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Analysis of Pb, Cu and Zn Metal Content in Sediments and Blood Cockles *(Anadara granosa)* in the Waters of Bangko Rokan Hilir

Sarah Sijabat[1*], Bintal Amin[1], Syahril Nedi[1]
[1]Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau, Pekanbaru 28293 Indonesia
Corresponding Author: sarahsijabat23@gmail.com

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ABSTRACT

Bangko waters are located in Bangko Rokan Hilir District, drained by the Rokan River and bordering the Malacca Strait, influenced by various coastal activities that have the potential to provide input of pollutants, such as heavy metals and accumulate in the bodies of biota. This condition can also threaten the ecosystem and the lives of aquatic biota, as Bangko waters are known as the centre of shellfish production in Riau Province. This study aims to determine the concentrations of Pb, Cu, and Zn in sediments and blood cockles, and to analyze the relationships between metal concentrations and levels of metal pollution in Bangko waters. Sediment and blood cockle sampling was conducted in the waters of Bangko, where people collect cockles for consumption or trade. The results showed that the highest metal content in sediment was Cu (6.208µg/g), while in blood cockles, the highest metal content was Zn (12.407µg/g). As the metal content of the sediment increases, the metal content of the blood cockles also increases. The I-geo value of Bangko waters falls into the category of unpolluted to moderately polluted. In contrast, the MPI value shows that the metal content in Bangko waters is still classified as a low level of pollution when compared to studies that have the same characteristics.

Keywords: Heavy Metals, Sediment, Blood Cockles, Bangko Rokan Hilir

1. INTRODUCTION

Coastal waters are unique and dynamic waters that act as a life support, so they are utilized by the community to meet their needs. Bangko waters are located in Bangko District, bordering the Malacca Strait, and are fed by the 350 km long Rokan River (Kholis et al., 2020). This condition makes water widely used by the community to meet their needs, such as catching fish or shellfish, conducting aquaculture businesses and as a means of transportation between regions.

Bangko waters are also known as the centre of blood clam production in Riau Province, with blood clam fishing locations scattered across several areas, including around the mouth of the Rokan River, Suak Jungkang, the Peninsula, and Berkey Island. The abundance of clam populations in this area is influenced by the characteristics of sloping beaches and substrates that support the availability of natural food, thus creating a suitable habitat for clam growth (Ridhawani et al., 2017).

The existence of this ideal habitat for blood cockles is increasingly threatened by anthropogenic activities around the waters, such as domestic waste disposal, fertilizer use in agriculture, and industrial waste, as well as transportation equipment such as ships, which accumulate hazardous pollutants, including heavy metals, in the waters. One form of pollution that needs to be aware of is the entry of heavy metals such as lead (Pb), copper (Cu) and zinc (Zn) into the marine ecosystem.

Heavy metals are elements that are naturally present in nature as a result of natural phenomena and are increasing due to anthropogenic activities. These metals are toxic and harmful when the concentration exceeds the threshold (Robi et al., 2021). Although Cu and Zn are essential metals, in high concentrations they remain toxic to aquatic organisms. At the same time, Pb is a non-essential metal that is highly toxic and harmful to human health and other organisms.

In aquatic environments, metals tend to settle to the bottom, especially on muddy substrates, and accumulate in benthic biota such as blood cockles because of their sedentary nature at the bottom and their filtering-feeding behaviour. Blood cockles are often used as biomonitors in monitoring heavy metal pollution (Nuri et al., 2023). The presence of metals such as Pb, Cu and Zn in sediments and blood cockles indicates environmental pollution that exceeds the quality standards for water quality and marine sediments. This condition indicates that Bangko waters are experiencing pollution pressure that can endanger the balance of aquatic ecosystems and the health of people who consume marine products. Therefore, it is necessary to monitor water quality, especially heavy metal levels.

2. RESEARCH METHOD

Time and Place

This study was conducted in January 2025. Water quality measurements and sampling of sediments and blood cockles were conducted in the waters of Bangko Rokan Hilir, Riau Province (Figure 1).

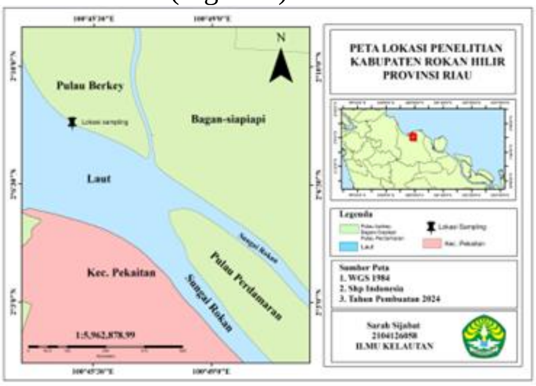

Figure 1. Research location

Method

The method used in this study was the survey method. The research location was carried out around the mouth of the Rokan River or the harbour around Berkey Island. Determination of this sampling is based on the habits of fishermen or the community in taking shellfish for consumption or sale. Sediment sampling was carried out at low tide using a small shovel, collecting as much as 500 g, with 9 replicates. Blood cockle samples were taken from as many as 10 heads in each replicate at the same location where the sediment was taken. The samples were placed in plastic vials labelled by replicate, taken to the laboratory in an ice box, and stored in the freezer until the metal concentration analysis by AAS was carried out.

Data Analysis

Analysis of Heavy Metal Content

Analysis of heavy metal content in sediments was carried out using the acid digestion method based on SNI 06-6992.3-2004 for Pb metal, SNI 06-6992.5-2004 for Cu metal and SNI 06-6992.8-2004 for Zn metal (SNI, 2021). Meanwhile, the metal content in blood cockles was determined using the dry method based on the procedure of Yap et al. (2003). Examination of heavy metal content using AAS. The metal content of the samples was calculated using the formula of (Razak, 2003).

$$K(\mu g/g) = \frac{D \; X \; B}{A}$$

Description:

K	:	Actual concentration of the sample (µg/g)
D	:	Content calculated based on absorbance value (µg/ml)
B	:	Sample volume (ml)
A	:	Sample weight (g)

Determination of the status of metal pollution in sediments and blood cockles in Bangko waters was carried out using I_geo and MPI.

Geo-accumulation Index (I_geo)

The geo-accumulation index (I_geo) is used to evaluate the level of heavy metal contamination in sediments. I.geo is calculated using the formula (Muller, 1969) as follows:

$$I\_geo = Log_2 \left[\frac{ci}{1{,}5 \; X \; bn}\right]$$

Description:

Ci	:	Metal concentration in the sample
Bn	:	Normal concentration of metal in nature
Factor 1.5	:	Constant

Metal Pollution Index (MPI)

Determination of heavy metal pollution status in blood cockles was done according to the formula used by Usero et al. (1997), which is as follows:

$$MPI = \sqrt[n]{C1 \; x \; C2 \; x \; C3 \ldots Cn}$$

Description:

MPI : Metal Pollution Index
N : Number of metal types
Cn : Metal content in mussel samples

3. RESULT AND DISCUSSION

Metal Content of Pb, Cu and Zn in Sediment

Table 1, it can be seen that the highest metal content in sediments in Bangko Waters was found in Cu (6.208µg/g), then Pb (5.966 µg/g) and the lowest content of Zn (5.888µg/g). These metal contents when compared to the

ERL and ERM standards by NOAA (National Oceanic and Atmospheric Administration, USA) and conducted by (Long and Chapman, 1985), the metal content of Pb, Cu and Zn in Bangko Waters is still far below the ERL (Effect Range Low) and ERM (Effect Range Median) values for Pb (46.7-218 µg/g), Cu (34-270 µg/g), and Zn (150-410 µg/g), which means that the metal content has not had a negative impact on organisms in these waters.

Table 1. Results of Pb, Cu and Zn Metal Content in Sediments

No	Type of metal	Metal concentration (µg/g)
1.	Pb	5.966 ± 0.633
2.	Cu	6.208 ± 1.133
3.	Zn	5.888 ± 0.625

The high content of Cu and Pb metals present in sediments in Bangko Waters is thought to be caused by anthropogenic activities in the region such as the existence of ports, intensive ship traffic contributes to the increase in Cu and Pb metals through residual combustion of ship fuel, ship painting and maintenance processes and input of residential waste materials through river flow and deposition in areas with weak currents. This is in accordance with Alfadillah et al. (2024) that settlement activities, such as agriculture and industry upstream, which then enter the river and are carried by river currents to settle at the bottom of the estuary waters in areas that have mud bottom substrates, become a source of heavy metals in the waters.

Meanwhile, the low level of Zn found in the sediment is because this metal is an essential metal needed by organisms in certain concentrations. However, at high concentrations, it becomes toxic and harmful to the health of its biota. According to Lestari & Budiyanto (2013), the heavy metal Zn is required by organisms in small amounts for metabolic processes. Zn metal is easily soluble in water, making it more readily absorbed by biota.

Metal Content of Pb, Cu and Zn in Blood cockles

The presence of metals in blood cockles not only affects the health of the cockles but also poses a risk to humans who consume them. Therefore, analysis of heavy metal content is needed to determine the levels in blood cockles from Bangko Waters. The concentration values of Pb, Cu and Zn are presented in Table 2.

Tabel 2. Results of Pb, Cu and Zn Metal Content in Blood Cockles

No	Type of metal	Metal concentration (µg/g)
1.	Pb	7.401 ± 0.503
2.	Cu	6.796 ± 1.191
3.	Zn	12.407± 1.779

The results showed that the highest metal content in blood cockles was Zn (12.407µg/g). The high accumulation of Zn metal is thought to result from its essential role in growth and metabolism. In addition, Pb metal (7.401µg/g) was also found in relatively high amounts, although it is non-essential and toxic. The metal Cu (6.796 µg/g) had the lowest concentration among the three metals analyzed. Based on Ministerial Decree of the Environment No. 51 Year 2004, blood cockles in Bangko Waters are still below the quality standards set where for Pb and Cu metals, the quality standard is 8 µg/g and Zn metal the quality standard is 50 µg/g, which means that the metal content in Bangko Waters is still suitable for the life of marine biota.

The high Zn metal content in blood cockles is because this metal is an essential metal needed by organisms, including blood cockles, to carry out the growth and development process, so that during this growth period, the absorption of Zn metal is also higher. This is in accordance with Prihati et al. (2020), which states that essential heavy metals such as copper (Cu), selenium (Se), iron (Fe), and zinc (Zn) function to maintain the body's metabolism in certain amounts; if excessive, they will cause toxicity to the body. Meanwhile, the high level of Pb metal in blood cockles is thought to be due to the fact that Pb metal is a non-essential metal that is difficult to be excreted by the body of the clam, so that it will continue to accumulate. According to, non-essential heavy metals in bivalves, including green mussels such as Pb, Cd, and Hg, are difficult to regulate so that they will accumulate continuously.

The presence of metals in the shellfish body is also influenced by the type and size of the shellfish, in this study the size of the shellfish studied, namely the size of 1-5cm, is included in the small category, where shellfish with smaller sizes of metal content in their bodies still tend to be smaller, because the food needed is less than shellfish with larger sizes. Research conducted by Muhtaroh et al. (2024) found that cockles of large sizes accumulate more metals, because larger cockles eat more than small cockles.

Meanwhile, the low Cu metal found in blood cockles in Bangko Waters is influenced by several factors, such as the length of time of accumulation, physical and biological factors and the large levels of heavy metals in the waters that cause accumulative properties with a long and continuous period of time. According to Selpiani & Rosalina (2015), the low concentration of heavy metals in the blood of cockles is because heavy metals that enter the blood of cockles have not been absorbed into body tissues.

The Relationship of Metal Content of Pb, Cu and Zn in Sediments and Blood Cockles

Heavy metals in sediments and blood cockles are closely related ecologically, given that blood cockles are benthic organisms that live and feed on the bottom of the water. The accumulation of heavy metals such as Pb, Cu and Zn in blood cockles is largely influenced by the concentration of these metals in the sediments where they live. The relationship between Pb, Cu, and Zn metal concentrations in sediments and blood clam tissues in Bangko Waters can be seen in Figure 2.

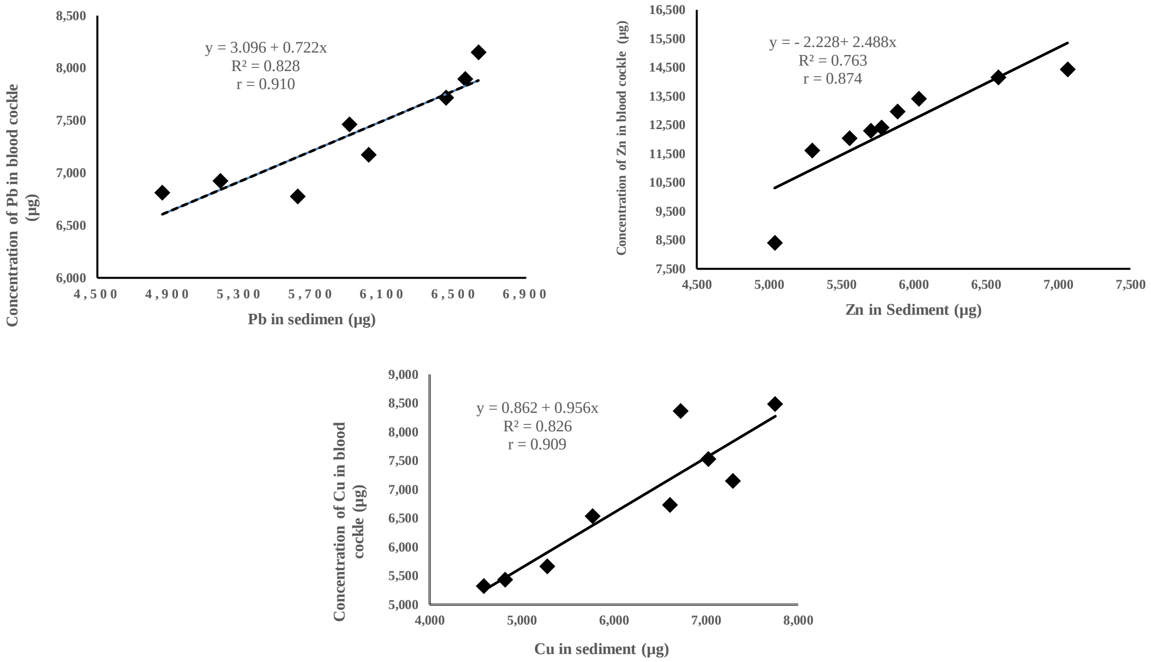

Figure 2. Relationship between Pb, Cu and Zn metal contents in sediments and blood cockles

The results of simple linear regression analysis of Pb, Cu and Zn metals in sediment and blood cockles obtained correlation coefficient (r) values of 0.910, 0.909 and 0.874, respectively. These values indicate that the sediment and blood cockles form a positive and strong to very strong linear relationship. Meanwhile, the coefficient of determination (R^2) values was 0.828, 0.826 and 0.763, respectively, indicating that more than 75% of the influence of sediment on blood cockles.

From the regression equation, it can be seen that the metal content in sediments influences the metal content in blood clam meat in Bangko Waters. According to (Sari et al. 2022), the strong relationship between sediment and blood cockles is due to the nature of blood cockles, which are filter feeders, so heavy metals in the waters enter the body of the clam. The higher the heavy metal content in sediment or water, the higher the potential for metal accumulation in the blood of cockles.

Geo-Accumulation Index (I_geo) on Sediments in Bangko Waters

The prediction of heavy metal pollution levels in sediments can be done using the geoaccumulation index (I_geo). This index is one of the commonly used evaluation methods to assess the extent to which heavy metals have accumulated in sediments. The results of the calculation of the geoaccumulation index

(I_geo) of Pb, Cu and Zn metals in sediments in Bangko Waters are presented in detail in Table 3.

Table 3. Result of Geo-accumulation index calculation of heavy metals in Bangko Waters

Type of metal	I_geo value	category
Timbal (Pb)	0.059	unpolluted to moderately polluted
Tembaga (Cu)	0.027	unpolluted to moderately polluted
Seng (Zn)	0.012	unpolluted to moderately polluted

Based on the calculation of the geo-accumulation index of Pb, Cu and Zn metals presented in Table 8, it can be seen that the I-geo value in Bangko Waters is in the range of $0 < I\_geo \leq 1$. This range indicates that the condition of sediments in Bangko Waters is included in the unpolluted to moderately polluted category. This category indicates that heavy metals have begun to accumulate but have not yet reached a severe level of pollution. This condition needs to be watched out for because the accumulation of heavy metals in sediments in the long term can have an impact on benthic organisms and food chains in aquatic ecosystems.

Metal Pollution Index (MPI) in Blood Cockles in Bangko Waters

Determination of heavy metal pollution status in Bangko Waters is done by calculating the Metal Pollution Index (MPI) value in blood cockles using the formula used by Usero et al. (1996). The results of the calculation of MPI values from the research location are then compared with MPI values from other water areas as a reference. For more details, see Table 4.

Table 4. Comparison of MPI Values of Bangko Waters with MPI Values of Research in Other Areas

Waters	Species	MPI	Reference
Bagansiapi-api	*A. granosa*	8.33	Amin et al. (2012)
Perairan muara Sungai Indragiri	*A. granosa*	4.93	Amin & Wahono (2013)
Pantai Utara Pulau Bengkalis	*Polymesoda expansa; Pharella acutidens*	18.28	Irawan et al. (2015)
Desa Gemuruh Pulau Kundur, Kabupaten Karimun	*A. Granosa*	2.04	Barus et al. (2017)
Teluk Merudu Malaysia	*Perna Viridis*	8.31	Denil & Ransangan (2017)
Muara Zuari Pantai Barat India	*Crassostrea cucullata*	25.31	Nasnodkar et al. (2021)
Perairan Goa, Pantai Barat India	*Polymesoda spp*	72.09	Bhutia et al. (2023)
Perairan Bangko	*A. granosa*	8.54	This Study, 2025

The MPI calculation results show that the MPI value of blood cockles in Bangko Waters is 8.54. The MPI value of Bangko Waters is generally lower than the MPI in several other areas, such as the Waters of Goa, the West Coast of India, Muara Zuarai, the West Coast of India, and the North Coast of Bengkalis Island. However, the MPI value of Bangko Waters is higher than that of Gemuruh Village, Kundur Island, Indragiri River Estuary Waters, Teluk Merudu, Malaysia and Bagansiapi-api.

The difference in MPI values with research in other waters is inseparable from community activities that occur around the waters. The more community activities that produce heavy metal waste, the higher the input of heavy metals into the waters and the accumulation in organisms that live around the area. Apart from the source of pollutants, the type of species will also affect the heavy metal content. The type of shellfish species accumulates heavy metals faster and higher because of their biological nature that filters water for food, and their life settles at the bottom of the waters.

4. CONCLUSION

Based on Metal content in sediments in Bangko Waters was highest in Cu (6.208µg/g), followed by Pb (5.966µg/g) and lowest in Zn (5.888µg/g). Meanwhile, the highest metal content in blood cockles was found in Zn (12.407µg/g), followed by Pb (7.401µg/g) and the lowest in Cu (6.796µg/g). Heavy metals in sediments and blood cockles have a strong relationship, and the higher the metal content in the sediment, the higher the metal accumulation in the body of blood cockles. Bangko Waters can be included in the unpolluted to moderately polluted category. As well as the Metal Pollution Index value of 8.54, this value shows that there has been an accumulation of heavy metals in the body of blood cockles, but it is still below the threshold of harmful pollution when compared to areas that have the same characteristics as this study

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