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Background Levels of Heavy Metals in Dissolved, Particulate Phases of Water and Sediment of Al-Hodeidah Red Sea Coast of Yemen

Hassan M.A. Heba, Majed A.M. Al-Edresi
Hamid T. Al-Saad and Mahmoud A. Abdelmoneim
Faculty of Marine Science and Environment, Al-Hodeidah University, Al-Hodeidah City, Republic of Yemen

Abstract. Al-Hodeidah is one of the main cities on the Red Sea. From the last few decades and up till now, this city has suffered from increasing in population, urbanization and industrial activities. Marine pollution of the Red Sea by heavy metals is attributed to a number of anthropogenic activities especially sewage and industrial waste effluents. The impact of these activities on the coastal area is the subject of the present work. Lack of data about the levels of heavy metals concentrations in the Red Sea Coast of Yemen impelled us to do such investigation.

Flame Atomic Absorption Spectrometry was used. The mean concentrations of dissolved metals (Zn, Cu, Cd, Pb, Cr, Fe, Ni, & Mn) ranged from: 0.00-9.45, 5.32-174.00, 0.04-2.65, 0.10-2.85, 0.024-29.05, 0.12-22.43, 3.48-206.50, and 0.12-8.00 (µg/l) respectively. While for particulate metals were: 1.11-472.60, 2.72-199.00, 0.22-101.63, 2.64-832.50, 1.54-534.60, 8.64-691.77, 4.32-194.50, and 98.10-6966.60 (µg/g dry weight) respectively. The concentrations of the same metals in sediments were: 4.02-18.25, 36.70-79.90, 0.20-5.80, 4.99-6.26, 6.38-38.46, 99.67-199.76, 7.10-116.40, and 9.17-26.71 (µg/g dry weight) respectively.

High concentrations of heavy metals were observed in front of Al-Hodeidah City, which could be due to the anthropogenic activities, while the low concentrations were observed in Al-Mandhar a remote area. Heavy metal contamination in water and sediment is partially caused also by atmospheric input of local particulates from motor vehicle and from the mountainous regions which drain its water from Yemen highland to the Red Sea through different vallies. Comparing our finding with other regional data clarifies that the heavy metals pollution in Al-Hodeidah coast is still localized and low. On the other hand, our data are considered the first study in this region and it could serve as a base for further studies in the future.

Introduction

There are numerous types of pollutants found in the environment, such as organic materials, major ions and trace metals which could be introduced to aquatic environment as a result of urbanization, industrial and agricultural activities (Heba *et al*., 2000). Metals in minerals and rocks are generally harmless and only become potentially toxic when they dissolve in water. They enter the environment naturally by weathering of rocks, leaching of soils, vegetation, and volcanic activity (Al-Saad *et al*., 1997). Human activities also introduce metals to the environment by mining, smelting, combustion of fossil fuel, and industrial wastes disposal. Most of metal loads are transported by water in a dissolved or particulate phase and most of it reaches the sea via rivers or land runoff. In addition, rainwater carries significant Cd, Cu, Zn and especially Pb from the atmosphere to the sea (Al-Taee, 1999).

Sediments act as a reservoir for many pollutants. A knowledge of the concentrations and distribution of trace metals in sediments can therefore play a key role in detecting sources of contaminants in aquatic system (Forstner and Wittmann 1979). Nevertheless, many studies in different regions of the world have used the sediment of rivers, estuaries and seas as indicators for pollution by trace metals (Al-Saad, 1995; Heba and Al-Mudaffer, 2000).

Marine pollution of the Red Sea had drawn the attention in the last two decades. Both of national and international agencies as well as a public awareness. Because of the enormous increment of pollutants particularly oil and trace metals. Also, the increase of sewage and industrial effluent discharged into the coastal area, which have seriously endangered the Red Sea ecosystem. Recently limited investigation dealing with presence of various pollutants have been done in this area recently (DouAbul and Heba, 1995; Heba and Al-Mudaffer, 2000; and Heba *et al*., 2000).

The present study deals with the levels of some trace metals in dissolved, particulate phases of water and sediment from Al-Hodeidah area along the Red Sea Coast of Yemen, in order to deduce the sources of trace metal pollution in this important area, whether, it is natural or anthropogenic? And also, to use these information as a baseline study for further investigations.

Materials and Methods

Water and sediment samples were collected from Al-Hodeidah area along the Red Sea coast of Yemen during the summer of 2001 (Fig. 1). Twelve stations were selected in this area depending on their special features. One of these stations was used as a reference. Ten liters of water samples were collected from every station using acid-washed polyethylene bottles. Those samples have been sucked and filtered through pre-washed and pre-weighted (0.45µm Millipore) membrane filters. Materials passing through the filters were considered as dissolved, while those retained as particulate. The analysis of the dissolved trace metals was done according to procedure of Rilry and Taylor (1968). The filtered water sample from each station was run through 50cm by 2cm ion-exchange column containing pre-washed chelex-100 resin with a rate of 5 ml/min.

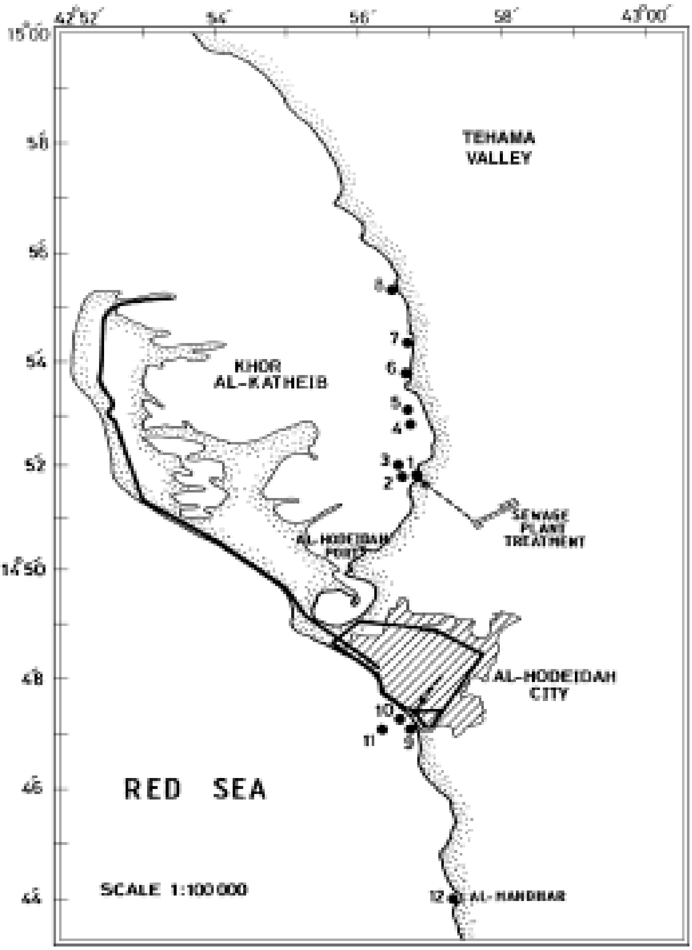

FIG. 1. Locations of samples.

After running of each water samples, the column was washed by 200 ml of deionized water and the trace metals were eluted by 30 ml of 2N HNO_3 which was collected in 50 ml plastic beaker. The eluted sample was evaporated to near dryness then residue was dissolved in 1ml of 0.5N HCI and made up to 25ml with deionized water awaiting for trace metals analysis by Perkin-Elmer 2380 atomic absorption spectrophotometer.

After filtration, the filter papers were dried in the oven at 60ºC for 6 hours to a constant weight where the particulate matter was calculated and taken for digestion.

Surficial sediment samples were obtained by means of a Van Veen grab sampler. Trace metals analysis was performed on the <63 µm fraction of the sediment which had been separated by sieving after drying and grinding. The determination of trace metals in particulate and sediment samples was done according to the following procedure described by Sturgeon *et al.* (1982). Concentrated HCI and HNO_3 (1:1) was added to each sample and evaporated to near dryness on the hotplate at 80ºC, then mixture of concentrated $HCIO_4$ and HF (1:1) was added. After heating to near dryness, 20 ml of 0.5 HCI were added and cooled for 10 min. the extraction was decanted into 25 ml plastic volumetric flask. This step was repeated twice and all supernatant were combined. Finally the volume of sample was made up to 25 ml with deionized water and the samples were stored for analysis. The grain size analysis of the sediment was done according to Folk (1974), while the total organic carbon (TOC) was determined according to El-Wakeel and Riley (1957).

Results and Discussion

The Red Sea is an enclosed sea, particularly vulnerable to pollutants from its surrounding countries (Boilis *et al*., 1984). Heavy metals are a major contaminants introduced into the aquatic ecosystem from anthropogenic and natural sources (Patel *et al*., 1985). Generally, their inputs include, weathering of rocks, urban run-off, industrial effluents, mining operations and atmospheric depositions. In water bodies metals are found in particulate or dissolved forms.

Physical parameters of all stations are presented in Table 1. From this, it is noticed that the water at the stations of seaport (Sts. 1,2 and 3) has the lowest salinity values (9.0-21.0 ppt) with a noticeable increase in salinity seaward. The northern section (Sts. 6,7 & 8) has higher salinities (36.8-38.2 ppt) with a noticeable increase in the values toward the open side of Khor Al-Katheib. Stations 9 and 11 in front of the city are of higher salinity while that at the mid distance (St.10) is of noticeable lower salinity (<20.0 ppt). On the other hand, the far south station (St.12) shows also a high value of salinity (38.1 ppt). From

TABLE 1. Some physical and chemical parameters of water samples along Al-Hodeidah Red Sea coast of Yemen.

Station number	Temperature ºC	Salinity ‰	Dissolved oxygen (mg/l)	pH	Total particulate matter (g/l)
1	38.5	9.0	3.2	6.98	0.16
2	38.5	10.2	3.2	6.99	0.20
3	39.0	21.0	3.5	6.05	0.44
4	38.0	36.8	4.1	7.20	0.05
5	37.5	37.0	4.2	7.02	0.09
6	39.0	38.2	4.2	7.26	0.04
7	38.0	38.2	4.1	7.39	0.05
8	37.5	38.2	3.9	7.35	0.05
9	38.5	38.9	3.4	7.85	0.01
10	39.0	19.2	2.6	3.39	0.40
11	38.0	36.4	3.5	7.90	0.05
12	39.5	38.1	4.1	7.30	0.08

above, the salinity of the water differs from one place to another. Generally, it ranged from a minimum (9.0 ppt) in the sea port to reach a maximum (38.9 ppt) at Station 9.

Dissolved oxygen (DO) varies in concentrations from place to another, more or less in a pattern parallel to that noticed in salinity. Where the low salinity water is also low in its DO content and vice versa. It seems that the low salinity water is mostly containing considerable amounts of oxygen consuming wastes (mostly organic matter). Obviously the high salinity water is noticed to be less affected by land runoff, but on the other hand mine confined water is most probably subjected to evaporation, as its salinity is exceptionally higher than that of neighbouring open Red Sea water (<40 ppt).

The pH values, that range from 6.05 to 7.90 have a distribution pattern more or less similar to that of the DO, where the water of low DO is also of low pH, and vice versa.

Results of analysis of the investigated dissolved heavy metals in the water samples are presented in Table 2 and Fig. 2. The mean concentrations ranges of Zn, Cu, Cd, Pb, Cr,Fe, Ni, and Mn are: (0.00-9.45, 5.32-174.00, 0.04-2.65, 0.10-2.85,0.24-29.05, 0.12-22.43, 3.48-206.50, and 0.12-8.00 µg/l) respectively.

TABLE 2. Mean concentration of the investigated metals in different forms: Dissolved (µg/l), particulate (µg/g) and sediments (µg/g) along Al-Hodeidah coast.

Metals	State	Stations											
		1	2	3	4	5	6	7	8	9	10	11	12
Zn	Dissolved	2.06	0.75	0.10	0.44	0.29	0.16	0.39	0.17	0.18	9.45	0.29	ND
	Particulate	472.60	258.0	39.13	1.11	1.66	3.15	2.05	4.77	11.86	75.68	1.95	31.99
	Sediment	17.49	8.71	7.18	15.08	12.71	4.02	10.16	10.15	12.74	18.25	16.30	5.14
Cu	Dissolved	127.50	174.00	55.60	5.32	5.70	5.58	6.16	6.50	8.88	161.50	6.60	6.26
	Particulate	199.00	133.50	51.20	4.66	7.46	2.72	5.14	8.22	6.40	112.50	7.28	9.84
	Sediment	62.30	72.10	42.20	56.60	53.50	36.70	76.40	53.40	69.80	79.90	78.30	51.00
Cd	Dissolved	2.50	1.16	0.95	0.10	0.05	0.06	0.04	0.08	0.10	2.65	0.06	0.08
	Particulate	101.63	80.54	3.19	0.22	0.24	0.33	0.27	0.32	1.51	20.54	0.36	5.15
	Sediment	0.80	3.70	3.10	5.20	0.20	5.80	3.10	3.60	1.94	3.00	3.60	2.40
Pb	Dissolved	2.85	2.57	1.02	0.12	0.11	0.13	0.12	0.11	0.10	2.15	0.11	0.10
	Particulate	832.50	697.10	48.60	2.64	2.83	3.83	3.56	5.06	14.23	231.03	4.00	57.31
	Sediment	5.33	5.78	5.31	5.83	5.90	5.41	5.25	4.99	5.89	5.56	6.26	5.81
Cr	Dissolved	29.05	7.40	4.10	0.36	0.29	0.28	0.34	0.29	0.32	9.95	0.31	0.24
	Particulate	534.6	427.60	32.60	1.60	1.54	3.01	2.96	3.22	13.81	127.70	3.07	31.16
	Sediment	10.41	14.96	6.38	14.22	13.42	33.98	31.35	14.51	12.89	29.22	38.46	12.15

TABLE 2. Contd.

Metals	State	Stations											
		1	2	3	4	5	6	7	8	9	10	11	12
Fe	Dissolved	22.43	10.65	1.32	0.17	0.13	0.18	0.36	0.12	0.12	9.80	0.21	0.16
	Particulate	691.77	513.90	135.90	19.14	16.20	33.98	31.12	41.30	69.85	587.20	8.64	224.26
	Sediment	132.28	99.75	197.67	199.12	99.67	161.18	199.70	199.69	199.76	199.76	199.37	180.16
Ni	Dissolved	206.50	133.00	28.60	6.10	3.90	7.90	3.48	4.80	4.96	185.50	5.04	6.38
	Particulate	158.00	119.80	46.40	6.32	5.80	4.32	4.82	7.14	5.41	194.50	7.94	8.06
	Sediment	95.50	55.80	62.70	77.30	52.90	7.10	82.90	10.10	46.10	116.40	37.50	42.90
Mn	Dissolved	6.05	2.60	0.82	0.12	0.30	0.41	0.32	0.16	0.34	8.00	0.50	0.50
	Particulate	6960.60	6602.50	838.00	111.50	98.55	193.20	175.98	232.10	638.30	1488.60	98.10	1010.70
	Sediment	10.07	9.17	9.24	24.21	12.37	15.19	26.71	16.72	17.87	21.60	23.70	10.38

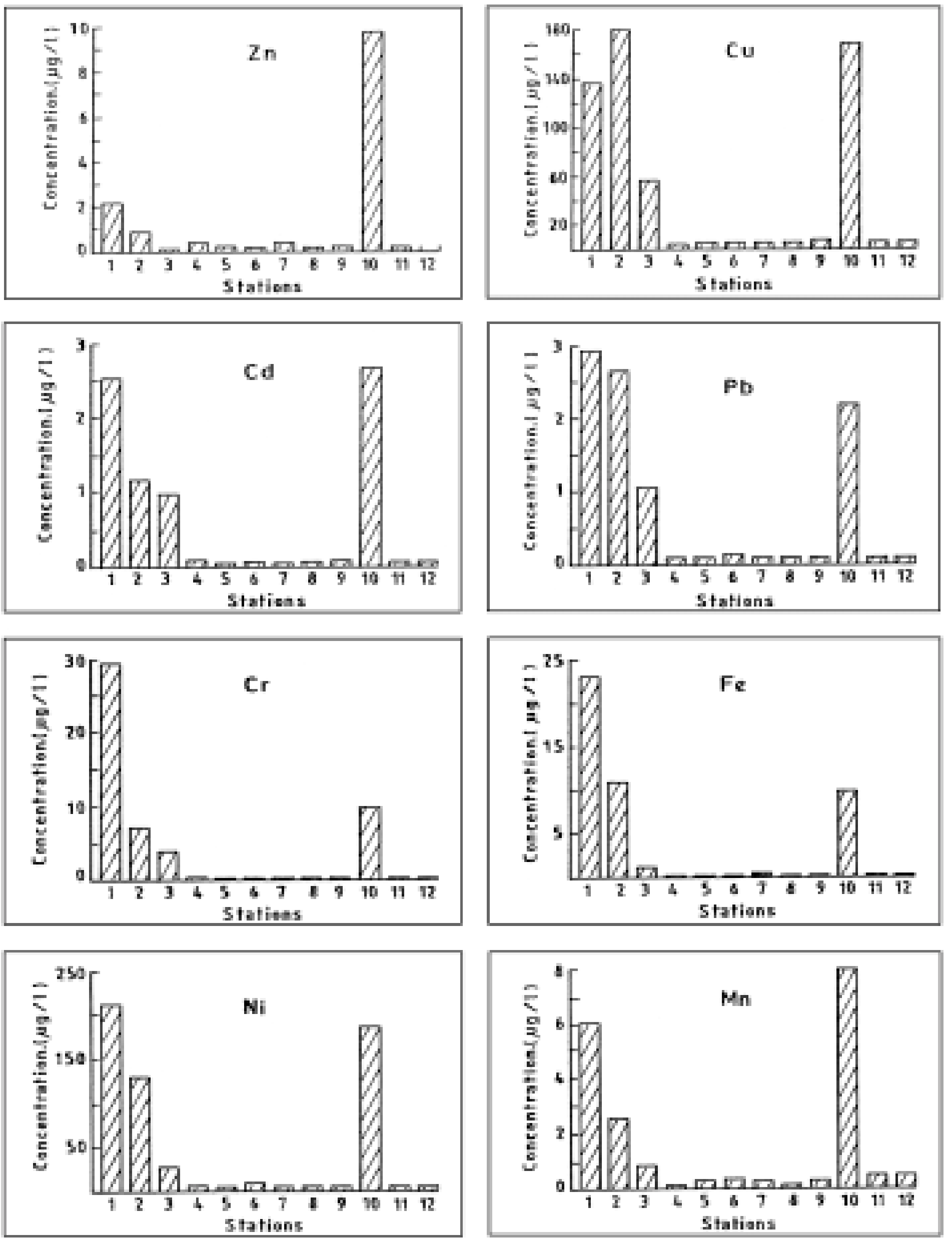

FIG. 2. Distribution of dissolved heavy metals in water samples from Al-Hodeidah coast of Yemen.

The mean concentration values of the dissolved elements are generally the lowest concentrations. This may be due to limited population density of the area free from potential sources of heavy metals pollution. Whereas, the highest concentration of Pb, Ni and Cd may be due to petroleum rich substrate of the area already described by Al-Shawafi (2000) and Heba *et al.*, (2000). There is a tendency of all metals on dissolved and particulate matter to show the highest concentration at stations 1, 2, & 3 and (Fig. 2 & 3). This probably may be due to the influence of sewage discharge and due to the deposition of these metals in particulate form. Metals enter into a number of reactions, which reflect their mobility and bio-availability. However, the partitioning of metals between dissolved and particulate phases determine their ultimate fate in the marine environment (MAFF, 1993).

The mean concentration range of particulate metals are presented in Table 2 & Fig. 3 for Zn, Cu, Pb, Cr, Fe, Ni, and Mn:1.11-472.60, 2.72-199.00, 0.22-101.63, 2.64-832.50, 1.60-534.60, 16.20-691.77, 4.32-158.0, and 98.10-6966.60 (μg/g dry weight) respectively.

A number of workers have discussed the sources of heavy metals in water (Forstner & Wittmann, 1979; Salomons & Forstner, 1984; and Furness & Rainbow, 1990). It was found that, the higher population densities of urbanization and industrialization have led to quite high contamination of coastal waters by heavy metals. High concentrations of some metals are reported near some industrial areas of the Red Sea such as Seaports, Power Stations and the Desalination Plants (Dicks, 1987).

Cadmium and copper are among the toxic heavy metals that are slowly concentrated in marine organisms. Levels of these metals are in continuous elevation where the wastes discharged from mining and dredging operations reach the sea (Castro and Huber, 1997).

The observed values of heavy metals in the present study were higher for some elements such as Ni, Pb and Mn at stations 1, 2, and 3. This may be due to the particulate heavy metals decreasing down direction from the source of sewage pollution. These concentrations in the trace metals depend on many factors such as discharge, seasonal variations of suspended particulate matter and plankton. It also, depends on disruptions and precipitation factors. It is generally accepted that mobilization processes, occurring when sewage discharge mixes with sea water, led to the release of heavy metals from particles (Al-Khafaji, 1996).

Such inputs could result from treated and untreated municipal, industrial wastes, agricultural run-off and from the atmospheric input (Abaychi & DouA-bul, 1985). The sources of heavy metals mainly emanate from oil fields, indus-

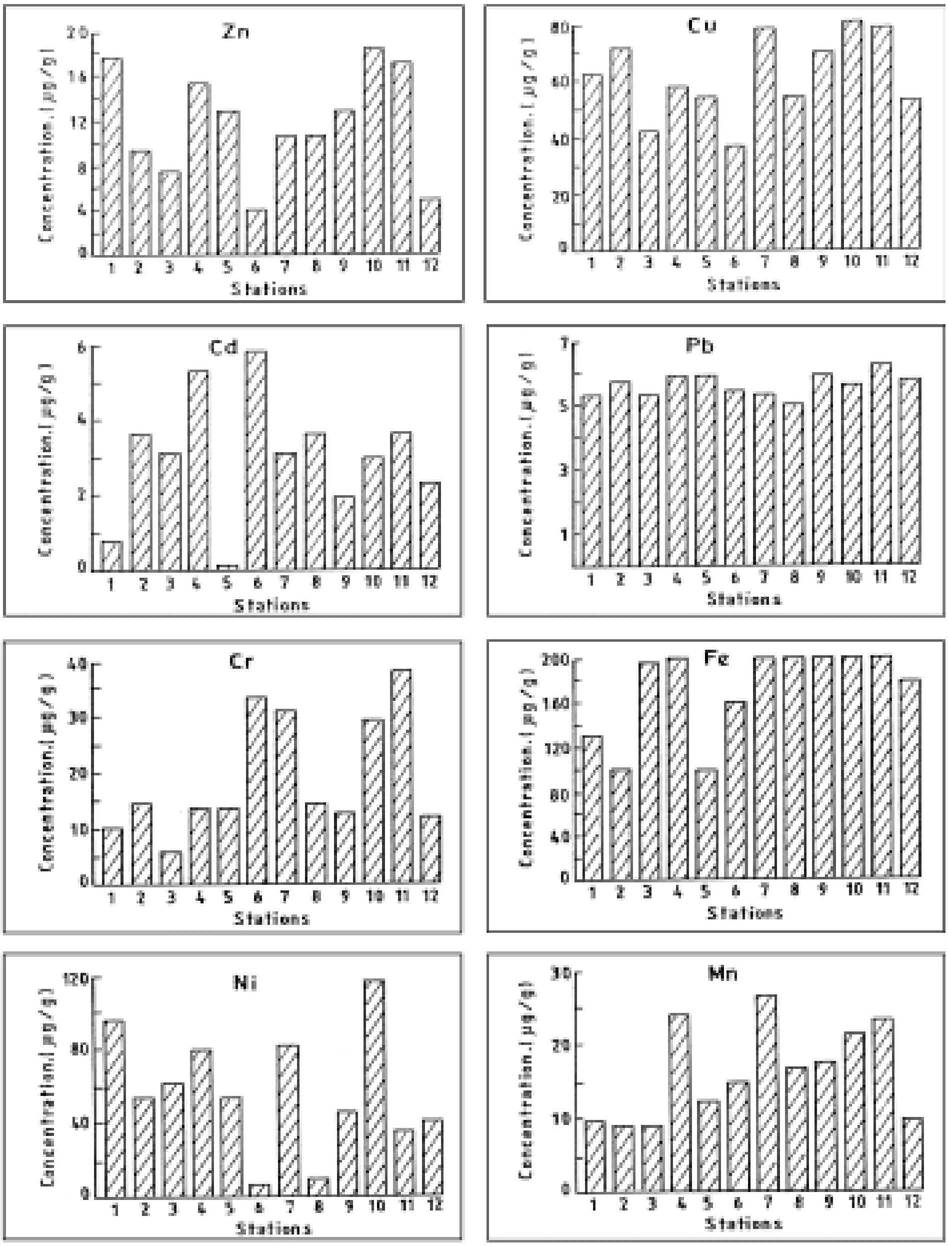

FIG. 3. Distribution of particulate heavy metals in water samples from Al-Hodeidah coast of Yemen.

trial wastes and sewage effluents (Abdelmoneim, 1995; Abdelmoneim & El-Sherif, 1997). Oregioni and Aston, (1984) observed that all sewage outfalls contain high levels of Iron, Copper, Zinc, Nickel, Cadmium, Manganese, Lead and Cobalt. However, the principal source of Pb contaminants in the marine environment appears to be the exhaust of vehicles which run with leaded fuels. Also, lead reaches the sea by rain and windblown dust (Castro and Huber, 1997).

In the present investigation, the high concentrations of metals were found at station 10 which is located to the north of Al-Hodeidah main port, and is referred to some waste effluents discharge from human activities in this site (Heba and Al-Mudaffer, 2000). However, the mean concentrations of both dissolved and particulate trace metals are within the range of those reported elsewhere (Tables 3 & 4). The only exception is that in stations 1, 2, 3, and 10 which might slightly be polluted due to human activities.

TABLE 3. Comparison between mean concentrations of dissolved heavy metals from Al-Hodeidah coast with other values (µg/l).

Location	Zn	Cu	Cd	Pb	Cr	Fe	Ni	Mn	Reference
Worldwide River	20.00	7.00	0.02	3.00	–	40.00	1.66	7.00	Burton (1967)
Euvoiks Gulf Mediterranean Sea	0.013	0.0019	–	0.0029	0.0062	0.0084	0.0019	0.0017	Scoullos & Dassenakis (1983)
Bombay Harbor / India	27.00	16.00	1.33	4.00	20.00	3.00	0.10	8.00	Patel *et al.* (1985)
Hindon River / India	122.20	95.70	4.12	76.20	111.20	276.80	10.50	115.00	Ajmal and Khan (1987)
Galabr River / Nigeria	10.30	3.20	1.35	13.90	–	188.00	–	24.00	Kakulu & Osibanjo (1992)
Ravi River / Pakistan	14.50	2.60	0.50	1.07	–	98.00	1.36	4.70	Tariq *et al.* (1994)
Tee Estuary / North Sea	8.40	3.80	0.03	0.46	–	–	0.70	42.60	MAFF (1993)
Tyne Estuary / North Sea	14.5	1.08	0.08	0.59	–	–	1.55	52.00	
Arabian Gulf	0.82	0.47	0.19	0.23	0.21	173.00	2.85	1.52	Al-Khafaji (1996)
Al-Hilla River / Iraq	8.73	1.81	1.11	4.21	5.27	6.74	0.27	0.96	Al-Taee (1999)
Al-Hodeidah Coast of Yemen	0.0-9.45	5.32-174	0.04-2.65	0.10-2.85	0.24-29.05	3.48-206.50	0.12-22.43	0.12-8.00	Present study

TABLE 4. Comparison between mean concentrations of heavy metals in the particulate phase from Al-Hodeidah coast with other values (µg/g dry wt).

Location	Zn	Cu	Cd	Pb	Cr	Fe	Ni	Mn	Reference
Euvoiks Gulf / Mediterranean Sea	0.0027	0.001	–	0.0012	0.0015	0.0005	0.0346	0.0026	Scoullos & Dassenakis (1983)
Dogger Bauk / North Sea	11.80	3.20	0.38	–	46.40	8.30	–	–	Fileman, *et al.* (1991)
Tee Estuary / North Sea	494.00	106.30	2.29	203.00	–	24.00	–	389.00	MAFF (1993)
Tyne Estuary / North Sea	723.00	100.00	2.50	331.00	–	37.00	–	414.00	
Shatt Al-Arab Estuary / Iraq	10.04	63.070	112.30	22.50	193.40	81.50	9466.00	35.70	Al-Saad, *et al.* (1996)
Arabian Gulf	24.45	267.05	46.23	6.07	493.65	101.74	2454.00	35.55	Al-Khafaji (1996)
El-Mex Bay Estuary / Egypt	14.54	4.93	0.03	0.83	–	–	95.70	31.30	El-Rayis, *et al.* (1998)
Al-Hilla River / Iraq	205.05	51.61	3.59	53.18	114.02	21.84	76302.15	623.42	Al-Taee (1999)
Al-Hodeidah Coast of Yemen	1.11-472.6	2.72-199	0.22-101.36	2.64-832.50	1.60-534.6	6.20-691.77	4.32-158.0	98.10 6966.60	Present study

As we mentioned before sediments act as a reservoir for many pollutants. A knowledge of the concentration and distribution of heavy metals in sediments can therefore, play a key role in detecting sources of pollution in aquatic ecosystems (Forstner and Wittmann, 1979).

Analysis of heavy metals in sediments offers more convenient and more accurate means of detecting and assessing the degree of pollution (Al-Taee, 1999). Table 2 and Fig. 4 show the mean concentrations range in the sediment samples from Al-Hodeidah area. The mean concentration of Zn, Cu, Cd, Pb, Cr, Fe, Ni, and Mn were (4.02-18.35, 36.7-79.90,0.20-5.80, 4.99-6.26, 6.38-38.40, 99.67-199.76,7.10-116.4, and 9.17-24.21 µg/g dry weight) respectively.

Many studies on different regions have used the sediments of rivers, estuaries and oceans as indicators for pollution by heavy metals. Fowler, (1988) studied the coastal pollution in Bahrain, Emiraties and Oman. He found that the concentrations of Cd, Cu and Pb in sediments from these countries fall within the worldwide range. Abaychi and DouAbul (1985); Abaychi and Al-Saad (1988) studied the concentration of heavy metals in the sediments from Shatt Al-Arab Estuary. They recorded higher concentration of Ni and V. Al-Hashimi and Salman (1985) showed that the concentrations of Ag, Cd, Co, Cu, Fe, Mn, Ni, Pb, V and Zn in sediments of North-West Arabian Gulf were within the natural limits of their occurrence and below the pollution levels. Hanna, (1992) carried out a comparative study on heavy metals of the Red Sea sediments using reference sample collected by R/V Mabahiss during the period (1933-1934), and new samples collected by National Institute of Oceanography and Fisheries (NIOF) in 1984. the average concentrations of Pb and Cd in 1984 were 5 and 3 times, respectively, greater than those of 1934. He suggested that, oil pollution and atmospheric fallout could be responsible for the increased levels.

Heba and Al-Mudaffer, (2000) studied the concentrations of heavy metals in fish mussels, shrimp and sediments from the Red Sea coast of Yemen. The results showed a slightly heavy metal pollution in Khor Al-Kathib and Al-Salif sediments of Cd, Cu, Fe, Mn, Zn and Pb. In the rest sites, the concentrations of heavy metals were relatively low and mainly attributed to natural rather than anthropogenic origin.

Heavy metals in sediments are affected by grain size and total organic carbon (TOC) content of the sediment (Al-Saad *et al*., 1996). The result of grain size analysis shows that sand and silt are the main constituents followed by less percentage of clay (Table 5). However, our results are in a good agreement with those found by Al-Shawafi, (2000). High concentrations of TOC are found in stations 1, 2 and 3, this refers to being these very close to sewage discharges. Total organic carbon (TOC) in sediment gave a good indicator for organic pollution (Al-Sadd, 1995). Nevertheless, the concentrations of heavy metals are not related to the organic content and/or grain size of the sediment. The same results were concluded by several workers such as: Abaychi & DouAbul (1985) in sediment from the NW Arabian Gulf, and also by Al-Taee, (1999) in his samples were collected from Al-Hilla River, Iraq.

The high concentrations of heavy metals in the sediments from the study area, especially near or close to Sts. 1, 2 & 3 and Fig. 4 refer to the sewage discharge of Al-Hodeibah City and also, may be due to the industrial pollution, ship wrecks, and oil enrichment in the vicinity areas.

The iron oxides content of tar, some of its particles were insoluble in acid, but the soluble was high in iron oxides (Attaway *et al*., 1973). This implies that a substantial fraction of pelagic tar lumps contains rust and was the product of discharges from steel tanks or other steel apparatus, for example: offshore drilling or waste from engines either on land or ships (Al-Shawafi, 2000).

Under natural condition, the most important inputs of heavy metals to coastal regions are the mechanical weathering of rocks (Bryan, 1976). Heavy minerals are usually common and represent 50% or more of the beach deposits in some

Table 5. Grain size analysis and total organic carbon (TOC) in sediment samples along Al-Hodeidah coast.

Stations no.	Sand %	Silt %	Clay %	Total organic carbon (TOC) %
1	55.70	30.65	13.00	2.33
2	48.50	46.20	5.25	1.43
3	30.50	56.85	10.30	1.35
4	15.40	70.30	13.35	1.65
5	47.40	46.05	7.35	1.65
6	77.45	18.50	3.30	2.65
7	42.20	38.90	17.80	2.10
8	52.95	36.55	9.85	1.85
9	91.15	7.05	0.20	0.70
10	86.40	9.05	4.64	1.93
11	44.85	52.85	1.50	1.05
12	6.10	89.55	3.90	0.85

places along the Red Sea coast of Yemen (El-Anbaawy & Al-Awah, 1993). These beach deposits are mainly derived from mountainous regions, which drain from the Yemen highlands to the sea through numerous vallies (Al-Shawafi, 1997).

Also, from the present study, elevated levels of Fe, Cr, Ni, Pb, and Zn in sediment samples were recorded (Fig. 4). However, high concentration levels of Pb in all sediment samples is associated with regions of high traffic density of motor cycles in the center of Al-Hodeidah City (Heba and Al-Mudaffer 2000). The obtained concentrations of metals in the sediments are in a good agreement with those reported elsewhere (Table 6). The partitioning of metals between dissolved and suspended particulate matter determines their ultimate fate in the aquatic environments. Therefore, the concentrations of trace metals in suspended particulate matter are higher than dissolved. The relatively high concentrations of metals in the sediments when compared to water could be due to one or more factors; like movement of pollutants, wastewater discharge from the city, physical characteristics of the Red Sea and effluents from Al-Hodeidah landing port (Heba *et al*., 2000).

Therefore, it could be concluded that:

1 – The concentrations of trace metals under this investigation were acceptable in the comparison with worldwide standard.

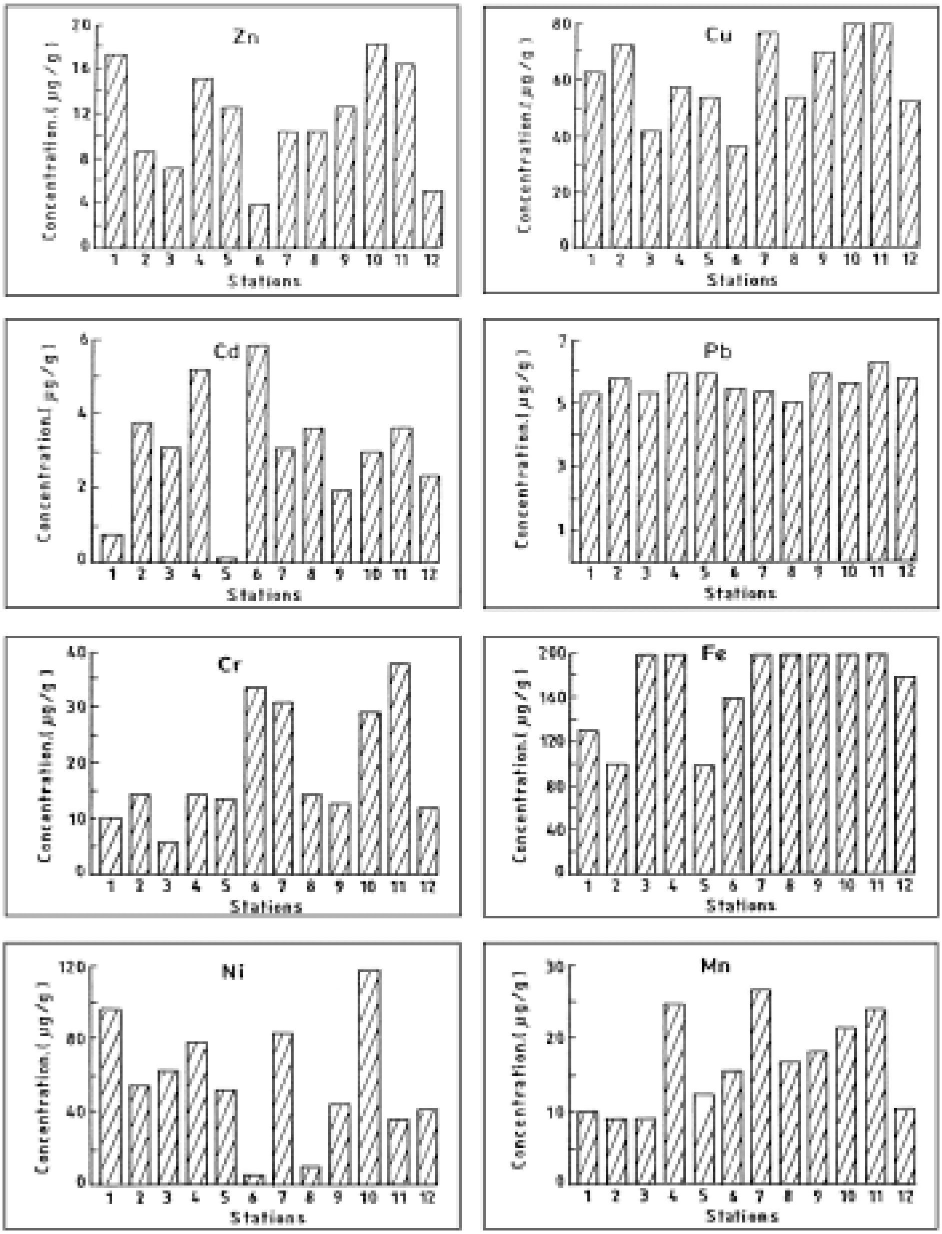

FIG. 4. Distribution of heavy metals in sediments collected from Al-Hodeidah coast of Yemen.

TABLE 6. Comparison between mean concentrations of heavy metals in the sediment from Al-Hodeidah coast with other values (µg/g) dry weight.

Location	Zn	Cu	Cd	Pb	Cr	Ni	Fe	Mn	Reference
Lagoon of Venice / Italy	84.30	21.00	2.57	40.80	28.60	34.60	13200	–	Danazzolo, *et al.* (1982)
Cadiz Gulf / Spain	197.00	31.00	1.69	56.00	–	–	22100	227.00	Gomezparra, *et al.* (1984)
Kuwait	280.00	20.50	1.50	22.70	2.85	96.90	15000	4099.00	Samhan, *et al.* (1986)
Chesapeake Bay Earth Crust	70.00	–	0.20	12.50	100.00	75.00	65300	950.00	Rule (1986)
Arabian Gulf	25.20	24.20	0.03	6.60	50.40	39.80	5869	751.00	Abaychi & Al-Saad (1988)
North Sea / UK	19.00	–	57.00	15.00	21.00	–	–	–	MAFF (1993)
Saudi Arabia	7.72	3.68	0.16	3.05	56.85	14.53	6296	94.63	Fowler, *et al.* (1993)
Florida Estuary / USA	160.00	36.80	1.20	58.90	82.80	18.80	–	–	Alexander, *et al.* (1993)
Papua Gulf / Australia	108.00	33.00	0.08	1300	83.00	34.00	50000	721.00	Alongi, *et al.* (1996)
El-Mex Gulf / Egypt	60.70	44.60	–	28.50	–	–	1771	143.80	El-Rayis, *et al.* (1998)
Al-Hodeidah Coast of Yemen	4.02-18.25	36.70-79.90	0.20-5.80	4.99 –6.26	6.38-38.46	99.67-199.76	7.10-116.4	9.17-24.21	Present study

2 – Because, there was a slight increase in the concentrations of some trace metals, the area could be considered slightly polluted by these metals especially near the sewage discharges (Sts. 1, 2 & 3) and the port of Al-Hodeidah (St. 10).

3 – Trace metals contamination in water and sediment is partially caused by atmospheric input of local particulates from motor vehicles and from the mountainous regions, which drain from the Yemen highland to the sea through different vallies.

4 – When comparing our findings with the other areas in the world, the heavy metals pollution in Al-Hodeidah coast is still localized and comparable with other findings in the world and within the acceptable worldwide ranges.

References

Abaychi, J.K. and **Al-Saad, H.T.** (1988) Trace elements in fish from the Arabian Gulf and Shatt Al-Arab river, *Iraq. Bull. Environ. Contam. Toxical.,* **40:** 226-232.

Abaychi, J.K. and **DouAbul, A.A.Z.** (1985) Trace metals in Shatt Al-Arab river, Iraq. *Wat. Res.,* **19**(4): 457-462.

Abdelmoneim, M.A. (1995) Assessment of cadmium, lead, copper and zinc in fish species reared in treated sewage effluents in Suez city, *Egypt. Bull. High Inst. Public Health,* **25:** 227-234.

Abdelmoneim, M.A. and **El-Sherif, Z.M.** (1997) Assessment of heavy metals in the treated wastewater of Suez Pond, *Egypt. Internat. J. Environ. Health Res. (England)*, **7:** 259-265.

Ajmal, M. and **Khan, A.V.** (1987) Heavy metals in water, sediments and fishes of Hindon, River, U.P. India, *Hydrobiology*, **148:** 151-157.

Alexander, R., Calder, F.D., Schropp, S.T. and **Windo, H.T.** (1993) The histological record of metal environment in two Florida estuaries, *Estuaries*, **6**(3B): 627-639.

Al-Hashimi, A.H. and **Salman, H.H.** (1985) *Trace metals in the sediment of the NW Coast of the Arabian Gulf, Mar. Pollut. Bull., **16:** 188-120.*

Al-Khafaji, B.Y. (1996) *Trace Metals in Water, Sediments and Fishes from Shatt Al-Arab, NW Arabian Gulf*, Ph.D. Thesis, Basrah, Univ. Iraq, 131 p.

Alongi, D.M., Boyle, S.G., Tirendi, F. and **Payn, C.** (1996) Composition and behavior of trace metals in post-oxic sediments of the Gulf of Papua, New Guinea, *Estuar. Coast. Shelf Sci*., **42:** 197-211.

Al-Saad, H.T. (1995) *Distribution and Sources of Hydrocarbons in Shatt Al-Arab estuary and NW of the Arabian Gulf*. Ph.D. Thesis, Basrah Univ., Iraq, 186 p.

Al-Saad, H.T., Al-Khafaji, B.Y. and **Sultan, A.A.** (1996) Distribution of trace metals in water, sediments and biota samples from Shatt Al-Arab estuary, *Mar. Meso.,* **11:** 63-77.

Al-Saad, H.T., Mustafa, Y.Z. and **Al-Imarah, F.J.** (1997) Distribution of trace metals in tissues of fish from Shatt Al-Arab estuary, *Iraq. Mar. Meso.*, **11:** 15-25.

Al-Shaafi, N. (1997) *A Baseline Study on Petroleum Hydrocarbons in Southern Red Sea*, M.Sc. Thesis, Depart. Earth Sci. & Environ., Fac. Sci., Sana'a Univ., Yemen, 121 p.

Al-Shawafi, N. (2000) *Beach Tar along the Red Sea Coast of Yemen "Quantitative Estimation and Qualitative Determination"*, Ph.D. Thesis, Depart. Earth Sci. & Environ., Fac. Sci., Sana'a Univ., 174 p.

Al-Taee, M.M.S. (1999) *Some Metals in Water, Sediment, Fishes and Plants of the Shatt Al-Hilla River*, Ph.D. Thesis, Univ. Babylon, Iraq, 130 p.

Attaway, D., Jadamec, I.R. and **McGwan, W.** (1973) Floating petroleum in the marine environment. U.S. Coast Guard, Groton, Conn., USA. (Unpublished manuscript).

Boilis, L., Zaunaisky, J. and **Gilles, R.** (1984) *Toxins, Drugs and Pollutants in Marine Animals*, Tokyo, 193 p.

Bryan, G.W. (1976) Metal concentration in the sea, *Mar. Pollut. Bull.,* **7:** 353-356.

Burton, J.D. (1979) Basic properties and processes in estuarine chemistry. Pp 1-36, In: *Estuarine Chemistry* (Burton, J.D. and Liss, P.S. eds), Academic Press, London, England.

Castro, P. and **Huber, M.E.** (1997) *Marine Biology*, Brown Publishers, U.S.A., 450 p.

Danazzolo, R., Orio, A.A. and **Pavoni, B.** (1982) Radiometric dating and pollutants profiles in a sediment core from the Lagoon of Venice, *Oceanal. Acta,* pp: 101-107.

Dicks, B. (1987) *Pollution in Red Sea*, *(key environments)*, Edited by Edwards, A.J. and Head, S.M., Pergamon Press, Oxford, England, 441 p.

DouAbul, A.A.Z. and **Heba, H.M.A.** (1995) *Investigations Following a Fish Kill in Bab el-El-Mandab (Red Sea) during November 1994*, Report submitted to Environmental Protection Council (EPC) Sana'a, Yemen, 105 p.

El-Anbaawy, M.I.H. and **Al-Awah, M.A.H.** (1993) Opaque mineralogy of some beach sand, Yemen Red Sea coastal areas, *Egypt. J. Geol.*, **37**(2): 39-52.

El-Rayis, O.A., Abuldahab, O.M., Halim, Y. and **Riley, J.P.** (1998) Heavy metals in dispersed suspended matter in brackish water of El-Mex bay Estuary, Alexandria, *Proc. 8^{th} Cong. "Environmental Protection is a Must"* Alexandria, 5-7 May, 1998, NIOF & Eyro-Arab Coop. Center (VEA), pp: 25-32.

El-Wakeel, S.K. and **Riley, J.P.** (1957) The determination of organic carbon in marine mud, *J. Cons. Int. Explor. Mer,* **12:** 180-183.

Fileman, C.F., Althaus, M., Low, R.J. and **Haslah, I.** (1991) Dissolved and particulate trace metals in surface water over the Dogger, bank, Central North Sea, *Mar. Pollut. Bull.,* **22:** 241-244.

Folk, R.L. (1974) *Petrology of Sedimentary Rocks*, Hemphill Publishing Co., Austin, Texas, USA, 182 p.

Forstner, U. and **Wittmann, G.T.W.** (1979) *Metal Pollution in the Aquatic Environment*, 2nd edition, Springer-Verlag, New York, 486 p.

Fowler, S.W. (1988) Coastal baseline studies of pollutants in Bahrain, UAE and Oman, *Proc. Symp. on Regional Marine Pollution Monitoring Research Programmes,* Al-Ain, UAE, Dec. 1985. *ROPME, Kuwait.* pp. 155-180.

Fowler, S.W., Readman, J.W., Oregioni, B., Villeneve, J.P. and **Macky, K.** (1993) Petroleum hydrocarbons and trace metals in near shore Arabian Gulf sediment and biota before and after the 1991 war: An assessment of temporal and spatial trends, *Mar. Pollut. Bull.,* **27:** 171-182.

Furness, R.W. and **Rianbow, P.S.** (1990) *Heavy Metals in the Marine Environment*, CRS Press, Boca Raton, Florida, USA.

Gomezparra, A., Establier, R. and **Escolar, D.** (1984) Heavy Metals in recent sediments from the Bay of Cadiz, Spain, *Mar. Pollut. Bull.,* **15**(8): 307-310.

Hanna, R.G.M. (1992) The levels of heavy metals in the Red Sea after 50 years, *Sci. Total Environ.,* **125:** 417-488.

Heba, H.M.A. and **Al-Mudaffer, N.** (2000) Trace metals in fish, mussles, shrimp and sediment from the Red Sea coast of Yemen, *Bull. Nat. Inst. Oceanogr. & Fish., ARE,* **26:** 151-165.

Heba, H.M.A., Maheub, A.R.S. and **Al-Shawafi, N.** (2000) Oil pollution in Gulf of Aden/ Arabian Sea Coasts of Yemen, *Bull. Nat. Inst. Oceanogr. & Fish., ARE,* **26:** 139-150.

Kakulu, S.E. and **Osibanjo, O.** (1992) Pollution studies of Nigerian River: Trace metals levels of surface waters in Niger Delta area, *Int. J. Environ Stud.,* **30:** 309-317.

MAFF, (1993) Monitoring of contaminants in marine fish and shellfish. Aquat. Environ. Monit., *Rep: MAFF Direct. Fish. Res. Lowestoft,* **36:** 7-16.

Oregioni, B. and **Aston, S.R.** (1984) Determination of selected trace metals in marine rediments by flame/flameless atomic absorption spectrophotometer. IAEA Monaco lab., Internal report. Now cited in reference method in pollution studies No. **38,** UNEP, 1986.

Patel, B., Bangera, V., Patel, S. and **Balani, M.C.** (1985) Heavy metal in the Bombay Harbour Area, *Mar. Pollut. Bull.,* **16**(1): 22-28.

Riley, J.P. and **Taylor, D.** (1968) Chelating resins for the concentration of trace elements from seawater and their analytical use in conjunction with atomic absorption spectrophotometry, *Anal. Chim. Acta,* **40:** 479-485.

Rule, J.H. (1986) Assessment of trace element geochemistry of Hampton roads harbor and Lower Chesapeake bay sediments area, *Geol. Water Sci.*, **8**(4): 209-219.

Salomons, W. and **Fostner, U.** (1984) *Metals in the Hydro Cycle*, Springer-Verlag, Berlin, 349 p.

Samhan, O., Zarbo, M. and **Anderlini, V.** (1986) Aeolian contribution of trace metals to marine sediment of Kuwait, *Environ. Internat.,* **12:** 611-617.

Scoullos, M. and **Dassenakis, K.** (1983) Trace Metals in Tidal Mediterranean Embayment, *Mar. Pollut. Bull.,* **14**(1): 24-29.

Sturgeon, R.E., Desaulniers, J.A., Berman, S.S. and **Russell, D.S.** (1982) Determination of trace metals in estuarine sediments by graphite furnace atomic absorption spectrophotometry, *Anal. Chim. Acta,* **134**: 283-291.

Tariq, J., Jaafar, M. and **Ashraf, M.** (1994) Trace metal concentration (distribution and correlation) in water, sediment and fish from the Ravi River, Pakistan, *Fish., Res.,* **19:** 131-139.

المستويات الأساسية للمعادن الثقيلة العالقة في المياه والرسوبيات لشاطيء الحديدة على البحر الأحمر – اليمن

حسان هبة ، و ماجد الإدريسي ، و حامد السعد ، و محمود عبد المنعم
كلية علوم البحار والبيئة ، جامعة الحديدة ، الجمهورية اليمنية

المستخلص. يعتبر ميناء الحديدة من أكبر وأهم الموانيء اليمنية المطلة على ساحل البحر الأحمر. لوحظ في السنوات الأخيرة ونتيجة للزيادة السكانية المطردة ارتفاع معدلات صب المخلفات الصناعية والصرف الصحي داخل المياه الإقليمية لليمن، لذا كان من الضروري القيام بدراسة تشمل كل ما يختص بحماية البيئة البحرية بصفة عامة من التلوث. وهذا البحث هو جزء من الدراسة التي انصبّت بوجه خاص على قياس مجموعة من المعادن الثقيلة في مياه ورواسب البحر الأحمر أمام مدينة الحديدة باستخدام جهاز طيف الامتصاص الذري.

اتضح من مناقشة نتائج هذه الدراسة أن معظم تراكيز هذه المعادن لم تصل بعد إلى الحد الضار ، وكانت هذه التراكيز على الوجه التالي: الزنك صفر–٩,٤٥، والنحاس ٠,٠٤–٢,٦٥، والكادميوم ٠,١–٢,٨٥، والرصاص ٠,٠٢–٢٩,٠٥، والحديد ٠,١٢–٢٢,٤٣، والنيكل ٣,٤٨–٢٠٦,٥، والمنجنيز ٠,١٢ –٨,٠ ميكروجرام/ لتر.

توصي الدراسة بضرورة إجراء مثل هذه القياسات كل عامين على الأكثر ، مع ضرورة معالجة هذه المخلفات قبل صرفها في البيئة البحرية ، للحد من زيادة تراكيز هذه المعادن ، وحتى تظل السواحل اليمنية نظيفة وخالية من التلوث بمثل هذه المعادن.