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Assessment of heavy metals contamination and its ecological risk in the surface sediments of al-mukalla coast, Yemen

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Abstract Surface sediments from selected sites of Al-Mukalla coast were sampled for the geochemical and environmental assessment of eight of heavy metals (Cr, Cu, Ni, Zn, Mn, Cd, Pb and Fe). The concentration of heavy metals were digested by using 3-steps acid attack in closed Teflon bombs system and measured by AAS. The results of this study showed that the concentration of heavy metals (µg/ g) were as follows: Cr (6.65-25.58); Cu (13.55- 39.95); Ni (11.71- 28.85); Zn (17.4- 74.61); Mn (28.95 -143.16); Cd (0.89- 2.83); Pb (5.65-20.13) and Fe (814, 08-2- 2999.89). They indicate that sediment grain size and total organic carbon did not play an important role in controlling the distribution of metals. Sediment quality guidelines and geochemical normalization methods were used to judge the potential risk and accumulation of metals.The results of their calculations indicated that the Cd was recorded high to very high degree of contamination, whereas the other metals ranged between uncontamination to moderate contamination degree. Pb, Cu, Zn, Ni, Fe and Cr recorded low risk comparing with Cd that pose very high risk to marine organisms in local ecosystem.

Keywords Contamination, metals, Sediments,Al-Mukalla; Yemen

Introduction

The marine environments of Yemen are subjects to contamination by organic and inorganic contamination. Heavy metals concentrations in coastal environment have been rapidly increased by human activities because the coastal environments are subjected to metals contamination throughout various inputs such as natural, industrial and urban sources. Coastal sediments are polluted by various contaminants arising from urbanization extended, domestic wastes, industrial processes, agricultural activities, and atmosphere deposition.

Sediments act as sinks for contaminants in marine environments. It can act as a scavenger agent for heavy metals and an adsorptive sink. It is therefore considered to be an appropriate indicator of heavy metals contamination. Sediments are more easily impacted by the negative factors of anthropogenic activities due to their close relationship with the water and atmosphere [1].

The amounts of most heavy metals deposited from anthropogenic activities are many times greater than depositions from natural background sources [2]. Metals are one of the serious contaminants in the environment due to their toxicity, persistence and bioaccumulation problems. They pose many adverse effects on human health during the food chain. The assessing sediment toxicity is very important to protect aquatic organisms from the harmful and toxic effects of polluted sediment. It is a useful tool for evaluating the potential of contaminants to persuade biological effects [3-4].

Few authors [5-8] studied the contamination in Gulf of Aden and recommended by the needing to more studies in different sites in the eastern of Gulf of Aden and Arabian Sea at Yemen, in order to monitor the contamination and constructing real base data of heavy metals contamination.

Many environmental problems, including the metal contamination and ecological stress in the Gulf of Aden and Arabian Sea are a major concern of all countries in the region. So, the present study aims to determine the spatial distribution; evaluate the contamination status of selected metals (Cr, Cu, Ni, Zn, Mn, Cd, Pb and Fe) in the surface sediments of Al-Mukalla coast and recognize the potential ecologicalrisk of these metals.

Material and Methods

Sampling and Samples Pretreatment

The study area is located within the latitude and longitude of 14° 40' and 14° 70' N and 49° 00' and 49° 43' E in the east of Yemen at Al-Mukalla city**.** Thirteen Surface sediment samples were collected in September 2011 from Al-Mukalla coast (Fig.1).During sampling, precautions were taken to minimize any disturbance in the original sediment. All materials used for treatment and storage of sediment samples were non-metallic.

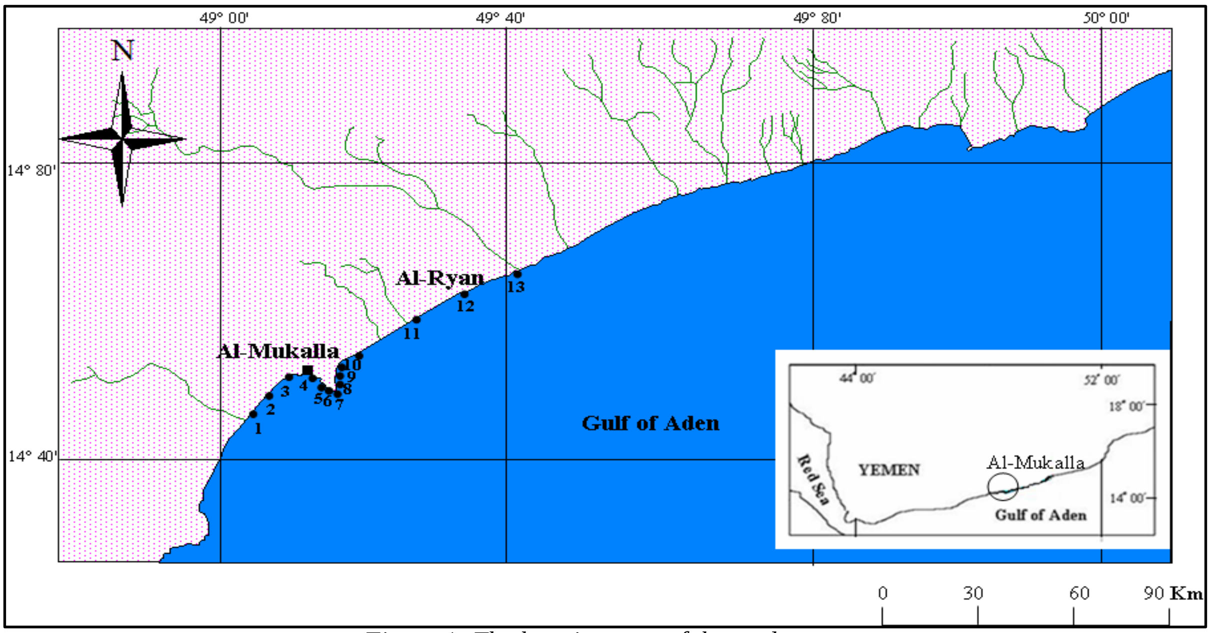

Figure 1: The location map of the study area

After collection, the samples were placed in tightly sealed plastic containers, and then transported to Laboratory and preserved in a refrigerator at 3°C until they were transported to the Department of Environmental Sciences, Faculty of Science (Alex University), Egypt. Before determination of metals concentration, sediment samples were freeze-dried and homogenized using a mechanical agate mortar.

Sample Analyses and Quality Control

The dry sediment samples were divided into two portions. The first portion was used for physiochemical parameters (TOM, $CaCO_3$ and grain size) and the second portion was used for chemical analysis. The total organic matter content (TOM) was determined by the method of loss in weight by ignition describing [9] and $CaCO_3$ was determined by titration technique [10]. Sediments grain size was determined by the procedure of [11] utilizing sieving to separate gravel and sand fraction from the clay and silt fractions. The total metals concentration (Cr, Cu, Ni, Zn, Mn, Cd, Pb and Fe) were determined by dissolving 0.5 gram in closed Teflon bombs in an oven for 24 hrs by using 3-steps acid attack (HNO_3, HCl and Boric acid) [12].

After completing cooling, the digested solution was then diluted to a final volume of 25 ml with double deionized water and measured by AAS (Perkin Elmer).All reagents were of extra pure quality, and all lab wares used were either new or thoroughly cleaned before utilization.

The quality assurance and quality control were controlled by method blanks, sample duplicates, randomly sample replicates and metals analysis data were checked using reference certified international marine sediments (BCSS1). There was no sign of contamination in the analysis (metal concentrations in the blanks <1% of the sediment samples), and all of the relative standard deviations of the replicate samples were <10%. The recovery rates for most of the metals in BCSS1 ranged between 92% and 105%. The relative variation factors of duplicates were < 17%. Four sets of TOC duplicate digests lead results consistent within 10%.

Data processing

Spatial distribution patterns of heavy metals were demonstrated by means of software SPSS version 10.0. Different modules of the statistical software such as the linear correlation method and the Factor Analysis were used to elucidate the relationships between heavy metals (Cr, Cu, Ni, Zn, Mn, Cd, Pb and Fe) and physiochemical characteristics (TOM, $CaCO_3$, Sand and Clay). The contamination status of metals in sediments of the study area was assessed by Sediment Quality Guidelines as well as by the Enrichment Factor [13], Anthropogenic Factor [14], Contamination Factor [15], Geoaccumulation Index [16], Degree of Contamination [17], Potential contamination index [18] and Potential ecological risk factor and Ecological risk index [19].

Result and Conclusion

Physico-Chemical Distribution

The results of particle size, total organic matter (TOM), total carbonate percentage ($CaCO_3$) and heavy metals in the surface sediments of Al-Mukalla coast are given in Table 1. The range and average value of $CaCO_3$were found to vary from about 29.67% to 55.87 % (Av: 41.68%). The simple variation of $CaCO_3$ content may be probably due to the nature and the extents to which sediment source materials are mixed. Sediment components in the study area consist mainly of carbonate. The relative percentage of clay and sand were in the range between (0.98–7.62) % for clay and (92.38–99.2) % for sand. Thesediments of the study area characterized by extensive sandy substrates that are extended the sandy beaches to more than 100 meters deep also distinguish the coast of the region [20].

The maximum concentration of TOM found in station M12 (0.39%) near the intermittent stream in the eastern part of Aryan airport, whereas the minimum concentration was recorded in station M1(0.12%). Generally no significant variation of TOM except thestations in Al-Mukalla port (M5,M6 and M7) which affected by port activities, organic waste of fisheries and wastewater, and stations (M12 and M13) which affected by waste water and the flow of intermittent stream in the eastern of Aryan Airport.

Spatial distribution of metals

The results of metals measured in sediments are shown in Figure2. The range and average concentration (μg/g) were: 6.65- 25.58 (14.09) for Cr, 6.84- 49.80 (24.57) for Cu, 11.71 - 25.85 (17.29) for Ni, 17.40– 75.09 (62.13) for Zn, 28.95-143.16 (81.64) for Mn, 0.89-2.83(2.04) for Cd, 5.65-20.13 (13.17) for Pb and 814.08-2999.89 (1719.01) for Fe. The content of metals in the sediments ordered to the following: Fe> Mn> Zn> Cu> Ni> Cr> Pb> Cd. Station M6 was recorded the highest contents of Cr, Cu, Ni, Zn, Mn, Cd, and Pb, whereas station M1 recorded low contents of Pb, Cd, Zn and Cu.These high contents of metals in M6 might be related to different activities of Al-Mukalla port. Station M13 recorded relatively high content of Pb (18.17μg/g). This station located between the oil terminal port and the internment stream.

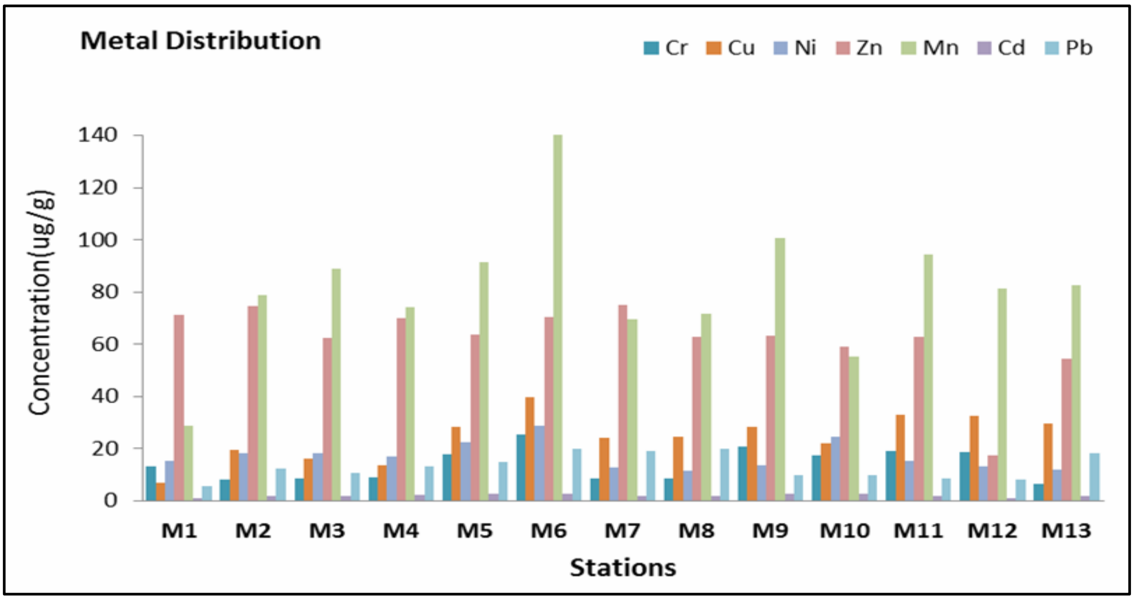

Figure 2: Distribution of heavy metals in sediments of Al-Mukalla coast

A correlation matrix between heavy metals and other characteristics of the sediments are shown in Table 2. It shows that the correlation of Cu with Mn, $CaCO_3$ is relatively strong (r= (0.78, 0.68 and 0.64) but the correlation between others parameters such as Fe with Cr, Cu, Ni, Mn, Cd, Pb, organic matter, $CaCO_3$ and clay fraction are not too strong (r =0.41, 0.56, 0.53, 0.25, 0.58, 0.26 and 0.46, 0.58 and 0.26 respectively). The negative correlation between organic matter and clay fraction (r = -0.50) shows that organic matter is non important component in the clay fraction. The negative correlations although they are not significant, illustrate the inverse relationships between clay and some metals such as Cr, Cu, Ni and Mn. Metals with strong positive correlations are thought to have the same origin, while those with strong negative correlations are believed to have different sources [21].

It is clear that the distribution of metals in Al-Mukalla coast is controlled by other factors. The Concentration of the investigated metals for the most stations substantially lower and fell within the ranges reported previously for these elements in Gulf of Aden [6- 9] and the neighboring coastal area [22, 23].

Table 1: Correlation matrix of sediments in Al-Mukalla Coast

	Cr	Cu	Ni	Zn	Mn	Cd	Pb	Fe	Clay	Sand	$CaCO_3$	TOM
Cr	1.0											
Cu	0.59*	1.0										
Ni	0.54*	0.20	1.0									
Zn	-0.22	-0.36	0.24	1.0								
Mn	0.52*	0.78*	0.41	-0.02	1.0							
Cd	0.40	0.40	0.63*	0.31	0.61*	1.0						
Pb	-0.21	0.40	0.10	0.29	0.43	0.41	1.0					
Fe	0.41	0.56*	0.53*	-0.42	0.25	0.58*	0.26	1.0				
Clay	-0.26	-0.11	-0.14	0.37	-0.10	0.32	0.27	0.10	1.0			
Sand	0.26	0.11	0.14	-0.37	0.10	0.32	-0.27	-0.10	-1.0*	1.0		
$CaCO_3$	0.09	0.68*	-0.22	-0.43	0.33	0.19	0.40	0.58*	-0.04	0.04	1.0	
TOM	0.22	0.64*	-0.04	-0.65*	0.37	-0.16	0.28	0.27	-0.50	0.50*	0.56*	1.0

*: Significant at the 0.05 level

Factor Analysis

The metals were distributed in different PCA factors on the basis of Varimax orthogonal rotation. According to the results of the PCA, the original variables could be reduced to three components with eigenvalues greater than 1, which accounted for 76.36% % of the total variance (Table.2 and Figure. 3). Factor one (F1) accounting for 34.46% of the total variance is characterized by very high positive loadings in $CaCO_3$ (0.91), Cu (0.79), OM (0.78), with statistically significant loadings in Fe (0.55), Pb (0.55), moderate loading with Mn (0.44). F1 is strongly association controlled by the biogenic carbonates, and plays an important role as a dilutant of metals in the samples. Cu showed very good positive correlations with Mn (0.78) and Fe (0.56). Cu, Mn and Fe mostly originated from an identical source (Figure.3). The sources of these metals most probably come from lithology. Factor 2 accounts for 25.30 % of the total variance. F2 is formed by Ni, Cd and Cr. It shows very high loadings in Ni (0.88), Cd (0.80) and Cr (0.76). Ni shows positive correlations with Cd (0.63) Cr (0.54). This Factor mainly related to anthropogenic inputs. Most probably, the sources of Cr, Ni, Cd and Pb can be anthropogenic sources such as domestic and industrial activities. Factor 3 accounting for 16.56 % of the total variance is characterized by high positive loading of clay (0.92), moderate loadings of Zn (0.54) and high negative loading with sand (-0.92), in addition to Pb and Cd (0.54 and o.47). Cd and Pb were contributed by moderate loadings with both F1 and F3 (Cd: 0.50 in F2 and 0.47 in F3; Pb: 0.50 in F1 and 0.54 in F3). F3 represents the mixed of F1 and F2 and indicates to occurs more than one of geochemical process in the sediments.

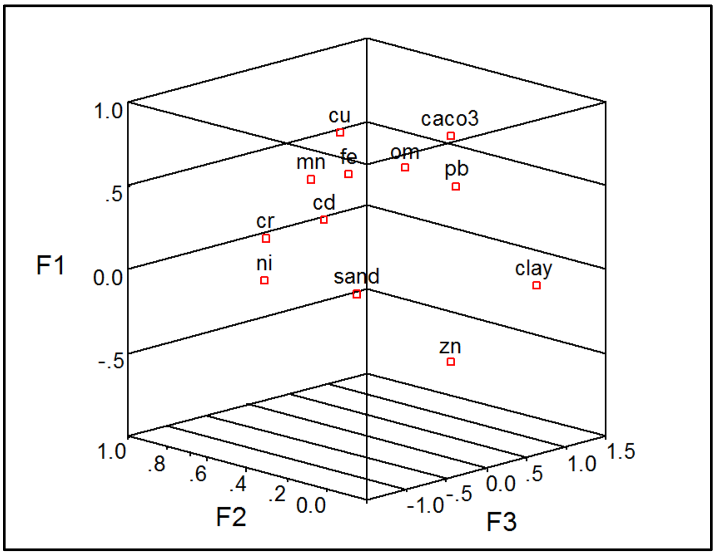

Figure 3: Factor loadings of different variables in sediments of Al-Mukalla coast

Table 2: Factor loadings of geochemical variables for Al-Mukalla coast

Variable	F1	F2	F3
Cr	0.11	0.76	-0.36
Cu	0.79	*0.51*	-0.07
Ni	-0.22	0.88	-0.07
Zn	*-0.56*	0.20	*0.54*
Mn	*0.44*	0.68	0.02
Cd	0.11	0.80	*0.47*
Pb	*0.50*	0.17	*0.54*
Fe	*0.50*	*0.55*	0.14
OM	0.78	0.02	*-0.48*
$CaCO_3$	0.91	0.01	0.07
Sand	0.07	0.08	-0.92
Clay	-0.07	-0.08	0.92
Eigen values	4.32	3.04	1.98
%Total of Variance	34.50	25.30	16.56
% accumulative of Variance	34.50	69.77	76.32

Note: High to very high loading (>0.6); Moderate loading (between 0.4 and 0.6); low loading (<0.4).

Assessment on Contamination of Metal

Enrichment Factor:

The enrichment factor (EF) is used to evaluate the anthropogenic influence of eight selected metals in sediment of Al-Mukalla coast. The enrichment factor calculated according to [24] as the following equation: EF= $[C_M/C_F] / [C_{Mb} /C_{Fb}]$, where; $C_{M:}$ concentration of metal in sediment sample; C_F: concentration of Fe in sediment sample; C_{Mb}: concentration of metal in background and C_{Fb}: concentration of Fe in background. This index contains five grades: EF < 2: minimal; 2 < EF < 5: moderate; 5 < EF < 20: significant; 20 < EF < 40: very high; EF < 40: extremely high enrichment. The results of enrichment factor (EF) values for metals in sediments are shown in Figure 4. Based on the average of EF values, metals followed this order: Cd> Zn> Pb>Cu> Ni> Cr> Mn.The range of EF value for Cd was between 103.78 and 277.12; for Zn 5.1 and 45.6; and for Pb 7.7 and 27.1.The total value of EF followed the order of the site: M4> M9> M2> M3> M6> M1>M8> M5> M7> M13> M10> M12.

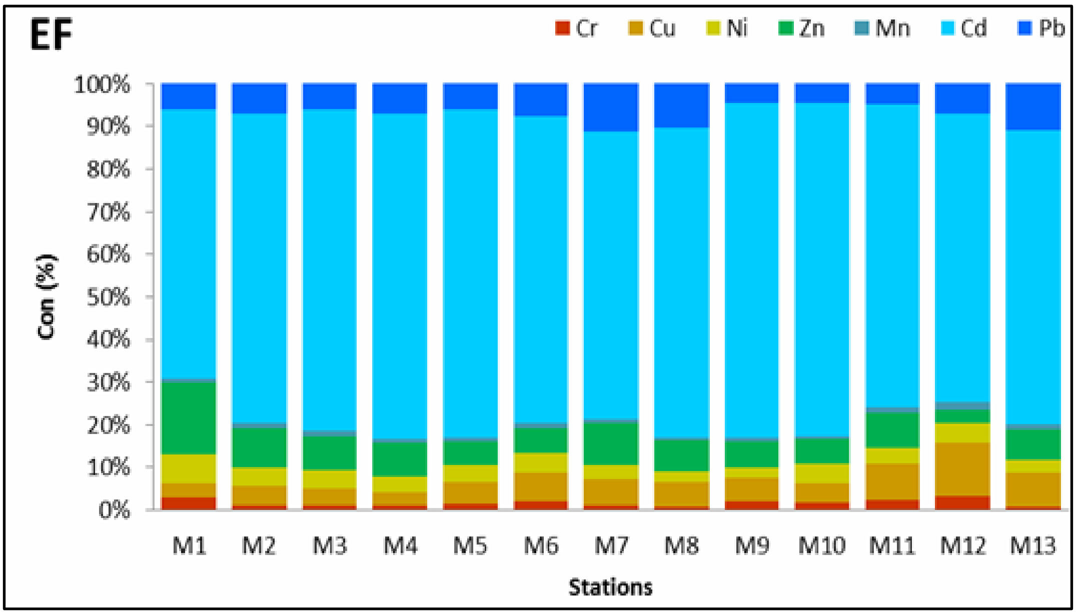

Figure 4: Enrichment factors (EFs) of metals in sediments of Al-Mukalla coast

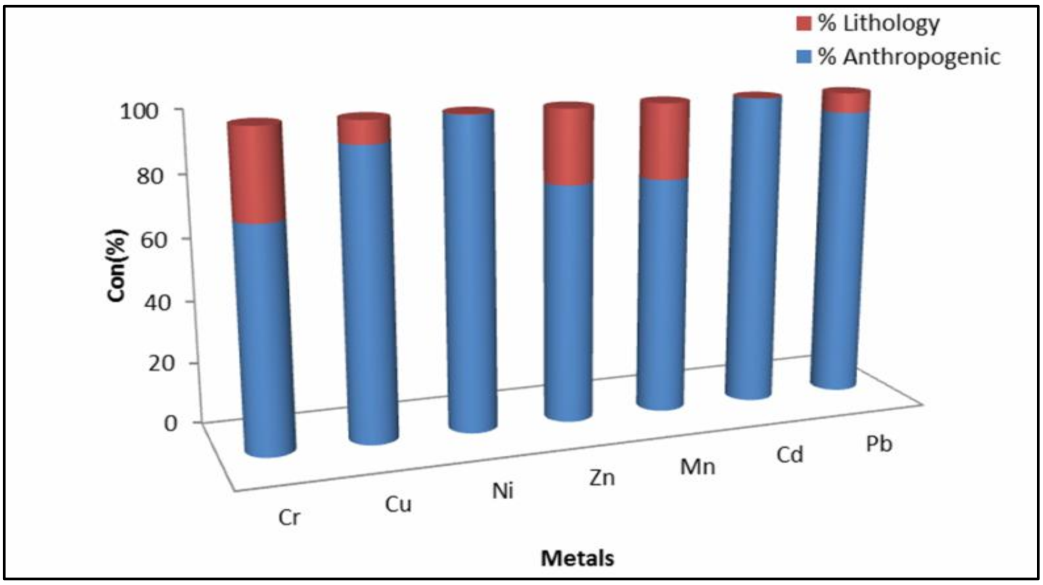

Figure 5: Lithology and anthropogenic of metals in the sediments of Al-Mukalla

The variations in EF values may be as a result of the difference in the magnitude of the input for each metal into sediments of the study area.The anthropogenic and lithology factor of metals was calculated according to[14]to evaluate the contaminationofmetals in more detail.The results of anthropogenic and lithology factor calculations are shown in Figure 5. The distribution of Cr and Pb from sources, lithology and anthropogenicillustrated in Figure 6. Generally, the percentage of anthropogenic input more than 50% for all metals in all stations (Figure 5).

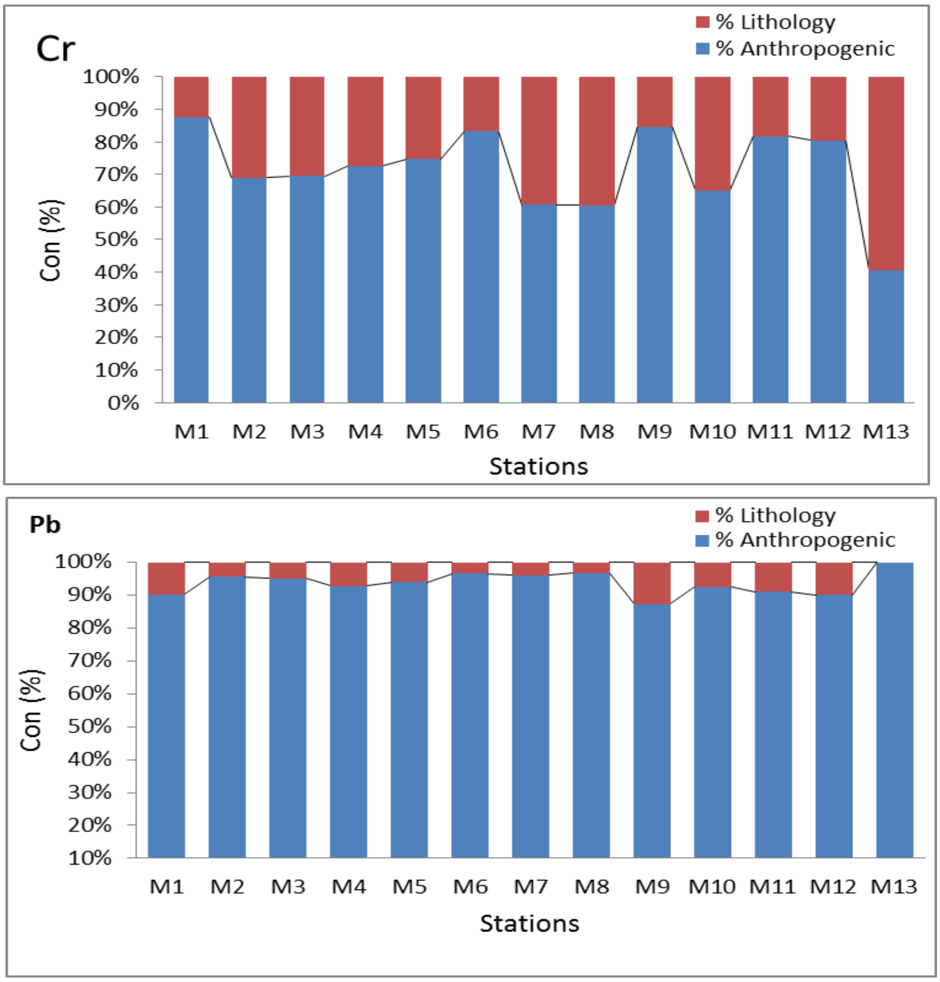

Figure 6: The anthropogenic and lithology percentage of Pb and Cr in all stations

Contamination Factor and *Degree of Contamination*

A contamination factor (CF) is defined as the metal concentration in sediment divided by some background base value for each metal. The background values that apply for calculating CF in this study was reported by[15]. The results of CF are given in Table 3. The highest CF value was obtained for Cd (Av: 6.8), which registered a moderate degree to very degree of contamination of with low contamination factors being registered for Fe (Av: 0.04**)** and Mn (Av: 0.10). The CF value was significantly high for Cd which suggests high Cd pollution due to anthropogenic activities**.** One reason for elevation Cd in sediments of study area, that Cd disposed together with household waste. On the basis of the average CF values, the sediments may be considered to be contaminated by the metals investigated in the following order: Cd> Pb> Zn> Cu> Ni> Cr> Mn <Fe. Pb recorded relatively high CF value in stations M6, M8, M7, M13 (1.01, 0.99, 0.95 and 0.91) respectively.

The degree of contamination (Dc) defined as the sum of all contamination factors for a given basin [17].The degree of contamination values of the metals studied and the ranges of Dc and their pollution grades and corresponding intensities are given in Table 3. Station M6 registered the highest degree of contamination, while Station M1 registered the lowest. Stations located in Al-Mukalla port have the high content of the DC comparing with the stations in the east and west of Al-Mukalla city. The degree of contamination is increasing according to the following order: M6> M5> M9> M10> M8> M4> M2> M3> M11> M12> M13.

Table 3: Contamination factor and degree of contamination in Sediments of Al-Mukalla

Station	CF								DC	
	Cr	Cu	Ni	Zn	Mn	Cd	Pb	Fe	Value	Order
M1	0.15	0.15	0.32	0.75	0.03	2.97	0.28	0.02	4.67	13th
M2	0.09	0.43	0.37	0.79	0.09	6.47	0.63	0.03	8.90	7th
M3	0.10	0.36	0.38	0.66	0.10	6.60	0.54	0.03	8.77	8th
M4	0.10	0.30	0.35	0.73	0.09	7.37	0.67	0.03	9.64	6th
M5	0.20	0.63	0.46	0.67	0.11	9.40	0.75	0.05	12.27	2nd
M6	0.28	0.88	0.59	0.74	0.17	9.43	1.01	0.05	13.15	1st
M7	0.10	0.54	0.27	0.79	0.08	5.73	0.95	0.04	8.50	10th
M8	0.10	0.54	0.24	0.66	0.08	7.00	0.99	0.04	9.65	5th
M9	0.23	0.63	0.28	0.66	0.12	9.00	0.50	0.03	11.45	3rd
M10	0.19	0.49	0.51	0.62	0.06	8.57	0.49	0.06	10.99	4th
M11	0.21	0.73	0.31	0.66	0.11	6.03	0.42	0.04	8.51	9th
M12	0.21	0.72	0.27	0.18	0.10	3.97	0.42	0.04	5.91	12th
M13	0.07	0.66	0.25	0.57	0.10	5.80	0.91	0.04	8.40	11th
Average	0.16	0.54	0.35	0.65	0.10	6.80	0.66	0.04	0.16	9.46
ERL	80.0	34.0	20.9	150	----	1.2	46.7	----	----	----
ERM	145.0	270.0	51.6	410	----	9.6	218	----	----	----

Note:CF < 1 and DC < 7: Low degree of contamination; 1 ≤ CF < 3 and 7 ≤ DC < 14: Moderate degree of contamination; 3 ≤ CF < 6 and 14 ≤ DC < 28: Considerable degree of contamination; CF ≥ 6 and DC > 28: Very degree of contamination; (1)[15]; (2): [17].

Geo-Accumulation Index

The geoaccumulation index (Igeo) was also used to assess metal pollution in sediments of Al-Mukalla coast. It is a quantitative measure of the degree of pollution in aquatic sediments [16]. The geoaccumulation index is expressed as follows:

$$I_{Geo} = \log_2 M_S * [1.5/ M_B]$$

Where, M_S is the measured concentration of the metal in the sediment, M_B is the geochemical background value in the average shale of metal, and 1.5 is the background matrix correction factor due to lithogenic effects. The results calculation of geoaccumulation index and its grades of pollution are printed in Table 5.The sediments in the study area were uncontaminated with Cr, Ni, Mn and Fe; Uncontaminated to moderately with Cu, Zn and Pb; and uncontaminated to strongly contaminated in Cd. The Igeo values for Cd in allstations are high which can be classified uncontaminated to moderately; moderately to strongly contaminate and strongly contaminated, and the average of the geoaccumulation index of Cd (3.03) suggested that the sediments of al-Mukalla coast is strongly contaminated by this metal.

Table 4: Results of geoaccumulation index in the coast of Al-Mukalla

Igeo(1)	Cr	Cu	Ni	Zn	Mn	Cd	Pb	Fe
<0	13*	10	13	3	13	0	8	13
1-0	0	3	0	10	0	1	5	0
2-1	0	0	0	0	0	0	0	0
2-3	0	0	0	0	0	2	0	0
3-4	0	0	0	0	0	10	0	0
4-5	0	0	0	0	0	0	0	0
<5	0	0	0	0	0	0	0	0

Note:
Igeo<0**:** Uncontaminated**;** Igeo 1-0:Uncontaminated to moderately; Igeo 2-1:Moderately contaminated;Igeo 2-3: Moderately to strongly contaminate;Igeo 3-4: Strongly contaminated Igeo 4-5: Strongly to extremely strongly contaminated;Igeo<5**:** Extremely contaminated [16]; *: number of stations.

Potential Contamination Index:

The potential contamination index (PC_{Index}) used to estimate of the amount of metallic elements detectable from sediment analysis according to[18]by using this formula: $PC_{Index} = [M]_{Max} / [M]_B$, Where, $[M]_{Max}$ is the maximum concentration of a metal in sediment, and $[M]_B$ is average value of the same metal in a background level.

The results of the potential contamination index that show in Figure.5 that indicates that the sediments were severe contamination (PC index >3) only with Cd (9.43) and unsevere contamination with others metals

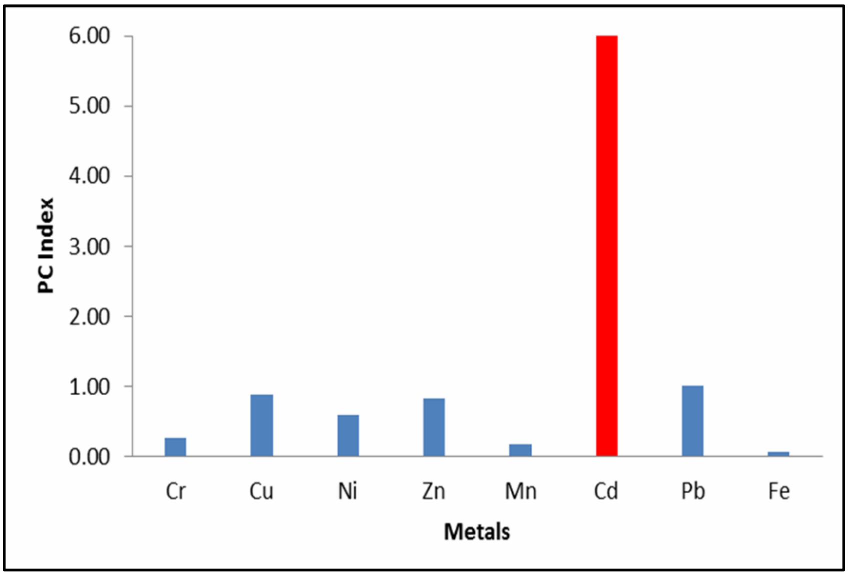

Figure 7: Degree of contamination in sediments of Al-Mukalla coast

Comparison of Metal Concentrations

Numerical sediment quality guidelines (SQGs) used to assess the toxicity of metals in sediments for marine organisms. The metal concentrations were compared with ERL/ERM [25].

As seen in Table 5, none of metal concentrations in the surface sediments of Al-Mukalla coast were as high as ERL values. The averages of all metals in the study area were below level of ERL, but some sites (M5, M6 and M10) were higher than ERL values for Ni and (M6) for Cu. Cadmium levels were higher than ERL values but were much lower than ERM values. The source of Cd and Pb are wastewaters including sewage effluents, unauthorized discharges from residences, shops, workshops, service station etc. Cd and Pb were found mostly distributed in Al-Mukalla port sediments and station (M13). Cd, Cu, Cr and Ni are toxic pollutants used in small amounts in petrol and diesel.

Table 5: Comparison of metals concentrations in sediments of Al-Mukalla with other studies

Location		Cr	Cu	Ni	Zn	Mn	Cd	Pb
Al-Mukalla(*)	Min	6.65	6.84	11.71	17.4	28.95	0.89	5.65
	Max	25.58	39.8	28.85	75.09	143.16	2.83	20.13
Gulf of Aden(27)	Min	17.00	8.06	17.0	21.85	138.23	--	14.80
	Max	233.93	111.0	48.07	263.49	658.87	--	138.06
Mumbai, India(23)	Min	9.60	15.3	44.6	28.5	327.2	14.2	30.6
	Max	526.9	48.10	94.10	83.4	793.40	21.7	125.5
Hadhramout coast(7)	Min	5.40	5.7	6.0	10.6	23.8	0.30	5.3
	Max	24.2	33.3	27.5	90.6	242.0	2.6	23.0
Arabian Sea, india(24)	Min	49.0	3.0	5.0	19.0	0.0	0.0	13.0
	Max	642.0	126.0	259.0	279.0	488.0	0.95	103.0
ERL		80	34.0	20.9	150	----	1.2	46.7
ERM		145	270	51.6	410	----	9.6	218

Note: (*):This study; [27]; [23]; [7] & [24].

Assessment of Potential Ecological Risk Index

The potential ecological risk is a commonly used as indicator to express a comprehensive assessment of the harmful effects of heavy metals. Potential ecological risk factor (Ei) and Ecological risk index (RI) were calculated according to[21], where, RI is the sum of all potential ecological risk factor for metals in sediments, $E_i$is the monomial potential ecological risk factor. To quantitatively express the potential ecological risk (Ei) of contaminant in sediment of Al-Mukalla coast, the potential ecological risk was calculated according to this equation: $[\mathbf{E}_i] = T_i * [C_i / C_b]$; *Ti*: the toxic-response factor of a certain metal (e.g., Cd = 30, Cu = Pb = 5, Cr = 2 and Zn = 1); *Ci*:the metal content in the sediments and C_b: the background value of metals.Table 6 shows the distribution of single risk indices (E_i) of the selected metals in Al-Mukalla coast sediments which ranked in the order of Cd > Pb> Cu > Ni> Zn> Cr. All Metals represent low potential ecological risk except Cd (203.85), which poses a very high risk to the local ecosystem organisms. Stations M5 and M6have the highest values of ecological risk, whereas station M1recorded the lowest value. The value of ecological risk is increasing according to the following order: M5> M6> M9> M10> M8> M4> M3> M2> M11> M13> M7>M12>M1.

The minimal ecological risk of Pb and Cu denoted low risk to the environment. The very high risk to environments posed by Cd should be widely concerned [27, 28]. Generally, metals mining, Harbours activities, manufacture and application of phosphate fertilizers that come from internment streams and wastewater are the main anthropogenic sources of Cd and others metals in the study area [7].

Table 6: The Potential ecological risk factor (Ei) and Ecological risk index (RI) values

Stations	(Ei)* Cd	Pb	Zn	Cu	Cr	Ni	(RI)* Value
M1	89.0	1.4	0.8	0.8	0.3	1.6	93.8
M2	194.0	3.2	0.8	2.2	0.2	1.9	202.1
M3	198.0	2.7	0.7	1.8	0.2	1.9	205.3
M4	221.0	3.3	0.8	1.5	0.2	1.8	228.5
M5	282.0	3.8	0.7	3.2	0.4	2.3	292.4
M6	283.0	5.0	0.8	4.4	0.6	2.9	296.7
M7	172.0	4.7	0.8	2.7	0.2	1.3	181.7
M8	210.0	5.0	0.7	2.7	0.2	1.2	219.8
M9	270.0	2.5	0.7	3.7	0.5	1.4	278.2
M10	257.0	2.5	0.7	2.5	0.4	2.5	265.5
M11	181.0	2.1	0.7	3.7	0.4	1.7	189.4
M12	119.0	2.1	0.2	3.6	0.4	1.4	126.7
M13	174.0	4.5	0.6	3.3	0.2	1.2	183.8
Average	**203.9**	3.3	0.7	2.7	0.3	1.8	212.6

Note: Ei< 40: low potential ecological risk; 40 <Ei< 80 moderate potential ecological risk; 80 <Ei< 160: considerable potential risk ecological risk, 160 <Ei< 320: high potential ecological risk; Ei> 320: very high potential ecological risk; Ri< 150: low ecological risk; 150 <Ri< 300: moderate ecological risk; 300 < RI <600: considerable risk ecological risk and RI > 600: very high ecological risk index.

*: The RI and E*i* from [20] and [30].

Conclusion

The contents of Cr, Cu, Ni, Zn, Mn, Cd, Pb and Fe in surface sediments of Al-Mukalla coast were analyzed, and assessed by applying, EF, AF,CF, DC, Igeo, E*i* andRI methods. The results indicate that all metals between low to moderate contamination except Cd recorded high contamination. The minimal ecological risk of Pb, Cu, Zn, Ni and Cr were low risk to local marine organisms, whereas Cd poses very high risk to the local ecosystem organisms. Generally, the sediments of the study area are relatively less contaminated with metals than sediments from other contaminated areas of the world. More studies of the biological and ecological in the future are very important to be carried out to elucidate the influence of factors to the ecosystems.

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References

[1]. Gupta, S.K., and Singh, J.**,** (2011). Evaluation of mollusc as sensitive indicators of heavy metal pollution in aquatic system. *Environmental Management Sustainable*, 2(1): 49–57.

[2]. Duce, R. A., & Tindale, N. W.**,** (1991). Atmospheric Transport of Iron and Its Deposition in the Ocean. *Limnology and Oceanography*, 36: 1715-1726.

[3]. Pekey, H, (2006). Heavy metal pollution assessment in sediments of Izmit Bay, Turkey. *Environmental Monitoring Assessment*, 123 (1-3): 219-231.

[4]. Okoro , H. K., Fatoki, O. S., Adekola, F. A., Ximba, B. J., & Snyman, R.G.. (2012), A Review of Sequential Extraction Procedures for Heavy Metals Speciation in Soil and Sediments. *Open Access Scientific Reports*, 1**(**1810): 3-9.

[5]. Kassem, M., & Al-Alimi, A. A., (2012). Environmental Assessment of metal pollution in surface sediments of Al-Dhabah Port oil, Hadhramout Seashore/Republic of Yemen. *Journal of nature and applied science*, 6(2): 421-431.

[6]. Mostafa, A. R., Al-Alimi, A. A., &Barakat, A.O. (2009). Metals in surface sediments and marine bivalves of the Hadhramout coastal area, Gulf of Aden, Yemen. *Marine Pollution Bulletin*, 58: 290–311.

[7]. Al-Alimi, A.A. (2008). Assessment of sources and levels of presistents organic pollutants (pops) in the coastal environment of Hadhramout governorate, Yemen. PhD thesis, Faculty of Science, Alex University, Egypt :245

[8]. Al-Kahali, M. S., Ba-Isa. A. A., & Al-Shawafi, N. A. (2002). Marine pollution of Hadhramout coast by heavy elements.*Bulletin, Environmental Resource* 5: 65–72.

[9]. Byers, S.C., Mills, L. E., & Stewart, P. L**.** (1987). A comparison of methods of determining organic matter in marine sediments, with suggestion for a standard method. *Hydrobiologia*, 58: 43-47.

[10]. Black, C. A, (1965). Methods of soil analysis, part 2, Chemical and microbiological properties, American society of Agronomy Inc., Madison, Wisc.

[11]. Folk, R. L, (1974). Petrology of Sedimentary Rocks, Hemphill Publishing Company, Austin, TX 78703, 184.

[12]. GERG, (1994) Geochemical and Environmental Research Group, Standard Operating Procedures (SOP-ST08). Taxes A & M University**.**

[13]. Simex, S. A., &Helz, G. R.,(1981). Regional geochemistry of trace elements in Chesapeake Bay. *Environmental Geology*, 3: 315-323.

[14]. Hernandez, L., Probst, A., Probst, J. L., & Ulrich, E.**,** (2003). Heavy metal distribution in some French forest soils: evidence for atmosphere contamination. *Science Total Environment*, 3(12): 195–210.

[15]. Wedepohl, K. H,(1995). The composition of the continental crust. *Geochemical Cosmocheim Acta*, 59: 1217- 1232.

[16]. Singh, V. K., Singh, K. P., & Mohan, C., (2005). Status of heavy metals in water and bed sediments of river Gomti – A tributary of the Ganga River, India. *Environmental Monitoring and Assessment*, 105: 43−67.

[17]. Pekey, H., Karakas, D., &Bakog, L. M., (2004). Source apportionment of trace metals in surface waters of a polluted stream using multivariate statistical analyses. *Marine Pollution Bulletin*, 49: 809-818.

[18]. Davaulter, V., & Rognerud, S., (2001). Heavy metal pollution in sediments of the Pasvik River drainage. *Chemosphere*, 42: 9-18.

[19]. Hakanson L, (1980). An ecological risk index for aquatic pollution-control- a sediment logical approach. *Water Resources*, 14: 975-1001

[20]. EPA, (2003). Yemen's national program of action for the protection of the marine environment from land based activities (NPA)**.**
[21]. Gurhan, Y. M, (2009). Heavy mineral distribution as related to environmental conditions for modern beach sediments from the Susanoglu (Atakent, Mersin, Turkey). *Environmental Geology*, 58(1): 119–129.
[22]. Jayasiri, H. B., Vennila, A., Purushothaman, C.S., (2013). Spatial and temporal variability of metals in inter-tidal beach sediment of Mumbai, India. Environmental Monitoring Assessment, DOI 10.1007/s10661-013-3441-7.
[23]. Swarnalatha, k., Letha, J., & Ayoob, S., (2003). Ecological risk assessment of a tropical lake system. *Journal of Urban and Environmental Engineering*,7 (2): 323-329.
[24]. Simex, S. A., &Helz, G. R.,(1981). Regional geochemistry of trace elements in Chesapeake Bay. *Environmental Geology*, 3: 315-323.
[25]. Long, E.R., McDonald, D. D., Smith, S. L., & Calder, F. D., (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediment. *Environmental Management*, 19: 18–97.
[26]. Nasr, S. M., Okbah, M. A., Kasem, M., 2006, Environmental Assessment of Heavy Metal Pollution in Bottom Sediments of Aden Port. *Yemen. International Journal of Oceans and Oceanography*, 1(1): 99-109.
[27]. Ghaleno, A. R; Sayadi, M. H. &Rezaei, M. R., (2015). Potential ecological risk assessment of heavy metals in sediments of water reservoir case study: ChahNimeh of Sistan. *International Academy of Ecology and Environmental Sciences*, 5(4): 89-96.
[28]. Xie, W., Wang, Y., Zheng, L., Huang, R., & Bing, L.**,** (2015). Concentrations of Heavy Metals in Six Municipal Sludges from Guangzhou and Their Potential Ecological Risk Assessment for Agricultural Land Use. *Journal of Environmental Studies* 24(1): 165-174.
[29]. Müller, G, (1969), Index of geo-accumulation in sediments of the Rhine River. *Geology Journal*, 2: 108-1181.