Ecological Risk Assessment of Heavy Metals Contamination in Lower Klang River

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Abstract. Estuarine and coastal environments are known to be major sinks for heavy metals. This ecosystem and its sustainability should be secured using the ecological as indicators. This study is conducted to quantify the heavy metal concentration and to assess the potential ecological risk levels of heavy metals in the sediments from Klang River Estuary. Three typical heavy metals such as cadmium (Cd), lead (Pb) and zinc (Zn) were identified. The surface sediment samples were collected from three sampling stations. The concentration of heavy metals in the sediments were arranged in a decreasing sequence of Pb > Zn > Cd. A range of pollution indicators based on single pollution indices such as Contamination Factor, Contamination Degree, Pollution Load Index and Geoaccumulation Index were considered for ecological risk analysis. In conclusion, the ecological risk levels of heavy metals in the sediments from Lower Klang River were low and unpolluted. However, an overall assessment regarding to the heavy metals’ concentrations, spatial distribution and their potential sources need to be monitored for a better understanding of the water-sediment interaction.

1. Introduction

In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by heavy metals. Heavy metals are defined as metallic elements that have a relatively high density compared to water where it naturally has a high atomic weight and a density at least 5 times greater than that of water [1]. It also has brought serious attention in terms of environmental problem which can enter the water system such as surface water and groundwater through various of process [2].

Heavy metals do not exist in soluble forms for a long time in waters; they are present mainly as suspended colloids or are fixed by organic and mineral substances [3]. This pollutant may arise from various of land use type along the river such as residential area, industrial effluent, domestic sewage, and aquaculture. The points or locations where the river collided with the sea is said to be among the most productive area which generates a lot of organic matters. It is also potentially acting as an organic trap due to their geographical and behavior which can trap and sink heavy metals and other organic matters in that area [4]. The diffused heavy metals in the water way which is finally deposited in the estuary are accumulated in sediments over times.

Heavy metal concentrations in estuarine and coastal environments are usually monitored by measuring its concentration in water, sediments, and biota [3]. In the estuarine environment, sediments have been widely used as environmental indicators for the assessment of heavy metals pollution in the natural water [5]. Moreover, estuarine environment also featured by fine-grained sedimentary texture,
enrichment of organic matters and seashells and relatively low hydrodynamic force (high-low tide force), thus have high-capacity adsorbing heavy metals. Heavy metals released to this estuarine are largely trapped by sediments and pose a serious threat to their surroundings. Therefore, it is necessary to determine the presence of heavy metal which could disrupting the environment if the level of the contamination of the heavy metals is high.

The aim of this study is to assess the contamination level and ecological risk of the heavy metals such as cadmium (Cd), lead (Pb) and zinc (Zn) in the surface sediments from Klang River Estuary, Selangor. This study offers the pilot data related to distribution and environmental status of heavy metals in surface sediments of Lower Klang River, which could be available for further environmental studies in this area.

2. Materials and Methods
A total of three (3) sampling sites were identified for surface sediments along Lower Klang River namely Pengkalan Batu, DID Sg. Udang and Jeti Kg. Delek as shown in Figure 1. The coordinates of sampling sites were recorded with Global Positioning System (GPS) and description of each sampling sites was given in Table 1. The land use near by the sampling sites ranging from residential, commercial, industrial, and agricultural. Generally, the sediment grain size in the selected study area is fines grain which consist of sand, silt and clay and normally found in estuary.

Top (0-5 cm) surface sediments samples were collected at each sampling sites by scraping the surface layer using a clean plastic spoon, placed in plastic bag, and instantly placed in ice box. Then, samples were brought to the Environmental Laboratory and allowed to dry at 105°C in an air circulating oven. The dried sediment was ground into a fine powder and were sieved through a 63 μm mesh size. Then, heavy metals (Cd, Pb and Zn) concentration analyses in the surface sediment sample method explained by [6] was adopted for this study.

Figure 1. Sampling sites at Lower Klang River.
Table 1. Descriptions of sampling sites along lower Klang River.

| Sites            | Coordinates          | Fine grains (%) | Site descriptions         |
|------------------|----------------------|-----------------|----------------------------|
| Pengkalan Batu   | 3.0473° N, 101.4429° E | 69.2            | Recreational Park          |
| DID Sg. Udang    | 3.0399° N, 101.4177° E | 62.4            | Jetty, receiving domestic wastes |
| Jeti Kg. Delek   | 3.0250° N, 101.4055° E | 70.5            | Jetty, receiving domestic wastes |

3. Results and Discussions

3.1. Heavy metals concentration

The total average concentrations of heavy metals in sediment are summarized in Table 2. Results show that Cd in sediment samples was found in the range of 0.044-0.053 mg/kg, Pb is 0.200-0.269 mg/kg and Zn is 0.180-0.250 mg/kg respectively. Generally, heavy metal concentrations in sediment samples were found in a decreasing sequence of Pb > Zn > Cd. The highest concentration of heavy metals was found in DID Sg. Udang. This may because this area is located near to DID storage warehouse and jetty for the local people. Their activity may influence the heavy metals concentration.

Table 2. Heavy metal concentrations in sediment.

| Sites            | Cd (mg/kg) | Pb (mg/kg) | Zn (mg/kg) |
|------------------|------------|------------|------------|
| Pengkalan Batu   | 0.044      | 0.200      | 0.180      |
| DID Sg. Udang    | 0.053      | 0.269      | 0.220      |
| Jeti Kg. Delek   | 0.053      | 0.225      | 0.250      |
| aBaseline data, C0 | 0.200      | 12.500     | 70.000     |

3.2. Ecological risks assessment

A range of pollution indicators based on single pollution indices was considered for this analysis. This includes Contamination Factor (Cf), Contamination Degree (Cd), and modified Contamination Degree (mCd), Pollution Load Index (PLI) and Geoaccumulation Index (Igeo). All this range of pollution indicators are summarized in Table 3.

Table 3. Range of pollution indicators.

| Sites            | Contamination Factor (Cf) | Contamination Degree (Cd) | Geoaccumulation Index (Igeo) | PLI |
|------------------|---------------------------|---------------------------|-----------------------------|-----|
|                  | Cd | Pb | Zn | Cd | mCd | Cd | Pb | Zn |
| Pengkalan Batu   | 0.220 | 0.016 | 0.003 | 0.239 | 0.080 | -2.77 | -0.59 | -0.74 | 0.021 |
| DID Sg. Udang    | 0.265 | 0.022 | 0.003 | 0.290 | 0.097 | -8.47 | -6.12 | -6.41 | 0.026 |
| Jeti Kg. Delek   | 0.265 | 0.018 | 0.004 | 0.287 | 0.096 | -11.00 | -8.87 | -8.71 | 0.026 |

3.2.1. Contamination Factor

Contamination Factor (Cf) values were computed using the Equation 1 [8], where Cs is the concentration of heavy metal in sampling locations and C0 is concentration of the same metal in the baseline sediments (mean worldwide soils) [7]. Table 4 shows the description of contamination based on the Cf values [9]. Results showed that Cf in sediment samples was found in the range of 0.220-0.265 for Cd, 0.016-0.022 for Pb and 0.003-0.004 for Zn. Therefore, based on the description of contamination in Table 3, the potential of contamination is low for all heavy metals at all sampling locations since all Cf values were less than one.
\[ Cf = \frac{Cs}{C0} \]  

(1)

### Table 4. Description of contamination based on contamination factor.

| Contamination factor value | Description of contamination |
|----------------------------|------------------------------|
| \(< 1\)                    | low                          |
| \(1 \leq Cf < 3\)          | moderate                     |
| \(3 \geq Cf < 6\)          | considerable                 |
| \(Cf \geq 6\)              | high                         |

3.2.2. Contamination Degree

Meanwhile, Contamination Degree (\(Cd\)) is calculated by summing all individual contamination factors [8]. A modified version of this cumulative index was introduced by [9], named modified Contamination Degree (\(mCd\)). \(Cd\) and \(mCd\) values were calculated by using equation (2) and equation (3), respectively and shown in Table 3, where \(n\) is the number of analyzed samples and \(Cf\) is the contamination factor. This modified equation permits the inclusion of assorted heavy metals without the restriction of an upper limit. Table 5 explains the description of contamination based on the modified degree of contamination [9]. Results showed that \(Cd\) of the sediment samples was found in the range of 0.239-0.290, while the \(mCd\) is in the range of 0.080-0.097. Therefore, based on the description of contamination in Table 5, the potential of contamination is nil to very low degree for all sampling locations since all \(mCd\) values were less than 1.5.

\[ Cd = CfCd + CfPb + CfZn + \ldots + Cfn \]  

(2)

\[ mCd = k \sum \frac{Cf}{n} \]  

(3)

### Table 5. Modified degree of contamination classification and description.

| Modified contamination degree value | Description of contamination       |
|-------------------------------------|------------------------------------|
| \(< 1.5\)                           | Nil to very low degree             |
| \(1.5 \leq mCd < 2\)                | Low degree                         |
| \(2 \leq mCd < 4\)                  | Moderate degree                    |
| \(4 \leq mCd < 8\)                  | High degree                        |
| \(8 \leq mCd < 16\)                 | Very high degree                   |
| \(16 \leq mCd < 32\)                | Extremely high degree              |

3.2.3. Pollution Load Index

The Pollution Load Index (PLI) is defined by [10] were used for estuarine sediments based on baseline metal concentrations. In the present study, we used average crust abundance as background value for the metals in the same way as for the computation of the \(mCd\), since no such data was available for the study area. The PLI is used as a standardized system for detecting pollution which permits comparison of pollution levels between different sites and at different times [11]. The PLI for all sampling locations were determined using equation (4) and shown in Table 3, where \(n\) is the number of analyzed samples and \(Cf\) is the contamination factor. A PLI value of zero suggests absence of baseline pollutants, a value of one suggests that only baseline levels of pollutants are present, and values larger than one would suggest progressive deterioration of sediment quality [10]. Results show that PLI of the sediment [10]. Results show that PLI of the sediment samples was found in the range of 0.021-0.026. Therefore, it was suggested that absence of baseline pollutants for all sampling locations since all PLI values were less than one and nearly zero.

\[ PLI = \frac{(CfCd \times CfPb \times CfZn \times \ldots \times Cfn)}{n} \]  

(4)
3.2.4. Geoaccumulation Index (Igeo)

Geoaccumulation Index, Igeo illustrates the accumulation of metal elements in sediment compared to baseline data. The values of Igeo were calculated by implementing equation (5) \[12\] and as shown in Table 3, where Cs is the measured concentration of heavy metals in the sediment and C0 is the concentration of the same metal in the baseline sediments \[7\]. \[12\] also suggested seven classes of the Igeo as follows in Table 6. Results showed that Igeo in sediment samples was found in the range of, Cd: -2.769 to -10.952, Pb: -0.585 to -8.866 and Zn: -0.737 to -8.714. Therefore, based on the description of contamination in Table 3, all sampling sites were classified in Class 0 and considered unpolluted since all Igeo values were less than zero.

\[
Igeo = \log_2 (Cs/1.5C0) \tag{5}
\]

| Geoaccumulation index value | Classification | Description of pollution          |
|-----------------------------|----------------|----------------------------------|
| Igeo < 0                    | Class 0        | unpolluted                       |
| 0 < Igeo ≤ 1               | Class 1        | weakly polluted                  |
| 1 < Igeo ≤ 2               | Class 2        | moderately polluted              |
| 2 < Igeo ≤ 3               | Class 3        | moderately to strongly polluted  |
| 3 < Igeo ≤ 4               | Class 4        | strongly polluted                |
| 4 < Igeo ≤ 5               | Class 5        | strongly to extremely polluted   |
| Igeo > 5                   | Class 6        | extremely polluted               |

4. Conclusions

Contamination and pollution by anthropogenic or natural processes were assessed using contamination factors, pollution load index and geo-accumulation index. The potential of contamination is low for all heavy metals at all sampling locations since all Cf values were less than one. Since all mCd values were less than 1.5, it was indicated that the area studied is nil to very low degree of contamination for all sampling locations. It was suggested that absence of baseline pollutants for all sampling locations since all PLI values were less than one and nearly zero. All sampling locations were classified in Class 0 and considered unpolluted since all Igeo values were less than zero.

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