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Heavy Metals in Suspended Particulate Matter Collected from Jeddah Transect Region, Saudi Arabia

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In this study, sea water samples were collected from the Red Sea coastal seawaters along Jeddah transect at seven zones (outside Sharm Obhor, Al-Noras, Al-Arbaeen Lake, Al-Shabab Lake, outside Al-Shabab Lake, Jeddah port and Al-Khumra) during autumn 2011. Concentrations of the heavy metals Cadmium (Cd) - Lead (Pb) - Iron (Fe) - Copper (Cu) - Zinc (Zn) were measured in the suspended particulate matter (SPM) at these zones. Al-Khumra zone attained significantly the highest heavy metal concentrations in (SPM), followed by Jeddah port zone. In Sea water at Al-Noras zone registered the highest concentration of Zn 5.59 (mg/kg dry weight), after Al-Khumra and Jeddah port 59.14, 25.01 (mg/kg dry weight) respectively, while Jeddah port and Al-Khumra seawaters gave the highest Cu concentrations 9.87, 29.43(mg/kg dry weight) respectively. The highest concentration of Iron (Fe) was remarkably recorded at Al-Khumra zone coastal seawater giving an average of 1968.52(mg/kg dry weight), also Zn concentration at Al-Khumra reached comparatively high value up to 59.14 (mg/kg dry weight), The other zones, Inside Al-Shabab and Al-Arbaeen zones have coastal seawaters with comparatively low heavy metal concentrations at its coastal seawaters. In general Al-Khumra area attained the highest heavy metal concentrations in the coastal sea water of the Red Sea.

Keywords: heavy metals, SPM, cadmium pollution, Copper, Zinc, Sharm Obhor, Al-Noras, Al-Arbaeen Lake, Al-Shabab Lake, outside Al-Shabab Lake, Jeddah port and Al-Khumra.

In recent years, marine pollution has become a globally concern since marine environments were affected by either point or nonpoint source of pollution like, chemicals such as oil-based products, pesticides, fertilizers heavy metals, and accidental oil spills, runoff coastal areas and plastic materials. Seawater pollution is a global problem, and human activities in the coastal area and marine water caused discharge of various kinds of pollutants such as heavy metals into the marine ecosystems (Censi *et al*. 2006; Pote *et al*. 2008). The effects of pollutants, other than sewage (Banner 1974; Smith 1977) and oil (Loya and Rinkevich 1980), in temperate seas have been comprehensively reviewed by a number of workers (Bryan 1971, 1980; Wright 1978) which attributed this to the increasing application of mineral extraction and concentration in shallow water and deep sea (Georghiou and Ford 1981). The main threat of heavy metal contamination is their persistent and their toxic properties, which can create several problems and could be accumulating in marine animals and organisms (Wen *et al*., 2007; Wcisio *et al*., 2008). Basaham *et al*. (2009) compared concentrations of Al, Fe, Mn, Cu, Zn, Cr, Cd and Pb in the Red Sea water southern

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Corniche area of Jeddah taken 1999 with those taken 2009 to study effect of sewage effluent dumping in this area, and found that concentrations of these heavy metals were doubled. El-Sayed and Niaz (1999) mentioned that Al-Khumra treatment plant receives daily about 200,000-300,000 m^3 sewage water and this amount is not wholly treated, and thus the plant dumps into the Red Sea water partially treated polluted sewage water. Saad and Fahmy (2009) determined the concentration of heavy metals in the Red Sea water in front of Jeddah based on abundance as that Zn, Mn, Cu, Cd with mean concentrations of 8.00, 2.43, 1.7 and 1.09 i1g/g respectively. Radwan *et al*. (2009) estimated the highest concentrations of the trace metals Zn, Cu and Ni in the Red Sea coastal water particularly Zn were at the southern Corniche area close to the sewage effluent indicating the influence of this sewage water on heavy metal concentrations. The treated and untreated sewage is dumped directly at 177 discharge point along Jeddah coast, and the most important of the effluent is that of Al-Khumra Sewage Treatment Plant (KSTP) which discharges its wastewater at the Southern Corniche area with daily amount of (300,000 **m3)**(El Sayed 2002b). The National Water Company declared the volume of sewage water discharged into the coastal Red Sea waters daily amounts to 250000 m^3 normally and reaching 375000 m^3 during rush hours (El-Riyadh Newspaper, 7-5-2012). El-Yami (2010) estimated the average concentrations of Fe, Cu and Zn in the sediment of the sewage effluent discharged in the sea water as 8574, 112 and 1557 µg/g.

US_EPA strongly recommends limiting the heavy metal concentrations for estuarine coastal aquatic life in the United States. Coban *et al*. (2009) determined the maximum concentrations of metals dissolved in seawater in the industrial areas and city of Zonguldak beaches as follows (Mn) Cd 15.0±O.98 around Çatalaz1 Power Station, Cr 12±8.6 in Alapl1 Creek delta, Mn 715±8.3 in Filyos creek delta, Cu i22± 1.5, Ni 142±1o.6, Pb 39±9.0 and Zn 834±4.1 in Zonguldak city beaches. Cannery industry can increase the Pb concentration in coastal area and the heavy metals in general and also can be accumulated in the tissues of the organisms (Gochfeld, 2003; Yi *et al* 2008). The aim of this study is to determine the concentrations of the heavy metals (Cadmium - Lead - Iron - Copper - Zinc) in the suspended particulate matter (SPM) at seven zones at the Red Sea coastal area along Jeddah transect, Saudi Arabia.

MATERIALS AND METHODS

Seawater samples were collected at the end of September (autumn) 2011 from the coastal region at a depth of 30 cm of the study area, to measure the heavy metals in the suspended particulate matter (SPM). 39 samples were collected from in and out shore line of the study area from north to south Jeddah Transect. The area was divided into 7 zones (outside Sharm Obhur, Al-Noras, Al-Arbaeen lake Al-Shabab lake, outside Al-Shabab lake, Jeddah port and Al-Khumra) (Fig. 1).

The water samples (5L) were filtered through GF/C membrane filter (0.45µm) using a filtration system. The filter papers were then dried hot air oven at 60ÚC for 24 hours. After that, the dried filter papers were hot digested following the procedure of Krishmunarty *et al*., (1976). In brief, 10 ml of concentrated nitric acid (HNO_3) was added to the dry filter samples and the flask sealed with a glass marble. After 2 hours of acid digestion at approximately 80 °C on a heater, the sample was allowed to cool for 15 minutes, two to three drops of hydrogen peroxide (H_2O_2) was then added to the samples. Heating was continued with intermittent stirring by swirling the flask held in tongs until 1 ml of the sample remained. The cooled digested sample was filtrated and made up to a volume of 20 ml by distilled water in polyethylene bottles. The heavy metals (Cd, Zn, Cu, Fe, Pb) content of each sample was determined using AAS (Atomic Absorption Spectrophotometry, 250 pls).The following formula was used to calculate the concentration in mg/kg of SPM: mg/kg (Dry weight) = Concentration* Dilution / Dry weigh

Statistical analysis

The collected data were statistically analyzed using the analysis of variance (ANOVA) and mean comparisons (Least Significant Difference (LSD) test) according to Al-Nakhlawy (2008), using SPSS (Statistical Package for the Social Sciences) version 13.0.

RESULTS

The results of variation of the heavy metals (Zn, Pb, Fe, Cu, Cd)concentrations in the Red Sea suspended particulate matter (SPM) samples collected from seven zones along Jeddah transect region, Saudi Arabia at the beginning of fall 2011 are presented in table (1)and figure (2).

Zinc (Zn)

Table (1) shows that the highest Zn seawater SPM concentration was at Al-Khumra coastal zone with 59.14 mg/kg, followed by Jeddah port zone with 25.0248 mg/kg, then Al-Noras zone with 5.5905 mg/kg, compared to Zn concentration at the other zones, inside Al-Shabab lake with 2.669, outside Sharm Obhur with 2.1183, outside Al-Shabab lake with 1.9878, and Al-Arbaeen Lake zone gave the lowest Zn concentration 0.2615 mg/kg.

Lead (Pb)

As illustratedin table (1) the average concentrations of Pb in the coastal seawater SPM at the seven studied zones are dominated by that at Al-Khumra and Jeddah port zones. At Al-Khumra zone the concentration of Pb in the suspended particulate matter along the coast reached the highest value 7.309 mg/kg compared to Pb concentration at all other zones. Jeddah port coastal area came next with 2.001 mg/kg Pb concentration compared to Pb concentrations in all other zones which gave below 1 ppm. Contamination of these two zones Al-Khumra and Jeddah port may be the reason behind this high increase in Pb seawater concentration.

Iron (Fe)

Table (1) illustrates averages of Fe concentrations in the coastal seawater SPM of the seven zones studied along this Red Sea coastal region along Jeddah transect. Al-Khumra zone the mostly contaminated zone rather than the other zones that receive the domestic and the industrial sewage effluent witnessed the highest concentration of Fe in its coastal seawater compared to all other areas. Iron concentration reached a remarkably high value 1968.52 mg/kg, followed by Jeddah port with 3.3118 mg/kg, then comes Al-Arbaeen with 2.1774 ppm and the least Fe concentration was in the coastal seawater at outside Sharm Obhur zone with only 0.5693 mg/kg

Copper (Cu)

The average concentrations of Cu in the

Table 1. Longitudes, latitudes, and mean concentrations (mg/kg dry weight) of the heavy metals in the SPM of the different studied zones

zone	longitude	latitude	No. of stations	Cd±SD	Cu±SD	Fe±SD	Pb±SD	Zn±SD
outside Sharm Obhur	39.006.573	21.706.895	4	0.1634±0.092c	6.2707±2.27c	0.5693±0.32e	0.8951±1.12c	2.1183±0.69d
Al-Noras	39.009.381	21.032.087	3	0.1633±0.133c	2.0293±1.40d	1.5209±1.11d	0.4638±0.62d	5.5905±0.69c
Al-arbaeen lake	39.006.433	21.036.196	6	0.0261±0.015d	0.8755±0.53e	2.1774±1.04c	0.0492±0.035e	0.2615±0.21e
Inside Alshbab lake	39.171.683	21.493.400	6	0.0784±0.094d	1.0666±0.61e	1.7312±0.97c	0.2036±0.15d	2.669±1.95d
Outside Alshbab lake	39.150.873	21.495.027	5	0.1170±0.062c	6.4095±4.76c	0.8408±0.56e	0.1856±0.136d	1.9878±0.14d
Jeddah port	39.071.21.		5	1.0936±0.884b	9.8707±4.65b	3.3118±1.47b	2.001±1.55a	25.0148±4.19b
Al-khumra	39.006.311	21.019.247	10	6.1170±2.0a	29.43±5.68a	1968.52a±1.0185	7.309±1.06a	59.14±2.86a
LSD				0.05	2.11	0.450	0.399	1.89

SPM = suspended particulate matter

Table (2): Metal concentration in the sediment of sewage effluent of Jeddah city at Al-Khumra (El-Yami, 2010).

Metal	Average concentration(µg/g)	Average release/d/kg	Average release/y/kg
Fe	8574	80	29000
Cu	112	1	365
Zn	1557	14.3	5200
Mn	168	1.5	548
Al	8970	82	30000
Cr	364	3.3	1205

Fig. 1. Map shows the sampling zones

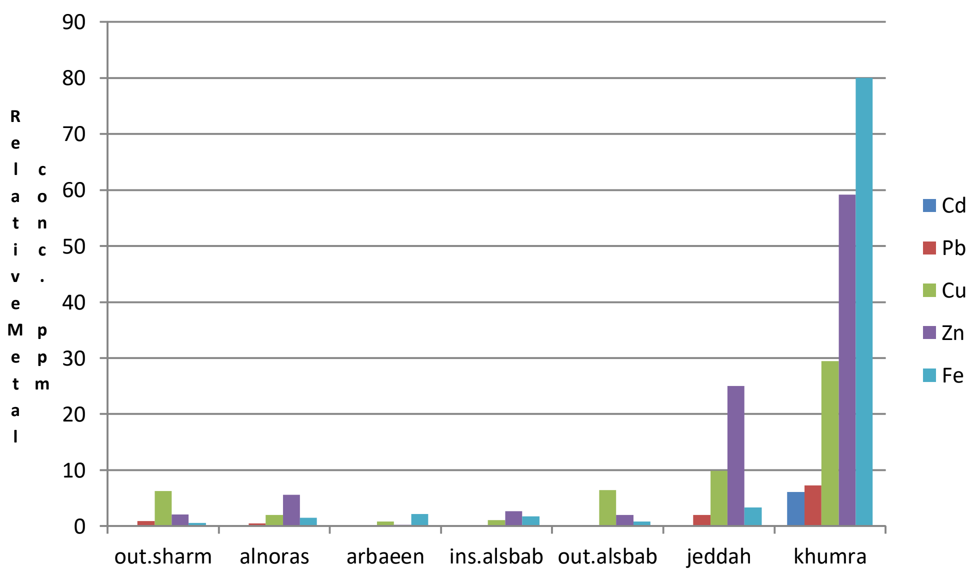

Fig. 2. Relative heavy metal concentrations at the 7 zones along Red Sea coast

coastal suspended particulate matter at the seven studied zones along this Red Sea coastal area are shown in table (1). The mostly contaminated zone with sewage water i.e. Al-Khumra zone dominated all other zones and its coastal sea water attained the highest Cu concentration giving 29.43 mg/kg, followed by Jeddah port zone with 9.8707 ppm, then the Outside Al-Shabab lake with 6.4095 mg/kg and Al-Arbaeen lake zone which gave the least Cu concentration 0.8755 mg/kg.

Cadmium (Cd)

The averages of concentration of cadmium (Cd) in sea water SPM samples collected from the seven coastal zones along the Rea Sea coast along Jeddah transect is illustrated in table (1). Cadmium sea water SPM concentration was the highest in the coastal area at the vicinity of Al-Khumra zone which represents the most polluted zone in this region giving an average of 6.1170 mg/kg compared to all other zones followed by Jeddah port zone with 1.0936 mg/kg, while all the other zones have concentrations of Cd below 1 mg/kg, and Al-Arbaeen zone gave the least Cd concentration 0.0261 mg/kg.

Figure illustrates the relative concentrations of seawater SPM. Al-Khumra zone is dominating having the highest heavy metal concentrations of all studied metals, with Fe recording significantly the highest concentration, followed by Zn, Cu and then comes Pb and Cd. Second to Al-Khumra is Jeddah port with Zn dominating giving the highest seawater concentration, followed by Cu and then Fe.

DISCUSSION

The variations of heavy metal concentrations in the seawater SPM collected from Jeddah coast Saudi Arabia at the end of fall of 2011 from the seven zones were summarized in table (1) and figure (2). Concerning variations between zones, the highest concentrations for all metals (Zn, Pb, Fe, Cu, Cd) were recorded at Al-Khumra zone. These high concentrations are attributed to many factors, Al-Khumra zone is the most polluted area in this coastal region. There are more than 450 factories working in the industrial area covering a wide variety of industrial activities, the most important of which are refineries, petrochemicals, food processing, paper mill, canning, car repair and painting, tanning, chemical and pharmaceutical, soap and cleaning products. All of these sewage water effluents (domestic and industrial) are discharged and dump their wastes into this zone. These values are supported by the findings of Basaham *et al*. (2009) who recorded double increase in the concentration of the heavy metals Fe, Zn, Cu, Pb, Cd, Mn and Al of the 2009 data records compared to the recorded data of 1999. Table (2) by (El-Yami, 2010) is illustrating the concentrations of daily and yearly releases of heavy metals in the sewage water that is discharged at Al-Khumra zone which strengthen and confirm the suggestion and belief that the source of the high heavy metal concentrations at Al-Khumra zone compared to the other zones is the city sewage water effluents that are discharged into it. On the other hand El-Sayed and Niaz (1999) mentioned that Al-Khumra treatment plant receives daily about 200,000-300,000 m^3 sewage water and this amount is not wholly treated, and thus the plant dumps into the Red Sea water partially treated polluted sewage water with high concentrations of heavy metals. Another reason for the high concentration of heavy metals at Al-Khumra area is because this area receives huge volumes of discharged sewage water from Jeddah city and sewage water reduces salinity of the seawater at Al-Khumra coastal area thus increasing the concentration of the heavy metals compared to the concentration of these metals in the other studied zones with high seawater salinity. Yeats and Loring (1991) found that the concentration of the dissolved Al, Fe, Mn, Co, Cu, Ni and Zn generally decreased significantly with increase in seawater salinity, and found that the distribution of these metals in St. Lawrence estuary were influenced by seasonally variable fresh water discharges. Also, Kim *et al*. (2010) stated that dissolved metals concentrations decrease as salinity increases. The remarkably high concentration of Fe in seawater at Al-Khumra zone is due to the fact that the zone receives the waste discharges coming from the industrial area where many factories are dealing with iron (Fe) works.

Jeddah port comes second to Al-Khumra giving the highest seawater heavy metal concentrations of (Zn, Pb, Fe, Cu and Cd) after Al-Khumra compared with all other zones. And this increase of heavy metals in the seawater at Jeddah port coastal area is due to the many coastal activities carried out at Jeddah such as shipping activities, fueling the ships, repairing, greasing, painting the ships, corrosion of ships hulls coatings and anti-fouling paints and many other activities. Jeddah is a big city with a refinery and receives a lot of ships daily. The increase of Cu metal at Jeddah port area may be due to corrosion of ships hulls coatings and anti-fouling paints. And the increase in Zn concentration in the seawater may be due to its consumption by phytoplankton's which are increasing in autumn season, as stated by El-Samra *et al*. (1995) and Abou-El-Sherbini and Hamed (2000) that phytoplankton aids removal of Zn from seawater during autumn. The remarkably highest heavy metal at Al-Khumra zone is Fe, ae Jeddah zone is Zn, at outside Al-Shabab zone is Cu, at inside Al-Shabab zone is Zn, Al-Arbaeen zone is dominated by Fe, at Al-Noras the highest is Zn while at Sharm Obhur the highest metal is Cu.

Based on suggestion by Suthar *et al*. (2009)the concentration of Zn in Al-Noras and Jeddah port and Al-Khumra can be considered as unpolluted to moderately polluted (5.59 – 59.14 mg/kg), Cu unpolluted (0.8755 – 29.43 mg/kg), Fe highly polluted (up to 1968.32 mg/kg), and Cd is very strong pollution (up to 6.1170 mg/kg).

Table (2) shows the average concentrations of the heavy metals in the sediment of the sewage effluent that is discharged at Al-Khumra area and that Fe, Zn and Cu concentrations with averages of 8970, 1557 and 112 mg/kg, with an average annual release of 29000, 5200 and 365 mg/ kg .

CONCLUSION

Concentrations of the heavy metals studied (Fe, Zn, Cu, Pb, Cd) in the Red Sea coastal waters in the seven zones along Jeddah transect were found to vary over space. Al-Khumra and Jeddah port zones showed the highest values of the tested elements in the suspended particulate matter (SPM) than the other zones. This will affect the fish ground, fishes and human health. So, this area should be considered as a dangerous areas for public health. More attention should be taken to reduce the heavy metals in the suspended particulate matter seawater.

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