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RESEARCH ARTICLE

Mercury Contamination in Mangrove Crabs *Scylla Serata* (Forskål, 1775) in Kayeli River Estuary, Buru Island, Indonesia

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ABSTRACT

This research aims to assess the mercury content in the habitat and body of mud crabs (Scylla serrata) in Kayeli Bay and assess the suitability of consuming mud crabs based on quality standards. Water, sediment, and mangrove crab samples were taken from various locations in Kayeli Bay and analyzed using the Mercury Analyzer method. The analysis results show that mercury concentrations in water and sediment in several locations exceed the limits set by national and international environmental standards. In addition, the mercury content in mud crab tissue also exceeds the safe limit for human consumption, indicating a significant health risk for people who consume mud crabs from this area. This research confirms that mud crabs can be bioindicators of mercury pollution in coastal environments. These findings highlight the need for mercury pollution mitigation efforts by local governments and stricter enforcement of environmental policies. Education to the public regarding the dangers of consuming marine biota contaminated with mercury is also crucial. This study has several limitations, including limited sample coverage and a short sampling period. Further research with a wider scope and a longer period is needed to obtain a more comprehensive picture of the dynamics of mercury pollution in Kayeli Bay. The results of this research not only provide valuable scientific information but encourage increased public awareness and better policymaking in coastal environmental management.

1. INTRODUCTION

The heavy metal mercury (Hg) is one of the most dangerous environmental pollutants and is often found in coastal ecosystems. Mercury is stable, difficult to decompose, and highly toxic to living things, although in small amounts some heavy metals are needed in biological processes. However, the accumulation of mercury in the body of organisms can have significant negative effects, especially in humans who are at the top of the food chain. Excessive exposure to mercury can cause various health problems such as neurotoxicity diseases, neurological diseases, genotoxicity and gene regulation, immunogenicity, pregnancy and reproductive system damage, cancer promotion, cardiotoxicity, pulmonary diseases, immune system disorders and kidney disease nerve disorders. Manifestation of kidney disease secondary to chronic mercury poisoning was nephrotic syndrome (Wu et al., 2024;Gao et al., 2019). Research in Purwokerto and Aceh shows that mercury contamination in river water used by the community causes skin diseases and other health impacts. The mercury levels in the river water have exceeded the normal threshold for quality standards according to the Ministerial Republic of Indonesia Number 57 of 2016 which is 0.001 (Yuniarno et al., 2024; Darmawan & Sriwahyuni, 2018; Edhi et al., 2024).

Mercury can enter the aquatic environment through various sources, both natural and due to human activities (Rodrigues et al., 2019). Some of the main sources of mercury pollution include gold mining activities, oil exploration, biomass burning, and shipping activities (Sari et al., 2016; Driscoll et al., 2013). In recent decades, mercury pollution in the aquatic environment has become a serious concern because of its impacts on marine life and humans. This heavy metal can accumulate in sediments, plants, and other marine biota, including mangrove crabs (*Scylla serrata*), which are then consumed by humans. Long-term consumption of marine biota contaminated with mercury can cause serious health problems, especially for vulnerable groups such as children and pregnant women (Mariwy et al., 2021).

Mangrove crab (*Scylla serrata*) is one of the species that plays an important role in the mangrove ecosystem and is an important food source for coastal communities. In addition, mangrove crabs are also known as effective bioindicators for monitoring the level of heavy metal pollution in the environment. Mangrove crabs have the ability to accumulate heavy metals in their bodies, especially in gill tissue, meat, and gonads. This makes mangrove crabs an ideal instrument for detecting the level of heavy metal contamination such as mercury in waters (Harris et al., 2014). Several studies have shown that mangrove crabs can accumulate significant amounts of heavy metals from their environment, which can then be a health risk if consumed by humans (Antonio et al., 2012; Zhang et al., 2019).

Kayeli Bay, located on Buru Island, Maluku, Indonesia, is one of the coastal areas with great potential in the field of capture fisheries and aquaculture. However, in recent years, Kayeli Bay has experienced serious environmental problems due to gold mining activities on Mount Botak. These mining activities produce waste containing mercury, which then pollutes the waters around Kayeli Bay through rivers such as the Waelata, Waeapo, and Anahoni River (Irsan et al., 2020; Salatutin et al., 2015). Mercury from these mining activities then accumulates in sediments and marine biota, including mangrove crabs, which are widely consumed by the local community.

Mercury pollution in Kayeli Bay is a serious concern because its impacts are not only on environmental health but also on the health of communities that rely on marine biota as a food source. Although previous studies have been conducted to measure mercury levels in Kayeli Bay, further research is needed to understand the level of contamination of this heavy metal in marine biota in more detail, especially in mangrove crabs that have the potential to be a source of contamination for humans. In addition, it is also important to assess the feasibility of consuming mangrove crabs from mercury-polluted waters, in order to provide information to the public about the health risks that may arise.

This study aims to measure mercury content in the habitat and body of mangrove crabs (*Scylla serrata*) in Kayeli Bay and assess the feasibility of mangrove crab consumption based on established quality standards. In addition, this study also aims to identify the impact of mercury pollution on the coastal ecosystem of Kayeli Bay and the health of the people living around it. With comprehensive data on mercury levels in water, sediment, and the body of mangrove crabs, this study is expected to be a basis for local governments and related parties in taking better environmental management steps to reduce the risk of mercury pollution in Kayeli Bay.

This study is also expected to provide important contributions in increasing public awareness of the dangers of consuming marine biota contaminated with mercury, as well as encouraging the implementation of stricter environmental policies by local governments to mitigate the impacts of mercury pollution. Given the high health risks posed by mercury contamination, monitoring and control of mercury pollution sources must be carried out routinely and systematically, so that coastal ecosystems and public health can be maintained.

MATERIAL AND METHODS

Study locations

This research was carried out in the period January to July 2022. Sampling was carried out at the mouth of the Kayeli Bay mangrove forest river, and testing for heavy metal content was carried out at the Integrated Research Laboratory at Gadjah Mada University, Yogyakarta. Samples were taken from five stations: Kayeli Bay River, Waelata River, Anahoni, Sanleko River, and Jikumerasa River. At each station, water, sediment, and mud crab (*Scylla serrata*) samples were taken for analysis. Water samples were collected at a depth of 30 cm using labeled polyethylene bottles, which were then stabilized by lowering the pH to 1-2 using concentrated HNO3 solution. Sediments were collected using an Eckmann Grab Sampler, with samples weighing ± 300 grams put into labeled polyethylene plastic. Three mangrove crabs were collected from each station, and tissues such as gills, meat, and gonads were separated for further testing.

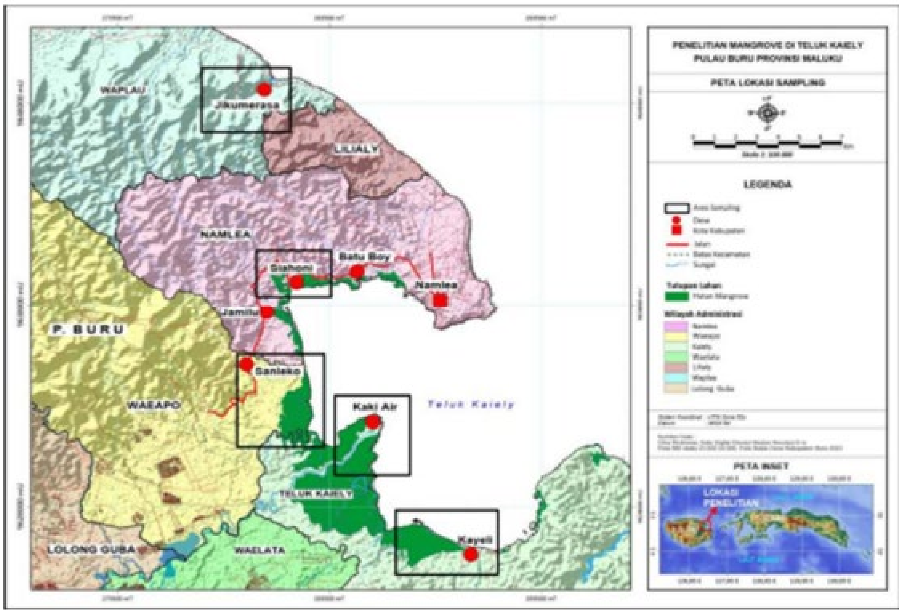

Figure 1: Map of research locations in the Kayeli Bay mangrove forest

Sampling:

a) Water sampling

Water samples were taken at a depth of 30 cm at each station. Water samples whose heavy metal (Hg) levels will be measured are placed in labeled polyethylene bottles. The binding of heavy metals is carried out by lowering the pH of the sample water to 1 or 2 by adding ±75 ml (±15 drops) of concentrated HNO3 solution and then cooling it in an ice box. Measurements of the heavy metal Hg were carried out at the UGM Integrated Research and Testing Laboratory (LPPT) using the Mercury Analyzer method which refers to seawater quality standards. Minister of Environment Decree No. 51 of 2004.

b) Sediment sampling

Sediment samples were taken as a composite of ±300 grams using an Eckmann Grab Sampler and placed in labeled polyethylene plastic. The sediment samples were then wrapped in plastic bags and cooled in an ice box for analysis in the Gadjah Mada University laboratory.

c) Crab sampling

Crab samples were obtained from five predetermined stations, namely: The first station on the Teluk Kayeli River, the second station on the Waelata River, the third station on Anahoni, the fourth station on the Sanleko River, and the fifth station on the Jikumerasa River. The number of mud crabs taken from each station was 3, so the total sample of mud crabs was 15. The crab samples were then dissected to separate tissues such as gills, flesh, and gonads.

d) Mercury content tested

Measurement of mercury content in water, sediment, and crab tissue was conducted at the UGM Integrated Research Laboratory using the Mercury Analyzer method. Testing standards refer to SNI 01-2354.6-2006 and SNI 06-6992.2-2004 for water and sediment, while testing of mercury levels in mud crab tissue was carried out with the standards of Kepmen LH No. 51 Year 2004. Mercury levels were calculated using the following formula:

Mercury content testing

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For water:

For crab sediment and tissue:

$$\text{Heavy Metal Levels (mg/kg)} = \frac{C\ x\ Vx\ FP}{B\ x\ (1-Ka/100)}$$

$$\text{Mercury Levels (Hg)} = \frac{(\text{D}-\text{E})x\ FP\ x\ V\ x\ 1000}{\text{W}}$$

Where C is the mercury content from the calibration curve, V is the final volume, and FP is the dilution factor.

Data analysis

The results of mercury levels measurements from water, sediment, and crab tissue were then analyzed statistically to determine the distribution of mercury concentrations at each sampling station. Comparison of mercury levels at each station and each type of tissue was analyzed using descriptive statistical tests. This analysis aims to identify stations with the highest mercury concentrations and crab tissues that accumulate the most heavy metals. Data were compared with quality standards to assess the suitability of mangrove crab consumption in the Kayeli Bay area.

RESULTS

Table 1: Average levels of mercury (Hg) in water and sediment in Teluk Kayeli

Sampling Location (Stasiun)	Waters (µg/L)	Sediment (mg/kg)
Kayeli Rivers	0.085	0.22
Waelata Rivers	1.10	1,69
Anahoni Rivers	0.087	0.69
Sanleko Rivers	0.089	0.10
Jikumarasa Rivers	0.084	0.07

Measurements of mercury (Hg) levels in air, sediment, and mangrove crab samples showed significant variations between sampling stations. The average mercury levels in water and sediment at each station are shown in Table 1.

The results of the analysis show that the two Waelata River stations have the highest mercury levels in both water samples (1.10 µg/L) and sediment (1.65 mg/kg), while the Jikumerasa River

Table 2: Average mercury (Hg) levels in mangrove crab tissue in Teluk Kayeli.

Sampling Location (Stasiun)	Gills (mg/kg)	Meets (mg/kg)	Gonads (mg/kg)
Kayeli Rivers	0.40	0.30	0.25
Waelata Rivers	0.50	0.40	0.35
Anahoni Rivers	0.38	0.28	0.30
Sanleko Rivers	0.45	0.35	0.22
Jikumarasa Rivers	0.35	0.25	0.20

Mercury levels in mud crabs were analyzed in gill tissue, flesh, and gonads. The average mercury levels in each network at each station are shown in Table 2. The results showed that the highest mercury levels were found in the gill tissue of mud crabs at Waelata station (0.50 mg/kg), while the lowest mercury levels were found in the gonad tissue of mud crabs at Jikumerasa river station (0.20 mg/kg).

Based on quality standards set by the Minister of Environment Decree No. 51 of 2004, the maximum limit for mercury levels allowed in seafood is 0.5 mg/kg. From the results of this research, the average mercury levels in mangrove crab meat at all stations were still below the maximum permitted limit, with the highest levels found at Waelata station (0.40 mg/kg).

The mercury content found in water, sediment, and mud crabs in Kayeli Bay shows that there is a risk of mercury contamination for people who consume mud crabs regularly. Therefore, regular control and monitoring efforts are needed by the Buru Regency Regional Government to ensure the safety of mud crab consumption and prevent negative impacts on public health.

DISCUSSION

This study aims to analyze mercury content in the habitat of mangrove crabs in Kayeli Bay and in the body tissues of mangrove crabs (*Scylla serrata*), considering its potential as a bioindicator of heavy metal pollution. The results of this study provide an in-depth view of the distribution and accumulation of mercury in the area, as well as its possible impacts on human health and the environment.

Mercury content in Kayeli Bay

The results showed that mercury content in water and sediment at various sampling stations in Kayeli Bay varied significantly. Waelata River Station recorded the highest mercury levels in both water (1.10 μg/L) and sediment (169 mg/kg), while Jikumerasa River Station had the lowest mercury levels in water (0.084 μg/L) and sediment (0.07 mg/kg). This variation reflects the differences in pollution sources at each location, where gold mining activities at Mount Botak are likely to be the main contributor to mercury pollution in Kayeli Bay. Mercury from these mining activities is discharged through rivers that flow into Kayeli Bay, resulting in increased mercury levels in the aquatic environment and contaminating the mangrove ecosystem in Kayeli Bay. (Septory et al., 2023; Ismail et al., 2020; Irsan et al., 2020).

Previous studies also support this finding, where areas close to mining activities showed higher levels of mercury pollution compared to areas far from the source of pollution (Ismail et al., 2020). This highlights the importance of strict monitoring of mining activities in the area, as well as the need for stronger regulations to prevent further contamination. In addition, factors such as ocean current patterns, sediment physical properties, and other human activities can also affect the distribution of mercury in the aquatic environment (Malov et al., 2022; Al et al., 2022). Therefore, further research is needed to understand the dynamics of mercury pollution in Kayeli Bay in more detail, including the factors that influence the accumulation of this heavy metal in various environmental compartments.

Mercury content in mangrove crabs

Mangrove crabs (*Scylla serrata*) are one of the marine biota that have the potential to be used as bioindicators of heavy metal pollution, including mercury, because of their ability to accumulate heavy metals in their bodies. The results showed that mangrove crabs in Kayeli Bay have varying mercury content depending on the sampling location. The highest mercury content was found in the gill tissue of mangrove crabs at Waelata Station (0.50 mg/kg), while the lowest content was found in the gonad tissue at Rivers Jikumerasa Station (0.20 mg/kg). This difference indicates that locations with higher levels of mercury pollution, such as Waelata Station, tend to produce crabs with higher mercury content.

The gill tissue of mangrove crabs tends to have a higher mercury content compared to the meat and gonad tissue. This may be due to the fact that the gills are the main organs that interact directly with water, making them more susceptible to the accumulation of heavy metals such as mercury (Zaynab et al., 2022). However, although the highest mercury content is found in the gills, mangrove crab meat remains a major concern because it is the part most often consumed by humans. The results of this study indicate that the average mercury content in mangrove crab meat at all stations is still below the maximum limit permitted by the Minister of Environment Decree No. 51 of 2004 (0.5 mg/kg), with the highest levels found at Waelata Station (0.40 mg/kg).

Although the mercury levels in mangrove crab meat are still below the permitted threshold, it should be noted that long-term consumption of marine biota contaminated with mercury can pose serious health risks. Several studies have shown that long-term exposure to mercury can cause disorders of the nervous system, kidney function, and human reproductive health (Ray & Vashishth, 2024; Emon et al., 2023). Therefore, regular monitoring of mercury content in marine biota in Kayeli Bay is needed to ensure the safety of consumption for the local community.

Implications for public health

The results of this study indicate that consumption of mangrove crabs from Kayeli Bay, especially those from locations with high levels of mercury pollution such as Waelata Station, can pose a health risk to the community. Although the mercury content in mangrove crab meat is still below the permitted threshold, exposure to mercury that accumulates in the human body through regular seafood consumption can cause serious health effects, especially for vulnerable groups such as children (Bose-O'Reilly et al., 2010), pregnant women (Hibbeln et al., 2018) and the elderly (Pamphlett, 2021). Mercury exposure to the fetus, for example, can interfere with the development of the nervous system, potentially causing birth defects or developmental disorders in children (Azevedo et al., 2012).

In addition, this study also shows that mangrove crabs from Kayeli Bay have the potential to be used as bioindicators in monitoring heavy metal pollution in coastal environments. Given that mangrove crabs have the ability to accumulate heavy metals in their bodies, they can serve as a monitoring tool to identify the level of mercury pollution in coastal ecosystems in a sustainable manner (Jay et al., 2024). This biomonitoring approach has been applied in various countries with effective results, where marine biota such as shellfish and fish are used to monitor the level of heavy metal pollution in the environment (Yousif et al., 2021 ; (Khair & Risjani, 2022).

Mitigation strategies and policy recommendations

Based on the results of this study, several mitigation measures are needed to reduce the impact of mercury pollution in Kayeli Bay and prevent health risks to the local community. First, the local government and related parties need to carry out stricter supervision of gold mining activities in Mount Botak, which is suspected to be the main source of mercury pollution in Kayeli Bay. Mitigation measures such as stricter enforcement of environmental regulations, implementation of environmentally friendly waste processing technology, and closure of illegal mines should be prioritized to prevent further contamination.

Second, it is important to raise public awareness of the health risks associated with consuming mercury-contaminated marine life. Public education campaigns on the negative impacts of mercury exposure on health, especially for vulnerable groups, should be conducted regularly. The public should be provided with sufficient information to make informed decisions about seafood consumption, including choosing safe seafood sources from unpolluted waters.

Third, regular monitoring of water quality, sediment, and marine biota in Kayeli Bay is needed to ensure that mercury pollution levels remain under control. This monitoring program must involve various parties, including local governments, academics, and local communities, to ensure that environmental management measures taken are comprehensive and sustainable.

Finally, the results of this study also highlight the importance of further research to gain a more complete picture of the dynamics of mercury pollution in Kayeli Bay. Additional research that includes seasonal and annual variations, as well as identification of other sources of pollution, would be helpful in developing more effective mitigation strategies. Further research is also needed to evaluate the long-term impacts of mercury-contaminated seafood consumption on public health.

CONCLUSION

This study provides important insights into mercury content in the habitat and body of mangrove crabs in Kayeli Bay. The results showed that the level of mercury pollution in several locations, especially around the Waelata River, is quite high and has the potential to pose a health risk to people who consume mangrove crabs from the area. Although the mercury content in mangrove crab meat is still below the permitted threshold, regular monitoring is needed to prevent long-term health risks. Recommended mitigation measures include strict supervision of mining activities, increasing public awareness of the dangers of consuming contaminated marine biota, and regular monitoring of environmental quality in Kayeli Bay. With more comprehensive data and appropriate management measures, it is hoped that mercury pollution in Kayeli Bay can be controlled, so that public health and the sustainability of coastal ecosystems can be maintained. Based on research conducted in Kayeli Bay, mercury concentrations in water, sediment, and the body of mangrove crabs (*Scylla serrata*) were found to exceed the safe threshold for consumption. Mangrove crabs have been shown to be effective bioindicators of heavy metal pollution, especially mercury. Although the mercury content in crab meat is still below the established standard, these results indicate a serious health risk for people who consume it regularly. Therefore, efforts are needed to mitigate mercury pollution, including stricter monitoring and regulation, as well as educating the public about the dangers of consuming contaminated marine biota.

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