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Analysis of Bioconcentration Factors of Blood Mussels (*Anadara granosa*) on Pulau Pasaran, Bandar Lampung

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Abstract:
Background. Pulau Pasaran, Teluk Betung Barat, Bandar Lampung, has an important role in supporting the fisheries sector and has been designated as a minapolitan area. This region is vulnerable to heavy metal contamination due to anthropogenic activities such as domestic and industrial waste.
Aims. This study aims to analyze the concentration of heavy metal copper (Cu) in seawater and blood cockles in the waters of Pulau Pasaran, Bandar Lampung, and to calculate the bioconcentration factor (BCF) as an indicator of the potential accumulation of these metals in marine organisms.
Methods. Samples were collected using a purposive sampling method during November–December 2025 at three locations: the Belau River estuary area, residential areas, and mangrove areas. Seawater and blood cockle samples were analyzed using the Inductively Coupled Plasma–Optical Emission Spectroscopy (ICP-OES) method in accordance with SNI 6989-82:2018 standards.
Result. The results showed that Cu concentrations in blood cockles ranged from 0.936 to 1.303 mg/kg, which are still below the quality standard threshold based on the Decree of the Director General of BPOM No. 03725/B/SK/VII/89. Meanwhile, Cu concentrations in seawater ranged from <0.003 mg/L and remained below the threshold established by Government Regulation of the Republic of Indonesia No. 22 of 2021. The BCF values were classified as moderate accumulation (209.46–422.56), falling within the range of 100–1000 L/kg, with the highest value observed in the mangrove area.
Conclusion. The results indicate that Pulau Pasaran waters are moderately contaminated with heavy metals, and that blood cockles can still be used as bioindicator organisms for monitoring heavy metal accumulation in aquatic environments.

Keywords: BCF, Bioaccumulation, blood cockle, Cu, ICP-OES, Pulau Pasaran

INTRODUCTION

Coastal and marine areas have great potential and strategic roles in supporting various activities in the surrounding land area. Ecologically, marine waters function as natural habitats for a variety of marine life, so their existence and sustainability need to be maintained and considered (Muftiadi *et al*., 2019). One type of pollutant that is harmful to the aquatic environment is heavy metals, which can be toxic to aquatic organisms and humans if they accumulate in the food chain (Suryono & Indardjo, 2023).

Pulau Pasaran is a coastal area located in Teluk Betung Barat, Bandar Lampung, with an area of 12.5 hectares (Figure 1). This area is known as a center for fisheries and salted fish processing activities and has a fairly dense population of 1,171 people (Noor *et al*., 2021), including blood mussels

Figure 1. Pasaran Island

The uniqueness of Pulau Pasar lies in its position directly adjacent to the capital of Lampung Province, which has quite high accessibility. The ease of access has increased due to the construction of a 200-meter crossing bridge connecting Pulau Pasar with the city of Bandar Lampung; the area has become easier to reach and visit, and this area has the potential to be a tourist attraction (marine tourism) (Ali, 2015). Heavy metals such as copper (Cu) can enter waters through natural processes, namely rock weathering and volcanic activity, as well as through anthropogenic activities, including the disposal of industrial, domestic, and agricultural waste (Sari *et al*., 2017).

Organisms often used as bioindicators of heavy metal pollution include blood shellfish (Anadara granosa), a benthic filter feeder that can absorb heavy metals from the aquatic environment (Trisnadi *et al*., 2024).

Blood shellfish (Figure 2) is a fishery commodity widely used as food by coastal communities because it has high nutritional value, including high protein and various essential minerals needed by the body (Sidabutar *et al*., 2024). The use of blood shellfish as food not only supports nutritional fulfillment but also contributes to increasing food security and the economy in coastal communities.

Figure 2. Kerang Darah (*Anadara granosa*)

Blood mussels have an ecological advantage: the ability to filter (filter feeders), which reduces turbidity in waters. This organism also plays a role in enriching benthic habitats through biodeposition (the deposition of organic matter to the bottom of the water resulting from the activity of shellfish). Blood mussels can also mitigate the negative impacts of eutrophication in shallow waters and contribute to carbon sequestration (Santoso, 2022). The ability of an organism to accumulate heavy metals from the environment can be measured using the Bioconcentration Factor (BCF) parameter, which is a comparison between the concentration of metals in the organism's body and the concentration of metals in the environment (Amelia *et al*., 2019), so that it can be used to evaluate the level of bioaccumulation as well as potential ecological and health risks. Blood shells, as benthic organisms and filter feeders, have a tendency to accumulate heavy metals such as Cu in certain amounts. High BCF values in blood shellfish indicate significant heavy metal accumulation capacity, which is generally influenced by anthropogenic activities, such as industrial and domestic waste in the waters (Rahmadhati *et al*., 2023).

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) is an analytical technique used to determine heavy metal content because it offers high sensitivity, good accuracy, and the ability to analyze a wide range of elements. In research using blood and shellfish samples, this method plays an important role in identifying and measuring the concentration of heavy metals, such as copper (Cu), that accumulate in the tissues of organisms. The working principle of ICP-OES is based on the emission of light from excited atoms or ions in a high-temperature plasma, where each element has a characteristic wavelength that allows it to be identified. In addition, this method has a low detection limit and a relatively short analysis time, making it very effective for analyzing biota samples such as blood, shells, water, and sediments. ICP-OES is applied in environmental and food safety research to accurately evaluate heavy metal contamination levels (Oktavia *et al*., 2023).

Although blood mussels have been widely used as bioindicators of heavy metal pollution, limited research has specifically examined Cu bioconcentration in *Anadara granosa* from Pulau Pasaran, Bandar Lampung. Previous studies have generally focused on heavy metal contamination in broader coastal areas or different aquatic organisms, without comparing accumulation patterns across distinct local environmental zones. Therefore, this study addresses the gap by analyzing Cu concentrations in seawater and blood mussels and calculating BCF values from estuary, residential, and mangrove areas of Pulau Pasaran.

The novelty of this study lies in its site-specific assessment of copper bioconcentration in blood mussels (*Anadara granosa*) from Pulau Pasaran, Bandar Lampung. By integrating ICP-OES-based Cu analysis with BCF calculation across estuary, residential, and mangrove zones, this research provides new evidence that blood mussels can serve as bioindicators of moderate Cu accumulation in local coastal ecosystems.

LITERATURE STUDY

Blood mussels (*Anadara granosa*) are benthic bivalve mollusks widely found in Indonesia's coastal waters and serve as bioindicators of pollution due to their ability to accumulate heavy metals and other pollutants in their soft tissues. As filter feeders, shellfish accumulate pollutants in their bodies, reflecting the environmental quality of the sediment and surrounding water (Handayani, Kurniawan, & Adibrata, 2020). Bioconcentration factor is defined as the ratio of the concentration of a pollutant compound in biota tissue to the concentration of the same compound in the environmental medium (water or sediment). In blood shells, some studies have shown that heavy metal bioconcentration factors for metals such as Cd and Pb are generally below 10, indicating moderate accumulation capacity depending on the metal type and environmental conditions (Handayani, Kurniawan, & Adibrata, 2020).

Environmental factors such as salinity, temperature, sediment organic matter content, and food availability greatly influence the bioaccumulation process in A. granosa. Decreased salinity and increased temperature can increase filtration rates, potentially increasing the absorption of heavy metals and xenobiotics. Muddy substrates with high organic matter content become habitats for blood shells and serve as reservoirs of heavy metals, thereby increasing the likelihood of bioconcentration (Anar, Santoso, & Jasmanindar, 2025). Research on the morphometry and reproductive characteristics of blood mussels suggests that the size and lifespan of mussels affect the heavy metal content in the tissues. Individuals of larger size and older age typically have higher heavy metal content due to longer exposure and greater total intake, so bioconcentration factors may increase. This underscores the need to consider the size class in bioconcentration analysis to ensure more representative results (Trisnadi, Muliadi, & Nurdiansyah, 2024).

RESEARCH METHODS

This research was conducted from November to December 2025 in the waters of Pulau Pasar, Bandar Lampung. The analysis of the heavy metal content of copper (Cu) in blood shells was carried out at the Integrated Laboratory and Technology Innovation Center (LTSIT) of the University of Lampung using the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) method and by calculating the Bioconcentration Factor (BCF).

Purposive sampling was used (Subhaktiyasa, 2024). Heavy metal analysis using an Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) instrument with Variant type 715-ES and wavelength 327.395 nm, beaker glass, measuring glass and flask, hot plate, sample bottle, ziplock plastic, 0.45µm porous membrane filter, burette, pH meter, water sampling, furnace, analytical balance, oven, coolbox, label paper, shovel, gloves, mortar and pestle. The materials used are blood and shellfish samples, seawater samples, mineral-free water, formalin, concentrated HCl, 65% nitric acid (HNO_3), standard solution, and field blank. The blood shellfish sample was cleaned, dried in an oven at 105°C for 24 hours, mashed, and destroyed with an acid mixture before analysis. Seawater samples were filtered through a 0.45 µm pore-size membrane and acidified with HNO_3 to pH ≤ 2 to stabilize metal ions in the samples (Iyabu *et al*., 2020). Samples were taken in three locations (Figure 3): the Belau River Estuary Area, mangrove forest areas, and residential areas.

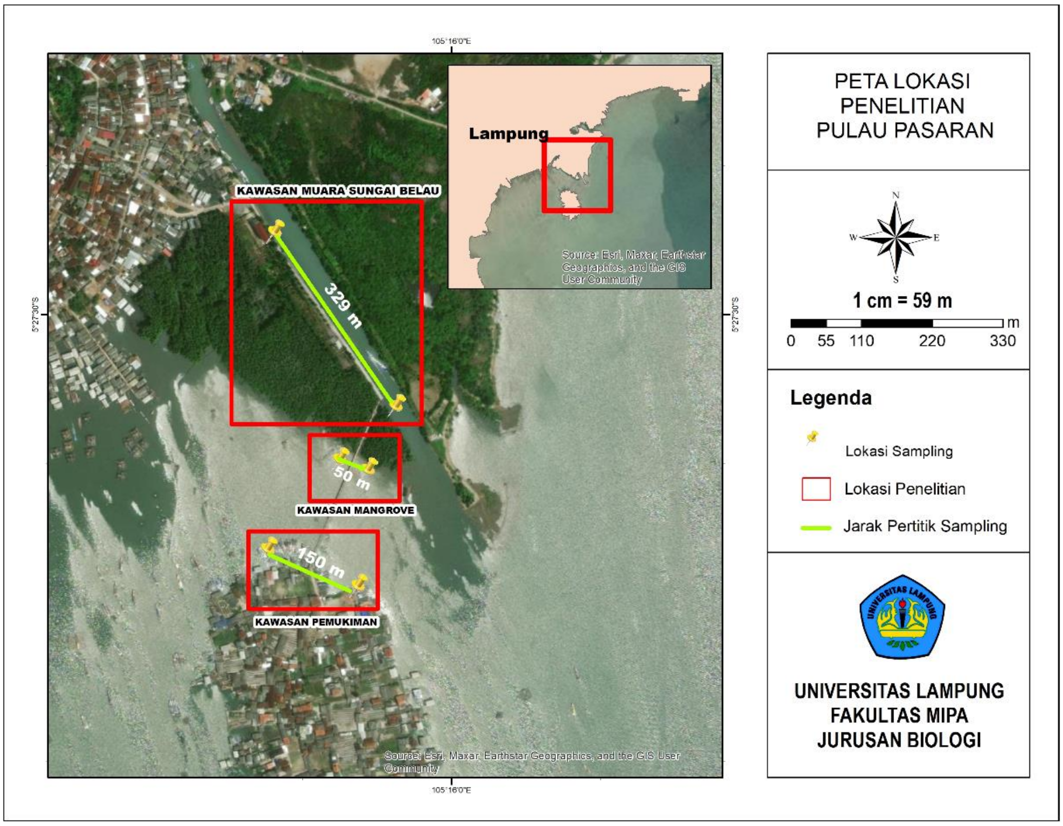

Figure 3. Sampling location

In the Belau River estuary area, it is used as a port location, where fishing boats show the environmental conditions that are densely active, the number of ships operating, and the accumulation of plastic waste around the waters that come from various polluting sources. Estuarine ecosystems are known to be vulnerable to pollution because they are transitional areas that receive inputs of pollutants from land and human activities in the water, such as shipping, industrial activities, and domestic waste disposal (Susilo *et al*., 2026). Mangrove forests are coastal ecosystems that play an important ecological role as coastal protectors against abrasion and wave action, wave absorbers, and filters of pollutants, including heavy metals, as well as habitats and nursery grounds for various aquatic biota. Mangroves also help maintain ecosystem balance by adsorbing sediment and improving water quality (Susilo *et al*., 2026). In the Pulau Pasar area, mangrove forests play a strategic role in supporting community fisheries and helping reduce the impact of pollution from domestic activities and surrounding waters.

Residential areas in coastal areas are a source of heavy metal entry into the aquatic environment due to domestic activities such as household waste disposal, chemical use, and community economic activities. Heavy metals that enter waters tend to accumulate in sediments and biota due to their low degradability (Afifudin et al., 2024). In the Pulau Pasar area, the high activity of settlement and the processing of fishery products are among the factors contributing to increased heavy metal content in the surrounding waters.

Data Analysis

The concentration of Cu in seawater is compared to the quality standard of Government Regulation of the Republic of Indonesia No. 22 of 2021, while the concentration of Cu in blood shellfish refers to the Decree of the Director General of BPOM No.03725/B/SK/VII/1989 regarding the maximum limit of heavy metal copper contamination in food, namely in the type of shellfish/mollusks. The BCF value is calculated using the formula:

$$\text{BCF (L/kg)}= \frac{\text{Heavy metal content on green mussles}\frac{\text{mg}}{\text{kg}})}{\text{Heavy metal content on marine water }(\frac{\text{mg}}{\text{L}})}$$

(Syukriah *et al*., 2024).

DISCUSSION

Sampling was carried out on November 26, 2025, with environmental conditions of around 27°C and sunny weather (Table 1). The Pulau Pasaran area is known for relatively high community activity, especially in the fisheries sector and the processing of aquatic products, which has the potential to affect the quality of the local environment.

Table 1. Measurements on the sampling location

Parameter	Data
Sampling location	Pulau Pasaran waters with 3 sampling locations
Date	26
Month	November

Time	09.52
Temperature	27°C
Weather	Clear

Concentration of Cu in blood mussels

Cu concentrations in Blood Shellfish range from 0.936–1.303 ppm (Table 2). According to the Decree of the Director General of BPOM No.03725/B/SK/VII/89, the Cu concentration in blood shells remains below the maximum limit of 20 mg/kg, making it relatively safe for consumption.

Table 2. Concentration of Heavy Metals Copper (Cu) in Blood Shells

Sample code	Cu Heavy metal concentration (Cu) (ppm)	Quality standard (mg/kg)
KD-01	0.936	20 mg/kg
KD-02	1.303	20 mg/kg
KD-03	0.975	20 mg/kg

Notes:

KD-01: Blood mussels in the estuary area of the Belau river

KD-02: Blood mussels in mangrove

KD-03: Blood mussels in residential areas

The results of the analysis of copper concentration were the highest among the three locations, namely in mangrove forest areas, influenced by the role of mangroves as a place for pollutant accumulation. The sediments and high organic matter content in mangroves can bind metals, thereby increasing the availability of Cu in the environment. Blood shells, as filter-feeding organisms, can accumulate metals from water and sediment into their bodies. Anthropogenic activities such as domestic waste and fisheries also increase metal levels, causing high accumulation of Cu in blood shells (Ritonga *et al*., 2018).

Cu Concentration in Seawater

Cu concentrations in seawater range from <0.0025–0.004 ppm (Table 3). The highest values are found in river estuary areas, which are affected by runoff from land and shipping activities (Susilo *et al*., 2026).

The results of the analysis are still below the quality standard of Government Regulation of the Republic of Indonesia No. 22 of 2021, which is 0.05 mg/L, so that the quality of the waters still meets environmental standards.

Table 3. Concentration of Heavy Metals Copper (Cu) in Seawater

Sample	Heavy Metal Concentration of Copper (Cu) (ppm)	Quality Standard (mg/L)
AL-01	< 0.004	0,05 (mg/L)
AL-02	0.003	0,05 (mg/L)
AL-03	< 0.0025	0,05 (mg/L)

Notes:
AL-01: Seawater in the Belau River Estuary Area
AL-02: Seawater in the mangrove Area
AL-03: Seawater in the residential area

The results showed that although the concentration of heavy metal copper (Cu) in seawater was still below the quality standard, the presence of Cu in the tissue of blood shellfish (*Anadara granosa*) indicated that there was a bioaccumulation process taking place. Conditions occur in coastal water ecosystems, where heavy metals tend to accumulate in sediments and then be absorbed by benthic organisms. Research by Hidayati et al. (2021) states that heavy metals in Indonesia's coastal waters are generally more concentrated in sediments and biota than in the water column because they readily settle and bind to organic matter.

Bioconcentration Factor (BCF)

The BCF Cu value ranges from 209.46–422.56 L/kg (Table 4), which falls into the category of moderate accumulation. The highest BCF value was identified in mangrove areas, which shows that environmental characteristics such as sediment conditions, current dynamics, and biota activity play a role in influencing the ability of organisms to accumulate heavy metals (Retnosari *et al*., 2024).

Tabel 4. Bioconcentration Value of Copper Heavy Metal Factor (Cu)

Sample code	Bioconcentration Factor Values (L/kg)	Status
KD/AL-01	< 209.46 (L/kg)	Medium cumulative
KD/AL-02	422.56 (L/kg)	Medium cumulative
KD/AL-03	< 393.67 (L/kg)	Medium cumulative

Notes:

KD/AL-01: Seawater in the Estuary Area, Belau River

KD/AL-02: Seawater in the Area of Mangrove

KD/AL-03: Seawater in the Residential Area

Ilhami *et al*., (2024) which shows that the concentration of Cu in sediments, as well as mangrove root and leaf tissues, varied between observation sites, indicating the strong influence of environmental factors on the metal accumulation process. The complex root structure of mangroves helps trap and bind heavy metals in sediments, thereby supporting bioaccumulation and functioning as a natural mechanism for controlling pollution in coastal areas.

The high value of Bioconcentration Factor (BCF) in mangrove areas shows that this ecosystem functions as an area of heavy metal accumulation in the coastal environment. The high organic matter content in mangrove sediments can bind heavy metals, thereby increasing their availability to benthic organisms such as blood clams. In addition, the dense and complex root structure of mangroves acts as a natural filter, capturing and retaining pollutants from land. Manikasari and Mahayani (2018) stated that mangrove ecosystems have a high capacity to accumulate heavy metals compared to open waters. In addition to environmental factors, the bioaccumulation of heavy metals in organisms is influenced by biological factors such as size and age. Organisms with larger body sizes generally have higher heavy metal content because they are exposed for longer periods.

This accumulation occurs gradually as the organism grows. This statement is supported by research by Putra *et al*. (2021), which shows a positive relationship between bivalve body size and heavy metal concentrations in tissue, attributable to long-term accumulation.

Aspect	Description
State of the Art	Previous studies have established that heavy metals such as Cu can accumulate in coastal waters, sediments, and benthic organisms. Blood mussels (*Anadara granosa*) are widely recognized as bioindicator organisms because they are filter feeders and can accumulate pollutants from water and sediment. The Bioconcentration Factor (BCF) is commonly used to evaluate the level of metal accumulation in aquatic organisms.
Research Gap	Most existing studies focus on general heavy metal contamination in coastal waters or on other bivalve species, while specific data on Cu bioconcentration in *Anadara granosa* from Pulau Pasaran, Bandar Lampung, remain limited. There is also limited site-based comparison among estuary, residential, and mangrove areas in relation to Cu accumulation and BCF values.
Novelty	This study provides specific empirical data on Cu concentration in seawater and blood mussels from Pulau Pasaran using ICP-OES analysis. It also compares BCF values across three different coastal zones—Belau River estuary, residential area, and mangrove area—showing that mangrove areas have the highest BCF value and function as important zones of heavy metal accumulation.

CONCLUSION

The concentration of Cu in blood shellfish ranges from 0.936–1.303 ppm and is still below the quality standard threshold according to the Decree of the Director General of BPOM No.03725/B/SK/VII/89, and the concentration of Cu in seawater is around <0.003 ppm which meets environmental quality standards with results below the quality standard threshold in accordance with Government Regulation of the Republic of Indonesia No. 21 of 2022. The Bioconcentration Factor (BCF) value, ranging from 209.46 to 422.56 L/kg, indicates moderate accumulation capacity, with the highest value observed in mangrove areas affected by sediment conditions and environmental factors. Blood mussels (*Anadara* *granosa*) in the waters of Pulau Pasar are still safe to consume and have potential as bioindicators for monitoring heavy metal content in the aquatic environment.

IMPLICATIONS

This research makes significant scientific contributions in the fields of marine biology and ecotoxicology. In addition, the main implications for the community are directly related to health and food safety. This publication also supports the government's agenda in coastal area management and food security.

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