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Assessment of metal contamination in coastal sediments of Al-Khobar area, Arabian Gulf, Saudi Arabia

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ABSTRACT

An assessment of marine pollution due to heavy metals was made to coastal sediments collected from Al-Khobar coastline, in the Arabian Gulf, Saudi Arabia by analyzing of Al, V, Cr, Mn, Cu, Zn, Cd, Pb, Hg, Mo, Sr, Se, As, Fe, Co and Ni using Inductively Coupled Plasma-Mass Spectrometer (ICP-MS). The results indicated that the distribution of most metals was largely controlled by inputs of terrigenous material and most strongly associated with distribution of Al in sediments. In general Sr, Cr, Zn, Cu, V, Hg, Mo and Se show severe enrichment factors. Average values of Cu and Hg highly exceed the ERL and the Canadian ISQG values. Average Ni was higher than the ERL and the ERM values. The severe enrichment of some metals in the studied sediment could be partially attributed to anthropogenic activities, notably oil spills from exploration, transportation and from saline water desalination plants in Al-Khobar coast, and other industrial activities in the region.

1. Introduction

Coastal environments are subjected to heavy metal pollutants as a result of industrial development along littoral zones worldwide (El Zrelli et al., 2015). The sources of heavy metals in coastal environments include anthropogenic activities and natural weathering processes (Sadiq and Alam, 1989; El-Sorogy et al., 2012, 2013a, b). Many complex processes of material exchange govern distribution of metals within the aquatic environments. These processes are affected by various anthropogenic activities and industrial wastewaters (Christophoridis et al., 2009).

Most of the anthropogenic metals in a marine coastal area are of terrestrial origin, coming from industrial and urban development, mining, and other human practices near aquatic environments (Carman et al., 2007). Many studies have dealt with assessment of heavy metal pollution worldwide on coastal areas. Most of these studies have used heavy metal analysis in sediments (Adamo et al., 2005; Gonzales-Macias et al., 2006; Carman et al., 2007; Vallius et al., 2007; Abrahim and Parker, 2008; Cevik et al., 2009; Fang et al., 2009; Diaz-de Alba et al., 2011; Hahladakis et al., 2013; Omar et al., 2015; Youssef et al., 2015; El-Sorogy et al., 2016). The more recent studies on the coastal area between Ras Tanura and Ras Abu Aly on the Saudi Arabian Gulf (El-Sorogy and Youssef, 2015; El-Sorogy et al., 2016; Youssef et al., 2015; Almasoud et al., 2015) concluded that these coastal areas were subjected to anthropogenic pollutants in the form of rejected water from desalination, landfills, sewage, oil wastes, as well as the various solid wastes related to new constructions along the coast.

Almasoud et al. (2015) in their study on the relationship between coastal sediments of the Arabian Gulf and industrial activities concluded that Cr values were higher than those of the soil common range as well as the geochemical background in average shale. Their sediment samples were enriched with Zn, Cu, Cr, Pb, of anthropogenic sources and Ni, Co, Mn, Fe originated from the soil parent materials and natural process. In their study on coastal sediments of the Tarut Island on the Arabian Gulf coast, Youssef et al. (2015) indicated these coastal sediments had very high As and high Hg values compared to coastal sediments from the Red Sea and the Gulf of Oman. Their values exceeded the wet threshold safety values (MEC, PEC). They attributed the high values of As and Hg to land filling, dredging, sewage, and oil pollution in the study area.

The primary surveying during this study along the Al-Khobar

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coastline indicated human stresses on some localities. These stresses are represented by landfilling, crowded fishing boats, seawater desalination plants, construction of artificial rocky shores and the presence of different solid wastes from human activities. Accordingly, the main objectives of the present study are to: 1) evaluate the levels of heavy metals along Al-Khobar coastal area; 2) assess the impact of human activities on the coastal environment, and 3) compare the rate of pollution in Al-Khobar coastal area with neighboring and worldwide coasts.

2. Material and methods

2.1. Study area

The Al-Khobar coast is located in the south of the Saudi Arabian Gulf between longitudes 49°58′- 50°14′ E and latitudes 25°56′- 26°18′ N (Fig. 1). According to sediment type, the Al-Khobar coast has three major types (Fig. 2): 1) Sandy-dominated shores, composed of a mixture of coarse sand to sandy mud and very few biogenic materials such as samples 11, 12, 13, 14, 20 and 26. Terrigenous matters in these sediments include angular to well-rounded quartz grains. Biogenic materials include bivalves, gastropods, foraminifers, ostracods and sea grass; 2) Biogenic-dominated shores composed mainly of seashells and calcareous sands, such as samples 22, 23, 25, 27, 29 and 30. Seashells are represented by accumulations of gastropods (mostly cerithiids) and bivalves (mostly venerids). Under the microscope, calcareous sands show the presence of foraminiferes (*Peneroplis, Quinqueloculina, Ammonia, Spiroloculina, Triloculina, Sorites and Textularaia* spp.), ostracods, bryozoans, echinoid fragments and embryonic stages of molluscs; 3) Artificial and natural Rocky shores. The artificial rocky shores were constructed from old rock blocks to protect cities and tourist villages from high tides and sea erosion. The natural rocky shores are composed of highly consolidated sands. Sediments beyond the natural rocky shores are composed of calcareous sands and seashells, like samples 24 and 28. Fractures and low biotopes in both artificial and natural rocky shores are inhabited with barnacles, worm tubes and gastropods.

2.2. Sampling and analytical methods

In this study, 29 coastal sediment samples were collected from 29 sites on the littoral zone of the Al-Khobar coastline (Fig. 1). Grain size analysis was determined according to Folk (1974). Samples were sieved to remove stones and shells, homogenized by being ground lightly in an agate mortar, and prepared for analysis. The total carbonate and silicate contents were estimated as described by Molnia (1974). About 5 g of dry sample was weighed in a clean dry beaker to which 25 ml 3N hydrochloric acid was added and heated to 50–60° C, left to react, after complete reaction, filtered through glass filter paper, washed repeatedly with distilled water, then dried at 40° C in an oven and the filter paper was reweighed. The difference in the two weights is the weight of carbonate and the residue of the non-carbonate fraction (silicate). Samples were analyzed for Al, V, Cr, Mn, Cu, Zn, Cd, Pb, Hg, Mo, Sr, Se, AS, Fe, Co and Ni using ICP-MS: NexION 300D (Perkin Elmer, USA) in the Central Laboratory of the College of Science, King Saud University.

Samples are dried in an oven at 115 °C, mechanically crushed, sieved through a 200 mesh sieve and about 100 mg of samples was put into dry and clean Teflon microwave digestion vessels. 2 ml of HNO_3, 6 ml HCl and 2 ml HF were added to the vessels. Samples are digested using a scientific microwave (Model Milestone Ethos 1600). The resulting solution was transferred to a 15 ml plastic volumetric tube and made up to mark using deionized water. A blank digest is carried out in the same manner.

2.3. Estimation of pollutant indicators

To calculate pollutant indicators of metal pollution in the studied coastal sediments, three factors are taken into consideration:1) Enrichment Factor (EF) to estimate the anthropogenic impact on sediments and to differentiate between the anthropogenic and natural sources of metals (Sinex and Helz, 1981); 2) Geoaccumulation Index (Igeo) to evaluate the trace metal pollution in sediments (Muller, 1979; Leopold et al., 2008); 3) Contamination Factor (CF), which describes the contamination of a given toxic substance in a basin (Hökanson, 1980). In order to establish the relations between trace elements in the Al-Khobar coastal

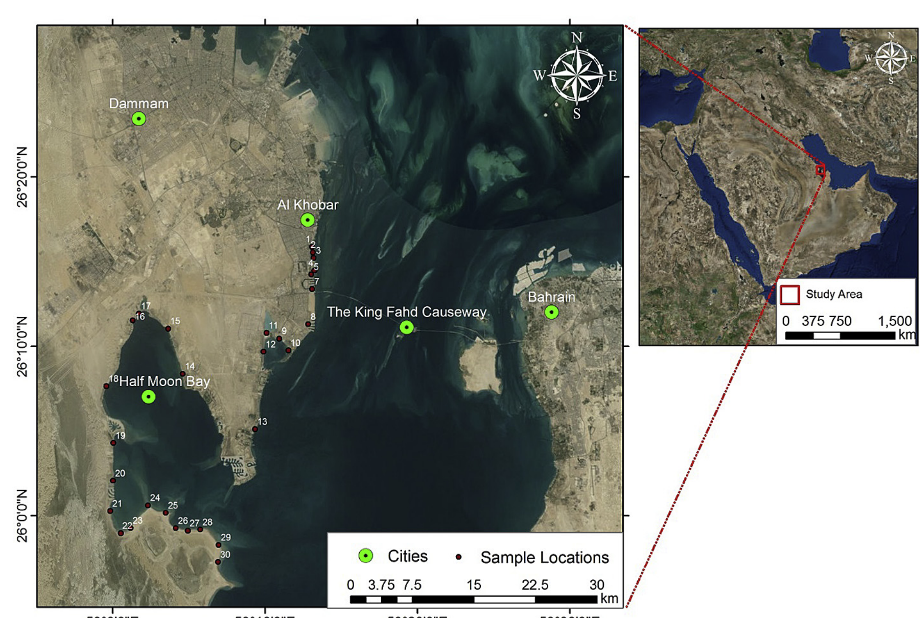

Fig. 1. Location map of Al-Khobar coastline and the locations of sediment samples along the coast.