

## Evaluation of the Heavy Metal Content of Lead and Mercury in Various Mussels Species in Indonesian Coastal Waters

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### Abstract

Indonesia's coastal waters have great potential wealth in supporting human life and as an ecosystem for several species. However, heavy metal pollution from industry and domestic activities eclipses this potential. The purpose of this study is to determine the concentrations of heavy metals mercury (Hg) and lead (Pb) in numerous species of mussels often found in Indonesian coastal waters. The research method used was a systematic literature review. The results showed that coastal waters in several regions in Indonesia, especially in Aceh, Central Java, Banten, West Java, East Java, and Jakarta, have significant concentrations of heavy metals. Some researchers have found 13 kinds of shells that are contaminated with heavy metals. But the most heavily polluted with heavy metals were lead (Pb) and mercury (Hg) were green mussels (*Perna viridis*). The results demonstrated that many varieties of mussels have higher concentrations of the heavy metals lead (Pb) and mercury (Hg) than the maximum allowed by BPOM Regulation No. 9 of 2022.

**Keywords : Accumulation, Mussels, Mercury, Coastal Waters, Lead**

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### Introduction

Indonesia's coastal waters have great potential to support human life, maintain the sustainability of marine ecosystems, and serve as habitats for a variety of species that rich in biodiversity (Arianto, 2020; Nuraini et al., 2017). Diverse flora and fauna, including fish, mollusks, and crustaceans, support ecosystem productivity. With thousands of species of fish that come in all shapes and sizes, coastal waters are important to the fishing industry, both small and large scale, which contributes significantly to the country's economy. Crustaceans such as shrimp, crabs, and lobsters are also abundant in coastal waters, along with mollusks such as clams, oysters, and octopus that form an integral part of Indonesia's abundant marine ecosystems, not only as food resources but also raw materials for the food and pharmaceutical industries (Abdullah et al., 2021; Mashuni et al., 2021).

Despite their vast potential, Indonesia's coastal waters face serious challenges due to heavy metal pollution. This pollution threatens the potential of Indonesia's coastal waters to support marine life and various human activities that depend on these ecosystems. Heavy metals are hazardous chemicals that can damage water sources (Permana & Andhikawati, 2022). Heavy metals are categorized as non-biodegradable components. Therefore, waste containing heavy metals will accumulate in soil and water when directly discharged into the environment (Widyasari, 2021). These components can enter the human body through food and drinking water, resulting in bioaccumulation or increased concentrations of chemicals in the body of living things

over a long period of time. Excessive levels cause heavy metals to be unable to be metabolized and cannot undergo biotransformation into other compounds (Hardani et al., 2022). Exposure to high concentrations of heavy metals in humans will result in potential harm through their toxic, genotoxic, and carcinogenic effects (Wulandari et al., 2021).

Heavy metals that contaminate coastal waterways include mercury (Hg) and lead (Pb). Mercury is one of the chemicals found in many cosmetic products. Lead is a heavy metal that mostly comes from transportation activities and is released in the form of smoke exhaust (Suryani & Apriani, 2022 ; Putra et al., 2022). Mercury and lead that are freely distributed in nature can be categorized as waste and are hazardous contaminant components of hazardous and toxic materials (B3), because they have toxic properties to the environment and to living things, especially humans (Angela & Marzuki, 2021). Mercury and lead can accumulate in marine organisms, one of which is mussels.

Mussels is one of the protein source foods from marine waters that are widely favored by the public (Notonegoro & Pratiwi, 2022). Mussels have a wide potential utilization, not only limited to the culinary field, but also includes various economic and socio-cultural activities. From an economic perspective, the maintenance and capture of scallops is a source of income for fishermen and scallop farmers. Socio-culturally, mussels consumption is part of the eating habits of people in various coastal areas. Mussels, being filter feeders that acquire their nutrition by filtering suspended organic particles and phytoplankton from the water, are consequently at risk of heavy metal contamination (Pungut et al., 2021). Therefore, mussels can be used as markers of heavy metal contamination in aquatic environments.

Because of this, determining the level of pollution in a water zone necessitates for measuring the heavy metal concentration of mussels. This study attempts to determine the levels of lead (Pb) and mercury (Hg) heavy metals in several species of mussels which are found in Indonesian coastal waters. Knowing the degree of heavy metal pollution in mussels allows us to better understand the environmental status of coastal waters as well as the possible implications for human consumers who consume mussels.

## Methods

Researchers used the systematic literature review research method in making this journal article. A systematic literature review is a variety of research methods that aim to find, evaluate, and interpret research findings related to research questions, subjects, or certain phenomena of concern (Nugroho et al., 2021). A systematic literature review is a research process that involves performing reviews of the literature using a structured approach by outlining certain steps (Larasati et al., 2021). The objectives of this systematic literature review include providing a theoretical background for future research, studying all research on topics of interest, and answering practical questions by understanding what is described in current research on related issues. This systematic literature review research method includes several stages or phases, namely the planning phase, conducting the review phase, and reporting the results.

In the planning phase, the researcher compiled research questions (RQ) that were designed based on the needs of the topic that had been chosen and would be the basis of the research. There are 3 research questions (RQ) that have been compiled by

researchers, which are as follows: RQ1: Where are the coastal waters contaminated by lead (Pb) and mercury (Hg) heavy metals? RQ2: What types of mussels are contaminated with heavy metals mercury (Hg) and lead (Pb)? RQ3: How's the discovery of heavy metals of mercury (Hg) and lead (Pb) in some kind of shell?

In conducting the review phase, researchers follow a process involving search, inclusion and exclusion criteria, quality assessment, data collection, and data analysis. Using Publish or Perish with Google Scholar, researchers search for relevant references using keywords such as mercury, lead, coastal waters, mussels, and accumulation, resulting in 584 articles. These articles are then selected based on inclusion and exclusion criteria by reviewing abstracts. The inclusion and exclusion criteria are presented in the following table.

**Table 1. Inclusion and Exclusion Criteria**

<b>Inclusion Criteria</b>	<b>Exclusion Criteria</b>
Literature published between 2018 and 2024	Literature not published between 2018 and 2024
The literature focuses on the heavy metal content of mercury, lead, or both in mussels and focuses on studies in Indonesian coastal waters.	The literature does not focus on the heavy metal content of mercury, lead, or both in mussels and the study was conducted outside Indonesian waters.
Indonesian or English literature	Literature not in Indonesian or English

Quality assessment involves evaluating articles for clear research objectives and content alignment with titles. In data collection, researchers gather necessary data from high-quality articles, which are then extracted according to the research question (RQ). Finally, the collected data is analyzed to answer the RQ, with researchers providing explanations or views on the findings.

Finally, the researcher presents the data from the collected articles for reporting the results that have undergone the review phase in tabular form. A comprehensive explanation follows to address the research question (RQ) that was posed. Out of the 584 articles identified, 30 were determined to be the primary focus of this study.

## Results and Discussion

The following are the results of the literature review that has been carried out by researchers.

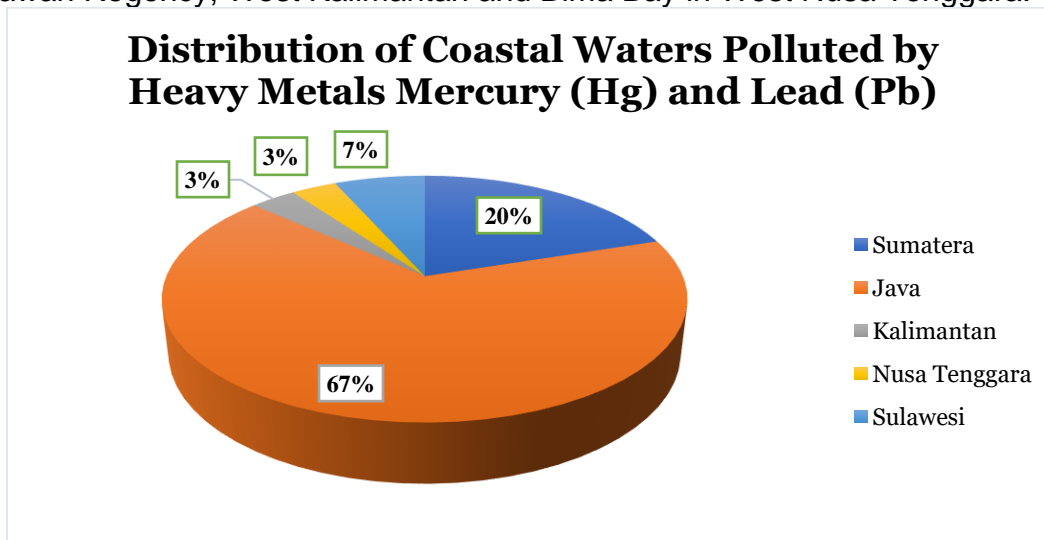
**Table 2. Literature Review Results**

Reference	Type of Shells	Location of Waters	Mercury (Hg) Concentration (mg/kg)	Mercury level according to the quality standards of BPOM regulation number 9 year 2022	Lead (Pb) Concentration (mg/kg)	Lead level according to the quality standards of BPOM regulation number 9 year 2022
(Kusuma et al., 2022)	<i>Perna viridis</i>	Tambak Lorok Waters, Semarang	-	0,50 mg/kg	3,204 – 13,448	0,30 mg/kg
(Ukhty et al., 2020)	<i>Geloina erosa</i>	West Aceh Waters	7,26 (13,2754; 1,2418) for the raw sample and 6,37 (12,5491; 0,1956) for boiled sample		-	
(Hasmizal & Bhernama, 2019)	<i>Perna viridis</i>	Waters Around Banda Aceh City	0,0000098		-	
(Putri & Rismaya, 2023)	<i>Perna viridis</i>	Coastal Estuary of a River in Tangerang Regency	0,1387 – 0,4543		-	
(Linda et al., 2022)	<i>Anadara granosa</i>	Sedanau Waters, Natuna Regency	-		0,0109 – 0,243	
(Nurhayati Putri, 2019)	<i>Perna viridis</i>	Cirebon Waters	1. 0,03 ± 0,04 (Rainy season) 2. 0,02 ± 0,02 (Summer)		1. 4,99 ± 0,84 (Rainy season) 2. 3,77 ± 0,75 (Summer)	
(Gunova et al., 2022)	<i>Geloina erosa</i>	Selat Baru Beach and Pambang Bay, Banten Sub-district, Bengkalis Regency	-		0,0468	
(Susilowati & Affandi, 2022)	<i>Perna viridis</i>	Bojonegara Coastal Waters of Banten Bay	< 0,001		< 0,030	
(Sari et al., 2022)	<i>Anadara granosa</i>	North Coast of Cirebon Regency	-		1,07	

(Yuliansari, 2020)	<i>Solen sp.</i>	Coastal Area of Bangkalan Regency	-	0,168 – 0,208
	<i>Anadara granosa</i>		-	0,152 – 0,231
	<i>Meretrix sp.</i>		-	0,161 – 0,288
	<i>Placamen isabellina</i>		-	0,143 – 0,169
(Sofiana et al., 2023)	<i>Geloina expansa</i>	Waters of Peniti Village Mangrove Ecosystem, Mempawah Regency	-	0,104 – 0,137
(Syam & Sulaeman, 2023)	<i>Perna viridis</i>	Tallo River, Makassar	0,0009	-
(Andriani et al., 2022)	<i>Perna viridis</i>	Waters of Paotere Fish Auction Area, Makassar City	-	5,9
(Juharna et al., 2022)	<i>Perna viridis</i>	Morosari Sayung Waters, Demak Regency	-	3,876 – 4,117
(Kharisma et al., 2023)	<i>Anadara granosa</i>	Loji River and Around the Beach	-	25,65 – 46,25
(Nuri et al., 2023)	<i>Anadara antiquata</i>	Bandengan Kendal Waters	-	0,840 – 4,093
(Siringoringo et al., 2022)	<i>Perna viridis</i>	Tanjung Mas Port, Semarang	< 0,002	0,697
		Mangunharjo Water Area, Semarang	< 0,002	0,253
(Suryo et al., 2021)	<i>Perna viridis</i>	Mekar Beach, Muara Gembong, Bekasi	-	± 0,129
(Wardana & Kuntjoro, 2023)	<i>Tegillarca granosa</i>	Waters of Teluk Lamong Port	-	Station 1 0,070 ± 0,009
			-	Station 2 0,046 ± 0,008
			-	Station 3 0,017 ± 0,005
(Handayani et al., 2020)	<i>Anadara granosa</i>	Sampur Beach, Central Bangka Regency	-	1. 0,324 – 0,436 for blood clams of size > 3 cm. 2. 0,472 –

					0,576 for blood clams of size < 3 cm.
(Salman, 2020)	<i>Perna viridis</i>	Waters Around Reclamation Islands C and D, Jakarta Bay	< 0,0004		0,50 – 5,46
(Ernaningsih et al., 2023)	<i>Perna viridis</i>	Waters of Ketapang Village, Tangerang Regency	0,04 (1 location)		1,2475 (Average of results from 4 locations; Highest 3,97 at sample site 1 (Cisadane river))
(Minarsih, 2019)	<i>Perna viridis</i>	Waters of Pekalongan City Harbor	-		1,7915
(Yulianto et al., 2019)	<i>Anadara granosa</i>	North Coast Waters of	-		5,24 ± 1,95
	<i>Meretrix lyrata</i>	Central Java	-		2,93 ± 1,99
	<i>Perna viridis</i>		-		1,27 ± 0,28
	<i>Amusium pleuronectes</i>		-		2,00 ± 0,07
(Dinulislam et al., 2021)	<i>Anadara granosa</i>	Cengkok Waters, Banten Bay	0,002 – 0,447		< 0,005
(Isroni & Maulida, 2022)	<i>Anadara antiquata</i>	Coastal Waters of Lekok, Pasuruan Regency	1,100		2,315
(Khairuddin & Yamin, 2021)	<i>Anadara granosa</i>	Bima Bay	-		0,756
	<i>Hiatula chinensis</i>		-		1,59
	<i>Siliqua winteriana</i>		-		1,171
(Suprpto et al., 2021)	<i>Perna viridis</i>	Semarang Bay	2,7 – 11,1		12,0 – 198,6
(Nurfadillah et al., 2018)	<i>Batissa violacea Lamarck</i>	Coastal Waters of Calang, Aceh Province	0,563 (0,71; 0,49; 0,49)		5,77 (6,93; 5,33; 5,07)
(Melinda et al., 2021)	<i>Perna viridis</i>	Cengkok Coastal Waters, Banten Bay	0,012 – 0,036		0,005 – 0,044

The table above shows that heavy metals mercury (Hg) and lead (Pb) which pollute coastal waters are spread across the islands of Sumatra, Java, Kalimantan, Sulawesi, and Nusa Tenggara. Coastal waters polluted by heavy metals mercury (Hg) and lead (Pb) on the island of Sumatra consist of six areas, concentrated in Aceh, Riau, Riau Islands, and Bangka Belitung. On the island of Java alone, there are 20 areas of polluted coastal waters, concentrated mostly in Central Java, followed by Banten, West Java, East Java, and Jakarta. On the island of Sulawesi, there are two areas of polluted coastal waters, namely the waters of the Tallo River and the waters of the Paotere Fish Auction Area, located in the city of Makassar, South Sulawesi. For Kalimantan and Nusa Tenggara islands, there is one coastal water area polluted with heavy metals mercury (Hg) and lead (Pb), namely the waters of Peniti Village Mangrove Ecosystem in Mempawah Regency, West Kalimantan and Bima Bay in West Nusa Tenggara.



**Graph 1. Distribution of Coastal Waters Polluted by Heavy Metals Mercury (Hg) and Lead (Pb)**

The degradation of coastal water quality on Java Island which is caused by heavy metal contamination like mercury (Hg) and lead (Pb), is substantiated. According to Arif and Nurwati (2022), the population of Java island reaches 56,1% of the total population of Indonesia, which is around 151,6 million people. This is a major factor that exacerbates the level of heavy metal pollution, especially in the coastal waters of the island. The rise in pollution particularly results from various factors, including intensive industrial activities and household waste.

The growing industrial activities on the island of Java, especially in urban areas, contribute significantly to the high levels of heavy metal pollution. In 1990, around 55% industrial centers on the island of Java were located in urban areas, which later increased to 60%. This continues to increase from year to year (Hidayah, 2023). Although industrial growth contributes positively to economic growth, it cannot be denied that its negative impact on the environment is increasingly evident and significant. One of the main impacts on the environment is the increase in heavy metal levels such as mercury (Hg) and lead (Pb) in aquatic ecosystems.

Waste generated from industrial activities has a higher heavy metal content compared to waste from household activities. This is due to the use of a mixture of

heavy metals in various industrial purposes, both as raw materials, additives, and driving materials or catalysts (Silalahi et al., 2023). Industrial waste containing heavy metals is often discharged directly into rivers or seas without adequate treatment. As a result, there is ongoing contamination of the water and surrounding living organisms.

Heavy metals can build up in the bodily tissues of aquatic biota, such as mussels and bivalves, that inhabit heavy metal-polluted waterways. The higher the heavy metal content in a body of water, the higher the heavy metal content accumulated in the body of the organism (Kusumastuti et al., 2020). A process known as bioaccumulation takes place when heavy metals enter the bodies of mussels or bivalves through food and water, leading to a gradual rise in the concentration of the metals. Consuming excessive amounts of heavy metal-contaminated mussels can adversely affect human health.

Mussels contaminated with mercury (Hg) in the form of  $HgCl_2$  has very toxic properties (Nursagita & Titah, 2021). Acute or chronic inorganic mercury poisoning is possible. Symptoms of its acute toxicity include stomatitis, albuminuria, anuria, uraemia, vomiting, loss of consciousness, stomach discomfort, diarrhea, and blood in the stool. Meanwhile, its chronic toxicity can result in disorders of the nervous system, such as tremors, bitter taste in the mouth, brittleness and loss of teeth, anemia, and damage to the kidneys and intestinal mucosa (Dewi, 2022).

Mussels contaminated with lead metal (Pb) have a high level of toxicity with a chronic nature (Jati & Kuntjoro, 2023). Lead has different physiological and neurological effects on humans. Lead poisoning can result in anemia and central nervous system disorders, leading to certain symptoms as well as restlessness, hyperactivity, confusion, memory loss, and mental retardation. In children, it can cause irreversible neurological damage, encephalopathy syndrome, and fetal abnormalities such as growth disorders, premature birth, and complications during pregnancy. Other effects of lead metal poisoning include progressive renal disease, reproductive disorders, hearing loss, anorexia, abdominal pain, insomnia, irritability, mood swings, and loss of coordination (Sidjabat et al., 2020).

Household waste also contributes to the increase of heavy metal pollution in the coastal waters of Java Island. Examples of household waste containing heavy metals include metabolic waste and corrosion of water pipes (Lukmanulhakim et al., 2023). Mercury (Hg) pollution can come from household waste such as fluorescent lamp waste, certain cosmetic products, and electronic devices such as televisions. Meanwhile, lead metal (Pb) from household activities is mainly generated from used oil and paint (Silalahi et al., 2022). Based on the following explanation, RQ1 can be answered well.

Furthermore, RQ2 is well answered. According to the collected data, 13 mussel species are contaminated with heavy metals, including mercury (Hg), lead (Pb), or both. The mussel species are *Perna viridis*, *Geloina erosa*, *Geloina expansa*, *Anadara granosa* or *Tegillarca granosa*, *Anadara antiquata*, *Solen sp*, *Meretrix sp*, *Meretrix lyrata*, *Placamen isabellina*, *Amusium pleuronectes*, *Hiatula chinensis*, *Siliqua winteriana*, and *Batissa violacea Lamarck*. Among the 13 mussel species, *Perna viridis*, or green mussel, is the various of mussel that mostly contaminated with heavy metals mercury (Hg) and lead (Pb).



**Figure 1. Green Mussels (*Perna viridis*)**  
**Source :** (Noor, 2015)

Green mussels (*Perna viridis*) are a group of soft-bodied animals (mollusks) that have two paired shells (bivalves) and are green in color. Green mussels (*Perna viridis*) live in muddy sand substrate habitats in estuary waters, as well as mangrove areas. Generally, they live sessile, attached and clustered at the bottom of hard substrates, such as coral rocks, wood, bamboo or hard mud (Katon et al., 2020). Green mussels are mollusca that have the ability to absorb small particles around or called filter feeders. Due to their filter-feeding nature, green mussels are employed as bioindicator of environmental pollution and as experimental subjects for testing the presence of heavy metals in the ocean (Chaerunnisa & Supardi, 2021).

Finally, RQ3 is also well answered. According to BPOM Regulation No. 9 Year 2022 on Maximum Limits of Heavy Metal Contaminants in Processed Food, the maximum limits for mercury (Hg) and lead (Pb) in fishery products, including mollusks, are respectively 0,50 mg/kg and 0,30 mg/kg. The results of the data collection showed that mussels living in 18 water areas had heavy metal contents that exceeded the established limits. Of these water bodies, mussels in 15 water bodies had mercury (Hg) or lead (Pb) heavy metal content exceeding the prescribed limits only. Meanwhile, in 3 other water areas, mussels with concentrations of more than one heavy metal, namely mercury (Hg) and lead (Pb), exceeded the prescribed thresholds. *Geloina erosa* mussels living in West Aceh waters showed the highest concentration of mercury (Hg) compared to other waters. Mercury (Hg) content in mussels varied depending on the sample treatment. For raw samples, the concentration of metal mercury (Hg) ranged between 1,2418 – 13,2754 mg/kg, while in the boiled sample, the concentration of mercury (Hg) ranged between 0,1956 – 12,5491 mg/kg. *Perna viridis* mussels living in Semarang Bay waters showed the highest concentration of lead metal (Pb) compared to other waters. The lead (Pb) content in these mussels was around 12,0 – 198,6 mg/kg.

## Conclusions

Based on the results of the study, it can be concluded that coastal water areas on several islands in Indonesia, especially on the islands of Sumatra, Java, Kalimantan, Sulawesi, and Nusa Tenggara, are polluted by heavy metals mercury (Hg) and lead (Pb). These areas have significant concentrations of heavy metals, especially in Aceh,

Central Java, Banten, West Java, East Java, and Jakarta Provinces. The mussels species polluted by these heavy metals include 13 species, such as *Perna viridis*, *Geloina erosa*, *Geloina expansa*, and others. *Perna viridis* or green mussels were the most contaminated with heavy metals mercury (Hg) and lead (Pb). The findings showed that the content of heavy metals mercury (Hg) and lead (Pb) in several types of mussels exceeded the maximum limits set by BPOM Regulation No. 9 of 2022. This indicates that there is a health risk for humans if they consume excessive amounts of heavy metal-contaminated mussels, especially for mussels species whose heavy metal content exceeds the specified limit.

### **Bibliography**

- Abdullah, A., Hidayat, T., & Seulalae, A. V. (2021). *Moluska: Karakteristik, Potensi dan Pemanfaatan Sebagai Bahan Baku Industri Pangan dan Non Pangan*. Syiah Kuala University Press.
- Andriani, T., Agustin, F., Chadijah, S., Adawiah, S. R., & Nur, A. (2022). Analisa Logam Berat Kadmium (Cd) dan Timbal (Pb) pada Kerang Hijau (*Perna viridis*) yang Beredar di Pelelangan Ikan Paotere Kota Makassar. *Chimica et Natura Acta*, 10(3), 112–116.
- Angela, A., & Marzuki, I. (2021). Kapasitas Bioadsorpsi Bakteri Simbiosis Spons Laut Terhadap Kontaminan Logam Berat. *KOVALEN: Jurnal Riset Kimia*, 7(1), 12–22.
- Arianto, M. F. (2020). Potensi wilayah pesisir di negara Indonesia. *Jurnal Geografi*, 10(1), 204–215.
- Arif, A. F. N., & Nurwati, N. (2022). Pengaruh Konsentrasi Penduduk Indonesia di Pulau Jawa terhadap Kesejahteraan Masyarakat. *Jurnal Ilmu Kesejahteraan Sosial HUMANITAS*, 4(1), 54–70.
- Chaerunnisa, R., & Supardi, U. S. (2021). Persentase Penurunan Kadar Logam Berat Timbal pada Kerang Hijau (*Perna viridis*) Pasca Proses Depurasi oleh Nelayan Teluk Jakarta. *EduBiologia: Biological Science and Education Journal*, 1(2), 121–127.
- Dewi, E. R. (2022). Analisis cemaran logam berat arsen, timbal, dan merkuri pada makanan di wilayah kota surabaya dan kabupaten Sidoarjo Jawa Timur. *Jurnal Ilmu Kesehatan Masyarakat*, 18(1), 1–9.
- Dinulislam, A., Lumbanbatu, D. T. F., & Affandi, R. (2021). Heavy metals (Pb, Hg) in blood cockle (*Anadara granosa*) in Cengkok Waters, Banten Bay, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 744(1), 012012.

- Ernaningsih, D., Patanda, M., Rahmani, U., & Telussa, R. F. (2023). Heavy Metal Content in Green Mussels (*Perna viridis*) Cultivated in Ketapang Village, Tangerang Regency. *Journal of Tropical Fisheries Management*, 7(1), 35–45.
- Gunova, M. T., Amin, B., & Nursyirwani, N. (2022). Analysis of Lead and Copper Concentrations in Mangrove Clams (*Geloina erosa*) and Sediments in The North Coast of Bengkalis Island. *Journal of Coastal and Ocean Sciences*, 3(2), 119–124.
- Handayani, P., Kurniawan, K., & Adibrata, S. (2020). Kandungan Logam Berat Pb pada Air Laut, Sedimen dan Kerang Darah (*Anadara granosa*) di Pantai Sampur Kabupaten Bangka Tengah. *PELAGICUS*, 1(2), 97–105.
- Hardani, P. T., Pramushinta, I. A. K., & Purbosari, I. (2022). PENYULUHAN PEMANFAATAN BELIMBING WULUH (*OREOCHROMIS MOSSAMBICUS* DAN ASAM SITRAT UNTUK MENGURANGI CEMARAN LOGAM BERAT PADA IKAN. *Pancasona: Pengabdian Dalam Cakupan Ilmu Sosial Dan Humaniora*, 1(1), 23–28.
- Hasmizal, H., & Bhernama, B. G. (2019). Analisis kadar logam Hg pada sampel *Perna viridis* L dengan menggunakan Atomic Absorption Spectrophotometer. *AMINA*, 1(3), 120–125.
- Hidayah, F. N. (2023). Perkembangan Pengaturan Hukum Limbah Bahan Berbahaya Dan Beracun (Limbah B3) Di Indonesia. *Jurnal Indonesia Sosial Teknologi*, 4(02), 211–225.
- Isroni, W., & Maulida, N. (2022). Accumulation of heavy metals Pb and Hg in feather shells (*Anadara antiquata*) in Lekok Coastal Waters, Pasuruan Regency. *IOP Conference Series: Earth and Environmental Science*, 1036(1), 012091.
- Jati, I. S. A., & Kuntjoro, S. (2023). Hubungan Keanekaragaman Jenis Bivalvia dengan Kadar Timbal (Pb) Air dan Sedimen di Pantai Joko Moersodo, Lamongan. *LenteraBio*.
- Juharna, F. M., Widowati, I., & Endrawati, H. (2022). Kandungan logam berat timbal (Pb) dan kromium (Cr) pada kerang hijau (*Perna viridis*) di Perairan Morosari, Sayung, Kabupaten Demak. *Buletin Oseanografi Marina*, 11(2), 139–148.
- Katon, M. R., Solichin, A., & Jati, O. E. (2020). Analisis Pendugaan Bakteri *Escherichia Coli* pada Kerang Hijau (*Perna Viridis*) di Morosari, Demak Analysis of Estimated Abundance of *Escherichia coli* Bacteria in Green Mussels (*Perna viridis*) in Morosari, Demak. *Management of Aquatic Resources Journal (MAQUARES)*, 9(1), 40–46.

- Khairuddin, K., & Yamin, M. (2021). Analysis of Cadmium (Cd) and Lead (Pb) Heavy Metal Content in Shell and Mangroves at Bima Bay. *Journal of Science and Science Education*, 2(1), 58–61.
- Kharisma, R. N., Yulianto, B., & Nuraini, R. A. T. (2023). Logam Berat Timbal (Pb) Pada Air, Sedimen, dan Kerang Darah (Anadara Granosa) di Muara Sungai Loji dan Perairan Pantai Sekitarnya, Kota Pekalongan. *Journal of Marine Research*, 12(2), 330–335.
- Kusuma, R. B., Supriyantini, E., & Munasik, M. (2022). Akumulasi logam Pb pada Air, Sedimen, dan Kerang Hijau (*Perna viridis*) di Perairan Tambak Lorok serta Analisis Batas Aman Konsumsi untuk Manusia. *Journal of Marine Research*, 11(2), 156–166.
- Kusumastuti, D., Setiani, O., & Joko, T. (2020). Analisis Frekuensi Konsumsi Makanan Laut dan Kandungan Logam Berat Pb dalam Darah Wanita Usia Subur (WUS) di Wilayah Kerja Puskesmas Bandarharjo. *Jurnal Kesehatan Masyarakat*, 8(5), 687–693.
- Larasati, I., Yusril, A. N., & Al Zukri, P. (2021). Systematic Literature Review Analisis Metode Agile Dalam Pengembangan Aplikasi Mobile. *SISTEMASI*, 10(2), 369–380.
- Linda, R., Hartanti, L., Warsidah, W., Ashari, A. M., & Kurniadi, B. (2022). KADAR LOGAM BERAT TIMBAL (Pb) PADA KERANG DARAH (*Anadara granosa*) DAN SEDIMEN ASAL PERAIRAN SEDANAU KABUPATEN NATUNA. *Marinade*, 5(02), 110–116.
- Lukmanulhakim, R. C., Hidayati, N. V., & Baedowi, M. (2023). Analisis Kandungan Logam Berat Kadmium (Cd) dan Kromium (Cr) pada Matriks Air di Sungai Pelus Kabupaten Banyumas, Jawa Tengah. *MAIYAH*, 2(1), 41–50.
- Mashuni, M., Natsir, M., Lestari, W. M., Hamid, F. H., & Jahiding, M. (2021). Pemanfaatan kitosan dari cangkang kepiting bakau (*Scylla serrata*) dengan metode microwave sebagai bahan dasar kapsul obat. *ALCHEMY Jurnal Penelitian Kimia*, 17(1), 74–82.
- Melinda, T., Samosir, A. M., & Simanjuntak, C. P. H. (2021). Bioaccumulation of lead (Pb) and mercury (Hg) in green mussel *Perna viridis* (Linnaeus, 1758) in Cengkok Coastal Waters, Banten Bay, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 800(1), 012015.
- Minarsih, T. (2019). Penetapan Kadar Cadmium (Cd) dan Timbal (Pb) dalam Kerang Hijau (*Perna viridis*) dari Perairan Kota Pekalongan. *Jurnal Surya Muda*, 1(1), 1–7.

- Noor, N. M. (2015). Prospek pengembangan usaha budidaya kerang hijau (*Perna viridis*) di Pulau Pasaran, Bandar Lampung. *Aquasains*, 3(2), 239–246.
- Notonegoro, H., & Pratiwi, F. D. (2022). Morfometri Kerang *Anadara granosa* Di Perairan Sukal Bangka Barat. *Aquatic Science*, 4(1), 18–22.
- Nugroho, D. A., Khasanah, D. N., Pangestuti, I. A. I., & Kholili, M. I. (2021). Problematika pelaksanaan bimbingan dan konseling di SMA: A systematic literature review (SLR). *TERAPUTIK: Jurnal Bimbingan Dan Konseling*, 5(1), 87–96.
- Nuraini, R. A. T., Endrawati, H., & Maulana, I. R. (2017). Analisis kandungan logam berat kromium (Cr) pada air, sedimen dan kerang hijau (*Perna viridis*) di perairan Trimulyo Semarang. *Jurnal Kelautan Tropis*, 20(1), 48–55.
- Nurfadillah, N., Praningtyas, I., Karina, S., & Perdana, A. W. (2018). Analysis of heavy metals content (Pb, Hg and Cd) of *Batissa violacea* Lamarck in the coastal waters of Calang. *IOP Conference Series: Earth and Environmental Science*, 216(1), 012016.
- Nurhayati, D., & Putri, D. A. (2019). Bioakumulasi logam berat pada kerang hijau (*perna viridis*) di perairan Cirebon berdasarkan musim yang berbeda. *Akuatika Indonesia*, 4(1), 6–10.
- Nuri, N. S., Santoso, A., & Widowati, I. (2023). Akumulasi Logam Berat Timbal (Pb) pada Kerang Bulu (*Anadara antiquata*) di Perairan Bandengan Kendal serta Analisis Batas Aman Konsumsi. *Journal of Marine Research*, 12(3), 403–412.
- Nursagita, Y. S., & Titah, H. S. (2021). Kajian Fitoremediasi untuk Menurunkan Konsentrasi Logam Berat di Wilayah Pesisir Menggunakan Tumbuhan Mangrove (Studi Kasus: Pencemaran Merkuri di Teluk Jakarta). *Jurnal Teknik ITS*, 10(1), G22–G28.
- Permana, R., & Andhikawati, A. (2022). METALLOTIONEIN PADA TANAMAN AKUATIK DAN PERANANNYA DALAM AKUMULASI LOGAM BERAT. *Jurnal Akuatek*, 3(1), 1–8.
- Pungut, P., Widyastuti, S., & Wiyarno, Y. (2021). Identifikasi Mikroplastik Pada Cangkang Kerang Darah (*Anadara granosa* Liin) Dengan Menggunakan Fourier Transform Infrared (FTIR) dan Scanning Electron Microscopy (SEM). *SNHRP*, 3, 109–120.

- Putra, M. D. N., Widada, S., & Atmodjo, W. (2022). Studi Kandungan Logam Berat Timbal (Pb) pada Sedimen Dasar di Perairan Banjir Kanal Timur Semarang. *Indonesian Journal of Oceanography*, 4(3), 13–21.
- Putri, U. R. P., & Rismaya, R. (2023). Penentuan Kadar Merkuri (Hg) pada Kerang Hijau (*Perna viridis*) di Pasar Serpong Menggunakan Mercury Analyzer Metode Direct Thermal Decomposition. *Food Scientia: Journal of Food Science and Technology*, 3(1), 27–39.
- Salman, S. (2020). Survei Parameter Fisika-Kimia Perairan dan Konsentrasi Logam Berat pada Kerang Hijau di Pulau Reklamasi C dan D, Teluk Jakarta. *Bio-Lectura: Jurnal Pendidikan Biologi*, 7(2), 122–129.
- Sari, M. P., Riyantini, I., & Ihsan, Y. N. (2022). Kontaminasi Logam Pb (Timbal) pada *Anadara granosa* di Pantai Utara Kabupaten Cirebon. *Buletin Oseanografi Marina*, 11(3), 248–254.
- Sidjabat, F. N., Alwi, V., Mahmudi, M., & Puspitasari, Y. (2020). Pengukuran timbal pada air sungai dan bioindikator lokal di Sungai Brantas Kota Kediri, Provinsi Jawa Timur. *Jurnal Ekologi Kesehatan*, 19(3), 161–173.
- Silalahi, F. R. W., Zainuri, M., & Wulandari, S. Y. (2023). Studi kandungan logam berat timbal (Pb) dan seng (Zn) di perairan muara sungai Cisadane Kabupaten Tangerang. *Indonesian Journal of Oceanography*, 5(1), 1–6.
- Silalahi, N. S. L., Amri, Y., & Wahyuningsih, P. (2022). Analisis kuantitatif logam berat dalam tiram (*Crassostrea* Sp.) dari Pesisir Kuala Langsa. *Jurnal Jeumpa*, 9(2), 784–794.
- Siringoringo, V. T., Pringgenies, D., & Ambariyanto, A. (2022). Kajian Kandungan Logam Berat Merkuri (Hg), Tembaga (Cu), dan Timbal (Pb) pada *Perna viridis* di Kota Semarang. *Journal of Marine Research*, 11(3), 539–546.
- Sofiana, M. S. J., Safitri, I., Apriansyah, A., & Irawan, S. (2023). The Concentration of Lead (Pb) in Kepah (*Geloina expansa*), Water, and Sediment of Mangrove Peniti Village Mempawah Regency West Kalimantan. *Jurnal Sumberdaya Akuatik Indopasifik*, 7(4), 401–410.
- Suprpto, D., Latifah, N., & Suryanti, S. (2021). Spatial distribution of heavy metal content in the water and green mussel (*Perna viridis*) in Semarang Bay, Indonesia. *Aquaculture, Aquarium, Conservation & Legislation*, 14(1), 298–308.
- Suryani, D., & Apriani, D. (2022). Faktor–Faktor Penentu dalam Pemilihan Kosmetik Non Merkuri. *Jurnal of Public Health*, 7(2), 2022.

- Suryo, R. A., Yulianto, B., & Santoso, A. (2021). Konsentrasi Logam Berat Timbal (Pb) pada Air Sedimen dan Kerang Hijau (*Perna viridis*) di Pantai Mekar Muara Gembong Bekasi. *Journal of Marine Research*, 10(3), 428–436.
- Susilowati, D. I., & Affandi, R. (2022). Analysis of heavy metals content Hg, Cd, Pb, and Cu of green mussel *Perna viridis* (Linnaeus, 1758) in Bojonegara Coastal Waters of Banten Bay, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 1083(1), 012046.
- Syam, N., & Sulaeman, U. (2023). Analisis Risiko Kesehatan Lingkungan Logam Berat Merkuri (Hg) pada Kerang Hijau (*Perna Viridis*) terhadap Nelayan di Kelurahan Kaluku Bodoa Kota Makassar. *Indonesian Journal of Health*, 3(2), 52–63.
- Ukhty, N., Nufus, H., Rozi, A., & Khairi, I. (2020). Studi Kandungan Logam Berat pada Kerang Lokan (*Geloina erosa*) di Perairan Aceh Barat. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 23(1), 77–85.
- Wardana, M. T., & Kuntjoro, S. (2023). Analisis Kadar Logam Berat Timbal (Pb) di Perairan Pelabuhan Teluk Lamong dan Korelasinya terhadap Kadar Pb Kerang darah (*Tegillarca granosa*). *LenteraBio: Berkala Ilmiah Biologi*, 12(1), 41–49.
- Widyasari, N. L. (2021). Kajian tanaman hiperakumulator pada teknik remediasi lahan tercemar logam berat. *Jurnal Ecocentrism*, 1(1), 17–24.
- Wulandari, D. D., Izzatunnisa, S., Herzhaputra, D. D., & Wuryaningrum, A. (2021). Literatur Review: Akumulasi Dan Toksisitas Logam Berat: Kadmium (Cd), Kromium (Cr) Dan Nikel (Ni). *Jurnal Kesehatan Lingkungan*, 11(2), 93–98.
- Yuliansari, D. (2020). Kandungan Logam Berat Timbal (PB) pada Beragam Jenis Bivalvia di Kawasan Pantai Kabupaten Bangkalan. *Bioscientist: Jurnal Ilmiah Biologi*, 8(1), 11–17.
- Yulianto, B., Oetari, P. S., Februhardi, S., Putranto, T. W. C., & Soegianto, A. (2019). Heavy metals (Cd, Pb, Cu, Zn) concentrations in edible bivalves harvested from northern coast of Central Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 259(1), 012005.