Prediction of sediment quality based on the concentration of heavy metals Cu, Zn, and Ni in Jakarta Bay using the index analysis approach

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Abstract. The purpose of this study was to predict the concentration of heavy metals Cu, Zn, and Ni in sediments and to predict the sediment quality based on an index analysis approach (contamination factors, geo accumulation index, ecological risk index, and potential ecological risks index). The sediment sample taken by using a sediment grab in Jakarta Bay. Heavy metal content measured by using Atomic Absorption Spectrophotometer (AAS). The results showed that the Cu range from 14.79 to 55.36 µg.g⁻¹ with an average of 33.178 µg.g⁻¹, Zn range from 82.05 to 441.91 µg.g⁻¹ with an average of 197.484 µg.g⁻¹ and Ni range from 16.47 to 22.09 µg.g⁻¹ with an average of 19.328 µg.g⁻¹. The mean levels of Zn and Cu were still lower than the threshold value of sediment quality, i.e., 108 µg.g⁻¹ for Cu, 271 µg.g⁻¹ for Zn, while for Ni is higher, ie, 16 µg.g⁻¹. The results of the index analysis showed that the average value of contamination factor (CF) of Cu, Zn, and Ni were 1.614, 2.018, Ni-0.138 respectively (1<CF<3, moderate contamination), the average of geo accumulation index values of Cu, Zn, and Ni were -0.136, -1.010, -0.138 (Igeo<0, unpolluted) respectively. The average Pollution Load Index value (PLI) is 1.637 (PLI>1); based on the PLI index, sediments are categorized as polluted by Cu, Zn, and Ni. Based on ecological risk index (Er) and potential ecological risk index (RI), sediment includes low risk ecology (Er<40) and low potential risk ecology (RI<150).

1. Introduction

Jakarta Bay is a densely populated area with various activities, and this is where pollutants from the land transported directly or indirectly through 13 river systems that flow in the DKI Jakarta area. These pollutants come from high anthropogenic activities such as industrial waste, ports, fisheries, and garbage. The waste contains materials that are toxic and dangerous. Subsequently, toxic materials and harmful materials such as heavy metals have been accumulating in sediment in Jakarta Bay.

Heavy metals considered a vital contaminant of the environment if they are present in more than their natural concentration [1] [2]. Heavy metals are a natural component of rocks. As a result of rocks weathering, they are transferred to soil and bottom sediments, where they are supplemented with metals originating from anthropogenic activity such as urbanization, industrialization, transportation, and energy production [3][4]. Due to their toxicity, persistence, and potential to bioaccumulate, heavy metals present severe environmental pollution [5] [6]. Heavy metals, both essential and non-essential, have essential meanings in ecotoxicology because both are persistent and toxic to living organisms. Heavy metals are chemical elements naturally found in marine waters, and aquatic organisms need low levels, but in high levels are toxic when exceeding their threshold values [7]. Heavy metals can come from industrial, agricultural, urban, and mining activities [8]. Heavy metals in marine sediments mainly come from nature (input from rivers) and anthropogenic sources (coastal human settlements).
If they enter to seawaters, their distribution strongly influenced by physical-chemical factors (sedimentation process, mineral decomposition, hydrodynamic transport, redox conditions, and biological extraction) and considered as contaminants if the levels exceed the safe threshold values for environmental protection [9].

The levels of heavy metals Cu, Zn, and Ni in sediments in the western part of Jakarta Bay are higher than in the central and eastern parts of Jakarta Bay [10]. The high levels of heavy metals in the sediments in the western part of the Jakarta Bay area due to ship activity, the number of industries, and the higher population density than Jakarta's central and western parts. According to Wahyunningsih (2014) [11], the high levels of heavy metals in Jakarta Bay are caused by the rivers' high pollution level coming to Jakarta Bay. Permanawati et al. (2013) [12] reported that the levels of heavy metals Cu and Zn from surface sediments in Jakarta Bay in October-November 2010 were relatively low and were still below the criteria set by sediment quality standards. According to Kusuma et al., (2016) [13], the source of heavy metals lead (Pb), copper (Cu), and zinc (Zn) comes from land, while cadmium (Cd) and (Ni) come from the sea. Most of the heavy metal sources in Jakarta Bay's waters come from lands, such as port and industrial activities. Most of the heavy metal sources originating from the mainland are from port activities such as ship painting, ballast water disposal, ship docking, and refueling, which can contribute heavy metals to the waters and various industries in coastal areas chemical, paint, textile factories. Furthermore, battery rock, which discharges its waste through rivers or drains to Jakarta Bay.

This study aimed to assess the quality of sediments of Jakarta Bay using the index analysis approach.

2. Materials and Method

2.1. Field work
The sediment samples collected from five sampling locations along coastal of Jakarta Bay during July 2015 (Figure 1). Thirty-one sediment samples collected from Jakarta Bay using a Smith-McIntyre grab mud sampler in July 2015. The sampling locations represent areas with increasing distances from the shoreline, which are estuary (river mouth) (code M), 5 km (code D), 10 km (code C), 15 km (code B), and 20 km (code A) away from the coastline. Triplicate sampling performed on each site. In the field, the sediment samples from each site homogenized to obtain a composite sediment sample, immediately stored in sample bottles, kept in a cooled icebox, and transported to the laboratory [14].

2.2. Sample treatment
The concentration of heavy metals Cu, Zn, and Ni in the sediment sample determined using a Flame Atomic Absorption Spectrophotometer (Varian Spectro AA 20) following the USEPA method [15]. A reference material, PACS-2, was used to ensure the accuracy of the data. The typical recovery ranges between 95-100%, and the percent difference for the reference material is <5%. The concentration of heavy metals expressed in mg of metals per kg of sediment (dry weight).
2.3. **Data Analysis**

2.3.1 **Contamination Factor (CF) and Degree of Contamination (DC)**. The contamination factor (CF) used to determine the contamination status of the study area. The formula and terminology for describing the contamination factor (CF) shown as follows [16, 17].

\[
CF = \frac{C_{metal}}{C_{background}}
\]  

Where \(C_{metal}\) = the concentration of a given metal in the sediment, and \(C_{background}\) is a metal concentration of a control sample. The CF value for describing the contamination levels. The range are low (CF<1), moderate (1≤CF<3), considerable (3≤CF<6), and very high (CF≥6).

2.3.2 **Assessment according to the pollution load index (PLI)**

The pollution load index (PLI) is a simple method to assess pollution in sediments. In this study, the pollution load index for each site evaluated using the procedure of [16]:

\[
PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n)^{1/n}
\]  

Where: \(n = \) number of metals and \(CF = \) contamination factor. PLI is a tool in heavy metal pollution evaluation. According [17]; \(PLI=0\) (background concentration), \(0<PLI\leq1\) (unpolluted), \(1<PLI\leq2\) (unpolluted to moderately), \(2<PLI\leq3\) (moderately polluted), \(3<PLI\leq4\) (moderately to highly polluted), \(4<PLI\leq5\) (highly polluted) and \(PLI>5\) (very highly polluted).

2.3.3 **Potential Ecological Risk Index Method (RI)**. The Assessment of ecological risks of heavy metals in sediment samples done using the Ecological Risk Assessment (Er), and Risks Index (RI) proposed by [16] and reported in [18]. The potential ecological risk index method RI used to evaluate heavy metals' harm in the sediment samples. RI was calculated by using the following formula [16,19]:

\[
RI = \sum Er
\]

Where: RI is the potential ecological risks index; \(Er = \) the ecological risk index for single heavy metal pollution and can be calculated as:

\[
Er = CF \times Tr
\]

\(Tr\) is the response coefficient for the toxicity of the single metal. CF is the contamination factor and defined as:

\[
CF = \frac{C_{metal}}{C_{background}}
\]
Where \( C_m \) is the concentration of heavy metal in the sediment, and \( C_{\text{background}} \) is the reference [20, 21].

Table 1. Shows the concentration of heavy metal in the controlled sample: CF and the response coefficient for single metal (Tr). The background values of the upper limits of heavy metals in Jakarta Bay in 1995, used as reference values to evaluate the pollution in the paper. The usage of local background as the background has been done [21] in Bohai Bay China.

**Table 1.** Environmental background of heavy metals in sediments from Jakarta Bay waters (\( C_{\text{background}} \)) [22] and toxicity coefficient of heavy metals (\( T_r \)) [21].

| Element | Cu     | Zn     | Ni     |
|---------|--------|--------|--------|
| \( C_{\text{background}} \) (mg/kg) | 20.552 | 89.155 | 14.121 |
| \( T_r \) | 5      | 1      | 5      |

Based on the calculated Er and RI, the grading standards of the elected heavy metals' potential ecological risk obtained. Table 2 shows the potential ecological risk index's value range and the potential toxicity index along with the ecological risk level.

**Table 2.** Relationship between RI, Er and pollution levels [16, 19]

| Range of potential ecological risk index (Er) | Ecological risk level | Range of potential toxicity index (RI) | General level of ecological risk |
|---------------------------------------------|-----------------------|---------------------------------------|----------------------------------|
| \(<40\) | Low risk | RI\(<150\) | Low ecological risk |
| \(40\leq Er<80\) | Moderate risk | 150\(\leq RI<300\) | Moderate ecological risk |
| \(80\leq Er<160\) | Considerable risk | 300\(\leq RI<600\) | Considerable ecological risk |
| \(160\leq Er<320\) | High risk | RI\(\geq600\) | Very high ecological risk |
| \(Er\geq320\) | Very high risk |

2.3.4 **Geo Accumulation Index.** The geo accumulation index (Igeo) used to assess the contamination level of metal in sediments. It is a quantitative measure of the degree of pollution in aquatic sediments. The geo accumulation index is generally used to determine the anthropogenic contamination in sediments, as introduced by [23, 24, 25]. This index evaluates the contamination levels by comparing present concentrations with background levels. The Igeo expressed using the following Muller equation:

\[
I_{\text{geo}} = \log_2 \left( \frac{C_n}{1.5B_n} \right)
\]  

Where: \( C_n \) = measured concentration of element \( n \) in the sediments. \( B_n \) = geochemical background for the element \( n \). 1.5 is incorporated in the relationship to account for possible variation in background data (the background matrix correction factor) owing to lithogenic effects. The geo accumulation index consists of seven grades (0 to 6) based on the increasing numerical value of the index and ranges from unpolluted to extremely polluted. The standard Igeo values are presented as follows; Igeo<0, class 0 (uncontaminated), 0<\( I_{\text{geo}} <1 \), class 1 (unpolluted to moderately), 1<\( I_{\text{geo}} <2 \), class 2 (moderately polluted), 2<\( I_{\text{geo}} <3 \), class 3 (moderately to heavy polluted), 3<\( I_{\text{geo}} <4 \), class 4 (heavily polluted), 4<\( I_{\text{geo}} <5 \), class 5 (heavily to extreme polluted) and Igeo>5, class 6 (extremely polluted)
3. Result And Discussion

The results of this research presented in Table 3. From that table can be seen the highest concentration of Cu was found at location M (estuary area about 0.5 km from the coastal line), and then following by D, C, B, and A, for Zn, the highest concentration was also found at M location and following by D, C, B, and A, for Ni, the highest concentration was found at D location, and then following C, M, A, and B.

| Location            | Concentration, µg. g⁻¹ | Number of Station |
|---------------------|------------------------|------------------|
| M (Estuary, 0.5 km from coastline) | 55.360                  | 7                |
| D (5 km from estuary)   | 46.460                  | 7                |
| C (10 km from estuary)  | 34.150                  | 5                |
| B (15 km from estuary)  | 15.130                  | 4                |
| A (20 km from estuary)  | 14.790                  | 9                |
| Min                  | 14.790                  |                  |
| Max                  | 55.360                  |                  |
| Average concentration | 33.178                  |                  |
| SD                   | 18.256                  |                  |

3.1. Distribution of heavy metal in sediment

The concentration of Cu, Zn, and Ni in the surface sediments in Jakarta Bay waters' five sites are listed in Table 1. Among the six elements studied, the highest concentration was Zn, then following Cu and Ni. The highest concentration of Zn was detected in the estuary (M), which is 441.91 mg kg⁻¹. Cu has also been detected in the estuary (M) which is 55.36 mg kg⁻¹, and Ni was detected in location (D) 5 km from the estuary that is 22.09 mg kg⁻¹.

The average concentration of Cu is low. Permanawati et al. (2013) [12] found Cu's concentration from October to November 2010 on 28 sediment samples in Jakarta Bay range from 15.000-169.500 mg kg⁻¹. These concentrations were higher compared to the results of this research relatively. Edward et al. (2004) [26] found the concentration of Cu at 15 stations in the estuary of Cisadane, Ciliwung, and Citarum in Jakarta Bay in July 2003 range from 15.34-19.02 mg kg⁻¹ with the average is 17.013 mg kg⁻¹, and in May 2004, the range from 14.28-18.12 mg kg⁻¹ with average is 16.02 mg kg⁻¹. Budiyanto et al. (2017) [27] found that the average concentration of Cu in sediment in Jakarta Bay in May and June was 46.90 mg kg⁻¹ and 49.80 mg kg⁻¹. The data above showed that the concentration of Cu is varied; this may be caused by the research's different station positions and time. The Canadian Council of Ministers for the Environment (2002) [28] states that the threshold value of Cu in sediments for marine organisms protection is 35.7 mg kg⁻¹. The Sediment Quality Guidelines (SQG) determine the uncontaminated sediment with Cu is <25 mg kg⁻¹ [29]. KLH (2010) [30] define threshold values of Cu in the sediments to marine organisms is 108 mg kg⁻¹, and the average concentration of Cu in the earth's surface is 45 ppm [25]. The Cu range from 14.79-55.36 mg kg⁻¹ with an average of 33.178 mg kg⁻¹, which did not exceed the background value 45 mg kg⁻¹. The highest concentration of Cu was found in Station M and the lowest in Station A. It indicates that M station receives more input of waste containing Cu. Thus, when referring to the [28] and [30] above, the sediments in these waters are still suitable for the marine organism exception M and D.

The Zn concentration ranges from 82.05-441.91 mg kg⁻¹, with an average of 197.484 mg kg⁻¹. The highest concentration of Zn found in Station M, and the lowest in Station A. Permanawati et al. (2013) [12] found Zn concentration in October to November 2010 on 28 sediment samples in Jakarta Bay range from 95.80-333.00 mg kg⁻¹. Edward et al. (2004) [26] found the concentration of Zn at 15 stations in the estuary of Cisadane, Ciliwung, and Citarum in Jakarta Bay in July 2003 range from 86.69-99.63 mg kg⁻¹ with the average is 94.633 mg kg⁻¹, and in May 2004, the range from 89.60-101.525 mg kg⁻¹ with an average is 93.88 mg kg⁻¹. Budiyanto et al. (2017) [27] found that Zn's average concentration of Zn was found in Station M and the lowest in Station A. The data above showed that the concentration of Zn in sediment is 197.484 mg kg⁻¹, which is higher compared to the results of this research relatively. The Sediment Quality Guidelines (SQG) recommend the lowest threshold value of Zn in the sediments to marine organisms is 108 mg kg⁻¹, with the average is 45 mg kg⁻¹. The Zn range from 82.05-441.91 mg kg⁻¹ with an average of 197.484 mg kg⁻¹, which did not exceed the background value 45 mg kg⁻¹. The highest concentration of Zn was found in Station M and the lowest in Station A. It indicates that M station receives more input of waste containing Zn. Thus, when referring to the [28] and [30] above, the sediments in these waters are still suitable for the marine organism exception M and D.

The Ni concentration ranges from 8.20-101.1 mg kg⁻¹, with an average of 53.67 mg kg⁻¹. The highest concentration of Ni was found at D location, and then following by A, B, and C. Edward et al. (2004) [26] found the concentration of Ni in the surface sediments in Jakarta Bay range from 8.20-101.1 mg kg⁻¹ with an average of 53.67 mg kg⁻¹, which did not exceed the background value 45 mg kg⁻¹. The Ni range from 8.20-101.1 mg kg⁻¹ with an average of 53.67 mg kg⁻¹, which did not exceed the background value 45 mg kg⁻¹. The highest concentration of Ni was found in Station M and the lowest in Station A. It indicates that M station receives more input of waste containing Ni. Thus, when referring to the [28] and [30] above, the sediments in these waters are still suitable for the marine organism exception M and D.
concentration in sediment in Jakarta Bay in May and June was 206.00 mg kg\(^{-1}\) and 408.00 mg kg\(^{-1}\). The data above showed that Zn's concentration is varied; this may caused by the different station positions and research time.

The average Zn level is higher than Zn's background levels, which is 90 mg kg\(^{-1}\) [29]. The Canadian Council of Ministers for the Environment [27] states that Zn's threshold value in sediment for marine organisms protection is 123 mg kg\(^{-1}\). KLH (2010) [30] sets Zn's threshold value in sediments for 271 mg kg\(^{-1}\) for marine organisms. Sediment Quality Guidelines (SQG) stated that Zn does not pollute sediment has a Zn concentration of less than 90 ppm [31]. The background level of Zn on the earth's surface is 95 mg kg\(^{-1}\). Thus, when referring to KLH showed that Zn concentration in sediments in these waters is still good for marine organisms protection.

Ni concentration ranged from 16.47 – 22.09 mg kg\(^{-1}\) with an average of 19.328 mg kg\(^{-1}\), which did not exceed the background value of 68 mg kg\(^{-1}\). The highest concentration of Ni found in Station D and the lowest in Station B. It indicates that Station D receives more input of waste containing Ni. Edward et al. (2004) [26] found the concentration of Ni at 15 stations in the estuary of Cisadane, Ciliwung, and Citarum in Jakarta Bay in July 2003 range from 6.25-8.89 mg kg\(^{-1}\) with the average is 7.62 mg kg\(^{-1}\), and in May 2004, range from 5.574-10.216 mg kg\(^{-1}\) with average is 7.60 mg kg\(^{-1}\). Budiyanto et al. (2017) [27] found that the average concentration of Ni in sediment in Jakarta Bay in May and June were 24.70 mg kg\(^{-1}\) and 29.40 mg kg\(^{-1}\). The data above showed that the concentration of Cu varied, like Cu and Zn; this condition also caused by the different station positions and time of research. This concentration is not too different from Ni concentration in the estuary in this research (location M). British Columbia Ministry of Water, Land, and Air Protection (BCMWLAP) [32] states that Ni lowest value in sediments that can harm marine organisms is 16 mg kg\(^{-1}\). Based on that BCMWLAP [32], Ni concentration is not suitable for marine organisms protection. Fig 12 shows that Ni concentrations in all stations have higher than the background value and the threshold value. The normal concentration of Ni in the background is 68 mg kg\(^{-1}\) [29]. Sediment Quality Guidelines (SQG) stated that the Ni concentration in non-polluted sediments is less than 20 mg/kg and in moderately polluted sediments range from 20-50 mg kg\(^{-1}\) [29].

Based on the average values, the metals follow the decreasing concentration in the order Zn>Cu>Ni. The data shows that Zn and Cu are the dominant metals found in the study area's surface sediment.

### 3.2. Correlation between heavy metals concentration with the station distance from coastal.

This Table 4 below shows the correlation between heavy metals and heavy metals with the station's distance. There is a correlation between Cu with Zn (r 0.915) but no correlation between Cu, Zn, and Ni (r 0.781, r 0.490). Asamuddin et al. (2011) [33] in their research in Sulu and Sulawesi Seas, found the correlation between Cu and Ni. Ra et al. (2013) [34] in their research in Korea, did not find the correlation between Ni with Cu and Zn. Gaspic et al. (2008) [35] in their research in Soline Bay, Croatia, reported there is no correlation between Cu, Zn, and Ni. Based on this correlation is predicted, Cu and Zn come from the same waste sources, while Cu and Ni, Zn, and Ni are predicted to come from different waste sources. For distance, there were correlations between Cu, Zn with distance (r = -0.974, r = -0.908), where the concentration of Cu and Zn is increased to a station near to the coastline, while Ni no correlation with the distance (r = 0.677).

Li et al. (2012) [36] in their research in Jinzhou Bay (China), also found a correlation between the station's distance from the coastline to the levels of Cu, Zn, and Ni, where the stations farther from the coast have lower levels than those near the coast. Additionally, levels of heavy metals are also variations at each station, and this variation is due to the different characteristics of each location as the physical and chemical properties of water. Li et al. (2013) [37] stated that the level of acidity (pH), temperature, dissolved oxygen, and current velocity affected variation in heavy metal levels in sediments. Hagan et al. (2011) [38] stated that dissolved or deposited metals in sediments are influenced by the waters' physical and chemical properties such as pH, salinity, conductivity, and organic matter.
The distribution of Cu and Zn in the research location is high on the coast and lower towards the sea. This was showed that the source of heavy metals for Cu and Zn comes from land, while the distribution of Ni is relatively varied; this data shows that the source of heavy metal Ni can come from the land and from the sea, such as from the activities of massive ships that do not load and unload in the coastal areas but loading and unloading in the middle of the sea.

### Table 4. Pearson correlation between heavy metals with distance

|        | Cu    | Zn    | Ni     | Distance |
|--------|-------|-------|--------|----------|
| Cu     | 1     | .915* | .781   | -.974**  |
| Sig. (2-tailed) | .029 | .119  | .005   |
| N      | 5     | 5     | 5      | 5        |
| Zn     | .915* | 1     | .490   | -.908*   |
| Sig. (2-tailed) | .029 | .402  | .033   |
| N      | 5     | 5     | 5      | 5        |
| Ni     | .781  | .490  | 1      | -.677    |
| Sig. (2-tailed) | .119 | .402  | .209   |
| N      | 5     | 5     | 5      | 5        |
| Distance | -.974** | -.908* | -.677 | 1        |
| Sig. (2-tailed) | .005 | .033  | .209   |
| N      | 5     | 5     | 5      | 5        |

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

In general, this study shows that heavy metals' distribution patterns in sediments indicate the source; this is because the sea surface is dynamic. There is an influence from the complex physicochemical properties of the waters such as addiction-diffusion, adsorption-desorption, and deposition-dissolution sediment. Most of the potential sources of heavy metals come from lands, such as port and industrial activities. Port activities such as ship painting, ballast water disposal, ship docking, and refueling can contribute heavy metals to the waters. Besides, various industries in coastal areas such as chemical, paint, textile, and battery stone factories estimated to dispose of their waste through rivers or drainage through the estuary to Jakarta Bay.

### 3.3. Estimating metals pollution impact

#### 3.3.1. Contamination factor and Geo accumulation indexes.

The average value of the Cu contamination factor is 1.614, and this value is higher than 1 (1<CF<31), which means that sediment is in category moderate contamination. The average Igeo value is -0.136; this value is smaller than 0 (Igeo <0), which means that sediment is categorized as unpolluted (Table 5).

### Table 5. Contamination Factors (CF) and Geoaccumulation Index (Igeo) Cu

| St | CF   | Igeo |
|----|------|------|
| M  | 2.693| 0.844|
| D  | 2.260| 0.591|
| C  | 1.661| 0.147|
| B  | 0.736| -1.206|
| A  | 0.719| -1.059|
| Min| 0.719| -1.206|
| Max| 2.693| 0.844|
| Average | 1.614| -0.136|
| SD  | 0.888| 0.944|
Table 6 shows the average of Zn contamination factor is 2.215, and this value is higher than 1 (1 < CF < 3), which means that sediment is including moderate contamination. The average of Igeo value is -1.010 is lower than zero (<0), which means that sediment is categorized as unpolluted (Igeo < 0).

| St  | CF  | Igeo |
|-----|-----|------|
| M   | 4.956 | 1.724 |
| D   | 2.563 | 0.772 |
| C   | 1.707 | 0.186 |
| B   | 0.927 | -0.692 |
| A   | 0.920 | -7.040 |
| Min | 0.920 | -7.040 |
| Max | 4.956 | 1.724 |
| Average | 2.215 | -1.010 |
| SD  | 1.675 | 3.483 |

Table 7 shows the average Ni contamination factor is 1.368, and this value is more significant than one and smaller than 3 (1 < CF < 3), which means that the sediment is categorized as moderate contaminated. The average Igeo value is -0.138; this value is smaller than 0, which means that sediment is categorized as unpolluted (Igeo < 0).

| St  | CF  | I_geo |
|-----|-----|-------|
| M   | 1.400 | -0.098 |
| D   | 1.564 | 0.060 |
| C   | 1.433 | -0.065 |
| B   | 1.166 | -0.362 |
| A   | 1.278 | -0.229 |
| Min | 1.166 | -0.362 |
| Max | 1.564 | 0.060 |
| Average | 1.368 | -0.138 |
| SD  | 0.152 | 0.161 |

3.3.2. Index of Pollution Load (PLI). Table 8 showed the PLI values at each station. PLI value ranges from 0.926-2.635 with an average of 1.637, and this value is higher than 1 (PLI > 1), which means that overall sediment in the waters of Jakarta Bay is categorized as polluted by metals Cu, Zn, and Ni. The levels of Cu, Zn, and Ni in sediments relatively varied at each station. Differences in each station position can cause this variation.

| St  | CF Cu  | CF Zn  | CF Ni  | PLI (Pollution Load Index) |
|-----|--------|--------|--------|---------------------------|
| M   | 2.693  | 4.956  | 1.400  | 2.635                     |
| D   | 2.260  | 2.563  | 1.564  | 2.084                     |
| C   | 1.661  | 1.707  | 1.433  | 1.595                     |
| B   | 0.736  | 0.927  | 1.166  | 0.926                     |
| A   | 0.719  | 0.920  | 1.278  | 0.945                     |
| Min | 0.719  | 0.920  | 1.166  | 0.926                     |
| Max | 2.693  | 4.956  | 1.564  | 2.635                     |
| Average | 1.614  | 2.215  | 1.368  | 1.637>1                   |
| SD  | 0.888  | 1.675  | 0.152  | 0.738                     |
3.3.3. Potential Ecological Risk Index (RI). The ecological risk assessment in sediments was carried out by the potential ecological risk index (RI) proposed by [16]. The ecological risk factor Er and potential ecological risk index (RI) presented in Tables 9 and 10.

Table 9. Ecological Risk Factor (Er = CF x Tr)

| Sampling location | Cu    | Zn    | Ni    |
|-------------------|-------|-------|-------|
| M                 | 13.468| 4.956 | 7.003 |
| D                 | 11.303| 2.563 | 7.821 |
| C                 | 8.308 | 1.707 | 7.166 |
| B                 | 3.680 | 0.927 | 5.831 |
| A                 | 3.598 | 0.920 | 6.394 |
| Average           | 8.071 | 2.214 | 6.843 |

Table 9 showed that the average of risk indices (Er) of all heavy metals indicated that Cu (8.071), Zn (2.214), and Ni (6.843) were within low risk ecological (<40).

The potential ecological risk factor is known as the Risk Index (RI) in each location is lower than 150 (<150), and this is including low potential ecological risk (Table 10).

Table 10. Potential Ecological Risk Index (RI)

| Sampling location | Cu    | Zn    | Ni    | ΣRI    | Ecology Risk criteria for environment |
|-------------------|-------|-------|-------|--------|---------------------------------------|
| M                 | 13.468| 4.956 | 7.003 | 25.427 | Low potential ecological risk          |
| D                 | 11.303| 2.563 | 7.821 | 21.687 | Low potential ecological risk          |
| C                 | 8.308 | 1.707 | 7.166 | 17.181 | Low potential ecological risk          |
| B                 | 3.680 | 0.927 | 5.831 | 10.438 | Low potential ecological risk          |
| A                 | 3.598 | 0.920 | 6.394 | 10.912 | Low potential ecological risk          |
| Average           | 8.071 | 2.214 | 6.843 | 17.129 | Low potential ecological risk          |

3.3.4. Comparison with Sediment Quality Standards (SQG) and Ecological Risk. Table 11 shows the comparison of metals in sediments in Jakarta Bay with geochemical background and toxicological reference values (mg kg⁻¹).

Table 11. Comparison of the average concentration of metals (mg/kg) with the standard for sediment [39]

| SQG (Sediment Quality Guideline) | Cu    | Zn    | Ni    |
|----------------------------------|-------|-------|-------|
| TEL (threshold effect level)      | 35.7  | 123   | 18    |
| ERL (effects range low)           | 70    | 120   | 30    |
| LEL (lowest effect level)         | 16    | 120   | 16    |
| MET (minimal effect threshold)    | 28    | 150   | 35    |
| CB TEC (Consensus-Based, threshold effect concentration) | 31.6 | 121 | 22.7 |
| EC (Environment Canada)TEL        | 18.7  | 124   | 15.9  |
| NOAA (National Oceanic, and Atmospheric Administration) ERL | 34  | 150 | 20.9 |
| ANZECC (Australian and New Zealand Environment and Conservation Council) ERL | 34  | 200 | 21 |
| ANZECC ISQG (Interim Sediment Quality Guidelines) Low | 65 | 200 | 21 |
| SQAV (Sediment Quality Advisory Value) TEL HA 28 | 28 | 98 | 20 |
| SQO Netherlands Target            | 36    | 140   | -     |
| Hongkong ISQG (Sediment Quality Objective) Low | 65 | 200 | 40 |
| This Study                       | 33.178| 197.484| 19.328|
In the table above shows that the mean levels of Cu were higher than LEL, MET, CB TEC, EC TEL, and SQAV TEL. Zn is higher than TEL, ERL, LEL, MET, CB TEC, EC TEL, NOAA ERL, SQAV TEL, and SQO Netherlands target. Ni is higher than TEL, LEL, and EC TEL.

4. Conclusion
The total levels of heavy metals detected in surface sediments Jakarta Bay waters corresponded to the order: Zn>Cu>Ni. Some of the levels of heavy metals in sediments in Jakarta Bay are still following the sediment quality standards, but some of them have passed the sediment quality standard. When referring to PLI values, sediments in these waters are generally categorized as polluted (PLI > 1); when referring to potential ecological risk, sediment in the waters include low ecological risk and low potential ecological risk.

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References
[1] Bing H, Zhou J, Wu Y, Wang X, Sun H, and Li R 2016 Current state, sources, and potential risk of heavy metals in sediments of Three Gorges Reservoir, China Environmental Pollution (Barking, Essex : 1987) 214:485—96.
[2] Sekabira K, Origa H O, Basamba T A, Mutumba G, and Kakudidi E 2010 Assessment of heavy metal pollution in the urban stream sediments and its tributaries International Journal of Environmental Science & Technology 7(3):435–46.
[3] Omwene P I, Öncel M S, Çelen M, and Kobya M 2018 Heavy metal pollution and spatial distribution in surface sediments of Mustafakemalpaşa stream located in the world’s largest borate basin (Turkey) Chemosphere 208:782–792.
[4] Xia F, Qu L, Wang T, Luo L, Chen H, Dahlgren R A, Zhang M, Mei K, and Huang H 2018 Distribution and source analysis of heavy metal pollutants in sediments of a rapid developing urban river system Chemosphere 207:218–28
[5] Islam S, Ahmed K, Habibullah-Al-Mamun, and Masunaga S 2015 Potential ecological risk of hazardous elements in different land-use urban soils of Bangladesh The Science of the Total Environment 94–102
[6] Vodyanitskii, Y N 2016 Standards for the contents of heavy metals in soils of some states Annals of Agrarian Science 14(3):257–63.
[7] Rainbow P S 2007 Trace metal bioaccumulation: Models, metabolic availability and toxicity Environment International 33(4):576–82 https://doi.org/10.1016/j.envint.2006.05.007
[8] Dixit R, Wasiullah, Malaviya D, Pandiyan K, Singh U B, Sahu A, Shukla R, Singh B P, Rai J P, Sharma P K, Lade H, and Paul D 2015 Bioremediation of heavy metals from soil and aquatic environment: An overview of principles and criteria of fundamental processes Sustainability (Switzerland) 7(2):2189–212
[9] Shaari H, Mohamad Azmi S N H, Sultan K, Bidai J, and Mohamad Y 2015 Spatial Distribution of Selected Heavy Metals in Surface Sediments of the EEZ of the East Coast of Peninsular Malaysia International Journal of Oceanography 1–10.
[10] Rochyatun E and Rozak A 2010 Observation on Heavy Metals in Sediment of Jakarta Bay Waters MAKARA of Science Series 11(1):28–36
[11] Wahyuningsih T R N 2014 Pollution of Pb (Lead) and Cd (Cadmium) in Marine Fisheries Products Caught by Fishermen Around Jakarta Bay Universitas Terbuka
[12] Permanawati Y, Zuraida R, and Ibrahim A 2016 Contains Of Heavy Metals (Cu, Pb, Zn, Cd, And Cr) In Water And Sediment In Jakarta Bay Waters Journal of Marine Geology 11(1):9
[13] Kusuma A H, Prartono T, Atmadipoera A S, and Arifin T 2016 Distribution Heavy Metal In
Water And Sediment In The Jakarta Bay At September 2014 Journal of Fishery and Marine Technology 6(1):41–9

[14] Cordova R M, Triyoni P, Rachma P, and DwI H 2017 Assessing contamination level of Jakarta Bay nearshore sediments using green mussel (Perna viridis) larvae Mar. Res. Indonesia 41(2):67–76.

[15] USEPA 2016 Guidance on the use of models and other analyses in attainment demonstrations for the 8hour ozone NAAQS DIANE Publishing.

[16] Hakanson L 1980 An ecological risk index for aquatic pollution control.a sedimentological approach Water Research 14(8):975–1001

[17] Tomlinson D L, Wilson J G, Harris C R., and Jeffrey D W 1980 Problems in the assessment of heavy-metal levels in estuaries and the formation of a pollution index Helgoländer Meeresuntersuchungen 33(1–4):566–75

[18] Huang H, Potter C J, Tao W, Li D M, Brogiolo W, Hafen E, Sun H, and Xu T 1999 PTEN affects cell size, cell proliferation and apoptosis during Drosophila eye development Development (Cambridge, England) 126(23):5365–72.

[19] Xu Z, S Ni, and X 2008 Tuo Calculation of heavy metals toxicity coefficient in the evaluation of potential ecological risk index Environ Sci Tech 31:112–5.

[20] Effendi H, Wardiatno Y, Kawaroe M, Mursalin, and Lestari D F 2017 Spatial distribution and ecological risk assessment of heavy metal on surface sediment in west part of Java Sea IOP Conference Series: Earth and Environmental Science 54(1):1–12.

[21] Guo W, Liu X, Liu Z, and Li G 2010 Pollution and potential Ecological Risk Evaluation of Heavy Metals in the sediments around Dongjiang Harbor. Tianjin Procedia Environmental sciences 2:729-36

[22] Marchand M and Martin J L 1985 Détermination de la pollution chimique dans la lagune d ’ Abidjan ( Côte d ’ ivoire ) par Z ’ étude des sédiments J. Océanogr. Trop. 20(52):25–39.

[23] Muller G 1979 Heavy-metals in sediment of the Rhine-changes since 1971. Umschau in Wissenschaft Und Technik 79(24):778–83.

[24] Muller G 1981 The heavy metal pollution of the sediments of Neckars and its tributary: a stocktaking Chemiker-Zeitung 105:157–64.

[25] Mohiuddin K M, Zakir H M, Otomo K, Sharmin S, and Shikazono N 2010 Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river International Journal of Environmental Science & Technology 7(1):17–28.

[26] Edward, Muhajir, and Fasmi A 2004 Accumulation of heavy metals Pb, Cd, Cu, Zn, and Cr in sediments at the estuaries of the Cisadane, Ciliwung and Citarum rivers, Jakarta Bay Scientific Journal: Sorohi 111:83–97.

[27] Budiyanto F and Lestari L 2017 Temporal and Spatial Distribution of Heavy Metal in Sediment of Urban Coastal Waters: A Case Study in Jakarta Bay, Indonesia Bulletin of the Marine Geology, 32(1).

[28] Canadian Council of Ministers for the Environment (CCME) 2002 Canadian Sediment Quality Guidelines for the Protection of Aquatic Life Summary Table. Winnipeg MB p 7

[29] Harikumar P S, Nasir U P, and Mujeebu R M P 2009 Distribution of heavy metals in the core sediments of a tropical wetland system International Journal of Environmental Science and Technology 6(2):225–232

[30] KLH Regulation of the Minister of State for the Environment No 01 2010 concerning Water Pollution Control Procedures, Menteri Negara Lingkungan Hidup p 169

[31] Shams M, Etemadi N, Baninasab B, Ramin A A, and Khoshgoftarmanesh A H 2012 Effect Of Boron And Calcium On Growth And Quality Of ‘Easy Lover’ Cut Rose Journal of Plant Nutrition, 35(9):1303–13.

[32] Touchinski, Sergei G, Thanh T, Nguyen, Shaun T, and Jennifer H 2010 Technical Data Report Surface Water and Sediment Quality In Enbridge Northern Gateway Project

[33] Asamuddin A H and Mohame C A 2011 Distribution of trace elements and total organic carbon
in surface sediments of the Sulu and Sulawesi Seas *Journal of Tropical Marine Ecosystem* 2(22–29)

[34] Ra K, Eun-Soo K, Kyung T K, Joung K K, Jung-Moo L, and Jin-Joung C 2013 Assessment of heavy metal contamination and its ecological risk in the surface sediments along the coast of Korea *Journal of Coastal Research* 65:105-10

[35] Gaspic K Z, Danijela B, and Ivana U 2009 Trace metals (Cd, Pb, Cu, Zn and Ni) in sediment of the submarine pit Dragon ear (Soline Bay, Rogoznica, Croatia) *Environ Geology* 8(4):751-60.

[36] Li X, Liu L, Wang Y, Luo G, Chen X, Yang X, Gao B, and He X 2012 Integrated assessment of heavy metal contamination in sediments from a coastal industrial basin, NE China *PLoS ONE*, 7(6) https://doi.org/10.1371/journal.pone.0039690

[37] Li H, Shi A, Li M, Zhang X 2013 Effect of pH, Temperature, Dissolved Oxygen, and Flow Rate of Overlying Water on Heavy Metals Release from Storm Sewer Sediments *Journal of Chemistry* 434012. https://doi.org/10.1155/2013/434012

[38] Hagan G B, Ofosu F G, Hayford E K, Osae E K, and Oduro A K 2011 Heavy metal contamination and Physico-chemical assessment of the Densu River basin in Ghana. *Research Journal of Environmental and Earth Sciences* 3(4): 385-92.

[39] Burton G and Allen J 2002 Sediment quality criteria in use around the world *Limnology* 3(2):65–76.