Marine Pollution Bulletin xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

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Distribution of heavy metals in the coastal area of Abu Dhabi in the United Arab Emirates

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ARTICLE INFO

Article history:
Received 10 February 2015
Revised 15 May 2015
Accepted 21 May 2015
Available online xxxx

Keywords:
Heavy metals contamination
Sediments
Abu Dhabi coastal area in the United Arab Emirates
Geoaccumulation index
Enrichment factor
Pollution load index

ABSTRACT

Fifty-seven sediment samples were collected from Abu Dhabi coastal area, United Arab Emirates (UAE). The concentrations of heavy metals including antimony, arsenic, barium, cadmium, cobalt, copper, mercury, lead, molybdenum, nickel and zinc were obtained using Inductively Coupled Plasma–Mass Spectroscopy (ICP–MS) and X-ray fluorescence. Heavy metal contaminations in Abu Dhabi had increased since 2004. Nevertheless, the enrichment factors, geoaccumulation indices and the pollution load index of 0.3 showed no pollution with any of the measured metals except arsenic.

Anthropogenic activities, municipal effluents, dredging and reclamation, nuclear weapons and power plants are major sources of heavy metals to coastal environments (Fu and Wang, 2011; Yu et al., 2008). While most of heavy metals are essential for life at low concentrations (Singh et al., 2011), many are toxic at high concentrations (Fu and Wang, 2011). This is because of their persistence and bioaccumulation characteristics, especially if improperly disposed (DeForest et al., 2007). Heavy metals could cause disorders in the central neurological system, damages in the brain, mental disabilities, birth defects, malfunctioning in the kidney and livers, severe damages to the bones, and cancer. In Iraq in 1972, approximately 6000 individuals became sick and 500 died after eating bread made from wheat treated with methyl mercury fungicides. In 1978, a sanction was imposed against the use of lead as it is highly poisonous in blood even in concentrations as low as 10 μg/L (Girard, 2013). The elements lead, mercury cadmium and arsenic have been recently classified among the top ten hazardous chemicals according to the National Priority List (*ATSDR, 2013*).

Kazemi et al. (2011) reported the following levels of heavy metals in the coastal zone of the Arabian Gulf: 0.86–180.78 ppm Pb, 0.61–6.48 ppm Cd, 5.99–37.66 ppm Zn and 3.01–43.33 ppm Cu. Heavy metal contaminations have been examined in several Emirates in the UAE (Shriadah, 1999; El-Sammak, 2001; De Mora et al., 2004; Howari, 2005; Abd El-Gawad and El-Sammak, 2008; Campbell et al., 2015). The objective of this study is to investigate the *current* distributions and concentrations of heavy metal along the coastal area of *Abu Dhabi*.

The UAE is in southwest Asia. It is surrounded by the Gulf of Oman to the east, the Kingdom of Saudi Arabia to the west and south, and the Arabian Gulf to the north. The coast of the UAE is approximately 900 km long (Alsharhan and Kendall, 2003). The UAE is south the Strait of Hormuz. The UAE can be divided into two different geographic, oceanographic and morphological regions. The Arabian Gulf side which is a flat area of dunes, and the Gulf of Oman coast which has narrow, alluvial plains. The Arabian Gulf is a shallow sea with a maximum depth of only 60 m, while the eastern coast faces open ocean. The soil in UAE is mainly infertile and sandy with high concentrations of quartz and carbonates (ICBA, 2009).

Samples were collected from the coastal area in Abu Dhabi (see Fig. 1). The soil samples were handled according to the 1981 EPA/CE-81-1 protocol (Plumb, 1981). The concentrations of following elements were measured: antimony (Sb), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), copper (Cu), mercury (Hg), lead (Pb), molybdenum (Mo), nickel (Ni), and zinc (Zn). Inductively Coupled Plasma–Mass Spectrometry (ICP–MS) analyses were ran out by the Acme Labs, Canada, and XRF spectrometry was

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http://dx.doi.org/10.1016/j.marpolbul.2015.05.052
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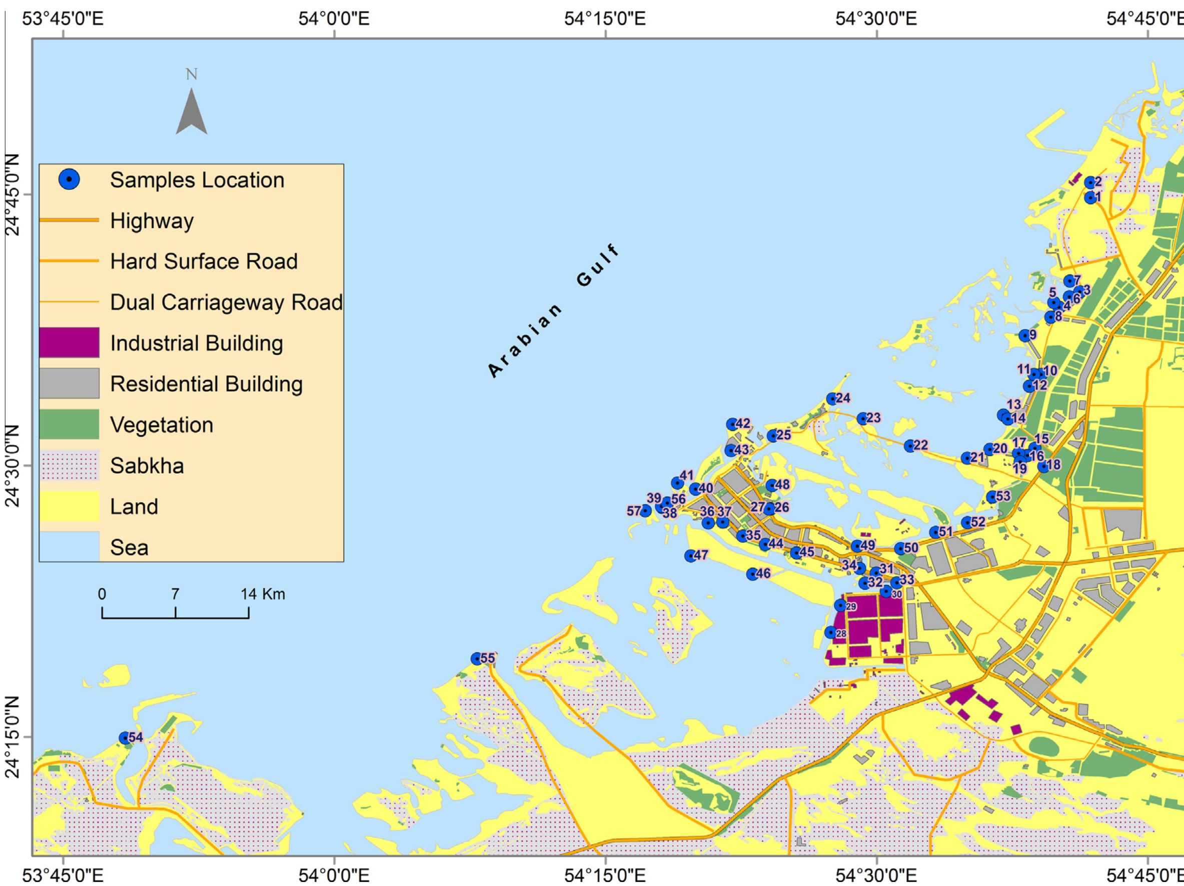

Fig. 1. Abu Dhabi map with blue dots positioning the 57 sampling locations. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

performed at the Central of Analytical Facilities, Stellenbosch University, South Africa. For details of methodology please refer to the Supplementary Material.

Antinomy and arsenic are released from the sulfide-ores processing. They are found realgar As_4S_4 and stibnite Sb_2S_3 (Cox, 2004). The level of antimony does not exceed 0.2 ppm in samples no. 3, 21, 22, 31, 39, 46, 47 and 56. The level of Sn, in rest of the samples, is $\leqslant$0.1 ppm. In all samples, the level of antimony is well below the safe limit (15 ppm), i.e. the Dutch guidelines (Lijzen et al., 2001).

Arsenic sources include mining, pesticides and power-generating plants (Newton, 2008). Arsenic concentrations in AD are negligible compared to the safe limit, 55 ppm. The maximum value is 5.0 ppm in sample no. 5, Yas Island. The minimum value of 1.4 ppm, in AD Island (sample 40), is in great agreement with the results from De Mora et al. (2004).

Barium concentrations vary from 28 to 227 ppm with an average of 136 ppm. The highest value in sample 30 (Musaffah Industrial) is only 36% of the safe limit, 625 ppm. Fourteen samples have less than 100 ppm of Ba, 38 samples have Ba ranging from 100 to <200 ppm and three samples have >200 ppm of Ba.

Cadmium sources include mining, industrial wastes, water pipes and electroplating plants (Newton, 2008). Cadmium is used in anti-corrosion coating (Cox, 2004). Half of the samples have Cd concentrations <0.1 ppm, while the rest do not exceed 0.3 ppm, with the safe limit being 12 ppm. These values are in good agreement with the 0.02 ppm value published by De Mora et al. (2004), but an order of magnitude smaller than the values reported by Shriadah (1999).

The maximum contamination of cobalt, in Musaffah Industrial, is <3% of the safe limit, 240 ppm. The values range from 0.4 to 7.2 ppm with an average of 4.1 ppm, which is an order of magnitude greater than the average reported by De Mora et al. (2004), and almost triple the value reported by Shriadah (1999).

Copper is released from electroplating, mining, and municipal wastes. The maximum contamination of Cu in AD is <3.4% of the safe limit, 190 ppm. Cu concentrations range from 1.8 ppm to 6.5 ppm with an average of 3.8 ppm. The average had doubled since 1999 or since 2004. The minimum values are, however, in good agreement with the 1.99 ppm reported by Shriadah (1999).

Mercury is used in small batteries (Miessler and Tarr, 2003). Mercury concentrations in AD range from <0.01 to 0.04 ppm, which is one fold greater than the 0.001 ppm value reported in 2004.

Lead is used in pipes for drinking water, paint, batteries and gasoline (Cox, 2004). Lead concentrations in AD range from 0.9 to 4.0 ppm with an average of 1.9 ppm, i.e. approximately three times greater than the lead contamination of 0.78 ppm reported in 2004.

Industrial wastes are the major source of molybdenum. Mo is essential to enzymes in plants to catalyze the formation of ammonia (Miessler and Tarr, 2003). The concentration of molybdenum in AD ranges from <0.1 to 1.7 ppm, well below the safe limit of 200 ppm.

Nickel is commonly used as catalyst in petroleum and chemical industries (Miessler and Tarr, 2003). It is also used in nickel metal-hydride or nickel–cadmium batteries (Atkins, 2010). The range of nickel concentrations in AD is 3.5–73.5 ppm, with an average of 25.3 ppm. The highest value reaches only 35% of the safe

Please cite this article in press as: Al Rashdi, S., et al. Distribution of heavy metals in the coastal area of Abu Dhabi in the United Arab Emirates. Mar. Pollut. Bull. (2015), http://dx.doi.org/10.1016/j.marpolbul.2015.05.052