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Analysis of heavy metals contamination in chue snails (*Faunus ater*) from estuary of the southwestern coast of Aceh Province, Indonesia

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ABSTRACT

The southwestern coast of Aceh Province is among the areas vulnerable to heavy metal pollution originating from human activities, including mining, agriculture, and household waste. Chue snails (*Faunus ater*) are among the aquatic organisms that can be used as a bioindicator of water pollution. Therefore, this study aimed to evaluate the content of Lead (Pb), Cadmium (Cd) and Mercury (Hg) in *F. ater* snails originating from seven estuary areas in the southwestern coast area of Aceh Province. Analysis was also carried out to determine the environmental factors affecting metal accumulation and potential risks to public health. Sampling was performed in various areas, including the Jembatan Kembar River (Aceh Singkil), Trumon River (South Aceh), Kuala Lama Tuha (Southwest Aceh), Peunaga Cut Ujong River (Nagan Raya), Suak Ribe Puteh (West Aceh), Teunom River (Aceh Jaya), and Leupung River (Aceh Besar). This study used a laboratory analysis method with Atomic Absorption Spectrophotometry (AAS) instruments to measure metal concentrations in *F. ater* tissue. The results showed that all samples from seven areas were contaminated with Pb, Cd, and Hg at levels ranging from 0.691 - 1.575 mg/kg, 0.285 - 0.311 mg/kg, and 0.001 – 0.030 mg/kg, respectively. Pb and Cd content showed high heavy metal content, which exceeded the safe threshold according to the Food and Drug Administration (BPOM), Republic of Indonesia, with the greatest concentration found in the Southwest Aceh Regency. These results showed that the consumption of *F. ater* had the potential to endanger public health. Therefore, it is necessary to conduct outreach to the community to increase environmental awareness and food safety.

Introduction

Sea waters of Aceh is divided into two main areas, namely the Eastern and the Southwestern Coast. The Eastern Coast includes several areas such as East Aceh, North Aceh, and Langsa City. Meanwhile, the Southwestern Coast includes seven areas, namely Aceh Jaya, West Aceh, Nagan Raya, Southwest Aceh, South Aceh, Aceh Singkil, and Aceh Besar. The southwestern coast of Aceh Province has a wealth of natural aquatic resources, including shellfish (molluscs). Investigations related to the diversity of molluscs in estuary water of the southwestern coast have been reported in several studies. Asiah *et al.* (2017) reported that in the littoral area of Lhok Seudu, Leupung, Aceh Besar, 20 species of gastropods were found belonging to five orders, with a low diversity index. Another study by Iqwanda *et al.* (2021) in water of Gunung Cut, South Aceh Regency, identified various species of gastropods playing an important role in the coastal ecosystem. Among several molluscs on the Southwestern Coast are *Chue* snails (*Faunus ater*). The presence of *F. ater* shows that the area has significant molluscs diversity potential, which can be used as an indicator of environmental health and an important biological resource for local communities.

F. ater snails are often consumed in Aceh, particularly in the southwestern coastal community, both as an additional side dish and main ingredient in typical Acehnese cuisine. These species are herbivorous animals that live on the bottom of sandy and muddy water (Khalidin *et al.*, 2024). The food sources are plankton, algae, and organic litter found on the bottom of water. This is *F. ater* are a detritivore

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and filter feeder that plays an important role in maintaining the balance of the benthic ecosystem (Octavina *et al.*, 2019; Razi *et al.*, 2021; Savira *et al.*, 2024). Due to high adaptability, *F. ater* are frequently used as a bioindicator for assessing water quality (Octavina *et al.*, 2021; Khalidin *et al.*, 2024).

The Southwestern region of Aceh is the epicenter of mining and palm oil plantation activities, including illegal mining (Rohim *et al.*, 2022; Razi *et al.*, 2023b) and land conversion to palm oil plantation. The rampant mining activities in areas near water sources have become a serious threat to the sustainability of the aquatic environment. Mining and agricultural wastes are potentially containing heavy metal such as lead (Pb), mercury (Hg), and cadmium (Cd) is carried downstream by rivers, polluting water and threatening aquatic biota, including *F. ater*. As a filter-feeding organism, *F. ater* are susceptible to accumulating heavy metal from the environment through the bioaccumulation process, and can be harmful when consumed by communities (Dewi *et al.*, 2022; Akbar and Rahayu, 2023). Ramadhaniaty *et al.* (2023) reported that *F. ater* in the estuaries of the Rasian and Asahan rivers in South Aceh had been contaminated with Hg, Pb, and Cd. In Aceh Besar, Agustina *et al.* (2018) showed that the accumulation of heavy metal in *F. ater* tissues was directly correlated with anthropogenic activities in the upstream. This showed the urgency of similar monitoring in the mining and agricultural-impacted southwestern area. Additionally, port activities, and domestic waste contributed the largest amount of heavy metal to water. The impact threatened the survival of aquatic biota with the potential to enter communities food chain through the consumption of contaminated snails. Health risks, including nervous disorders, kidney failure, and cancer, have been documented by Pratiwi (2020). The condition was caused by exposure to heavy metal, emphasizing the importance of this study as a basis for pollution mitigation and protection of the coastal ecosystem in the southwestern part of Aceh Province.

Heavy metal has similar characteristics to others and differ in impact when bound to or entering the bodies of living organisms. There is also a negative influence on biological processes, particularly in dissolved form, which can be toxic even in suspension form (Razi *et al.*, 2023a; Singh *et al.*, 2024). Cd, and Pb have shown potential to interfere with enzymatic function, damage cell structure, and cause accumulation in the body tissues of organisms, thereby disrupting the food chain and human health (Suhani *et al.*, 2021; Al Mazed *et al.*, 2022). Cd and Pb can bind to membrane cells, inhibiting the transformation process through the cell walls. Heavy metal is also capable of precipitating biological phosphate compounds or catalyzing the decomposition (Ali *et al.*, 2019). Pb affects health because the toxic properties can cause death (Mandal *et al.*, 2022). Another impact of Pb, heavy metal that accumulates in the environment, is the inability to be decomposed biologically (Collin *et al.*, 2022; Razi *et al.*, 2023a). Cd prefers oxidation levels and is also obtained from human activities, namely the chemical industry, textile factories, cement factories, oil spills, mining, metal processing, fuel combustion, and the manufacture and use of phosphate fertilizers (Angon *et al.*, 2024). In everyday life, children's toys, photography, vinyl bags, and coats are sources of Cd (Turner, 2018). In addition, this metal is used for electrolysis, pigment materials for the paint, enamel, and plastic industries, as well as found in the alloy industry, Zn purification, pesticides, and others (Alfian and Hutagalung, 2024).

Several results have provided an overview that the condition of the southeastern water of Aceh, particularly in estuary area, can be contaminated with heavy metal (Ramadhaniaty *et al.*, 2023). Based on the overview, a more comprehensive study with a wider scope is needed to provide concrete picture of heavy metal pollution, particularly Pb and Cd, in *F. ater*. Therefore, this study aimed to analyze the content of Pb and Cd accumulated in *F. ater* from the southwestern coast of Aceh and compare results with environmental quality standards as well as food safety thresholds in Indonesia.

Materials and Methods

Location and time of research

This study was conducted from May to June 2025 in the southwestern coast of Aceh Province. Analysis of Pb and Cd content in *F. ater* meat using atomic absorption spectrophotometry (AAS) was performed at the Agricultural Laboratory of the Faculty of Agriculture, Syiah Kuala University.

Determination of sampling area

Sampling was conducted at seven areas representing each area in the southwest coast, namely Kilangan, Aceh Singkil (2°17'3.80"N; 97°46'10.10"E); Ie Meudama, South Aceh (2°43'31.90"N; 97°38'29.00"E); Kedai Susoh, South West Aceh(n/a); Kuala Tuha, Nagan Raya (n/a), Suak Ribe, West Aceh (n/a); Panton, Aceh Jaya (n/a), and Leupung, Aceh Besar (n/a) (Figure 1). The determination of these areas was carried out using purposive sampling, specifically by selecting the estuaries of the main rivers with the potential for heavy metal accumulation and serving as the natural

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habitat of *F. ater*. The selection process considered accessibility, anthropogenic activities around water, and the presence of a fairly abundant *F. ater* population.

Sampling of chue snail *F. ater*

F. ater sampling was conducted directly in estuary water of the Southwestern Coast of Aceh Province, which served as the natural habitat. The sampling area was selected based on the presence of a fairly abundant population and site accessibility. Samples were collected manually at low tide by picking up species visible on the surface of the muddy substrate or those partially buried in the sediment. To ensure representativeness, sampling was conducted at several observation points at certain distances within a single area. Each *F. ater* collected was placed in a clean, labeled plastic container and rinsed with local seawater to remove any sediment particles. The samples were stored in a cooler filled with crushed ice to maintain tissue quality for laboratory analysis. During the sampling process, environmental data such as water temperature, salinity, pH, and substrate conditions were recorded to support the interpretation of the results. All procedures were conducted in accordance with the sampling protocol for heavy metal analysis to prevent cross-contamination and maintain sample integrity.

Sample Preparation

Sample preparation for heavy metal analysis in *F. ater* meat started with collection and cleaning. *F. ater* was collected from natural habitat, determined according to the study objectives. Subsequently, the specimen was thoroughly cleaned of any foreign material, such as mud, sand, or other organisms that could attach to the body. The cleaning process was carried out using clean water, followed by rinsing with distilled water to remove surface contaminants that could affect the analysis results.

After cleaning, meat sample was dried using an oven or dryer at a carefully controlled temperature to ensure complete evaporation of water content without damaging the chemical structure. This drying was performed to prevent the influence of humidity on the results of heavy metal analysis. The dried sample was crushed using a clean crusher or grinder to obtain smaller and more homogeneous particle sizes. This grinding aimed to achieve uniformity for more accurate and representative analysis. During this process, care must be taken to avoid cross-contamination of the equipment used.

The ground sample was then filtered to remove unwanted coarse particles. Filtering was performed using a sieve with a specific size to obtain uniformly sized particles. After the filtering process, the sample was acidified or ashed to dissolve heavy metal present in the *F. ater* tissue. Typically, strong acids such as nitric acid (HNO_3), hydrochloric acid (HCl), or a mixture of the two were used, with concentrations adjusted to optimize the dissolution process without damaging metal compounds. The dissolved sample was washed using an appropriate solvent to remove any remaining contaminants. The concentration process, achieved through manual evaporation or a rotary evaporator, was conducted to obtain a heavy metal suitable for further analysis.

The final stage of the preparation process was laboratory analysis to measure the concentration of heavy metal in the sample. Commonly used methods were AAS, Inductively Coupled Plasma Mass Spectrometry (ICP-MS), offering high sensitivity for detecting heavy metal elements. This analysis would provide an overview of heavy metal contamination levels in *F. ater* from estuary area of the southwestern coast of Aceh Province. The formula used to determine metal levels was the Concentration regression obtained based on the regression value of the calibration curve to determine the levels Pb, Cd, and Hg as follows:

Heavy metal concentration (mg/kg) = (Creg x P x V)/ G

Where, Creg is Read concentration (mg/L), P is the dilution factor, G is the sample weight (kg), and V is the sample solution volume (L)

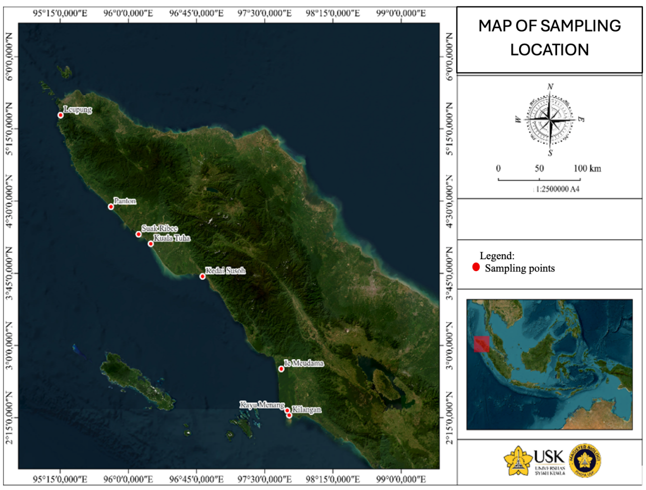

Figure 1. The map of Aceh province showing the sanpling location (highlighted on red cyrcle)

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Data analysis

Heavy metal data are shown in the form of images and graphs, followed by a comparison with quality standards based on the Food and Drug Administration (BPOM) of the Republic of Indonesia 2017. The data were analyzed descriptively by comparing with results from previous studies and relevant references.

Results

The results of laboratory analysis showed that all samples were contaminated with Pb, ranging from 0.691 to 1.575 mg/kg. The highest Pb content was found in sample from the southwestern Aceh (1.575 mg/kg), the lowest in West Aceh 0.525 mg/kg (Table 1). Based on the results, Pb content from the seven areas exceeded the tolerance threshold (Figure 2a). Furthermore, all *F. ater* samples had been contaminated with Cd, ranging from 0.285 to 0.311 mg/kg. The highest Cd levels were found in samples from Southwestern Aceh, and the lowest was in Aceh Singkil (Table 1). Further analysis showed that Cd levels in all areas had exceeded the threshold (Figure 2b). The Hg content ranged from 0.001 to 0.030 mg/kg, where the highest Hg level was found at the Lama Muda mouth river, Aceh Barat Daya District, and the lowest was found at the Leupung River, Aceh Besar District (Table 1). However, the values have not exceeded the threshold limit (Figure 2c).

Measurement results for the main water quality parameters showed variations in temperature (27.3–32.6°C), salinity (11–24 ppt), dissolved oxygen (4.6–6.8 mg/L), and pH (6.1–8.7). The highest temperature was recorded in water of Aceh Singkil (32.6°C), while the lowest was measured in southwestern Aceh (27.3°C). The lowest salinity was found in Southwest Aceh (11 ppt), and the highest in West Aceh (24 ppt). The highest pH was detected in Aceh Singkil (8.7) and the lowest in West Aceh (6.1). As shown in Table 2, the lowest DO was found in Aceh Jaya (4.6 mg/L) and the highest in Aceh Singkil (6.8 mg/L).

Table 1. Concentration of Lead (Pb) and Cadmium (Cd) in the *Chue* snail (*Faunus ater*) from Southwest of Aceh estuaries, Indonesia

Sampling location	Pb (mg/kg)	Cd (mg/kg)	Hg (mg/kg)
Lama Muda River, Aceh Barat Daya	1.575±0.0046	0.311±0.0023	0.030±0.007
Peunaga Cut Ujong River, Nagan Raya	1.412±0.0000	0.300±0.0000	0.028±0.000
Jembatan Kembar River, Aceh Singkil	1.189±0.0083	0.299±0.0023	0.023±0.000
Leupung River, Aceh Besar	0.744±0.0106	0.296±0.0000	0.001±0.000
Teunom River, Aceh Jaya	0.691±0.0061	0.295±0.0023	0.023±0.001
Trumon River, Aceh Selatan	0.551±0.0023	0.295±0.0023	0.013±0.004
Suak Ribe River, Aceh Barat	0.525±0.0023	0.285±0.0023	0.013±0.002

Table 2. Main water quality parameter measured *in situ* from Southwest of Aceh estuaries, Indonesia

Sampling location	Water temp. (°C)	Salinity (ppt)	Dissolved Oxygen (mg/L)	pH
Jembatan Kembar River,Aceh Singkil	32.6	22.0	6.8	8.7
Trumon River, Aceh Selatan	29.8	16.0	5.7	6.9
Lama Muda River, Aceh Barat Daya	27.3	11.0	6.4	7.2
Peunaga Cut Ujong River, Nagan Raya	28.4	19.0	5.2	8.3
Suak Ribe River, Aceh Barat	31.3	24.0	5.8	6.1
Teunom River, Aceh Jaya	28.2	13.0	4.6	6.7
Leupung River, Aceh Besar	29.4	18.0	5.3	7.5

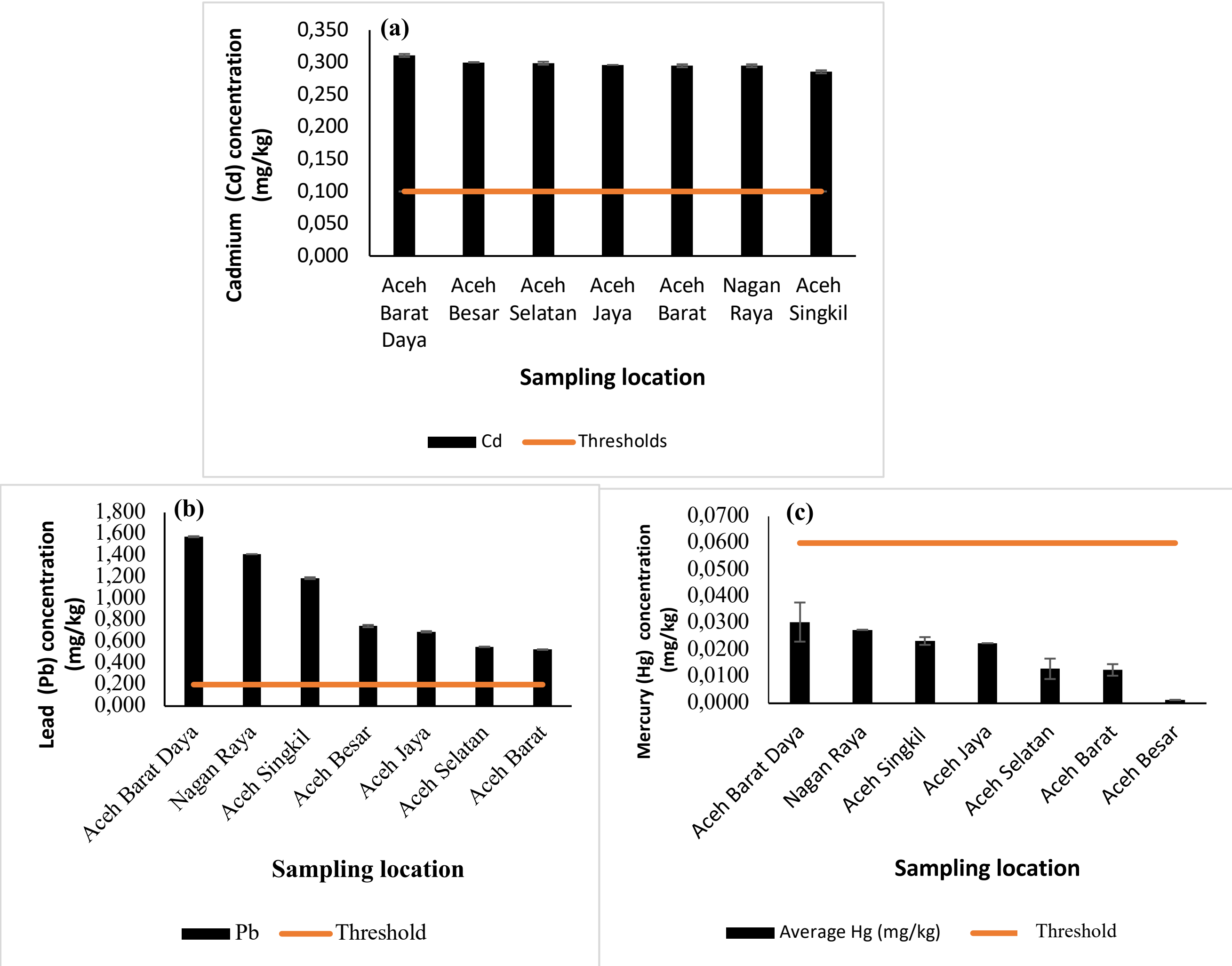

Figure 2. Comparison heavy metals concentration and threshold based on Food and Drug Administration (BPOM) Republic of Indonesia 2017; (a) Lead, (b) Cadmium, (c) Mercury

Discussion

Analysis of heavy metal content showed that all samples of *F. ater* from seven main rivers on the southwestern coast of Aceh Province were contaminated with Pb, Cd, and Hg. The contamination levels of Ob and Cd exceeded the safe threshold according to Food and Drug Administration (BPOM) Republic of Indonesia 2017 an all locations, but the Hg concentration was still below the threshold. The highest Pb levels were found in samples from Kuala Lama Muda, Southwest Aceh Regency, at 1.575 mg/kg, and the lowest was in West Aceh at 0.525 mg/kg. The concentration of Cd metal content was relatively more uniform, but also exceeded the threshold, with the highest value in Southwest Aceh Regency at 0.311 mg/kg and the lowest in Aceh Singkil Regency at 0.285 mg/kg.

The high content of Pb and Cd in Lama Muda is correlated with various activities such as mining, fishing, households, and agriculture. Additionally, it is a coastal area with estuary formed by the Lama Muda River, which merges with several branches of the river in Blangpidie, Susoh, and Kuala Bate. Therefore, various waste products from human activities around the area accumulate in the habitat of the *F. ater*. The main source of Pb is from the remains of diesel fuel from fishing boat activities and household waste near the sampling area. Meanwhile, the source of Cd is from agricultural waste such as fertilizers and pesticides originating from the middle and upstream reaches of the river, where numerous oil palm plantations and rice fields are located.

Pb and Cd, originating from human activities, are toxic elements that accumulate in water and cause serious impacts. Specifically, Pb originates from various sources, particularly industrial waste from batteries, paint, metal plating, fossil fuel combustion, and motor vehicle waste. In urban environments and industrial areas, Pb can also come from leachate from landfills (TPA) and household waste disposal activities (Collin *et al.*, 2022; Razi *et al.*, 2023a). Cd is widely found in industrial processes such as metal smelting, PVC plastic manufacturing, phosphate fertilizers, as well as waste from the agricultural and

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textile areas. Additionally, Cd is released into the environment through natural rock weathering, with the largest contribution being human activities, such as the use of pesticides and artificial fertilizers containing heavy metal (Ali *et al.*, 2019; Angon *et al.*, 2024).

The introduction of Pb and Cd into water body is through various pathways, such as surface runoff during rain that carries contaminated particles from agricultural areas, industry, and highways to rivers. Additionally, the discharge of untreated liquid waste from households, industries, or agriculture has a significant impact on heavy metal pollution in water. Atmospheric deposition is another pathway, where particles from the air due to vehicle and industrial emissions can directly settle into water body (Boahen, 2024; Piwowarska *et al.*, 2024). Heavy metal that has accumulated in riverbed sediments can also dissolve back into water in response to environmental changes, such as pH fluctuations or disturbances in the river current (Alfee and Bloor, 2025; Nie *et al.*, 2025). Specifically, Pb and Cd have bioaccumulative properties, with the potential to accumulate in the body of aquatic organisms and experience a biomagnification process, namely an increase in concentration in the tissues of organisms as the trophic level in the food chain increases (Angon *et al.*, 2024; Singh and Sharma, 2024). These characteristics make the presence of heavy metal in rivers very dangerous, even at low concentrations.

Several studies in southwestern coast of Aceh showed that *F. ater* samples in the Krueng Reuleung River were contaminated with Pb (Jannah, 2022). Similar results regarding the presence of heavy metal contamination in *F. ater* and other aquatic biota in different areas in Aceh had also been reported by Hidayat *et al.* (2020) and Lensoni *et al.* (2020). Nasir *et al.* (2021) reported that the Krueng Sabee in Aceh Province had experienced heavy metal contamination detected in water, sediment, and fish samples taken from the river. These results showed a potential risk to aquatic ecosystems and human health. Ramadhaniaty *et al.* (2023) evaluated the diversity of macrozoobenthos and heavy metal contamination in *F. ater* species in the Rasian River, the southern coastal area of Aceh, and found a relationship between heavy metal content and the ecological conditions. Furthermore, bivalve and gastropod molluscs have been shown to be effective in recording contamination history due to the bioaccumulative ability and physiological sensitivity to heavy metal (Yap *et al.*, 2006; Chahouri *et al.*, 2023). A study by Mayk *et al.* (2022) on *Nucella lapillus* snails in water also reported similar results.

Molluscs, particularly the bivalve and gastropod classes such as the *F. ater* snail, are a good as bioindicators of heavy metal contamination in estuary water (Rahman *et al.*, 2016). These species are sessile or move very slowly, showing local environmental conditions more accurately than more mobile organisms. The presence of a relatively long lifespan also allows assessment of changes in environmental quality over time (Chahouri *et al.*, 2023). The physiology of molluscs is sensitive to chemical changes in water, which promotes the ability to show biological responses to heavy metal exposure, both in the form of tissue accumulation and reproductive functions (Yap *et al.*, 2006; Waqas *et al.*, 2024).

The heavy metal content in the body of *F. ater* has great potential to enter the food chain. This poses a significant health risk for coastal communities in various areas in Aceh Province due to heavy metal contamination through bioaccumulation and biomagnification (Ali *et al.*, 2019; Mohiuddin *et al.*, 2022; Angon *et al.*, 2024). From an ecological and public health perspective, heavy metal content in the tissue of *F. ater* is a significant concern. Pb and Cd contamination pose serious health risks, by entering the body through food or water, inhalation, or skin contact. Long-term exposure to heavy metal can cause central nervous system disorders, kidney damage, respiratory disorders, and various types of cancer (Suhani *et al.*, 2021; Al Mazed *et al.*, 2022). For example, Pb causes cognitive decline and behavioral disorders (Obeng-Gyasi, 2018; Fu *et al.*, 2024), while Cd leads to chronic kidney damage and bone damage (Chakraborty *et al.*, 2013; Ma *et al.*, 2022). Therefore, monitoring and controlling heavy metal contamination in the environment is very important to prevent health risks to communities (Gelaye, 2024).

The results of water quality measurements at sampling areas showed that low salinity in Southwest Aceh (11 ppt) was associated with high levels of Pb and Cd in the body of *F. ater*. This supported the theory that low salinity increased the solubility of heavy metal and their availability to aquatic organisms (Angon *et al.*, 2024; Bhaumik and Chakraborty, 2024). Areas with neutral pH, which tended to be acidic (pH 6.1–7.2), found in the West and Southwest Aceh, had high bioaccumulation of heavy metal. This was because low pH increased the mobility of metal ions (Ahmed *et al.*, 2017; Ali *et al.*, 2019). The lowest DO content was found in Aceh Jaya (4.6 mg/L) and Nagan Raya (5.2 mg/L), showing degraded water quality due to organic pollution and human activities such as domestic and agricultural waste. Furthermore, *F. ater* showed a high capacity for accumulating heavy metal, as indicated by previous studies (Rahman *et al*., 2016; Jannah, 2022).

Conclusion

In conclusion, the chue snail *Faunus ater* in all sampling locations have been contaminated by Pb, Cd, and Hg. The highest content of Pb heavy metal in *F. ater* was found in samples from Aceh Barat Daya Regency at 1.575 mg/kg, and the lowest was recorded in West Aceh at 0.525 mg/kg. The highest content of Cd heavy metal was found in samples from Aceh Barat Daya Regency at 0.311 mg/kg, while the lowest was recorded in Aceh Singkil at 0.285 mg/kg. The highest Hg concentration was recorded at Aceh Barat Daya district, and the lowest was in Leupung River, Aceh Besar, below the threshood limit. The Pb and Cd concentrations in *F. ater* samples from the seven areas on the southwestern coast of Aceh Province exceeded the safe quality standard and were not recommended for consumption.

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