The Assessment of Sediment Quality in Northport Based on the Index Analysis Approach


Abstract—The coastal sediments of North Port of Malaysia was monitored from Nov. 2009 to Oct. 2010 to assess spatial distribution of heavy metals As, Cu, Cd, Cr, Hg, Ni, Zn and Pb. Sediment samples were collected from 6 stations. The geo-accumulation index (Igeo) and the enrichment factor (EF) were considered to assess sediment contamination degree based on background values. The results show that the concentrations of some metals, such as As, Cd and Hg were significantly higher than the background values. This is considered a critical environmental issue for this region. Spatial distribution maps of heavy metals would aid in the identification of pollution sources and vulnerable Stations.

Keywords—Heavy metals, Sediment Quality, North Port, Malaysia

I. INTRODUCTION

MARINE sediments are sensitive media for monitoring contaminants in aquatic ecosystems. The bottom sediments are a reservoir for heavy metals and therefore deserve special consideration in the planning and design of aquatic pollution research studies [1, 2]. According to Caeiro et al [2] the concentration of metal contaminants can be classified into three types which are (i) contamination indices—compare the contaminants with the clean or polluted stations measured elsewhere; (ii) Background enrichments indices—which compare the results for the contaminants with the baseline or background levels and (iii) ecological risk indices—which compare the results for the contaminants with Sediment Quality Guidelines (SQG).

These indexes are providing comprehensive assessment of environmental quality, planning and management for local and regional researchers [3]. Heavy metal contamination in sediment is a critical factor for evaluating potential environment effects because of the associated bio-toxicity, high environmental stability and high occurrence of bioaccumulation in the food chain [3, 4]. More studies indicated that in the aquatic environment, the minor quantities of some metals such as: copper, zinc, iron, manganese and nickel are essential for biological systems to function, but their excessive concentration can be toxic to living organisms. Other metals such as cadmium, mercury, arsenic and lead are non-essential, and therefore have toxic effects on living organisms [5]. Northport is strategically located midway on the West Coast of Peninsular Malaysia overlooking the world's busiest waterway, the Straits of Malacca. It is in the Free Commercial Zone of Port Klang, in the state of Selangor. It is further complemented by Malaysia's premier business township, the Klang Valley and is only 60 kilometers away from the federal capital, Kuala Lumpur. The main objectives of this research are; (1) to provide basic data of heavy metals concentration and compare these data with geochemical background value to assess impacts of the industrial and economic activities in the Northport (2) To use different types of indices to evaluate the sediment quality based on the heavy metal contamination. With regard to the importance of the Northport as an international shipping route, and ecological habitat, it is necessary to evaluate environmental properties in order to control pollution occurrence and protect living organisms.

II. MATERIAL AND METHODS

A. Study area

From November 2009 to October 2010, sediment samples were collected two times in year, from 6 stations where located along transects parallel to the berths line with three different distances (Fig 1). Sediments were collected in triplicate from surface of sediments by Petersen Grab sampler. Surface sediments were chosen for this study as this layer controls the exchange of metals between sediment and water.
B. Sampling and Experimental analysis

Sediment grain size was determined using a multi-wavelength particle size analyzer (model LS 13 320), and results were divided into sand (>64 μm), silt (2 μm < size < 64 μm) and clay (<2 μm) fractions for the determination of heavy metals in the contaminated soil [6, 7]. Total organic carbon (TOC) was measured in surface sediment by using a Perkin-Elmer 2400 carbon–hydrogen–nitrogen–sulfur (CHNS) elemental analyzer at a 950°C combustion temperature [6, 7]. Dried samples were sieved through a 2mm sieve, after that About 2g of the sediment to be used for metal analysis was treated with 2ml of 48% hydrofluoric acid (HF) and 2ml of 65% nitric acid3 (HNO3), heated to dryness, and allowed to cool. 0.5g of 99.99% boric acid was added to the cooled solution and the resulting suspensions was centrifuged. The decanted solution from the centrifugal operation was filtered using Whatman No. 40 filter-paper and the volume made up to 50 ml with demonized water for measurement of total concentration of heavy metals. Plasma mass spectrometry (ICP/MS) was used to analyze the following suite of metals: preparation procedure described above for the metal analyses is the same as the one adopted in [6]. The indexes used in this research were Enrichment Factor (EF) and Geo-accumulation Index (Igeo). The Geo-accumulation Index (Igeo) introduced by Muller are also used to assess metal pollution in sediments [8][9][10]. It is expressed as in Eq. 1, and [8][9][10].

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

Where Cn is heavy metal concentration in sediment of study area, Bn is the geochemical background value; I is the background matrix correction in factor due to lithogenic effects. The contamination level was classified in 6 scale: Igeo ≤ 0 = unpolluted, Igeo < 1 = unpolluted to moderately polluted, 1 < Igeo ≤ 2 = moderately polluted, Igeo 2 < Igeo ≤ 3 = moderately to strongly polluted, Igeo 3 < Igeo ≤ 4 = strongly polluted, Igeo 4 < Igeo ≤ 5 = strongly to very strongly polluted. Igeo > 5 = very strongly polluted [11, 12]. EF is estimated based on the concentration ratio of measured heavy metals to normalising elements (Al, Fe, Cs, Rb, Li, Si) in sediment samples that is divided by the ratio of metal background to the normalising elements [13].

\[
EF = \frac{C_{metal}/C_{normalizer}_{Soil}}{C_{metal}/C_{normalizer}_{background\,value}}
\]  

(2)

According to the enrichment factor, sediment is classified into groups by river, estuary and coastal environments. EF ≤ 2 indicates that metal contamination might be entirely from natural sources, an EF value of 2–5 indicates that a moderate portion of heavy metals originated from an anthropogenic source or non-natural process, an EF of 5–20 indicates that a significant portion are from anthropogenic sources, an EF of 20 to 40 indicates that a high portion of contamination is derived from anthropogenic sources, and an EF > 40 indicates an extremely high portion of contamination. [7, 14]

Statistical analyses were performed using Microsoft Excel and SPSS 17 software. To statistically evaluate the data, Kendall’s tau-b correlation analysis and the two-way ANOVA test (level of significant is 0.05) were employed to understand the relationship between heavy metals in sediment and other parameters. Geo-statistical analysis was performed using Surfer 8 software (GPS value of stations) based on geospatial methods to better understand contaminant pathways and to provide a comprehensive contour map of the spatial distribution of contaminants over a large area.

III. RESULT AND DISCUSSION

Analysis of sediment grain size demonstrated that fine-grained sediment (<64 μm) predominated at almost all stations (49.6–73.7%). The maximum of fine fractions were measured at stations close to the mangrove line. According to the Two-Way ANOVA, there is significant differences (p< 0.05, df= 21, f=8.82, sig= .00) between distribution of fine grained sediment at different stations and stations 3 and 6 were not homogenous to other stations. Several factors affected grain size variation in marine system, such as sediment transportation and sedimentary process [15, 16]. In this study, areas with high percentage of fine sediment were found near the mangrove forest. This may be due to the land-based runoff and sedimentary process of mangrove forests. Several studies showed that mangrove forests can increase the suspended solid deposition by decreasing the water dynamic energy and provide enough time for deposition of fine grain sediment [17-21]. The TOC content of sediment ranged between 10.08-17.04 and its concentrations were significantly different at different stations (p< 0.05, df= 21, f=10.10, sig= .00). The distribution of TOC follows the same pattern as fine-grained sediment in North Port with high concentrations at stations 3 and 6 (along the mangrove line) and the lower concentration at stations 2 and 5. the correlation analysis showed the high relation between the TOC and fine-grained sediment in study area(r= 0.716). Several research showed that TOC concentration increase when the mean grain size decreased because the fine particle size, particularly the clay colloid, has a high tendency to adsorb TOC [22]. According to Fig. 2, In North Port, the distribution of As, Cr, Hg, and Zn generally showed a bimodal pattern that varied from a high to low concentration from north to south and exhibited a high trend
to the east (along the berth line). The high concentration of Cu and Pb also occurred in the east direction and to the northwest. These areas are adjoining to land runoff and industrial outlets, which can directly release organic and inorganic pollutants. The distribution Cd showed the highest trend in the western part of the strait with the mangrove forest, which had the same distribution pattern of TOC and fine-grained sediment. The distribution Cd showed the same pattern with fine particle sized sediments and TOC distribution. The highest concentration occurred in the western part of strait and along the mangrove forest fringes, which was related to the higher concentration of TOC and fine grain size in mangrove sediment. In this study, there was a significant correlation \(0.4<r, P<0.01\) between fine particle size and the following metals: Cd (0.406), Cu (0.447) and TOC (0.716). The results indicate that these metals were better enriched in finer particles compared to the sand particles; therefore, high concentrations were estimated around the mangrove line. The distribution of Ni was unique because it was high along the mangrove coastline. Generally, the lowest concentration of metals (except for As) was found close to the stations 2 and 5 in North Port. This may be due to the strong water currents which decrease the chemical reactions between metals and sediments. Moreover, these stations had substrates with a high percentage of sand grain sized sediments compared to other stations.

### TABLE I

**Average and standard division (SD) of heavy metals concentrations (µg/g) and percentage of TOC and fine particle size in surface sediment during sampling periods**

<table>
<thead>
<tr>
<th>Stations</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>75.6</td>
<td>60.3</td>
<td>76.2</td>
<td>38.0</td>
<td>34.2</td>
<td>48.6</td>
</tr>
<tr>
<td>Cu</td>
<td>17.4</td>
<td>4.5</td>
<td>21.0</td>
<td>16.6</td>
<td>12.4</td>
<td>17.6</td>
</tr>
<tr>
<td>Cd</td>
<td>0.8</td>
<td>0.7</td>
<td>0.9</td>
<td>0.9</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Cr</td>
<td>44.4</td>
<td>5.0</td>
<td>44.5</td>
<td>40.0</td>
<td>30.3</td>
<td>37.7</td>
</tr>
<tr>
<td>Ni</td>
<td>11.1</td>
<td>4.5</td>
<td>10.5</td>
<td>12.4</td>
<td>6.2</td>
<td>11.8</td>
</tr>
<tr>
<td>Pb</td>
<td>58.6</td>
<td>47.6</td>
<td>68.5</td>
<td>53.2</td>
<td>47.4</td>
<td>48.9</td>
</tr>
<tr>
<td>Hg</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Zn</td>
<td>52.3</td>
<td>20.5</td>
<td>56.6</td>
<td>46.2</td>
<td>42.3</td>
<td>50.2</td>
</tr>
<tr>
<td>TOC</td>
<td>12.49</td>
<td>10.1</td>
<td>17.04</td>
<td>11.47</td>
<td>10.08</td>
<td>14.17</td>
</tr>
<tr>
<td>Fine particle</td>
<td>58.2</td>
<td>49.6</td>
<td>73.7</td>
<td>59.7</td>
<td>50.8</td>
<td>65.1</td>
</tr>
</tbody>
</table>
According to the Table 2, the average concentration of As, Cd, Pb and Hg are significantly higher than their background concentration in the North port while other metals are lower than background value. This implies that heavy metals are originated from many sources such as runoff due to rainfall and anthropogenic activities in the study area. These sources cause disturbance in environment and change geochemical concentrations ratio of metals and increase metals concentration from their background value. Generally more research stated that, when geochemical metals concentration suffered from disturbance due to potential change in environmental, the relative concentration ratio of metals goes beyond their background levels in sediment [23, 24]. Moreover table 2 shows the sediment quality according ecological indexes. According to the Geo-accumulation Index, Zn, Cu, Cr and Ni elements are unpolluted, Pb is moderately polluted, As and Hg elements are highly polluted and Cd element is very highly polluted. The enrichment factor (EF) was also applied to evaluate sediment quality in surface sediments. The EF value of Zn, Ni, Cr and Cu were between $2 < EF < 5$, indicating that the sediment of North Port had moderate anthropogenic inputs of these heavy metals. There were significant enrichment of Pb, As, Hg and Cd in sediments, which suggests that a significant proportion of these metals were from anthropogenic sources exception Cd that was highly derived from anthropogenic sourced. According to these results heavy metal contamination in marine sediments of North Port was attributed human activities (anthropogenic) and its sediments were considered to be polluted with Cd, As and Hg.

### Table II

<table>
<thead>
<tr>
<th>Metal</th>
<th>Metals concentration in present study</th>
<th>Heavy metal Background value</th>
<th>Igeo Index</th>
<th>Enrichment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>55.48</td>
<td>18.3</td>
<td>5.3</td>
<td>19.67</td>
</tr>
<tr>
<td>Cu</td>
<td>14.9</td>
<td>23.21</td>
<td>0</td>
<td>4.6</td>
</tr>
<tr>
<td>Cd</td>
<td>0.83</td>
<td>0.18</td>
<td>8.7</td>
<td>27.9</td>
</tr>
<tr>
<td>Cr</td>
<td>33.65</td>
<td>53.71</td>
<td>0</td>
<td>4.7</td>
</tr>
<tr>
<td>Ni</td>
<td>9.41</td>
<td>32.77</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Pb</td>
<td>54.03</td>
<td>39.8</td>
<td>0.3</td>
<td>9.06</td>
</tr>
<tr>
<td>Hg</td>
<td>0.18</td>
<td>0.08</td>
<td>4.1</td>
<td>16.22</td>
</tr>
<tr>
<td>Zn</td>
<td>44.68</td>
<td>141.22</td>
<td>0</td>
<td>2.02</td>
</tr>
</tbody>
</table>

### IV. Conclusion

The extent of pollution was clarified by the use of the spatial distribution map and geo-statistical index to assess the degree of contamination of surface sediments at spatial scales. This data revealed that the geo-statistical index of sediments is in a pristine state with respect to metal contamination, except for Cd, As and Hg. Furthermore the concentration of Cd, As and Hg were significantly greater the background value. Therefore these metals can be considered as serious threat to biological communities and human health. In summary, the present study has provides basic data for the first time in North Port which is useful for long-term monitoring of heavy metal pollution in future.

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### References
