

Lead Bioaccumulation and Sediment-Biota Transfer in Gonggong Snail (*Strombus canarium*) From Batam, Indonesia

Yanty Prawita Sari^{1,2*}, Zahidah Hasan³, Yuniar Mulyani³, Heti Herawati³

¹Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Sumedang 45363, Indonesia

²Marine Conservation Study program, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Sumedang 45363, Indonesia

³Department of Fisheries, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Sumedang 45363, Indonesia

*Corresponding author: yanty22001@mail.unpad.ac.id

Manuscript received: 19 April. 2026. Revision accepted: 27 June 2026

Abstract. The coastal waters of Batam City, an industrial and maritime area, are exposed to intensive anthropogenic activities that may contribute to lead (Pb) contamination. As a persistent and toxic metal, Pb can accumulate in sediments and transfer to benthic organisms. The edible Gonggong snail (*Strombus canarium*) is widely consumed and may reflect environmental metal exposure. This study aimed to evaluate Pb concentrations in sediments and snail flesh and assess sediment-biota transfer. Sampling was conducted from August to December 2025 at four stations. Pb concentrations were analyzed using Atomic Absorption Spectrophotometry (AAS). Sediment Pb ranged from 1,73 to 7,72 mg/kg, below the ISQG-Low guideline (50 mg/kg). Pb in snail flesh was consistently low (0,002 mg/kg) and below the permissible limit (SNI 7387:2009; 1,5 mg/kg). Bioconcentration Factor (BCF) values (0,00026–0,00116) indicate limited transfer from sediment to tissue. The low accumulation in muscle tissue is likely associated with physiological detoxification processes occurring in the digestive tract, where metals are sequestered before reaching the edible tissue. Although Pb concentrations were below regulatory limits, its presence reflects ongoing metal inputs in the coastal environment, underscoring the importance of continuous monitoring to support seafood safety and public health protection.

Keywords: Batam City, Contamination, Gonggong Snail, Lead (Pb)

INTRODUCTION

The ocean has the capacity to dilute pollutants due to its large volume and dynamic nature (Sun *et al.* 2020). However, this assumption often leads to the underestimation of marine pollution problems, particularly in coastal areas where anthropogenic inputs are concentrated (Willis *et al.* 2022). Human activities such as industrial operations, maritime transportation, and coastal settlements contribute significantly to the introduction of pollutants into coastal waters (Setiawan 2015). Continuous accumulation of these contaminants can reduce water quality and disrupt ecosystem balance, affecting both abiotic and biotic components (Suryo *et al.* 2021).

One coastal area experiencing substantial anthropogenic pressure is Batam City, an industrial and maritime center in the Riau Islands Province. Its strategic location near Singapore and Malaysia, combined with intensive manufacturing activities, port operations, and coastal development, increases the potential for pollutant discharge into surrounding waters (Lovina 2023). Coastal ecosystems under economic and industrial pressure are particularly vulnerable to contamination from domestic, industrial, and shipping waste (KLHK 2024).

Among various pollutants, lead (Pb) is of particular concern due to its toxicity, persistence, and non-degradable nature (Gameli *et al.* 2022). In marine environments, Pb tends to bind to suspended particles and accumulate in sediments, which act as both sinks and potential secondary sources of contamination. From sediments, Pb may enter aquatic organisms through bioconcentration processes and potentially accumulate in benthic species (Sinulingga *et al.* 2018).

The Gonggong snail (*Strombus canarium*), an edible benthic gastropod with economic importance in Batam, inhabits sediment-associated habitats and remains in direct contact with bottom substrates. This ecological characteristic makes the species susceptible to sediment-

associated metal exposure and a potential bioindicator of heavy metal contamination. However, information regarding sediment–biota transfer of Pb in *Strombus canarium* from Batam waters remains limited. Therefore, this study aimed to quantify Pb concentrations in sediments and snail flesh, evaluate sediment–biota transfer through bioconcentration analysis, and assess its implications relative to food safety standards.

METHODS

Study Area and Sampling Design

This study was conducted from August to December 2025 in the coastal waters of Batam City, Riau Islands, Indonesia (**Figure 1**). Sampling stations were selected using purposive sampling to represent areas with different levels of anthropogenic activity and potential sources of Pb contamination. Sediment and Gonggong snail samples were collected from four stations.

- Station 1 (Tanjung Riau: 1°05'19.22"N 103°55'32.90"E) is located near residential areas, ferry port activities, and a shipyard in Sekupang, representing moderate anthropogenic influence.
- Station 2 (Pantai Nongsa: 1°11'54.76"N 104°04'53.43"E) is situated in a tourism and port area influenced by coastal development.
- Station 3 (Batu Ampar: 1°12'21.75"N 104°01'10.02"E) is located in an industrial and shipyard zone in Batu Ampar, characterized by intensive industrial and shipping activities.
- Station 4 (Dapur Tiga, Pulau Galang: 0°49'39.95"N 104°16'19.98"E) represents an area influenced by agricultural and small-scale fishing activities.

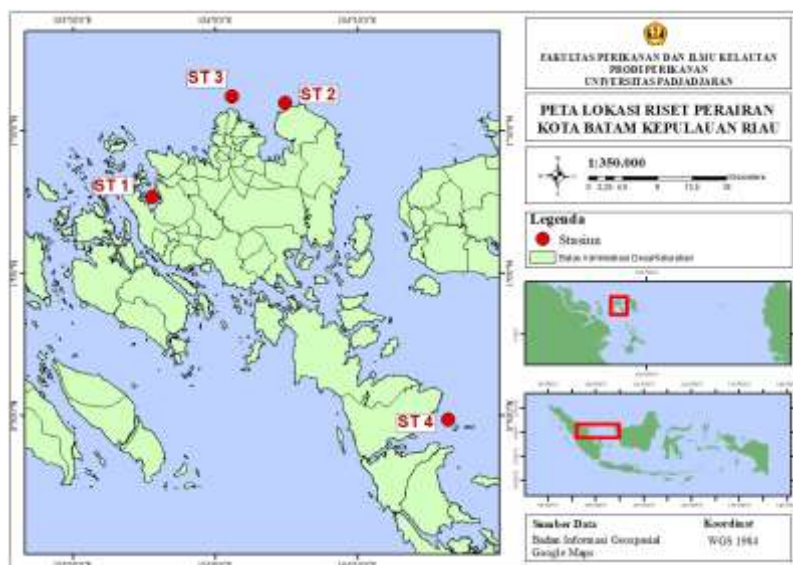


Figure 1. Study Location

Sample Collection and Handling

At each station, surface sediment (0–10 cm) was collected using a sediment grab sampler following standard procedures (USEPA 2020b). Gonggong snails were collected manually from intertidal areas using a metal sieve. The shells were removed, and only the edible muscle tissue was retained for analysis. The digestive tract and internal organs were separated and excluded to focus on the edible portion. The muscle tissues were then homogenized prior to digestion and analysis. All samples were transported in cool boxes with ice gel and stored at 4°C until preparation. Each composite sample was analyzed in duplicate to ensure analytical reliability. The specimens of Gonggong snails were collected from the local coastal area without experimental manipulation. This study did not require ethical approval because it

involved no experimental manipulation, handling, or intervention on live animals. The analyzed Gonggong snails originated from commercially harvested seafood products, and all research activities were restricted to laboratory analyses of collected samples.

In Situ and Ex Situ Water Quality Measurement

Physicochemical parameters were measured in situ at each station during sampling. Water temperature and dissolved oxygen (DO) were measured using a DO meter (Lutron DO-550), while pH was measured using a pH meter (Lutron PH-207). Salinity was determined using a handheld refractometer, and water depth was measured directly at each station. Measurements were conducted concurrently with sediment and Gonggong snail sampling.

Ex situ analyses included total suspended solids (TSS) and lead (Pb) concentrations in sediment and Gonggong snail muscle tissue. Sediment and biological samples were transported to the laboratory in cool boxes with ice gel and stored at 4°C prior to analysis. Current velocity data corresponding to the sampling period were obtained from the Marine Copernicus oceanographic dataset.

Lead (Pb) Concentration Analysis

The concentration of lead (Pb) in sediment and *Strombus canarium* samples was analyzed at the Central Laboratory of Universitas Padjadjaran. Sediment samples were digested following United States Environmental Protection Agency Method 3050B, while snail samples were digested according to SNI 2354.5 for seafood products. Pb concentrations were determined using Atomic Absorption Spectrophotometry (AAS), and results were expressed in mg/kg dry weight. Detailed sample preparation and digestion procedures are described in **Section 2.4.2**.

Instrumental Analysis and Calibration

Quantitative analysis of lead (Pb) was performed using a PerkinElmer Analyst Atomic Absorption Spectrophotometer (AAS). A wavelength of 217,0 nm was used for snail flesh samples, while 283,3 nm was applied for sediment samples. The instrument was calibrated using an external calibration curve prepared from certified Pb standard solutions. Linearity was confirmed with a correlation coefficient (r^2) of 0,9991.

Sample Preparation

All sample preparation and digestion were conducted in a controlled laboratory environment to prevent cross-contamination. Analytical-grade reagents (HNO₃ and HCl) and high-purity deionized water were used throughout the analysis. All glassware and equipment were acid-washed (soaked in 10% HNO₃ for 24 h) and thoroughly rinsed with deionized water prior to use. As described in **Section 2.2**, samples were stored at 4°C and processed within 72 h of collection. Each field sample was prepared and digested in duplicate ($n = 2$) to assess analytical precision. A procedural blank was included in each digestion batch to monitor potential contamination.

Quality Assurance and Quality Control (QA/QC)

Robust quality assurance and quality control (QA/QC) procedures were implemented to ensure analytical accuracy and precision. Procedural blanks were included with each batch of samples, and all blank values were below the limit of detection (LOD). Each final sample solution was analyzed in duplicate ($n = 2$), with the relative standard deviation (RSD) maintained below 5%. The analysis was performed using a PerkinElmer Analyst 400 Flame Atomic Absorption Spectrophotometer (AAS). The instrument's limit of detection (LOD) and limit of quantification (LOQ) for Pb were 0,005 mg/L and 0,015 mg/L, respectively. All measured concentrations were above the LOQ.

Sediment Samples

Sediment samples were digested following the aqua regia extraction procedure described in Aqisman et al. (2019). Approximately 5 g of homogenized sediment were treated with a mixture of HNO₃ and HCl and heated at 180–200°C until a clear solution was obtained. The digestate was diluted to 100 mL with deionized water and filtered prior to analysis. Lead (Pb) concentrations were determined using AAS at 283,0 nm. Each sample was prepared in duplicate, and a procedural blank was included in each batch.

Gonggong Snail Tissue Analysis

The concentration of Pb in Gonggong snail flesh was determined using the same procedure as for sediment samples, with all laboratory preparation and digestion steps identical. The only difference was the wavelength used in the Atomic Absorption Spectrophotometer, which was set at 217,0 nm specific for Pb. All analyses were conducted in duplicate to ensure precision, and Pb concentrations were calculated based on the initial tissue weight and final dilution volume, expressed in mg/kg.

Data Analysis

Data Handling and Descriptive Statistics

All raw data were compiled and screened for anomalous values prior to statistical analysis. No outliers requiring removal were identified. Descriptive statistics, including mean, standard deviation (SD), minimum and maximum values (range), were calculated for all parameters. The results were presented in tables and visualized using bar graphs for spatial comparison.

To compare Pb concentrations in sediment and *Strombus canarium* among four stations, inferential statistical analyses were performed. Data were tested for normality using the Shapiro–Wilk test and for homogeneity of variance using Levene’s test. Because the data were not normally distributed ($p < 0,05$), differences among stations were analyzed using the Kruskal–Walls test. Morphometric parameters, including shell size and soft tissue weight, were analyzed descriptively. All statistical analyses were performed using RStudio (Version: 2025.05.1+513) with R (Version: 4.5.1) the primary package used were stats for core statistical tests and ggplot2 for data visualization. The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request.

Benchmark Comparison

Concentration in each matrix was directly compared to the established benchmark values from relevant standards (PP No.22/2021 for seawater parameters, ANZECC/ARMCANZ 2000 for sediment, SNI 7387:2009 for Gonggong snail tissue).

Comparative Analysis Among Stations

Differences in Pb concentrations among stations were assessed using the Kruskal–Walls test, following normality checks. This non-parametric approach is suitable for environmental data, which often violate parametric assumptions (Inadjo et al. 2022)

Correlation Between Sediment and Biota Pb

Spearman correlation was used to assess the relationship between Pb in sediment and snail tissue, as data variability was heterogeneous. Positive correlation coefficients indicate higher sediment Pb corresponds to higher snail Pb, reflecting bioaccumulation patterns (Melake & Endalew 2023).

Bioconcentration Factor (BCF)

BCF was calculated to evaluate the snail's ability to accumulate Pb from sediment. $BCF \geq 1$ indicates high accumulation potential $BCF < 1$ indicates low accumulation (Najamuddin et al. 2024).

$$BCF = \frac{C_b}{C_w}$$

RESULTS AND DISCUSSION

Physicochemical Water Parameters

Water quality parameters in Batam waters during the study period showed in **Table 1**. All measured parameters were within the quality standards established by Government Regulation No. 22 of 2021.

Table 1. Physicochemical characteristics of seawater in Batam coastal waters.

Station	Parameters					
	Temperature (°C)	Depth (m)	DO (mg/L)	Salinity ‰	pH	TSS (mg/L)
1	29,85 ± 0,21	1,5	6,10 ± 0,75	28,5 ± 0,71	7,20 ± 0,14	50,5 ± 3,54
2	28,05 ± 0,64	1,5	6,68 ± 1,42	29,5 ± 0,71	7,38 ± 0,10	59,5 ± 0,71
3	28,40 ± 0,14	1,7	6,53 ± 0,21	29,0 ± 1,41	7,57 ± 0,05	52,0 ± 1,41
4	29,25 ± 1,06	1	7,38 ± 0,21	29,5 ± 0,71	7,25 ± 0,13	45,0 ± 12,73
seawater quality standard*	Dev <3	1-4,5 m	≥ 5 mg/L	25-30 ‰	6 – 8,5	<20 mg/L (protected marine waters) <80 mg/L (Seawater)

*Adapted from government regulation No. 22/2021 regarding environmental protection and management

3.2 Lead (Pb) concentrations in sediment and *Gonggong* snail flesh

The mean concentrations of Lead (Pb) in sediment and *Gonggong* snail flesh samples from the four stations are presented in **Table 2**.

Table 2. Lead (Pb) concentrations in sediment and *Gonggong* snail flesh

Station	Pb Concentration	
	Sediment (mg/kg)	<i>Gonggong</i> snail flesh (mg/kg)
1	1,93 ± 1,98	2,0 × 10 ⁻³
2	7,72 ± 9,33	2,0 × 10 ⁻³
3	1,73 ± 0,98	2,0 × 10 ⁻³
4	2,29 ± 1,18	2,0 × 10 ⁻³
Quality guidelines in sediments (ANZECC/ARMCANZ)*	50 mg/kg*	-
SNI 7387:2009**	-	1,5 mg/kg**

*ANZECC/ARMCANZ (2000): Australian and New Zealand environment and conservation council and agriculture and resource management council of Australia and New Zealand

** SNI: Standard Nasional Indonesia (Indonesia National Standard 2009)

Pb concentrations in sediments were higher than those detected in *Strombus canarium* flesh. Sediment Pb ranged from 1,73 ± 0,98 mg/kg (Station 3) to 7,72 ± 9,33 mg/kg (Station 2). In contrast, Pb concentrations in snail flesh were uniform across all stations (2,0 × 10⁻³ mg/kg). All sediment Pb concentrations were below the sediment quality guideline values of 50 mg/kg (ISQG-Low) and 46,7 mg/kg (ERL), and Pb levels in snail flesh were below the maximum permissible limit for seafood (1,5 mg/kg) according to SNI 7387:2009 (**Table 2**). The bioconcentration factor (BCF) values ranged from 0,00026 – 0,00116 which fall within the low accumulation category (**Table 3**)

The correlation between Pb accumulation in sediment and Gonggong snail flesh

The relationship between Pb concentrations in sediments and *Strombus canarium* flesh was analyzed using Spearman's rank correlation due to non-homogeneous data distribution (Irfan Syahroni 2022). However, the very small variation in Pb concentrations within snail tissues limited rank differentiation, making the statistical relationship undetectable. Therefore, the relationship between sediment Pb and tissue Pb was evaluated descriptively.

Bioconcentration Factor of Lead (Pb)

The Bioconcentration Factor (BCF) was calculated to evaluate the ability of Gonggong snails to accumulate Pb from sediments hidup (USEPA 2008c). Results showed that BCF values were very low (<1) at all stations (**Table 3**). Based on standard interpretation, these values indicate that Gonggong snails fall into the low accumulation category for Pb.

Table 3. Bioconcentration Factor of Lead

Stasiun	BCF
1	0,00104
2	0,00026
3	0,00116
4	0,00087

Discussion

Water Quality Parameters at Each Sampling Station

In situ measurements of physical and chemical parameters, including temperature, current, depth, dissolved oxygen (DO), salinity, pH, and total suspended solids (TSS), indicated that water quality at all stations met the Class 3 seawater standards of PP RI No. 22/2021 (**Table 1**). Although TSS concentrations complied with the Class 3 seawater standard for general waters, all stations exceeded the threshold established for protected and recreational marine waters (<20 mg/L), indicating relatively high suspended particulate loads in the study area. These elevated TSS levels are likely associated with anthropogenic activities in the coastal zone, including marine transportation, tourism, and shoreline settlements, which can enhance sediment resuspension and increase particulate matter in the water column. Elevated TSS may also influence the environmental fate of Pb, as suspended particles provide adsorption sites for dissolved metals and facilitate their transport within aquatic systems (Basha *et al.* 2007). Upon settling, particle-bound Pb can accumulate in bottom sediments, which may serve as a long-term sink for metal contamination (Miranda *et al.* 2022). This process is particularly relevant to benthic organisms such as Gonggong snails which inhabit sediment-associated environments and may be exposed to Pb through sediment contact and dietary uptake (Ananda *et al.* 2022).

Spatial Distribution of Lead (Pb) in Coastal Sediments

Lead (Pb) in aquatic environments accumulates predominantly in sediments due to its affinity for suspended particles and organic matter. However, its spatial variability is strongly influenced by local hydrodynamics, anthropogenic inputs, and physicochemical conditions (Kachoueian & Atmianlu 2024).

Pb accumulation in sediments at Station 2 was higher than at the other stations and was associated with intensive tourism and marine transportation activities. Its location opposite Pulau Putri, a major local tourist destination, results in continuous traffic of small boats and jetskis. Such activities potentially release Pb from fuel residues, lubricants, and boat paints (Pratiwi *et al.* 2016). The presence of ports and resort facilities around the station creates weak current zones (Huzairiah & Agung 2022). Facilitating the deposition of suspended particles

that have adsorbed Pb and enhancing accumulation in bottom sediments (Riter et al. 2018). The combination of high anthropogenic pressure and hydrodynamic conditions favorable to sedimentation explains the elevated Pb accumulation at Station 2.

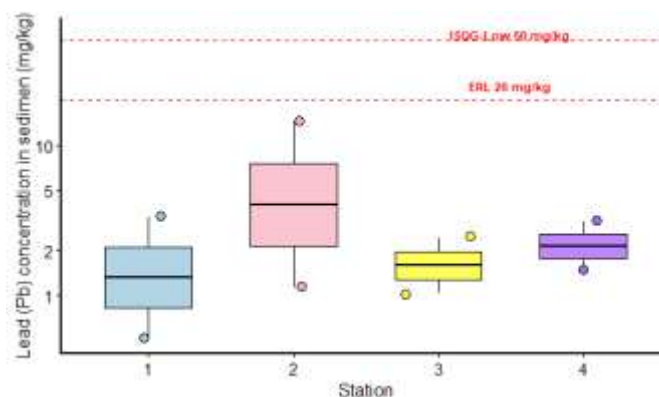


Figure 2. Lead (Pb) Concentration in Sedimen (mg/kg)

In contrast, Station 3 showed the lowest Pb concentration despite its proximity to an active shipyard, indicating that industrial activity does not always result in elevated sediment contamination (Ervina et al. 2025). Industrial wastes such as paint residues, sandblasting waste, lubricants, and ballast water are strictly managed under the Regulation of the Minister of Environment and Forestry No. 6 of 2021 (Sari et al. 2025). Treatment through IPAL systems reduces dissolved Pb prior to discharge (Sanjay & Kumar 2021). Via processes such as coagulation, flocculation, sedimentation, filtration, and pH adjustment, which convert Pb into more stable and less bioavailable forms (A. Setiawan et al. 2020). Moreover, its location in open waters along a main shipping lane enhances turbulence and sediment resuspension due to intensive vessel traffic limiting permanent Pb deposition (Amelia et al. 2019). Post-rain sampling may have further redistributed Pb into the water column (Lim et al. 2022). These combined factors explain the low sediment Pb observed at Station 3.

Factors Affecting Low Accumulation Lead in Gonggong Flesh

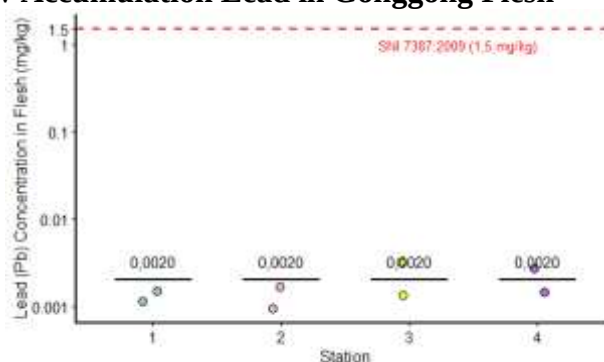


Figure 3. Lead (Pb) Concentration in Flesh (mg/kg)

Pb accumulation in Gonggong flesh remained low across all stations, indicating that despite exposure from sediments and coastal anthropogenic activities, edible tissue shows minimal accumulation (Kabir et al. 2024). Gastropods absorb heavy metals primarily through direct diffusion across epithelia and gills and ingestion of sediment-bound particles (Shabi et al. 2022). Once absorbed, Pb is transported via hemolymph to internal organs where it is sequestered by metallothioneins and other detoxification proteins, limiting its transfer to muscle tissue (Datta et al. 2015). This physiological regulation results in consistently low Pb

concentrations in the flesh. The low Pb concentration in the flesh indicates an interaction between environmental exposure and internal physiological regulation mechanisms within the organism (Tirtama & Bengen 2024). However, heavy metal distribution within the organism is not homogeneous, and certain internal organs may accumulate Pb at higher concentrations than muscle tissue (Sze et al. 2021). Although Pb concentrations in edible tissue were low, further studies are required to evaluate Pb accumulation in digestive organs, which may exhibit different accumulation patterns.

Ecological Link Between Pb in Sediments and Gonggong Flesh

Although Pb concentrations in Gonggong flesh are consistently low, sediments act as the primary ecological source of Pb exposure (Budiyanto et al. 2018). The limited bioaccumulation in tissue results from physiological detoxification mechanisms, including metallothionein binding and internal compartmentalization, which restrict Pb transfer to edible flesh (Matras et al. 2022). Environmental factors such as water pH, hydrodynamics, and sediment resuspension after rainfall influence Pb bioavailability, but organismal regulation is the main control on tissue accumulation (Khan et al. 2018). This underscores that sediment Pb levels alone do not directly determine Pb in benthic organisms, emphasizing the complex interplay between environmental exposure and biological detoxification (Osae et al. 2026).

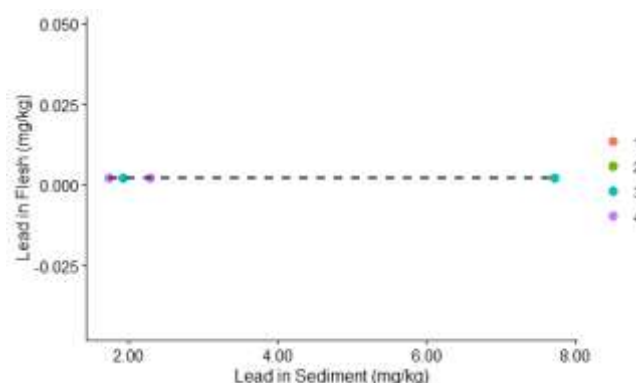


Figure 4. Ecological Link Between Pb in Sediments and Gonggong Flesh

Based on **Figure 4**, sediment Pb concentrations ranged from 1,73 to 7,72 mg/kg, whereas tissue Pb remained nearly constant at $2,0 \times 10^{-3}$ mg/kg across all stations. The lack of variation in tissue Pb prevented statistical correlation analysis using Spearman's test. Nevertheless, sediments remain the main ecological source of Pb for Gonggong, while low tissue concentrations reflect biological detoxification mechanisms that limit Pb accumulation in edible flesh. This demonstrates that the link between sediment and tissue Pb is modulated by environmental conditions and physiological regulation rather than sediment Pb alone.

- **Station 1:** Sediment Pb $1,93 \pm 1,98$ mg/kg; tissue Pb $2,0 \times 10^{-3}$ mg/kg. Proximity to dense residential areas and restaurants increases Pb input from domestic wastewater, paints, batteries, and household materials (Susanto et al. 2018). Weak currents, shallow depth, and slightly alkaline pH favor fine particle deposition, enhancing Pb accumulation in sediment (Riter et al. 2018).
- **Station 2:** Sediment Pb $7,72 \pm 9,33$ mg/kg; tissue Pb $2,0 \times 10^{-3}$ mg/kg. High anthropogenic activity including tourism, resorts, ports, and maritime transport contributes continuous Pb input (Handjanny et al. 2024). Despite higher sediment contamination, detoxification limits tissue accumulation.

- **Station 3:** Sediment Pb $1,73 \pm 0,98$ mg/kg; tissue Pb $2,0 \times 10^{-3}$ mg/kg. Low sediment Pb results from post-rainfall dilution and B3 industrial waste management (Lim et al. 2022). Even near shipyards and ports, sediment Pb remains low, indicating limited bioavailability.
- **Station 4:** Sediment Pb $2,29 \pm 1,18$ mg/kg; tissue Pb $2,0 \times 10^{-3}$ mg/kg. Artisanal fisheries and traditional boat activities contribute Pb via oil, fuel residues, and antifouling paint degradation Budiyo et al. (2022). Weak currents allow fine particles to settle, leading to Pb accumulation in sediment despite the site being distant from heavy industry (Riter et al. 2018).

In summary, the ecological link between sediment and tissue Pb demonstrates that tissue accumulation is governed not only by total sediment concentrations but also by bioavailability, hydrodynamics, and biological detoxification mechanisms. This complex interaction explains why Pb in Gonggong flesh remains low even when sediment concentrations vary, emphasizing the importance of considering both environmental and physiological factors in assessing metal transfer in benthic ecosystems (Khotimah et al. 2022).

Effectiveness of Gonggong as a Bioindicator

Gonggong snails have potential as bioindicators of bioavailable Pb in coastal sediments due to their close association with benthic habitats, they maintain continuous contact with sediments the primary metal reservoir (Askara et al. 2020). By ingesting sediment bound particles and organic matter, they integrate metal exposure over time and reflect benthic contamination more consistently than waterbased indicators (Nico et al. 2023). Their physiological regulation, particularly through metal binding proteins such as metallothioneins, allows them to accumulate bioavailable metal fractions without reaching toxic levels, making tissue concentrations representative of environmental bioavailability rather than total sediment content (Datta et al. 2015). This combination of ecological relevance, temporal integration, and biological response supports their effectiveness as indicators of sediment quality and coastal ecosystem health (El-sharkawy et al. 2025).

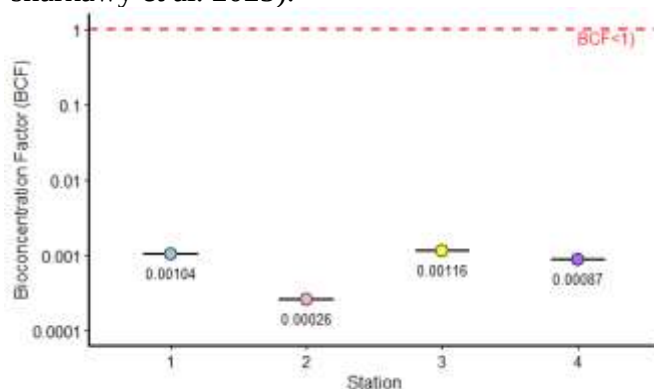


Figure 5. Bioconcentration Factor

Based on **Figure 5**. The Bioconcentration Factor (BCF) of lead (Pb) in Gonggong snails from all four stations in the Batam waters was consistently below 1 ($BCF < 1$), indicating a generally low capacity of these snails to accumulate Pb from sediments. The variation in BCF values demonstrates that the accumulation of heavy metals in organisms is not solely determined by the total concentration of Pb in sediments and tissue but is also influenced by the physicochemical characteristics of the water, which affect metal bioavailability (Nugraha et al. 2019). Therefore, the low BCF values observed across all four stations suggest that Pb bioavailability was generally low, limiting its uptake by benthic organisms.

Among the stations, Station 3 exhibited the highest BCF value at 0,00116. This suggests that despite lower total Pb concentrations in the sediment compared to other stations, Pb bioavailability at this location was higher. The lower sediment Pb concentration could be attributed to sampling conducted after rainfall, which caused dilution and redistribution of suspended particles, resulting in decreased Pb content in the sediment (Budiyanto *et al.* 2022). However, hydrodynamic conditions at Station 3, such as near-neutral to slightly alkaline pH and relatively high total suspended solids (TSS), enhanced the effectiveness of metal-binding receptors in the snails, allowing efficient Pb uptake (Deforest *et al.* 2007)

Conversely, Station 2 showed the lowest BCF value at 0,00026. This lower accumulation is likely due to relatively high Pb concentrations in the sediment, which can saturate the metal-binding mechanisms in the snails, reducing the efficiency of Pb uptake. This pattern aligns with the findings Deforest *et al.* (2007), who reported that BCF values tend to decrease as environmental exposure concentrations increase. Despite the lower BCF, Pb in the sediments at Station 2 remained bioavailable due to favorable hydrodynamic conditions, such as weak currents and near-neutral to slightly alkaline pH, which facilitate continued metal availability for benthic organisms (Riter *et al.* 2018).

In summary, the BCF values across all stations highlight the complex interplay between sediment metal concentrations, water physicochemical parameters, and the physiological capacity of Gonggong snails. These findings reinforce the role of Gonggong snails as reliable indicators of bioavailable heavy metals in coastal sediments, reflecting both environmental contamination and the potential risk to benthic ecosystems.

CONCLUSION AND SUGGESTION

Conclusion

Pb concentrations in sediments from the coastal waters of Batam City, with average values ranging from 1,73 to 7,72 mg/kg, were all below the ISQG-Low guideline (50 mg/kg), indicating no signs of hazardous Pb contamination.

Pb concentrations in Gonggong snail flesh across all sampling stations, with an average of $2,0 \times 10^{-3}$ mg/kg, were below the maximum permissible limit established by SNI 7387:2009 (1,5 mg/kg), indicating that the analyzed edible tissue met seafood safety standards and is safe for human consumption.

The Bioconcentration Factor (BCF) values for Pb in Gonggong snails ranged from 0,00026 to 0,00116, indicating low Pb bioavailability and limited accumulation in edible tissues across all sampling stations, consistent with physiological mechanisms that restrict metal transfer to muscle tissue.

Suggestion

Further research should be conducted to measure Pb concentrations in the hepatopancreas and muscle tissues, as well as in sediments and the water column. Additionally, expanding the number of sampling stations and the monitoring period is recommended to capture seasonal variations and to map Pb distribution more comprehensively.

Future studies should measure additional bioaccumulative heavy metals (e.g., Cd, Cu, Hg) to enable a more comprehensive ecological risk assessment.

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