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Research article

Control of sediment grainsize on lead (Pb) content in the reef sediment systems: A case study of Panjang Island, Banten Bay, Indonesia

Ayu U. Nurhidayati[1], Dwi A. Utami[1], M. Hendrizan[1], T. Solihuddin[1], R. Rachmayani[2], Sri Y. Cahyarini[1]

[1] Paleoclimate and Paleoenvironment Research Group, Research Center for Climate and Atmosphere, Research Organization for Earth Science and Marime, National Research and Innovation Agency (BRIN), KST Samaun Samadikun, BASICS Bld. Jl Sangkuriang, Bandung, Indonesia 40135
[2] Research Group of Oceanography, Faculty of Earth Sciences and Technology, Bandung Institute of Technology (ITB), Bandung, Indonesia 40132

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Corresponding author:
Ayu U. Nurhidayati
Email address:
ayuutaminurhidayati@gmail.com

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ABSTRACT

Sediments are known to accumulate pollutants from terrestrial and coastal waters, and can be used as an indicator to monitor metal pollution in the biosphere and the effects of anthropogenic events in the environment. Eight samples of reef surface sediments were collected from the north and east coasts of Panjang Island. Panjang Island, located to the north of Banten Bay, was chosen for this study because of its proximity to many industrial areas. Nevertheless, the island supports a natural ecosystem, including coral reefs, seagrass, and mangroves. The samples were analyzed for the grainsize, component analysis, and Pb concentrationusing AAS flame method. The result indicated Pb concentration in the grain-supported surface sediment in Panjang Island is varied. The detected Pb concentrations were 0-28.68 mg/kg in dry weight. The study indicated that the different concentration of Pb value is mainly controlled by the different of sediment grainsize. The highest Pb accumulation occurs in the areas with very fine sediment grainsize, which have better adsorption capabilities for heavy metals. This study also suggests that the medium sand fraction may accumulate different Pb values. The result indicated that, according to the classification of ANZECC/ARMCANZ, all sediment samples in the study area is in the low risk of toxicant level. Additionally, the SQG-Q (Sediment Quality Guidelines) quotient analysis indicates that Pb concentration in the study area posed a low-moderate impact to adverse biological effect.

INTRODUCTION

Marine pollution has been defined as a negative impact that endangers marine life and ecosystems, as well as humans. One of the contaminants that generate marine pollution is heavy metals. Heavy metals refer to metallic elements with a density value of more than 5 gr/m^3, which are classified as pollutants (Juniardi et al., 2022). Heavy metals can be sourced from nature due to tectonic and volcanic activity, upwelling, and intake from the atmosphere. Heavy metals can also be introduced to the environment through anthropogenic factors such as mining, fishing, farming, industry, city waste, and marine tourism (Ismail et al., 2016). Since heavy metals are easily accumulate in the aquatic environment, sediments, and marine biota, therefore marine pollution can have an immediate or indirect impact (Ismarti et al., 2017; Malau et al., 2018).

Panjang Island, located to the north of Banten Bay, was chosen for this study because of its proximity to many industrial areas. The beach on Banten Bay is composed of coral and fragments of marine biota shells (Rustam et al., 2018), similar to other beaches in the Java Sea, which represented the environment of the coral reef ecosystem (Solihuddin et al., 2019; Utami et al., 2018, 2021). The beaches along Banten Bay contain muddy substrate, and mangroves are usually profound to find (Rustam et al., 2018). Panjang Island support natural ecosystems including coral reef, sea grass, and mangroves. The coral reef ecosystem occurs in the north of Panjang Island. The condition of coral reefs ecosystem in the north of Panjang Island is relatively in poor condition (Rustam et al., 2018). The bioavailability of marine pollutants in reef sediments allows biological interactions with deposit and detritus-feeding biota and finally to human through seafood consumption which may disadvantage health (Utami et al., 2023).

One of the heavy metals that can be a contaminant and degrade the quality of the habitat and biota is lead (Pb). The existence of Pb in the coastal area will affect the quality of the environment and threaten human health through the contamination of the food chain. Pb is not expected to exist in the bodies of organisms, even in very small amounts, since it is very poisonous (Taguge et al., 2014). In addition, Pb also can be used as a proxy for other heavy metals and contaminants. The entry of Pb into the body of an organism can be through the digestive tract (gastrointestinal), respiratory tract (inhalation), and penetration through the skin (topical) (Usman et al., 2013).

Pb accumulation in reef sediment can affect the marine ecosystem such as coral reef. The study took place in Panjang Island, Banten Bay, Indonesia. Banten Bay is a shallow semi-enclosed water that receives various sediment loads from several rivers and known as an industrial area. It may play an important role in accumulating marine pollution in Banten Bay by allowing heavy metal pollution from the land to concentrate in the bay through the river flow. The study aims to quantify Pb accumulation in reef sediment of the coastal area and reef systems of Panjang Island and its relation to grainsize. In addition, to analyzed the ecological effect due to Pb accumulation to the marine ecosystems around Panjang Island.

MATERIAL AND METHODS

Panjang Island is administratively located in Serang Regency, Banten Province, and is geographically located at 6°25’18”-6°28’12” S and 106°22’9”-106°25’36” E (Fig. 1). The total area of Panjang Island is approximately 8.2 km^2. Panjang Island has strategic value due to its proximity to Bojonegara Port and is included in the Exclusive Economic Zone of Serang Regency. Panjang Island is well-known for having a diverse benthic community, mainly covered by reefs, seagrass communities, and sand, constituting 63.62 ha, 46.3 ha, and 35.36 ha, respectively (Daud & Putra, 2019).

Figure 1. The study area located in Panjang Island, off the coast of Banten (red rectangle), red pin indicated steel industry in the west of Java Island. Source: https://google.com/maps.

This study focuses on the surface sediment of the coastal area and reef environment of Panjang Island. The reef system is more abundant in the northern and eastern parts of Panjang Island. Therefore, eight surface sediment samples from the reef flat, reef crest, and reef slope have been collected from the north and east parts of Panjang Island in November 2021 using grab sampling (Fig. 2). In this study, we used the separation grain-size method by sieving the samples to <63 µm following the method from Förstner and Salomons, 1980. This method has advantageous that only few samples from a particular locality are needed (Förstner and Salomons, 1980). In addition, the reef flat on Panjang Island is relatively narrow, approximately 60 meters in length. Therefore, it is considered sufficient to collect four samples at each station to study the dynamics of surface sediment in the area. The sediment samples were put in a polyethylene bag subsequently. The geographic locations of the sampling points were recorded with a global positioning system (GPS) and plotted on an ESRI satellite image using QGIS (Ver. 3.16.9).

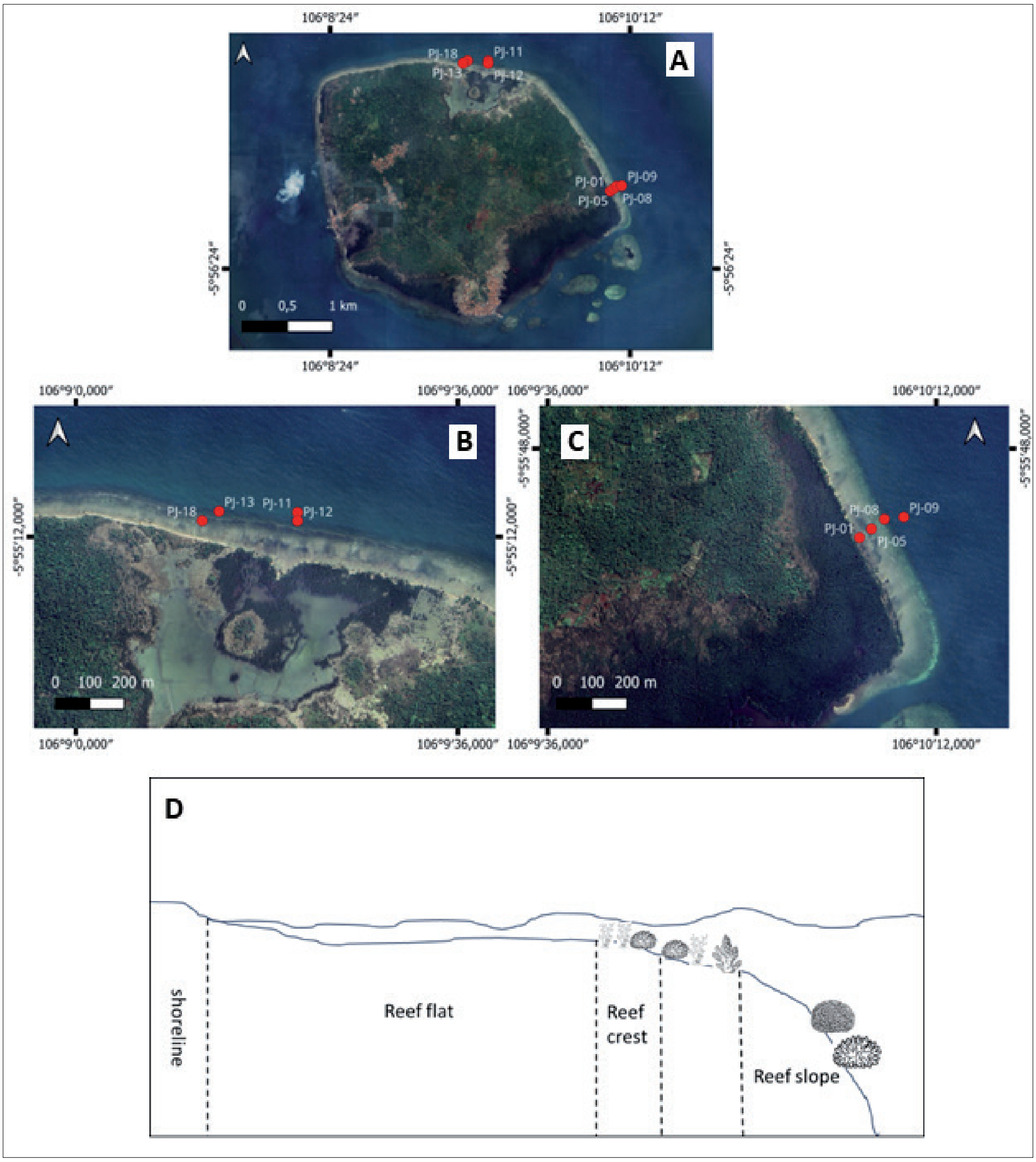

Figure 2. A. Eight sediment sampling spots (north and east) on the reef platform of Panjang Island were used in this study. B. Sediment sampling on the north coast of Panjang Island. C. Sediment sampling on the east coast of Panjang Island. D. Schematic reef zonation in Panjang Island.

All samples were collected from the tidal area. Sample PJ 01 was taken from a location approximately 10 meters inland. Panjang reef flat is relatively narrow, spanning only about 60 meters (Fig. 2). The purpose of collecting samples from different sites is to understand the variations in sediment dynamics across different coral reef zones, namely the reef flat, reef crest, and reef front. The differences in coral reef zones also reflecting different sediment grainsize.

All of sediment samples collection were treated in the laboratory of Engineering Geology Laboratory BRIN, KST Samaun Samadikun to be then dried using a Memmert™ oven set to 80° C for 8 hours. Subsequently, a Durham Geo Slope Indicator (DGIS) sieve shakers were used to sieve the sediment samples through a 125 μm sieve size. About 5 grams of the split of the > 125 μm fraction were then stored for component analysis. The coarse fraction that remains was then sieve through 250 μm, 500 μm, 1 mm, and 2 mm sieves. Then, individual grain-size fraction was digitally weighed, respectively. Gradistat software (Blott & Pye, 2001) was used to calculate mean grain size following the quantification of Folk and Ward (1957). For component analysis, the split of the coarse fraction was counted to 300 grains and individually analyzed under a microscope binocular zoom Olympus series 230039 in the Optical Laboratorium BRIN, KST Samaun Samadikun.

To obtain the concentration value of Pb, Flame Atomic Absorption Spectrophotometry (AAS) analysis was performed to all samples using the AAS Duo System by Agilent Technologies, 2000 Series AA in the laboratory of Advance Characterization BRIN, KST Samaun Samadikun. Before the AAS was performed, the samples were prepared by mixed acid digestion of the sediment following the procedure of Özkan et al. (1980) for heavy metal extraction from marine sediment for AAS, with a slight modification. In this study, we eliminated the use of $HClO_3$, because $HClO_3$ used in Özkan's study was stated for the different type of sediment, while in this study the type of sediment is mostly uniform which is carbonate sediment. In addition, we also modified the volume of dissolve sediment dilution with ultrapure deionized water to 100 ml instead of 50 ml. This modification has followed the molarity calculation to keep the accuracy. This modification was made to anticipate the amount of liquid needed for AAS analysis, since we applied the triplicate measurement of AAS.

The sediment from the respective location was digitally weighed around 0.5000-0.5010 gram. The sediment weighed were those which have fraction size of <63 μm. This decision was made because the fraction <63 μm is recommended since (1) the trace metals have been found to be present mainly in clay/silt particles, (2) this fraction is most nearly equivalent to the material carried in suspension, (3) sieving does not alter metal concentration by remobilization, and (4) numerous metal studies have already been performed on the suggested <63 μm fraction (Förstner and Solomons 1980).

After that, the sediment was dissolved altogether with 1 ml of concentrated HNO_3, 1 ml of concentrated H_2SO_4, and 10 ml of HF on the hot plate until the liquid was reduced in the Chemistry Laboratory BRIN, KST Samaun Samadikun. Subsequently, for around 5 minutes until it cooled down, the 25 ml of concentrated HCl was added to dissolve the sediment by putting it on the hot plate for around 2-5 minutes. The dissolved sediment was then diluted with ultrapure deionized water and filtered with filter paper Whatman No. 41, ashless, diameter 125 mm (CAT No. 1441-125) and made up to 100 mL with ultrapure deionized water (DIW) in the 100 ml volumetric flask.

Standard solutions (Centipur, Germany) were used for calibration. Blank sample (ultrapure deionized water only) and triplicate analysis were performed to achieve good precision and accuracy. During the digestion procedure, lead standard reference material (traceable to SRM from NIST 1.19776.0100) were run in the same way in each batch of sediment digestion to check the quality of the digestion and analytical procedure. Each sample was analyzed in triplicate and their mean values were recorded.

Pb concentration obtained from the AAS analysis will be classified based on the classification of the SQG-Q (Sediment Quality Guidelines) quotient guidelines for heavy metal concentration in sediments and attention to marine life (Tab. 1) (Macdonald et al., 1996). The SQG-Q index was calculated to assess the potential for adverse biological effects of study area and the threshold value was calculated as well. The SQG-Q was calculated using the following equations (Caeiro et al., 2005):

$$SQG\text{-}Q = (\Sigma PEL\text{-}Q_i)/n \qquad (1)$$

$$PEL\text{-}Q_i = C_i/PEL \qquad (2)$$

Where n and C_i are the number and concentration of heavy metals, respectively. PEL-Q_i is the probable effect level quotient for each contaminant, and PEL is probable effect level for each contaminant. The PEL value of Pb used in present study followed guideline from Macdonald et al. (1996) which is 112 mg/kg. The threshold effect level (TEL) of Pb (30.6 mg/kg) also considered to compare with the Pb concentrations value in present study. If Pb concentrations below the TEL value, it represents a *minimal-effects* range which intended to estimate conditions where effects would be rarely observed. While, if the concentration is equal to above the PEL and below the TEL, it represents a *possible-effects* range within which effects would occasionally occur. Finally, if the concentrations equivalent to and above the TEL value, it represents a *probable-effects* range within which effects would frequently occur. The SQG-Q values consist of three categories as shown on the Table 1.

Table 1. SQG-Q Categories (Macdonald et al., 1996).

Class	Category
SQG-Q <0.1	Unimpacted, the lowest potential to observe adverse biological effect
0.1<SQG-Q<1	moderate potential to observe adverse biological effect
SQG-Q ≥ 1	The most potential to observe adverse biological effect

The ANZECC/ARMCANZ (2000) classification by Australian and New Zealand Guidelines for fresh and marine water quality that follow Default Guideline Value (DGV) for toxicant sediment, was also performed in present study to know the standard quality of sediment compared to the published sediment quality in other region in other country. ANZECC/ARMCANZ (2000) has three categories of sediment quality of Pb toxicant level: 1) low risk (<50 mg/kg), 2) moderate risk (50-220 mg/kg), and high risk (>50 mg/kg) in dry weight respectively.

RESULTS

All sediment samples in the study area are grain-supported (Tab. 3). No matrix-supported sediment was found in the study area. Mean grain size sediments are mostly medium sand (n=5), although very fine sand (n=1), fine sand (n=1), and coarse sand (n=1) also occur. Sediment in the east coast of Panjang Island is all medium sand. Fine to very fine sand samples are originating from the reef slope on Panjang Island's north coast. Coarse sand samples are from the reef flat on the north coast of Panjang Island (Tab. 3).

Coral fragments are the most common sediment constituent in the study area, followed by mollusk shells (Tab. 2). Red algae, foraminifera, *Halimeda* flakes, and echinoderms were also discovered in small quantities. Fragments of branching coral from the genera of *Acropora* are dominant in the coral assemblage, while *Calcarina* sp. is abundant in the sandy shallow marine environments. The green algae *Halimeda* occurs more abundantly on the slope and reef front. Fine grain sediment is dominant in the deeper water, with sponge needles occurring in a very small amount.

Table 2. Reef sediment constituent and sediment sorting in Panjang Island.

Sampling site	coral	mollusc	red algae	Halimeda	Foram	Echinoderm	Sorting
East coast							
PJ-01	51%	36%	1%	4%	6%	2%	Very Poorly Sorted
PJ-05	52%	38%	1%	4%	5%	0%	Poorly Sorted
PJ-08	58%	36%	0%	1%	5%	0%	Moderately Sorted
PJ-09	45%	45%	1%	0%	7%	2%	Poorly Sorted
North coast							
PJ-11	15%	62%	3%	6%	11%	3%	Very Poorly Sorted
PJ-12	56%	34%	1%	3%	6%	0%	Moderately Sorted
PJ-13	50%	35%	1%	3%	11%	0%	Poorly Sorted
PJ-18	62%	31%	1%	2%	2%	1%	Poorly Sorted

Pb is distributed in the reef sediment on the north and east coast of Panjang Island with various value (Tab. 3). Three samples yield a Pb value of <0 mg/kg, which can be considered an indication that Pb accumulation is not found or below detection limit in the sediment sample. The maximum Pb value in the sediment sample is 28.68 mg/kg, found on the reef slope north of Panjang Island. The mean Pb value in the reef sediment samples is 3.11 mg/kg. Pb content in the reef sediment on the north coast of Panjang Island is higher (mean value of 2.01 mg/kg) compared to Pb content on the east coast (mean value of 13.00 mg/kg).

Table 3. Water depth, grain size (%), and Pb concentration (in dry weight) in reef sediment.

Sampling sites	water depth (m)	> 2 mm (%)	2-1 mm (%)	1-0.5 mm (%)	0.5-0.25 mm (%)	0.25-0.125 mm (%)	< 0.125 mm (%)	Mean grain-size	Pb concen-tration (mg/kg)	Reef zona-tion
East coast										
PJ-01	0.55	13.10	5.40	27.60	28.70	9.50	15.70	medium sand	0.97	reef flat
PJ-05	0.50	25.80	2.30	6.30	20.80	38.10	6.80	medium sand	0.31	reef flat
PJ-08	2.00	4.10	2.20	12.00	56.00	24.90	0.70	medium sand	<0	reef crest
PJ-09	9.00	4.50	5.00	18.30	26.60	29.30	16.40	medium sand	6.76	reef front
North coast										
PJ-11	8.00	1.40	2.20	17.00	18.50	23.70	37.20	very fine sand	28.68	slope
PJ-12	1.50	6.02	3.50	29.00	51.20	9.50	0.60	medium sand	0.74	reef front
PJ-13	3.00	0.20	0.60	9.40	35.30	43.60	10.90	fine sand	14.17	slope
PJ-18	0.50	15.70	7.70	39.70	24.80	10.50	1.60	coarse sand	8.41	reef flat
Min									<0	
Max									28.68	
Mean									7.47	

Based on Pb concentration in reef surface sediment, it suggests that all of sediment samples in the study area is categorize in the low-risk contamination of Pb as follow to ANZECC/ARMCANZ classification. The calculation in equation (1) and (2) also assigned to know the sediment quality to adverse biological effect in the study area. The SQG-Q value in the study area is categorized from low-moderately potential to adverse biological effect. Five locations have low SQG-Q value and three locations have moderately SQG-Q value. In general, the highest SQG-Q value is in the north coast of Panjang Island (PJ-11) and the lowest value is in the east coast of Panjang Island (PJ-08 and PJ-05). The result of sediment quality in present study is suggested in Table 4.

Table 4. Sediment Quality Assessment of Pb from reef sediment surface in Panjang Island.

Station ID	Pb Concentration (mg/kg)	SQG-Q	SQG-Q Class	ANZECC/ARMCANZ Class
East Coast				
PJ-01	0.97	0.01	Low impacted	Low risk
PJ05	0.31	0.00	Low impacted	Low risk
PJ-08	0.00	0.00	Low impacted	Low risk
PJ-09	6.76	0.06	Moderately impacted	Low risk
North Coast				
PJ-11	28.68	0.26	Moderately impacted	Low risk
PJ-12	0.74	0.01	Low impacted	Low risk
PJ-13	14.17	0.13	Moderately impacted	Low risk
PJ-18	8.41	0.08	Low impacted	Low risk

DISCUSSION

Correlation of Grainsize and Pb content

The Pb concentration in the reef sediments of Panjang Island is varied (Tab. 3). There is undetected Pb content (n=1), but in the rest sites, Pb were indicated contain in the sediment samples in present study. Sediment on the north coast of Panjang Island yields undetected Pb content (n=1). However, among all of samples, the highest Pb concentration also occurs on the northern coast (n=2) (Fig. 3). The mean grainsize sediment of PJ-18 is coarse sand, predominantly composed of coarse coral fragments. It is commonly known that finer sediments contain more heavy metals compared to coarser sediments, since finer grain sediment has a larger surface-to-volume ratio (Salomons, 1984). The constituents of sediments dictate their ability to concentrate heavy metals, such as clays that tend to concentrate most heavy metals, while others, like carbonates have less ability to concentrate heavy metals, especially in marine systems (Talbot & Chegwidden, 1983).

From all of samples analyzed, the highest Pb accumulation in the sediment was at the northernmost of the sampling site (Fig. 2). At this site, the sediment grain size is very fine, hence it can adsorb heavy metals better compared to other coarser grainsize in this area. However, some studies have pointed out that heavy metal concentration in the coarser grain fraction can be comparable to those in finer sediment (Maslennikova et al., 2012; Singh et al., 1999). Our results indicate that the medium sand fraction may accumulate different Pb values (Tab. 3). For instance, all of sediment samples in the east coast of Panjang Island has the medium sand grainsize, but the Pb concentrations varied from undetected to very high concentration.

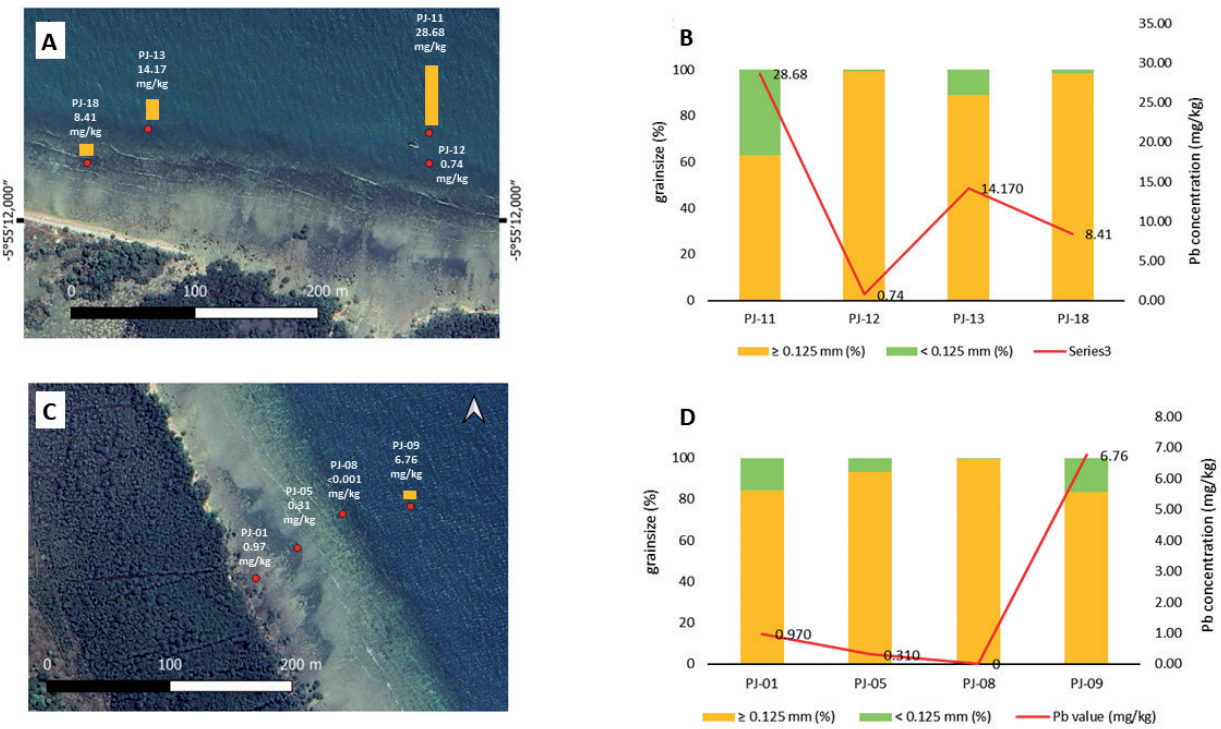

Figure 3. A. Map of Pb concentration distributions on the north coast of Panjang Island. B. Sediment grain size and its respective Pb content for the sediment on the north coast of Panjang Island. C. Map of Pb concentration distributions on the east coast of Panjang Island. D. Sediment grain size and its respective Pb content for the sediment on the east coast of Panjang Island.

The highest Pb concentration in the sediment from east coast of Panjang Island occurs in the reef front. In the reef flat, Pb concentrations also occur, while in reef crest is undetected. Since the sediment samples in the east coast of Panjang Island has the uniform grainsize, it is quite difficult to analyze the Pb concentration to the grainsize itself. According to the Fig.3, generally the samples that had much finer grain sediment will have the higher Pb concentrations, such as in PJ-01, PJ-05, PJ-09, PJ-11, and PJ-13, and vice versa such as in the PJ-08, PJ-12, and PJ-18.

Comparison with prior study

Generally, based on comparison with several prior studies (Tab. 4) about Pb concentration in sediment around Panjang Island and Banten Bay, Pb concentration in this study area is relatively still in the same range with other prior study, especially with the prior study in Panjang Island. Therefore, it can be inferred that Pb concentration in the sediment of Panjang Island has not significantly increased with time, as it remains within the same range of values as in previous studies.

There is the same shore side of study location between present study and Falah et al.'s (2020) study, which is in the east coast of Panjang Island (however not precisely the same site), but different monsoon. In the present study, the sediment sampling was collected in November (transitional monsoon) while in Falah et al.'s (2020) study, the samples were collected in December (west monsoon). In the west monsoon, Tropical Island will experience the rainy (wet) season. It will affect the sediment run-off to the ocean increases compared to transitional and east monsoon. Heavy metal concentration in dry season will be less than in wet season (Najamuddin et al., 2016). Heavy metals including Pb will be suspended in sediment. Since the sediment run-off is higher during the rainy season, Pb concentration will also increase. Therefore, Pb concentration in the east coast of Panjang Island of Falah et al.'s (2020) is slightly higher than in the present study.

Table 4. Comparison study of Pb concentration in marine sediment around Panjang Island and Banten Bay.

No.	Location	Pb content (mg/kg)	Time	Number of samples	Study
1	Panjang Island (N Coast)	4.26-11.26	November	4	Present Study
2	Panjang Island (E Coast)	0.92-5.2	November	4	Present Study
3	Panjang Island (SW Coast)	7.455	November	2	Falah et al. (2020)
4	Panjang Island (E Coast)	6.19	December	2	Falah et al. (2020)
5	Lima Island (SW-W Coast)	8.55	November	2	Falah et al. (2020)
6	Lima Island (NE-E Coast)	5.59	December	2	Falah et al. (2020)
7	Panjang Island (W Coast)	0.148	May	3	Juniardi et al. (2022)
8	Panjang Island (S Coast)	6.351	June	3	Juniardi et al. (2022)
9	Panjang Island (E Coast)	1.222	July	3	Juniardi et al. (2022)
10	Pamujaan Island (N Coast)	<0.002	May	3	Juniardi et al. (2022)
11	Pamujaan Island (E Coast)	12.917	June	3	Juniardi et al. (2022)
12	Pamujaan Island (SW Coast)	0.355	July	3	Juniardi et al. (2022)
13	Cengkok Beach, Banten Bay (N Coast)	0.005	April	1	Dinulislam et al. (2021)
14	Cengkok Beach, Banten Bay (N Coast)	0.005	May	1	Dinulislam et al. (2021)
15	Cengkok Beach, Banten Bay (N Coast)	0.108	July	1	Dinulislam et al. (2021)
16	Cengkok Beach, Banten Bay (N Coast)	0.002	August	1	Dinulislam et al. (2021)
17	Pelabuhan Karangantu (E Port Karangantu, landward)	0.0005-0.0004	July	10	Putri (2012)
18	Pelabuhan Karangantu (W Port Karangantu, oceanward)	0.004-0.0005	July	10	Putri (2012)
19	Banten Bay (oceanward)	0.0006-0.066	July	10	Putri (2012)
20	Cengkok Coastal Waters, Banten Bay	<0.000	April	N/A	Wardani et al. (2020)
21	Cengkok Coastal Waters, Banten Bay	<0.000	May	N/A	Wardani et al., (2020)
22	Cengkok Coastal Waters, Banten Bay	<0.000	Juli	N/A	Wardani et al. (2020)
23	Cengkok Coastal Waters, Banten Bay	<0.000	August	N/A	Wardani et al. (2020)

The different value of Pb concentration in Panjang Island between present study and Falah et al.'s (2020) study due to the discrete sampling sites. For instances in the same month, which is November, Falah et al.'s (2020) study was performed in the different shore side of Panjang Island with present study. The discrete sampling sites will be correlated with various grainsizes of the sediment samples, generating different values of Pb concentrations.

Sediment Quality

ANZECC/ARMCANZ classification used DGV and GV-high (upper guideline value) to assess the sediment toxicant level of substance. The sediment DGV's indicate the concentrations that there is a low risk of unacceptable effects occurring, and should be used with other evidence to protect aquatic ecosystems. In contrast, the 'upper' guideline values (GV-high) provide an indication of concentrations at which we might already expect to observe toxicity-related adverse effects. As such, the GV-high value should only be used as an indicator of potential high-level toxicity problems, not as a guideline value to ensure protection of ecosystems (ANZECC/ARMCANZ). In the study area, all of samples categorized to low-risk toxicant level of Pb in sediment based on the classification.

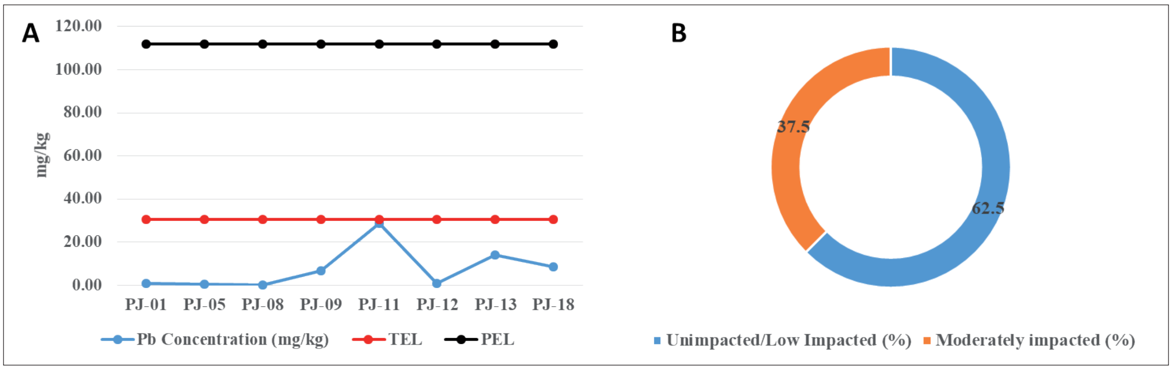

Figure 4. A. Sediment Toxicant Level of Pb and compared to TEL and PEL value. B. Distribution of sediment quality due to Pb toxicant level in reef surface sediment, Panjang Island based on SQG-Q.

However, to have a better insight on the adverse biological effects of Pb contaminant, the other assessment has been performed. The obtained data should be compared with the following SQGs: TEL and PEL (Long et al., 1995; Macdonald et al., 1996). Our result indicated that the Pb concentration in the study area is all below both, the TEL and PEL. This made Pb contaminant in study area is not expected to have adverse on biological effect (Fig.4A).

To have a more realistic measure of predicted toxicity, the SQG-Q was calculated. In present study, the SQG-Q of the reef surface sediment samples classified into two categories, which is low impacted to moderately impacted (Table 3). According to SQG-Q value in respective sample, it suggests that the 62.5% of reef surface sediment samples has low impact to adverse biological effect, while 37.5% is moderately potential to adverse biological effect (Fig.4B).

This finding can be used as preliminary study to perform another heavy metal analysis in Panjang Island. Since Pb can be accumulated in sediment, it is possible if the SQG-Q of sediment in Panjang Island can increase or enrich to a higher classification. Therefore, the monitoring of Pb or heavy metals in general, should be conducted in an ongoing basis.

CONCLUSIONS

This study highlights the relationship between sediment grainsize and Pb accumulation in reef sediments. The mean grainsize in reef surface sediment in Panjang Island is varied from very fine to coarse sand. Most of the sample analyzed in the study area is medium sand grainsize. Pb accumulation in the study area in November 2021 is varied from <0 – 28.68 mg/kg in dry weight. The variation of Pb concentration value in the study area is mainly controlled by sediment grainsize. The finer grainsize will relatively has the higher Pb concentration value, and vice versa. In the medium sand grainsize, Pb concentration is also varied. According to comparison with prior study, besides the grainsize, the monsoon and sediment run-off also played the role to Pb concentration in the sediment. In general, west monsoon and high influx of sediment run-off affected high concentration of Pb and vice versa. According to the classification of ANZECC/ARMCANZ (2000), all of sediment samples in the study area was in the low risk of Pb toxicant level. While, based on the SQG-Q (Sediment Quality Guidelines) quotient guidelines for heavy metal concentration in sediments and attention to marine life, Pb concentration in the reef surface sediment in study area has a low impact to moderately impact to adverse biological effects. Future research can focus on exploring the relationship between $CaCO_3$ content and heavy metal concentrations in reef sediments. Expanding sampling location and monitoring other heavy metals analysis can be conducted to ensure long-term environmental protection.

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CRediT AUTHORSHIP CONTRIBUTION STATEMENT

AUN: Conceptualization, Methodology, Investigation, Resources, Data Curation, Writing - Original Draft, Visualization. **DAU:** Conceptualization, Methodology, Investigation, Writing - Review and Editing, Visualization. **MH:** Investigation, Writing – Review and Editing. **TS:** Funding Acquisition, Writing – Review and Editing. **RR**: Funding Acquisition, Writing – Review and Editing. **SYC:** Funding Acquisition, Writing – Review and Editing.

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