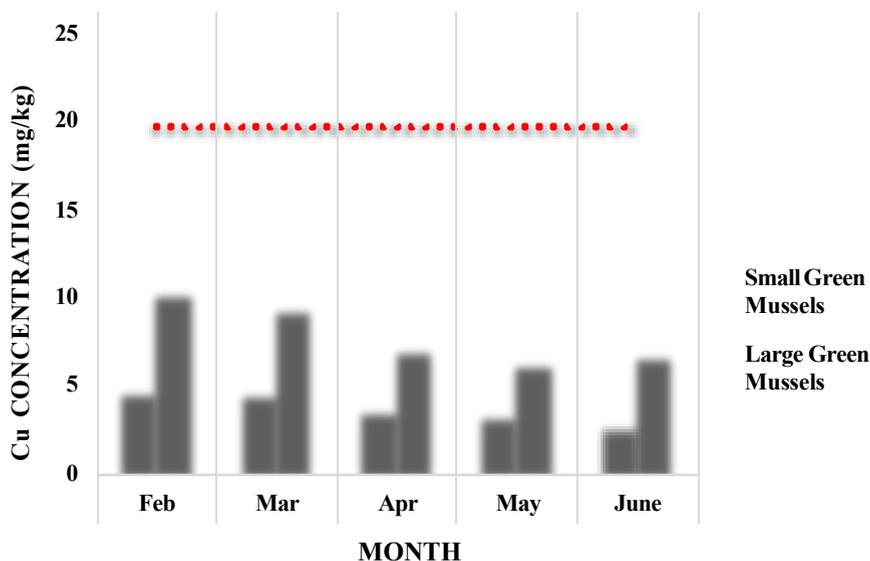
Fig. 3. Cu contamination levels in small green mussels and large green mussels. (---) indicates the Cu contamination standard limit.

The outcomes of the two-way ANOVA analysis for lead (Pb) and copper (Cu) concentrations in relation to green mussel size are presented in Table 2. Statistical analysis revealed that variations in mussel size did not significantly influence the levels of heavy metals accumulated in their tissues ($p < 0.05$). This observation supports the findings of [3], which suggest that while larger mussels may exhibit higher levels of heavy metal accumulation due to prolonged exposure, the differences are not statistically significant, likely because larger mussels possess more efficient mechanisms for eliminating non-essential metals compared to smaller individuals. The presence of heavy metals in mussel tissues primarily reflects the contamination levels of the surrounding seawater [4].

This study also found that copper concentrations in green mussel tissues were consistently higher than those of lead, a trend similarly reported by [11] for green mussels collected from Jakarta Bay. Even at low environmental concentrations, heavy metals can bioaccumulate within aquatic organisms, with variability in uptake and retention across different species, tissues, and organs. Additionally, the concentrations of Pb and Cu in green mussel tissues were significantly higher than those in the surrounding water. This pattern aligns with previous research [4], which characterizes green mussels as effective bioaccumulators—often referred to as "biological filters"—capable of concentrating heavy metals from their environment.

Table 2. Two way ANOVA based on size of green mussels.

Source	Sum of Square	df	Mean Square	F	Sig
Pb	8.15	1	8.15	13.03	0.0210
Cu	43.13	1	43.13	81.95	0.0008

3.2 Bioconcentration factor (BCF)

The bioconcentration factor (BCF) is used to explain the ability of aquatic biota to absorb heavy metal pollutants by comparing the concentration of heavy metals in the organism's body to the concentration of heavy metals in the surrounding water. The bioconcentration factors for heavy metals in green mussels are presented in (Table 3).

Table 3. Bioconcentration factor of green mussels.

Month	Small Size		Large Size	
	Pb	**Cu**	**Pb**	**Cu**
February	21.8	59.1	31.16	128.5
March	18.1	64.4	37.21	133
April	8.5	61.0	25.8	117.3
May	*0	86.8	15.36	169.2
June	*0	101.5	*0	249.3

*Heavy metal contamination value below the limit detection of AAS.

Based on the analysis results, it was found that the bioconcentration factor for heavy metal in small mussels and large mussels is different but not significance according to ANOVA analysis. Pb accumulation is categorized as low accumulation (<100), while the bioconcentration factor for heavy metal Cu in small mussels is also categorized as low accumulation (<100), except in June, when it falls into the moderate accumulation category (100-1000). For large mussels, the analysis results indicate that the bioconcentration factor for Pb remains within the low accumulation category (<100), while the bioconcentration factor for Cu in large green mussels falls into the moderate accumulation category (100-1000). The highest bioconcentration factor for heavy metal Cu in large mussels was observed in June with the value of 249.3.

3.3 Contaminations of heavy metals Pb and Cu in the water

Heavy metal contamination in the waters is closely related to the environmental conditions, as evidenced by the physical and biological quality parameters of the water. The results of in-situ quality parameter analysis can be presented in (Table 4). Based on the in-situ water quality analysis from February to June, pH levels remained below the quality standards for water throughout all seasons. Salinity levels were also below the quality standards during all seasons. The temperature in Ancol Waters during all observation months fell within the quality standards for seawater.

Table 4. Water quality in Ancol Waters, Jakarta Bay.

Parameter	Season		Quality Standard
	NWM (Feb-Mar)	**SEM (Apr-Jun)**	
pH	6.833 ± 0.138	6.675 ± 0.506	7.5-8.5
Salinity	29.35 ± 0.141	29.36 ± 0.558	33-34
Temperature	29.55 ± 1.061	30.26 ± 0.448	28-32
DO	7.15 ± 0.354	6.5 ± 2.179	>5
Turbidity	7.37 ± 0.233	5.088 ± 0.89	5
Transparency	2.1 ± 0.071	2.417 ± 0.375	>5

Dissolved oxygen (DO) levels met the quality standards for seawater and aquatic biota throughout the observation period. Turbidity was close to the quality standards for water, but during the North-West Monsoon (NWM), it appeared murkier compared to the South-East Monsoon (SEM). This is in contrast to transparency, which was below the quality standards for seawater in all seasons. The quality standards for all parameters refer to. Heavy metal contamination arises from various anthropogenic activities.

Table 5. Heavy metals concentration in Ancol Waters.

Heavy Metals (mg/L)	NWM		SEM			Banten Bay	Fujian, China	Valencia, Spain
	February	**March**	**April**	**May**	**June**			
Pb	0.173	0.140	0.150	0.140	0.117	<0.002	0.110	0,025

Cu	0.080	0.070	0.060	0.037	0.027	0.005-0.007	0,063	0,028

Based on the analysis results shown in Table 5, the concentrations of heavy metals in Ancol waters during all observed months exceeded the threshold values established for marine aquatic life protection, as outlined in. The peak concentration of lead (Pb) was detected in February at 0.173 mg/L, while the minimum value was recorded in June at 0.117 mg/L. Similarly, copper (Cu) reached its highest level in January at 0.080 mg/L, with the lowest concentration occurring in June at 0.027 mg/L. When compared globally, the Pb concentration in Ancol waters is substantially higher than that in Banten Bay (<0.002 mg/L) [7], Fujian Bay in China (0.110 mg/L) [12], and the coastal waters of Valencia, Spain (0.025 mg/L) [13]. The average Cu levels in Ancol also surpass those reported in Banten Bay (0.005–0.007 mg/L), Fujian Bay (0.063 mg/L), and Valencia (0.028 mg/L). These findings suggest a notably high degree of heavy metal contamination in Ancol waters relative to other international coastal environments.

A strong correlation was observed between heavy metal concentrations in the water and their corresponding accumulation in green mussels. Specifically, the correlation coefficient between Pb levels in water and mussel tissues was 81.8%, while Cu showed an even stronger relationship at 88.1%. As noted by [7], the presence of heavy metals in aquatic organisms is influenced by ambient concentrations in the surrounding water, as certain metals are absorbed and utilized in metabolic functions. Among water quality parameters, pH plays a significant role in regulating metal solubility. An increase in pH tends to reduce the solubility of heavy metals due to a chemical shift from carbonate to hydroxide forms, which promotes adsorption onto particles and eventual sedimentation.

Seasonal variations also impact metal concentrations. Elevated heavy metal levels are generally associated with the Northwest Monsoon (NWM) season, driven by increased rainfall and enhanced hydrodynamic activity, which leads to greater sediment resuspension. In contrast, during the Southeast Monsoon (SEM), higher temperatures and evaporation rates contribute to pollutant accumulation in localized areas, potentially exacerbating contamination levels.

3.4 Maximum tolerable intake (MTI)

The maximum tolerable intake of green mussel meat for children, assuming a weight of 15 kilograms, and for adults, assuming a weight of 50 kilograms, within one week is presented in (Table 6). The maximum tolerable intake (MTI) for the heavy metal Pb for children is 0.19 kg/week, while for adults, it is 0.66 kg/week. The maximum tolerable intake for the heavy metal Cu is 6.62 kg/week for children and 22.08 kg/week for adults.

Table 6. Safety consumption level of green mussels (kilograms per week).

MTI (kg/week)	Children (15 kg)	Adult (50 kg)
Pb	0.19	0.66
Cu	6.62	22.08
Total	6.81	22.74

Establishing safe consumption thresholds for green mussels is essential to limit human intake of heavy metals and mitigate potential health risks associated with long-term exposure. Findings from this study suggest that green mussels harvested from Ancol Waters remain fit for human consumption when intake is maintained within recommended safety margins. Prolonged ingestion of heavy metals can result in their gradual accumulation in bodily tissues over time. Elements such as lead (Pb) and copper (Cu) are readily absorbed through the gastrointestinal tract, and once in the body, these metals can exert

toxic effects, particularly targeting the nervous system. Such toxicity may lead to cellular damage, reproductive dysfunction, and developmental issues in offspring. Consequently, regulating the intake of food items contaminated with heavy metals is crucial to safeguard public health [4].

4 Conclusion

The concentrations of lead (Pb) and copper (Cu) detected in Ancol Waters ranged from 0.117 to 0.173 mg/L and 0.027 to 0.080 mg/L, respectively. In green mussel tissues, Pb levels varied from below 0.23 up to 5.39 mg/L, while Cu concentrations ranged between 6.26 and 10.28 mg/L. For smaller-sized mussels, Pb levels ranged from non-detectable to 3.78 mg/L and Cu concentrations from 2.74 to 4.73 mg/L. Bioconcentration factor (BCF) analysis indicated that small green mussels exhibited low accumulation potential for Pb, whereas larger individuals showed a moderate accumulation tendency. Although the metal concentrations were higher in larger mussels compared to smaller ones, the differences were not statistically significant. A strong positive correlation was observed between metal levels in water and mussel tissue, with Pb and Cu showing correlation coefficients of 81.8% and 88.1%, respectively. Based on the concentrations found, green mussels harvested from Ancol Waters remain safe for human consumption, including both children and adults, provided intake remains within established safety guidelines.

References

1. R. Endang, A. Rozak, Makara Sains. **11,** 1 (2007)
2. O. Jitar, C. Teodosiu, A. Oros, G. Plavan, M. Nicoara, New biotechnology, **32**(3) (2015).
3. N. Cahyani, D.T.F.L. Batu, Sulistiono, J. Pengol. Has. Perikan. Indones. **19** (2016).
4. E. Riani, M.R. Cordova, Z. Arifin, Mar. Poll. Bull. **133** (2018)
5. Firdaus, Aunurohim, J. Sains Seni ITS, **8,** 2 (2020)
6. G. Hariharan, R. Purvaja, R. Ramesh, J. Toxic. Environ. Health, A **77,** 5 (2014)
7. Juwana, R. Nurjayati, R. Maria, H. Santoso, D. Marganingrum, IOP Conference Series: Earth and Environmental Science. **1263,** 1 (2023)
8. D.I. Susilowati, R. AffandiI, IOP Conference Series: Earth and Environmental Science. **1083,** 1 2022
9. M. D. LaGrega, P. L. Buckingham, J. C. Evans (Hazardous waste management, Waveland Press, 2010).
10. V. G. J. Esch, (Procceding of the 2nd Int. Symp. on Aquatic Pollutans. New York 1977)
11. T. Y. Le, S. Zimmermann, B. Sures. Environ. Poll. **212** (2016)

12. L. Zhao, W. You, Haiqing. H, W. Hong, X. Liao, S. Xiao, R. Wang, J. Cai, X. Fang, Y. Tan, D. He. J. Forest. Res. **26,** 3 (2015)
13. C. Herandez-Crespo, M. Martin. Catena. **133** (2016)
14. S. Usman, N. L. Nafie, M. Ramang, Mar. Chim. Acta. **14,** 2 (2013)