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Sediment Heavy Metals Distribution in Relation to Grain Size at Johor Port: East Coast Peninsular Malaysia

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Abstract: A total of 20 surficial sediment samples were collected from Johor Port, East Coast of Peninsular Malaysiaon May 2014 by using Smith McIntyre grab. These sediments were analyzed for its grain size using particle size analyzer (PSA) to find out the relationship between grain size and heavy metal concentrations. The concentration of heavy metals were measured from the 63 um fraction of the dried sediments and analyzed using ICPMS. The heavy metals studied were: Fe, Mn, Zn, Cr, Cu, Ni, Pb, As, Co, Cd and Hg. Results showed that the study area was dominated with silt loam (90%) and same percentages of loamy sand (5%) and sandy loam (5%). Based on the results, generally the sediments in the study area were fine. For heavy metals concentration, Fe concentration ranged from 3.52%-4.70%, 75.28-411.96µg/g for Cr, 18.86-1886.05µg/g for Mn, 4.56-10.66µg/g for Co, 15.47-314.85µg/g for Ni, 25.15-212.72µg/g for Cu, 86.22-721.36µg/g for Zn, 10.18-19.68µg/g for As, 0.38-1.26µg/g for Cd, 38.91-138.61µg/g for Pb and 0.10 -0.49µg/g for Hg on dry weight basis. The trend of mean concentrations of these heavy metals in a decreasing manner was: Fe >Mn> Zn > Cr > Cu > Ni >Pb> As > Co > Cd > Hg. Enrichment factor (EF) is used to evaluate the dominant source of the elements and as indication of pollution. The mean EF for Cr, Mn, Co and Ni shows a deficient or minimal enrichment which indicated that these heavy metals were of natural origin. Moderate enrichment for Cu, Cd and Hg was observed which is an indication of minor enrichment while As Zn, and Pb, shows a significant enrichment which is an indication of anthropogenic sources.

Key words: Sediments, heavy metals, grain size, Johor Port, Malaysia, pollution.

1. Introduction

Heavy metals are one of the most serious pollutants in our natural environment due to their toxicity, persistence and bioaccumulation problems [1]. Heavy metals are non-degradable and are detoxified by binding to certain proteins or metallothionein or depositing them as granules. All heavy metals exists in surface water in colloidal form, particulate and dissolved phases, although dissolved concentration are generally low [2]. Pollution or contamination may come from atmospheric inputs, natural disasters and also anthropogenic activities. The anthropogenic activities are one of the major contributors towards pollution such as mining and industrial processing of ores and metals also one of the factors that may contribute to the contamination of the ocean.

Sediments are considered as an important indicator for environmental pollution; they act as permanent or temporary traps for materials spread into the environment [3]. Another important factor that influences heavy metal concentration in sediments is the geochemical properties of the sediment. It has shown that the amount of heavy metal retention in sediment is affected by sediment characteristics such as; grain size, cation-exchange capacity (CEC), organic matter and mineral constituents [4]. Average contents of most elements increase with the decrease of grain size due to high surface area to grain size ratio. Few studies [5] found that metal concentrations in sea water within South China Sea off Kemaman coast region are generally comparable except in certain areas that may be polluted by certain metals due to agricultural, industrial run-off and effluent

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discharges. This study was conducted to assessed pollution status in the study area.

2. Materials and Methods

2.1 Description of the Study Area

Johor Port is located at the southern-most tip of Peninsular Malaysia. It is near the town of PasirGudang and close to Singapore-Johor Strait known as the Tebrau Strait, a narrow sea that separates Johor, Malaysia with Singapore which is approximately about 60km between the mouth of Sungai Pulai and mount of Sungai Johor. Johor Port is most strategically positioned in the heart of the sprawling 8,000-acre PasirGudang Industrial Estate. PasirGudang Port is linked to the important commercial and also industrial centers in Malaysia as well as other ports and neighboring countries. Nowadays, PasirGudang Port is the largest palm oil terminal in the world, ranked 6 out of 35 worldwide LME accredited ports, and the main gateway for Southern Malaysia’s import/export requirements. Johor Port is also near Johor Bahru city central area, industrial area and a wide range of development area. This made the sources of water pollution problems that occur in Johor Strait. Johor Port also is a strategic route for trading ships.

2.2 Collection of samples

Surface sediment samples were collected from 20 stations using a Smith McIntyre grab. The sediments were taken from the middle of the grab with plastic scope to avoid contamination then was put in an acid-washed plastic bag and kept frozen until ready for analysis.

Figure 1 shows the location of sampling stations in the study area.

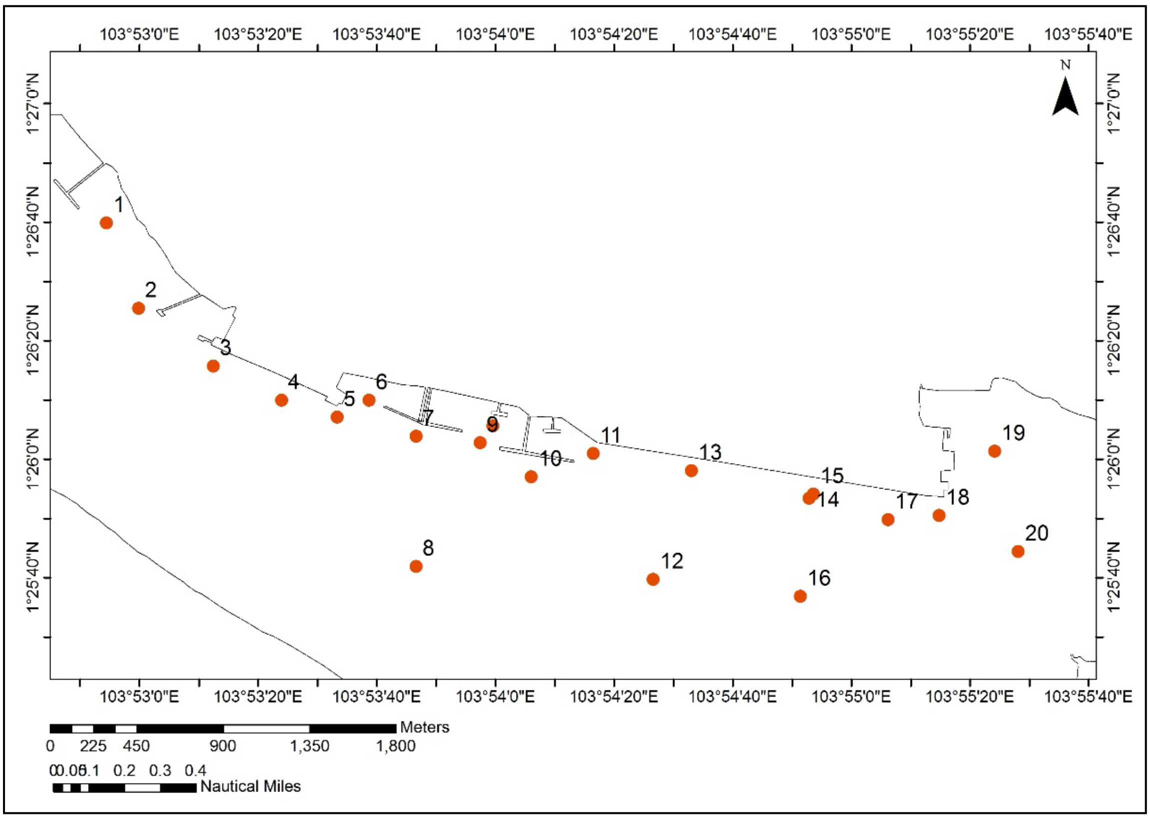


Fig. 1 Location of stations in the study area.

2.3 Sample Preparation

The sediment samples were dried at 150ºC for 7 hours then lightly ground to break up the particles and sieved through a 63µm mesh. The samples were then kept in a cleaned polyethylene bottles.

2.4 Determination of Heavy Metals: Microwave Digestion

Sediment samples were digested for metal contents following standard methodologies with some modifications [6]. The digestion procedure involved heating of 0.05g sediment sample in a sealed Teflon vessel with a 1.5ml mixed acid solution of concentrated HNO3, HCl and HF with 3:3:1 ratio. The vessel was heated at 150°C for 7 hours. After cooling to room temperature, the digested sample was transferred into 15ml centrifuge tube and diluted to 10ml with ultra-pure water. For the validation method, a certified reference material NBS 1646a estuarine sediment was analyzed and digested to determine the recovery levels and accuracy of heavy metal analysis. The recoveries for all metals ranged between 91.08%-137.5% with slightly higher recoveries obtained for Pb and Hg. Heavy metals were analyzed using an inductively-coupled plasma mass spectrometer (ICP-MS). A certified reference material, estuarine sediment (NST1646a) was used as a precision check. The percentage of recoveries for certified and measured concentration was satisfactory, with recoveries of 81.66%-118.48%.

3. Results and Discussion

Table 1 shows the concentrations of heavy metals in the study area. Results showed that Fe ranged from 3.52%-4.70%; 75.28-411.96µg/g for Cr; 18.86-1886.05µg/g for Mn; 4.56-10.66µg/g for Co; 15.47-314.85µg/g for Ni; 25.15-212.72µg/g for Cu; 86.22-721.36µg/g for Zn; 10.18-19.68µg/g for As; 0.38-1.26µg/g for Cd; 38.91-138.61µg/g for Pb and 0.10-0.49µg/g for Hg. Highest concentration of Fe, Zn, Cd and Pb were recorded at station JB19 with values of 4.70%, 721.36µg/g, 1.26µg/g and 138.61µg/g, respectively. Furthermore, the highest concentration of Cr, Co, Ni was found at station JB7 with values of 411.96µg/g, 10.66µg/g and 314.85µg/g, respectively. Highest concentration of Cu and Hg can be found at station JB6 with values of 212.72µg/g and 0.49µg/g. Mn and As however, were found to have highest concentration at stations JB17 and JB12 with values of 1886.05µg/g and 19.68µg/g, respectively. Taking into account that Johor Port is one of busiest port in the region, significant increase in the concentration of heavy metals cannot be hidden. The used of antifouling paints that protect vessels from microorganisms which can be washout and being leached from the paints could elevate the heavy metals in the study area. The highest concentration of As in JB10 reflects from agricultural activities such as palm oil plantation. It is known that many agricultural products needed such as; fertilizers, pesticides, insecticides and others contain As in various forms in high concentrations. In addition, as Johor Port is a main hub for bulk operation, such as grain, iron ore and coal, this could elevate higher concentration of As. As is a natural component of Pb, Zn, Cu and gold-bearing ores and consequently can contaminate the sediment during mining and smelting operation. For Pb however, the atmospheric deposition of Pb mainly focuses in station JB19 through emission from automobiles. In addition, the traffic intensity in and around the Johor Port carrying bulk goods can significantly contributed to the significant enrichment of Pb in the area. Furthermore, leaded fuel, lubricating oil and grease from anchored boats transporting the goods are possible sources of Pb.

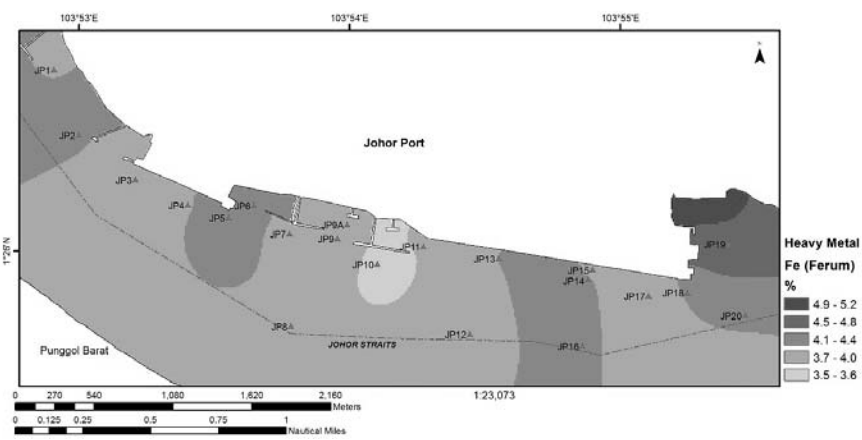
Lowest concentrations of Fe and Cr can be found at station JB10 with values of 3.52% and 75.28µg/g, respectively. The lowest concentration of Mn, Co, Ni, Cu, Zn and Pb were found at station JB12 with values of 18.86µg/g, 4.56µg/g, 15.47µg/g, 25.15µg/g, 86.22µg/g and 38.91µg/g, respectively. As for As, lowest concentration can be found at station JB9 (10.18µg/g). The lowest concentration of Cd can be found at station JB8 (0.38µg/g), while for Hg, lowest concentration was found at station JB7 (0.10µg/g). The lowest and highest concentrations of heavy metals might be due to the texture and mineralogy of the sediments in the study area (see Table 2). The trend of mean concentrations of heavy metals was Fe > Mn > Zn > Cr > Cu > Ni >Pb> As > Co > Cd > Hg.

Figures 2 to 7 show the distribution patterns of heavy metals in the study area.

Figures 8 to 10 show the distribution patterns of %sand, %silt and %clay in the study area.

Table 1 Heavy metals concentration in surface sediment of Johor Port (µg/g dry weight) and % for Fe.

	Fe	Cr	Mn	Co	Ni	Cu	Zn	As	Cd	Pb	Hg
JB1	3.98	77.88	1053.05	8.79	41.06	123.38	261.09	12.69	0.61	63.44	0.19
JB2	4.09	80.52	1227.54	8.91	41.72	99.40	273.24	12.10	0.65	58.07	0.19
JB3	3.66	75.67	942.91	9.18	46.26	90.94	255.70	10.55	0.68	61.01	0.12
JB4	3.94	71.79	1864.54	8.03	38.05	85.06	252.78	14.06	0.63	57.16	0.19
JB5	4.37	90.18	1594.06	8.18	49.70	99.60	310.68	14.38	0.61	54.44	0.30
JB6	4.31	189.74	189.46	7.92	234.59	212.72	689.65	11.65	1.01	80.10	0.49
JB7	3.72	411.96	934.65	10.66	314.85	101.19	259.20	10.42	0.53	46.72	0.10
JB8	3.77	81.79	1151.09	8.37	37.97	60.24	182.10	11.65	0.38	47.90	0.13
JB9	3.81	86.64	788.54	7.55	51.38	100.00	327.85	10.18	0.68	53.74	0.16
JB10	3.52	75.28	276.00	7.88	45.20	61.00	207.79	15.52	0.50	55.58	0.15
JB11	3.63	90.16	958.33	7.64	38.69	79.76	275.58	11.23	0.51	56.33	0.17
JB12	3.85	81.72	18.86	4.56	15.47	25.15	86.22	19.68	0.48	38.91	0.15
JB13	4.00	90.81	781.07	10.56	49.90	80.28	277.90	13.53	0.60	74.74	0.26
JB14	4.06	88.73	1422.31	8.95	36.65	77.29	302.58	13.67	0.64	78.07	0.16
JB15	3.89	92.52	884.69	10.66	45.73	85.09	284.08	13.24	0.76	68.37	0.15
JB16	4.05	83.98	729.62	10.34	38.77	54.47	165.00	14.63	0.41	61.81	0.14
JB17	3.83	88.68	1886.05	8.18	35.56	71.51	298.42	12.10	0.60	65.41	0.15
JB18	4.04	82.22	1736.11	9.15	33.73	73.21	293.44	13.41	0.60	65.66	0.14
JB19	4.70	124.78	598.04	10.30	54.31	152.55	721.36	13.45	1.26	138.61	0.27
JB20	4.08	97.95	1025.15	9.89	41.01	67.70	249.31	14.04	0.41	61.11	0.14



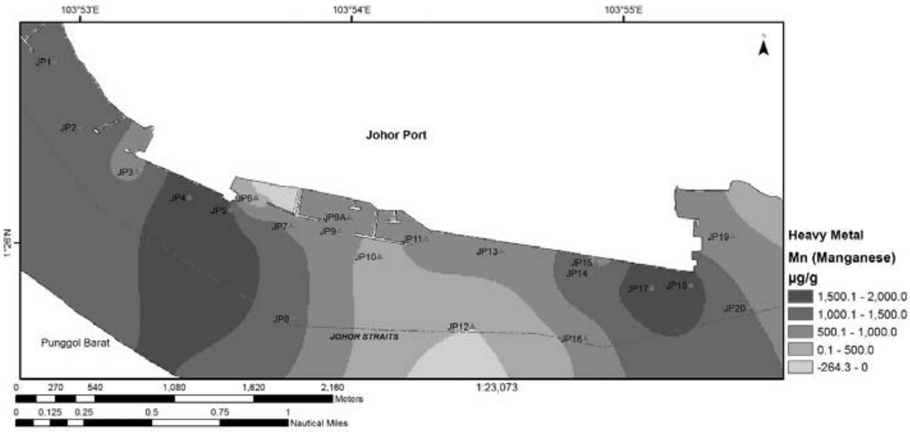


Fig. 2 Distribution patterns of (a) Fe and (b) Mn at Johor Port.

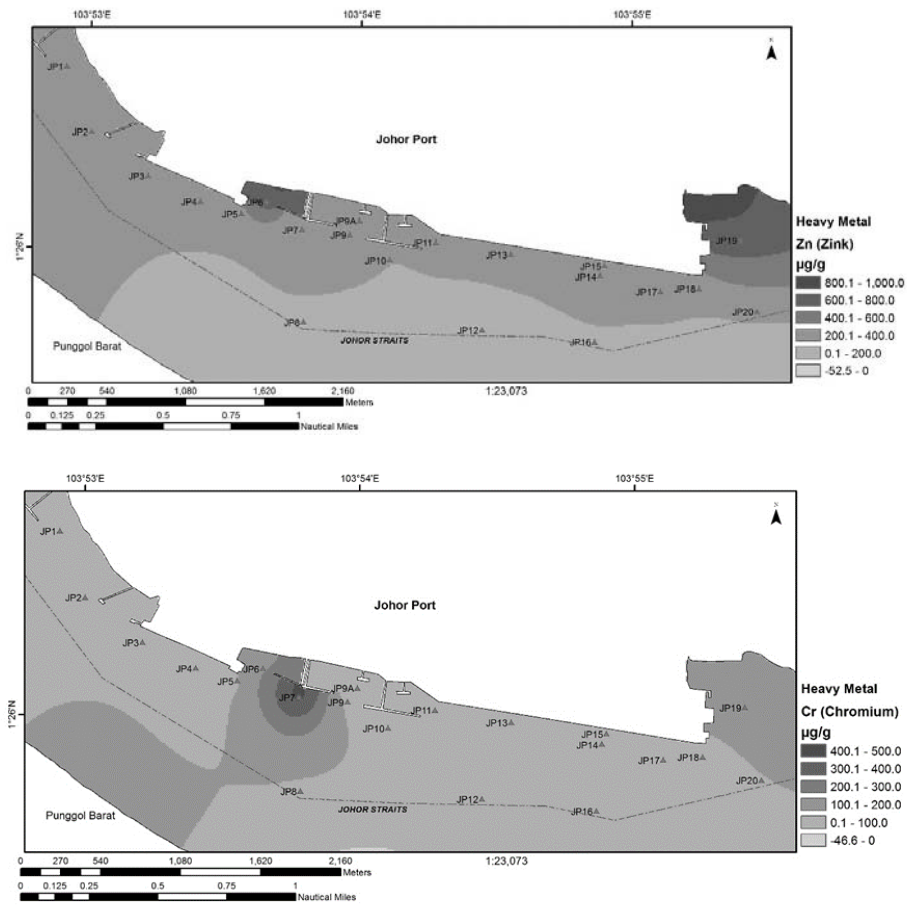


Fig. 3 Distribution patterns of (a) Zn and (b) Cr at Johor Port.

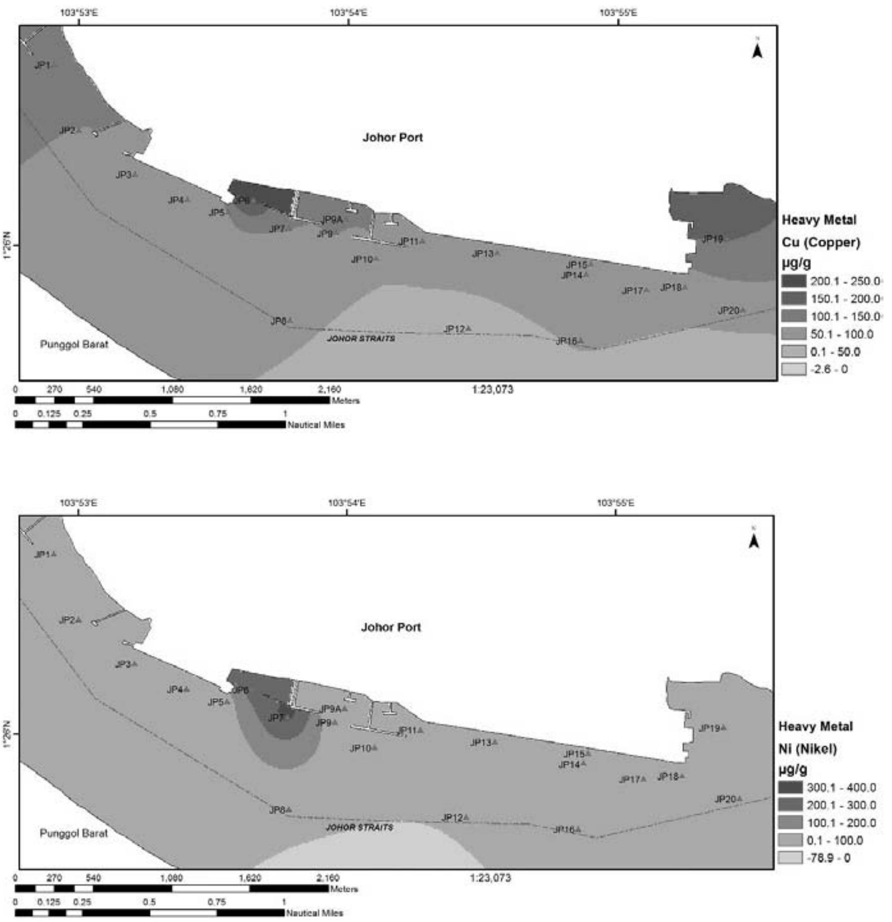
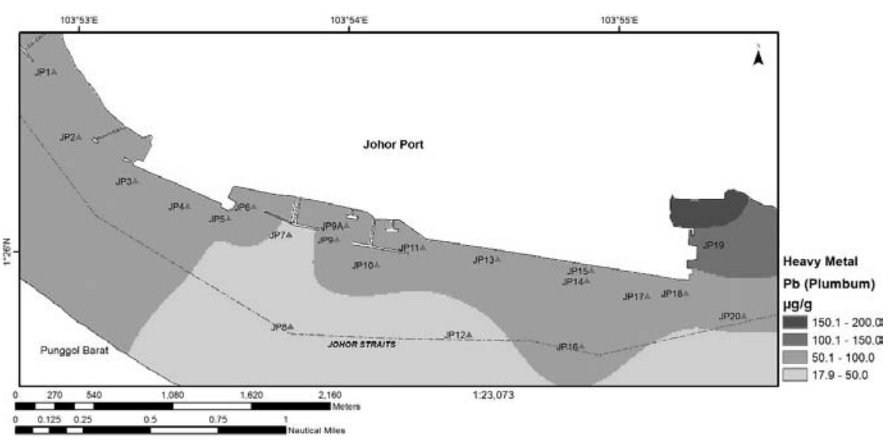


Fig. 4 Distribution patterns of (a) Cu and (b) Ni at Johor Port.



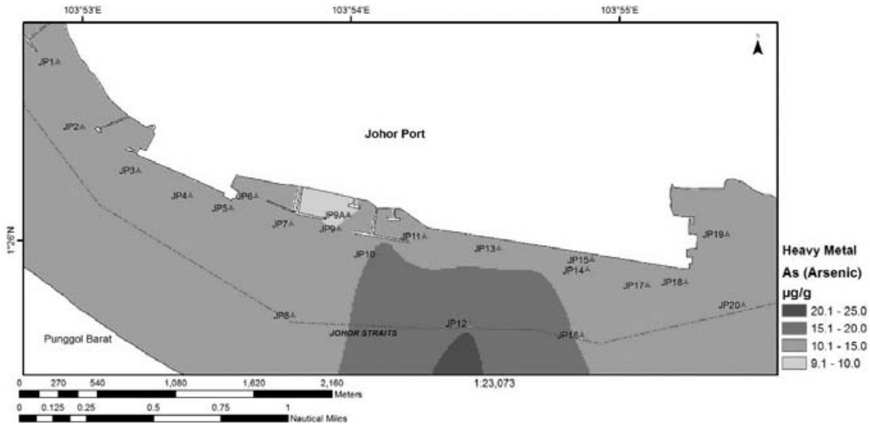


Fig. 5 Distribution patterns of (a) Pb and (b) As at Johor Port.

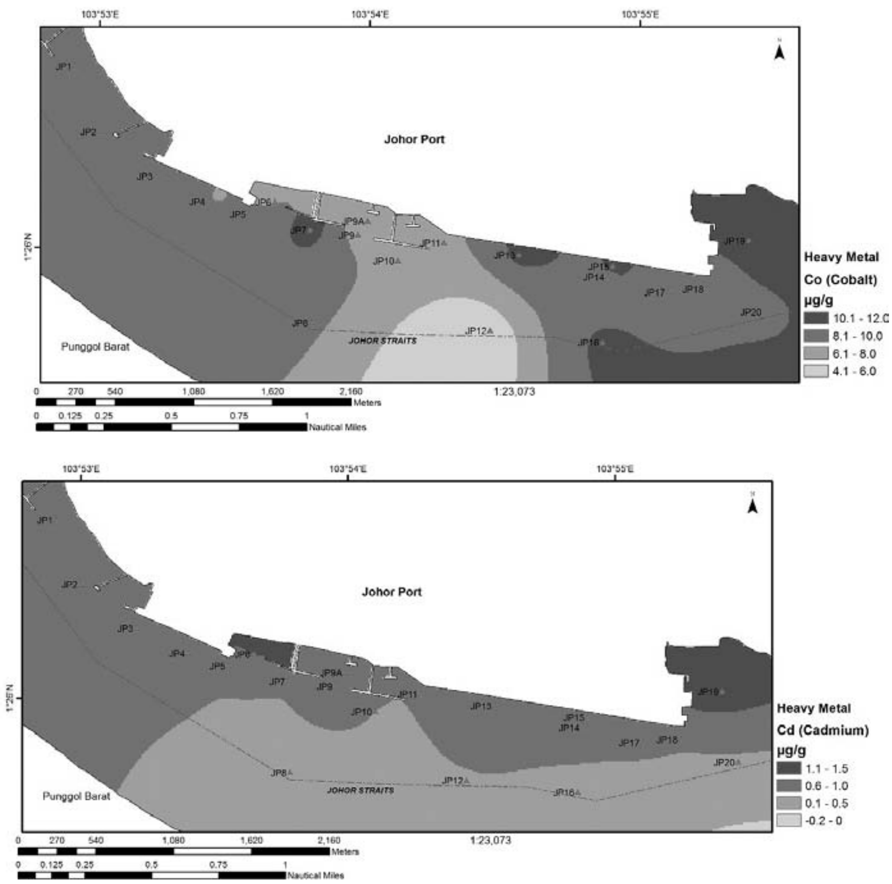


Fig. 6 Distribution patterns of (a) Co and (b) Cd at Johor Port.

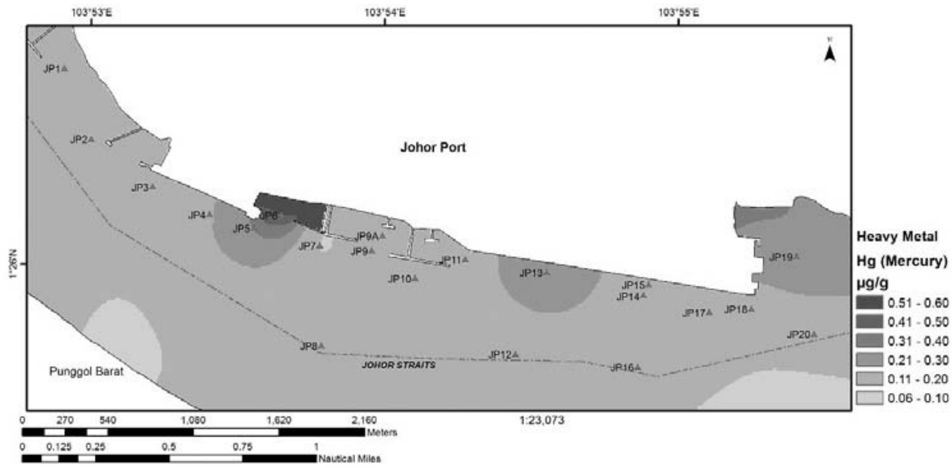


Fig. 7 Distribution patterns of Hg at Johor Port.

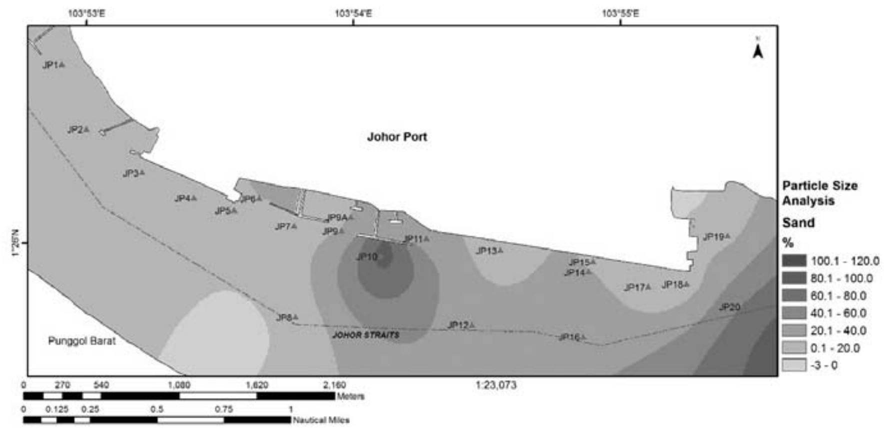


Fig. 8 Distribution patterns of %sand in the study area.

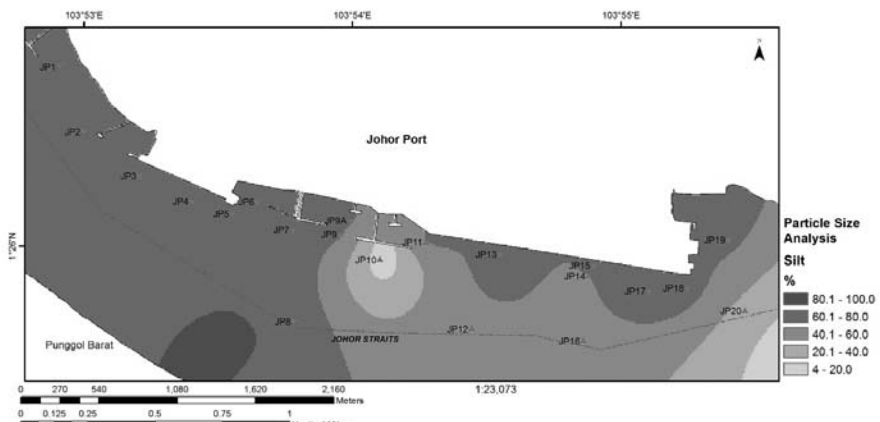


Fig. 9 Distribution patterns of %silt in the study area.

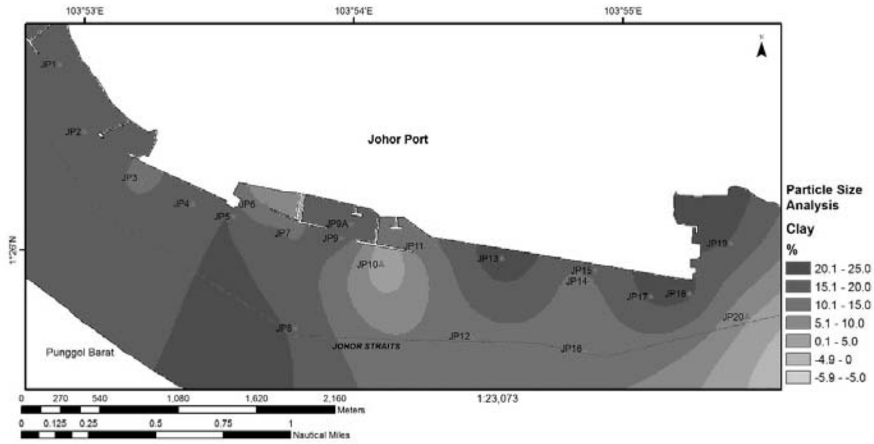


Fig. 10 Distribution patterns of %clay in the study area.

Table 2 %sand, %silt and %clay and textural classes of the sediments in the study area.

Station	% Sand	% Silt	% Clay	Sediment Texture
JB1	16.76	64.9	18.34	Silt Loam
JB2	7.14	75.05	17.81	Silt Loam
JB3	12.69	72.76	14.55	Silt Loam
JB4	18.38	65.05	16.57	Silt Loam
JB5	5.23	75.52	19.25	Silt Loam
JB6	19.05	70.42	10.53	Silt Loam
JB7	14.06	71.49	14.45	Silt Loam
JB8	6.69	73.99	19.32	Silt Loam
JB9	21.03	61.81	17.16	Silt Loam
JB10	84.24	13.36	2.4	Loamy Sand
JB11	27.47	59.07	13.46	Silt Loam
JB12	33.08	54.07	12.85	Silt Loam
JB13	9.13	67.09	23.78	Silt Loam
JB14	26.73	59.07	14.2	Silt Loam
JB15	6.65	75.25	18.1	Silt Loam
JB16	30.06	56.06	12.88	Silt Loam
JB17	7.44	71.87	20.69	Silt Loam
JB18	8.99	70.14	20.87	Silt Loam
JB19	14.65	65.8	19.55	Silt Loam
JB20	61.61	32.67	5.72	Sandy Loam

4. CONCLUSION

In general, higher levels of heavy metals studied were found at stations with fine texture. Fine sediments absorbed most heavy metals due to its binding agents like clay and organic matter. Lower concentrations of most heavy metals are found in areas which have coarser sediments. In general, coarse sediments holds less heavy metals compared to fine sediments.

Enrichment of heavy metals like Pb and As might be due to anthropogenic sources like emissions from vehicles and agriculture activities.

References

[1] N.F.Y. Tam, W.S. Wong, Spatial variation of heavy metals in surface sediments of Hong Kong mangrove swamps, Environmental Pollution 110 (2000) 195-205.

[2] M.J. Kennish, Practical Handbook of Estuarine and Marine Pollution, CRC Press, 1996, pp. 524.

[3] I. De Gregori,H. Pinochet, M. Arancibia, A. Vidal, Grain-size effect of trace metals distribution in sediments from two coastal areas of Chile, Bull Environ Contam Toxic Pollut 57 (1996) 163-170.

[4] A. Vertacnik, E. Prohic, S. Kozar, M. Juracic, Behavior of some trace elements in alluvial sediments, Zagreb water-well field area, Croatia, Water Research 29 (1995) 237-46.

[5] M.C. Ong, B.Y. Kamaruzzaman, An assessment of metal (Pb and Cu) contamination in bottom sediments from South China Sea coastal waters, Malaysia., American Journal of Applied Science 6 (7) (2009) 1418-1423.

[6] B.Y. Kamaruzzaman, Geochemistry of the Marine Sediments: Its Paleoceanographic Significance, Ph.D. Thesis, Hokkaido University, Japan, 1999.