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# Heavy Metals Pb, Cd and Cu in Palu Bay Waters

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**ABSTRACT**

The coastal waters of Palu Bay are vulnerable to pollution from various activities of the surrounding population. This study aimed to determine the content of heavy metals Pb, Cd, and Cu in the water and sediment of the coastal waters of Palu Bay. The analysis of heavy metal content (Pb, Cd, and Cu) in water and sediment was conducted using an Atomic Absorption Spectrophotometer (AAS). Based on the research, the results showed that the heavy metal content in the water ranged from undetected to 0.04 mg/L for Pb, undetected for Cd and Cu. The heavy metals content in the sediment ranged from 2.17 to 13.8 mg/kg for Pb, undetected to 0.17 mg/kg for Cd, and 5.02 to 37.67 mg/kg for Cu. The Pb content in the water has significantly exceeded the quality standard as stipulated in the Minister of Environment Decree No. 51 of 2004. The Pb content in the sediment is still within safe limits according to Canadian quality standards. The Cd content in the sediment exceeded the quality standard at station 6, while for the other 9 stations, it was not detected. The Cu content in the sediment at 5 stations (2, 3, 4, 5, and 10) has exceeded the Canadian quality standard of 18.7 mg/kg.

**Keywords:** Heavy metals, Seawater, Sediment, Palu Bay

## INTRODUCTION

Heavy metal contamination has become a serious environmental issue and continues to increase along with population growth and industrial activities. Heavy metals such as lead (Pb) and cadmium (Cd) are hazardous pollutants to aquatic ecosystems and human health (Mulyati et al., 2023). The entry of harmful heavy metals into water bodies can lead to pollution in those waters (Hariyoto, 2017). Pollution of coastal water areas originates from various human activities on land, such as industrial waste disposal, agriculture, mining, and domestic waste (Firmansyah & Sustiyani, 2021; Herawati et al., 2023). Heavy metal contamination in aquatic environments increases the concentration of these metals in water and sediments. An increase in heavy metal concentrations in water poses a threat to aquatic biota and communities that depend on water resources. Therefore, monitoring the levels of heavy metals in water and sediments is essential for understanding the impact of pollution, especially heavy metals.

Palu Bay is a water body vulnerable to contamination from various activities of the surrounding population. The presence of gold mining to the east of Palu City is one of the potential sources of pollution, particularly heavy metal pollution (Paundanan et al., 2015; Said et al., 2014). Likewise, the many sand mining companies operating along the Palu-Donggala main road also have the potential to contribute to heavy metal pollution in Palu Bay. Mining is one of the sources of heavy metal pollution in water bodies (Shang et al., 2023). In addition, pollution sources from anthropogenic activities in Palu City also have the potential to cause heavy metal contamination in Palu Bay waters. According to Karubuy et al., (2023), anthropogenic activities on land, such as industry, mining, shipping, aquaculture, agriculture, and household activities, have the potential to pollute marine ecosystems. This occurs because waste generated from human activities that is disposed of into the environment will inevitably be carried into rivers and ultimately reach the sea.

The continuous influx of heavy metals into Palu Bay waters will increase their concentration in the water. The increasing concentration of heavy metals in the water will settle into the sediments at the bottom of the water (Paundanan et al., 2023; Robi et al., 2021), and may even contaminate aquatic biota such as shellfish, fish, and other marine organisms (Pratiwi, 2020; Yona et al., 2021). If this continues and exceeds the safe threshold, it could result in a decline in water quality in Palu Bay, which could also affect human health if they consume fish contaminated with heavy metals (Riani, 2015). This is particularly

concerning as Palu Bay remains a fishing ground for fishermen living along the coast of Palu Bay.

The decline in water quality due to pollutants like heavy metals can directly impact the productivity of aquatic ecosystems (Natan et al., 2023). The heavy metal content in water is greatly influenced by physical and chemical parameters (Nurhamiddin & Ibrahim, 2018). High concentrations of pollutants, particularly heavy metals in the water, can affect the survival of organisms living in it and may also impact human health if they consume fish contaminated with heavy metals (Yolanda et al., 2017). Heavy metals can naturally be found in seawater in low concentrations necessary for aquatic organisms' metabolic processes, but when they exceed tolerance limits, they become toxic to marine life (Edward, 2020; Huseen & Mohammed, 2019). High levels of heavy metals in the water can accumulate in sediments, posing a danger to biota living there (Edu, L. Edwin-W, et al., 2015; Edu, Udensi, et al., 2015; Raza'i et al., 2022). Heavy metals in sediments can also be absorbed by aquatic plants like seagrass (Rosalina et al., 2022). The distribution of heavy metals in marine sediments is greatly influenced by physical-chemical factors (Shang et al., 2023), the structure, size, and hydrodynamic conditions of the sediments (Nugraha et al., 2022).

This study aims to determine the concentrations of heavy metals Pb, Cd, and Cu in water and sediments in the coastal waters of Palu Bay. The data from this study can serve as a basis for the government and relevant authorities in formulating policies to address pollution in Palu Bay waters.

## RESEARCH METHODS

The determination of sampling stations was carried out using a purposive sampling method, considering the sources of pollution entering Palu Bay's waters. Research stations were selected based on the number and proximity of pollution sources and the level of activities that could cause pollution in Palu Bay, such as the Palu River Estuary, areas near hotels, and recreational spots (Said et al., 2014). Samples were collected at 10 stations (Figure 1). Sampling took place in September 2024. Temperature and pH measurements were conducted directly in the field during the study, while analysis of water quality parameters such as Dissolved Oxygen (DO) and Salinity was performed at the Environmental Laboratory Unit, Central Sulawesi Provincial Environmental Agency.

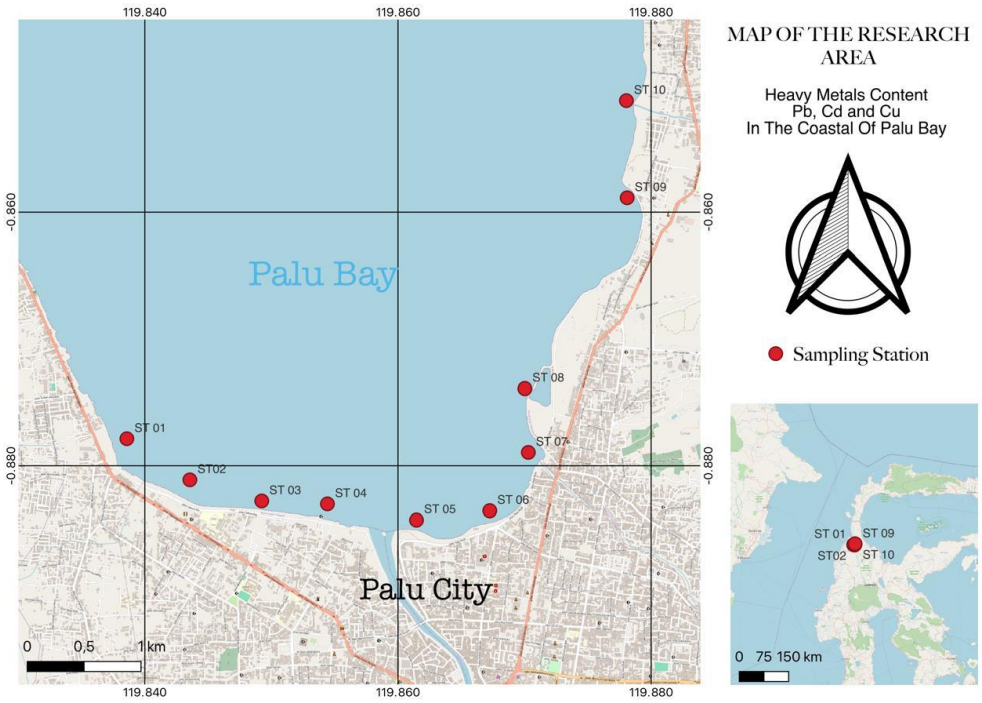


**Figure 1.** Map of Research Areas in Palu Bay

Seawater samples were collected from the surface using a sample bottle. The water samples for heavy metal analysis were stored in polyethylene (PE) bottles and preserved with nitric acid (HNO3) until the pH reached <2. Sediment samples were collected using a PVC pipe, with 250 grams of sediment taken from the surface layer. The sediment samples were then homogenized by compositing them (Barokah et al., 2019), placed in polyethylene (PE) plastic bags, and stored in a box containing ice (at 4°C) (Yogafanny, 2015).

Subsequently, the water and sediment samples were taken to the laboratory for heavy metal analysis (Pb, Cd, and Cu) using an atomic absorption spectrophotometer (AAS). The heavy metal analysis in water and sediment was conducted at the UPTD Testing and Certification of Goods Quality Laboratory, Department of Industry and Trade, Central Sulawesi Province. The analysis results for heavy metals in water were compared with the water quality standards set by Decree of the

Minister of Environment No. 51 of 2004 on Marine Water Quality Standards for Marine Biota. Meanwhile, the heavy metal data for sediments were compared with guidelines from Canada and Australia, as there are no established heavy metal sediment quality standards in Indonesia (Paundanan et al., 2015).

## RESULTS AND DISCUSSION

### Water Quality Conditions

Table 1 presents the analysis results of several water quality parameters, including Temperature, pH, DO, and Salinity. The results obtained generally comply with the water quality standards set by Decree of the Minister of Environment No. 51 of 2004. Increases in water quality parameters significantly affect aquatic biota and can trigger an increase in heavy metal concentrations in the water (Tirtama et al., 2024). Water quality measurements were carried out as an initial step to assess and provide an overview of the heavy metal content under investigation.

The water quality measurement results show that Station 10 has the highest temperature, recorded at 30.10°C. However, the temperature values at all study stations still meet the marine water quality standards for biota, as stipulated in Decree of the Minister of Environment No. 51 of 2004, which is between 28-32°C. According to Suprapti et al. (2016), elevated water temperatures can influence the accumulation and toxicity of heavy metals, making temperature a contributing factor to higher heavy metal accumulation values in water. Additionally, temperature can enhance the solubility of heavy metals in water and accelerate ion formation reactions, potentially impacting the heavy metal concentrations observed in the study.

The pH measurements in the waters of Palu Bay ranged from 7.50 to 7.90, with an average of 7.75. The results are still within the acceptable range for biota, which is 7-8.50. This indicates that the waters of Palu Bay are in good condition. The pH concentration in water can be influenced by anthropogenic activities on land, which produce waste, and rainfall, which tends to increase the pH concentration in the water (Riani et al., 2017). This suggests that high pH concentrations can affect the solubility of heavy metals in water bodies (Tirtama et al., 2024). According to the study results, the highest pH values were found at stations 1 and 7. This is suspected to be due to these stations receiving significant input from anthropogenic waste activities, as they are located near shopping centers, hotels, and hospitals. This is consistent with the research by Anzori et al. (2019), which reported that an increase in pH concentration in water contributes to the elevated levels of heavy metals in the water.

**Table 1.**
SEA WATER QUALITY PARAMETER DATA

| Station | Temperature (°C) | pH | DO (mg/L) | Salinity (ppt) |
|---|---|---|---|---|
| 1 | 28.00 | 7.90 | 6.68 | 37.77 |
| 2 | 29.00 | 7.80 | 4.92 | 40.75 |
| 3 | 29.50 | 7.70 | 4.92 | 39.92 |
| 4 | 27.20 | 7.80 | 7.04 | 14.47 |
| 5 | 26.50 | 7.60 | 6.33 | 26.06 |
| 6 | 29.50 | 7.50 | 7.04 | 42.58 |
| 7 | 28.50 | 7.90 | 7.04 | 23.10 |
| 8 | 30.00 | 7.80 | 5.63 | 33.77 |
| 9 | 30.00 | 7.80 | 3.16 | 43.86 |
| 10 | 30.10 | 7.70 | 7.74 | 45.10 |
| Average | 28.83 | 7.75 | 6.05 | 34.74 |
| Standard | 28-32 | 7-8.50 | >5 | ≤34 |

The average Dissolved Oxygen (DO) concentration in the waters of Palu Bay is generally within good condition, but there are stations (2, 3, and 9) where the DO value is below the established standard (>5) set by Decree of the Minister of Environment No. 51 of 2004. This may be due to ongoing tsunami wave barrier construction projects at these stations, which could lead to decreased DO levels. These stations are also located near river mouths, which bring organic waste from densely populated areas. The main cause of low DO in the water is the entry of organic waste, which consumes oxygen during decomposition (Koniyo, 2020). Low DO concentrations in the water can negatively affect the survival of aquatic organisms, including reducing their appetite, growth, and swimming speed (Eddiwan, 2018). Compared to previous studies, the average DO value obtained in this study is lower, at 6.05 mg/L.

Salinity concentrations in Palu Bay ranged from 14.47 to 45.10 ppt, with an average of 34 ppt. The seawater salinity standard for marine biota is regulated by Decree of the Minister of Environment No. 51 of 2004, which is ≤34 ppt. The lowest salinity concentration was found at Station 4, and the highest concentration was at Station 10. The low salinity at Station 4 is due to its location at the Palu River mouth, where freshwater mixes with seawater. Similarly, Station 7 is located at the mouth of the Komodo River. When compared to other studies, the average salinity concentration in this study is still consistent with typical seawater salinity, which generally ranges from 30.00 to 35.00 ppt in Indonesian waters (Eddiwan, 2018).

### Heavy Metals Pb, Cd, and Cu in Sea Water and Sediment

The results of heavy metal analysis in water and sediment are shown in Table 2. The Pb content in water at sampling points 4 to 10 (0.01-0.04 mg/L) indicates that it has significantly exceeded the water quality standard of 0.008 mg/L as per Decree of the Minister of Environment No. 51 of 2004. This is most likely due to the entry of domestic waste and fishing vessel activities. Heavy metals in water can come from various anthropogenic activities, such as boat painting and fuel spills from ships or boats (Rosalina et al., 2022). Pb contamination in the water may also stem from fishing boat activities, such as fuel spills or leaks from fishing vessels (Wahyuningsih et al., 2021). Heavy metal contamination in the water can also originate from mining activities on land (Paundanan et al., 2023;

Raza'i et al., 2022). High concentrations of Pb in the water column can accumulate in sediments (Paundanan et al., 2015; Riani, 2015). On the other hand, Cu and Cd were not detected, possibly due to dilution in open waters. Additionally, the waters of Palu Bay are still in a natural condition and have not been contaminated by Cd and Cu. It may also be because these metals are more easily diluted by seawater and can easily migrate (Noor & Kabangnga, 2021).

**Table 2.**
RESULTS OF HEAVY METAL ANALYSIS OF Pb, Cd, AND Cu IN SEA WATER AND SEDIMENT

| Sampling Point | Sea Water | | | Sediment | | |
|---|---|---|---|---|---|---|
| | Pb (mg/L) | Cd (mg/L) | Cu (mg/L) | Pb(mg/kg) | Cd (mg/kg) | Cu (mg/kg) |
| 1 | 0* | 0* | 0* | 3.63 | 0* | 14.57 |
| 2 | 0* | 0* | 0* | 13.80 | 0* | 37.67 |
| 3 | 0* | 0* | 0* | 7.31 | 0* | 24.35 |
| 4 | 0.04 | 0* | 0* | 7.11 | 0* | 23.43 |
| 5 | 0.01 | 0* | 0* | 7.90 | 0* | 27.09 |
| 6 | 0.01 | 0* | 0* | 2.47 | 0.11 | 9.72 |
| 7 | 0.01 | 0* | 0* | 2.61 | 0* | 15.67 |
| 8 | 0.02 | 0* | 0* | 6.33 | 0* | 15.91 |
| 9 | 0.03 | 0* | 0* | 2.17 | 0* | 5.02 |
| 10 | 0.02 | 0* | 0* | 6.78 | 0* | 28.59 |

*Note: * = Not Detected

The results of this study align with previous research conducted by Paundanan et al. (2015), which reported that the Pb content in seawater exceeded the water quality standard with an average value of 0.0297 mg/L. Table 3 shows some previous studies that also reported Pb concentrations in seawater exceeding the standard. For example, Komalasari et al. (2020) reported Pb levels in the waters of Teluk Kelabat exceeding the standard, ranging from 0.1042 mg/L to 0.1748 mg/L. Pb concentrations in seawater have also been reported between 0.024-0.031 mg/L in the Bondet River Estuary, Cirebon (Wahyuningsih et al., 2021). Barokah et al. (2019) reported Pb levels in the waters of Jakarta Bay exceeding the standard, with Pb at 0.368 mg/L and Cd at 0.007 mg/L. Additionally, Aliviyanti et al. (2023) found Pb concentrations in seawater along the Lamongan coast ranging from 0.08 to 1.88 mg/L.

The Pb content in the sediments of the Palu Bay coastal waters ranges from 2.17 mg/kg to 13.8 mg/kg, with the highest concentration found at station 2 and the lowest at station 9. The concentration of Cd in the sediment was only detected at station 6, at 0.11 mg/kg. This is likely because station 6 is located at the river mouth, where Pb contamination from nearby human activities is carried into the river mouth and settles into the sediment. The concentration of Cu in the sediment ranges from 5.02 mg/kg to 37 mg/kg. The lowest Cu concentration is found at station 9, while the highest is at station 2. At station 2, the Pb concentration is 13.8 mg/kg, and the Cu concentration is 37.67 mg/kg, indicating significant contamination. This may be due to surrounding human activities, such as shopping centers, workshops, and hotels. High concentrations of heavy metals in sediments can be influenced by high salinity and low temperatures, which cause heavy metals to settle at the bottom of the water column (Putri et al., 2014). The accumulation and deposition of heavy metals at the sediment surface are also influenced by the chemical properties of the heavy metals themselves (Darmansyah et al., 2020). Additionally, heavy metal content in sediments is influenced by water depth, DO, temperature, and pH. In this study, temperature and DO values remain within normal conditions according to the required water quality standards for the survival of aquatic biota.

**Tabel 3.**
Comparison of Heavy Metal Content in Sea Water at the Palu Bay Coastline with Quality Standards and Other Locations in Indonesia

| Location | Pb (mg/L) | Cd (mg/L) | Cu (mg/L) | Reference |
|---|---|---|---|---|
| Palu Bay Coastline | 0* - 0.04 | 0* | 0* | This study |
| Segara Anakan Cilacap | - | 0.0021 – 0.0051 | 0.0034 - 0.0052 | (Prayogo et al., 2024) |
| Pulau Merak Kecil | 0.40 | <0.003 | 0.20 | (Cantika et al., 2023) |
| Nambo Kendaro Beach | 0.0034 | 0.0019 | - | (Ikhsan et al., 2023) |
| Pangandaran Beach | 2.55 – 3.56 | - | - | (Herawati et al., 2023) |
| Tanjung Pinang | 0.0204 – 0.0636 | - | - | (Tirtama et al., 2024) |
| East Surabaya Coast | - | - | 0.03 – 0.08 | (Mahmiah et al., 2023) |
| Madura Waters | 0.02 ± 0.05 | 0.01 ± 0.004 | 1.1 ± 1.59 | (Yona et al., 2021) |
| Bintan Island Waters | 0.0010 ± 0.00048 | 0.0013 ± 0.00056 | 0.0010 ± 00074 | (Raza'i et al., 2022) |
| Balikpapan Bay Coastline | 0.064 – 0.142 | 0.088 – 0.112 | 0.035 – 0.056 | (Sitorus et al., 2020) |

| | | | | |
|---|---|---|---|---|
| Banyuwangi Waters | 0.0173 | - | 0.0104 | (Setyaningrum et al., 2021) |
| Lampung Bay | 0* - 0.23 | - | 0* - 0.008 | (Permata et al., 2018) |
| Kepulauan Seribu | 0.0015 – 0.0180 | 0.0006 – 0.004 | - | (Riani et al., 2017) |
| Standards | 0.008 | 0.001 | 0.008 | (KLH, 2004) |

Note: * = Not Detected; - = Not studied in the respective research; ** = Water Quality Standards: According to the Decree of the Minister of Environment No. 51/2004 on the Quality Standards for Seawater for Marine Biota.

**Table 4.**
Comparison of Heavy Metal Content in Sediment at the Palu Bay Coastline with Sediment Guidelines and Other Locations in Indonesia

| Location | Pb (mg/kg) | Cd (mg/kg) | Cu (mg/kg) | Reference |
|---|---|---|---|---|
| Palu Bay Coastline | 2.17 – 13.80 | 0* - 0.17 | 5.02 – 37.67 | This study |
| Segara Anakan Cilacap | - | 2.182 – 3.964 | 2.168–3.964 | (Prayogo et al., 2024) |
| Pulau Merak Kecil | 0.5947 – 0.9407 | - | - | (Cantika et al., 2023) |
| Nambo Kendaro Beach | - | - | 0.01 – 0.03 | (Ikhsan et al., 2023) |
| Pangandaran Beach | 2.01 ± 0.95 | 0* | 4.35 ± 2.33 | (Herawati et al., 2023) |
| Tanjung Pinang | 6.37255 – 7.7531 | 3.456 – 4.6766 | - | (Tirtama et al., 2024) |
| East Surabaya Coast | 0.12 – 0.18 | 0.02 – 0.04 | 0.01 | (Mahmiah et al., 2023) |
| Madura Waters | <0.05 – 6.408 | 0.042 – 0.605 | 0.059 – 8.791 | (Yona et al., 2021) |
| Bintan Island Waters | 2.555 – 2.616 | 2.433 – 2.609 | 1.289 – 1.553 | (Raza'i et al., 2022) |
| Balikpapan Bay Coastline | 15.41 – 32.66 | - | 1.02 – 38.75 | (Sitorus et al., 2020) |
| Banyuwangi Waters | 0.033 – 0.134 | 0.017 – 0.083 | - | (Setyaningrum et al., 2021) |
| Lampung Bay | 0.40 – 0.65 | 0.20 – 4.00 | - | (Permata et al., 2018) |
| **SQGs** | | | | |
| CCME (2002) | 30,2 | 0,7 | 18,7 | ISGQ |
| | 112 | 4,2 | 108 | PEL |
| ANZECC/ARMCANZ | 50 | 1,5 | 65 | Low |
| Guidelines (2000) | 220 | 10 | 270 | High |

Note: * = Not Detected; - = Not studied in the respective research; SQGs = Sediment Quality Guidelines; ISQG = Interim Sediment Quality Guidelines; PEL = Probable Effect Level

The heavy metal content in sediments is higher compared to seawater. Heavy metals are generally lower in seawater due to dilution and their tendency to settle at the bottom of the water column, eventually accumulating in the sediment (Wardani et al., 2020). When heavy metals are released into the water, they bind with suspended particulate matter and settle into the sediment (Wahyuningsih et al., 2021). Contaminated sediments can pose risks to organisms living at the sediment-water interface, such as green mussels (Barokah et al., 2019; Nurhayati & Putri, 2019). These contaminants can accumulate in aquatic organisms through the food chain (Hadiyanto et al., 2022), and ultimately affect human health if consumed regularly, leading to health disturbances due to bioaccumulation (Riani, 2015).

10 and the presence of Cd and Cu in the sediment. The elevated concentrations of heavy metals above the set thresholds indicate significant pollution, most likely from industrial, mining, and domestic activities around Palu Bay. This situation could potentially cause detrimental impacts on the aquatic ecosystem, public health, and the local economy. Therefore, it is crucial for the local government and all stakeholders to take serious measures to implement stricter environmental management policies. This includes monitoring the disposal of industrial, mining,

The comparison of heavy metal content in sediment from the Palu Bay coastline with other locations in Indonesia can be seen in Table 4. Since Indonesia does not have specific regulations regarding sediment heavy metal quality standards, we can refer to guidelines set by other countries, such as Canada and Australia (Nugraha et al., 2022). When compared to Canada's quality standards, the Pb and Cd levels in sediment from the Palu Bay coastline remain within safe limits, i.e., 30.2 mg/kg for Pb and 0.7 mg/kg for Cd. However, the Cu content in sediment at five stations (2, 3, 4, 5, and 10) exceeds Canada's quality standard of 18.7 mg/kg.

The findings from this study raise concerns about the environmental quality of Palu Bay, particularly the heavy metal contamination of Pb in water at stations 4 to and domestic waste, as well as initiating educational programs to raise awareness in the community about the importance of maintaining cleanliness and preserving the environment, especially the aquatic environment. In doing so, it is hoped that the water quality of Palu Bay can be restored, ensuring the sustainability of its aquatic ecosystem and the well-being of the surrounding communities.

## CONCLUSION

The Pb content in water has significantly exceeded the quality standard as stipulated in Minister of Environment Decree No. 51 of 2004. The heavy metal Pb content in sediment in the waters of Palu Bay is still within safe limits according to Canada's quality standards. However, the Cd heavy metal content in sediment detected at station 6 has exceeded Canada's quality standards. The Cu heavy metal content in sediment at five stations has also exceeded the quality standards based on sediment quality guidelines from Canada.

## RECOMMENDATION

The high levels of Pb in water, Cd in sediment at one station, and Cu above the quality standards at several stations indicate heavy metal contamination that may pose various health risks to humans. Therefore, further research is needed to identify the sources of heavy metal pollution in Palu Bay waters, such as industrial, mining, or domestic activities. Conducting bioaccumulation studies on aquatic organisms (e.g., fish, shellfish) is essential to determine the level of heavy metal accumulation in their bodies. Additionally, further health risk assessment studies should be conducted to evaluate the potential impacts of heavy metal exposure on communities living around Palu Bay.

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