Oceanologia (2015) 57, 236–250

Available online at www.sciencedirect.com

ScienceDirect

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

ORIGINAL RESEARCH ARTICLE

# Heavy metals contamination and distribution of benthic foraminifera from the Red Sea coastal area, Jeddah, Saudi Arabia☆

**Mohamed Youssef** [a,b,*]

[a] *Department of Geology and Geophysics, College of Science, King Saud University, Riyadh, Saudi Arabia*
[b] *Department of Geology, Faculty of Science, South Valley University, Qena, Egypt*

Received 1 March 2015; accepted 14 April 2015
Available online 29 April 2015

**KEYWORDS**
Benthic foraminifera;
Heavy metals;
Red Sea;
Saudi Arabia

**Summary** The distribution of benthic foraminifera was studied in two stations in the coastal area, located around Jeddah, Red Sea coast, Saudi Arabia. Thirty-three species belonging to 15 genera, 14 families and three suborders were recorded in twenty samples. Some foraminiferal tests display abnormalities in their coiling, general shape of chambers and apertures. On the other hand, concentrations of Fe, Mn, Zn, Cu, Pb, Ni, Cr, and Cd were measured in the tests of the two most common living species of benthic foraminifera (*Sorites marginalis* and *Peneroplis planatus*). Significant spatial differences in the metal concentrations of benthic foraminifera were recorded at the two sites. Benthic foraminifera yielded significantly high concentrations of Fe, Mn, Pb and Cu, which may attribute to anthropogenic activities at the studied coastal areas. The anthropogenic activities have a considerable impact, besides other factors, in the abnormalities of foraminiferal test.


☆ This project was supported by King Saud University, Deanship of Scientific Research, and College of Science Research Center.
* Correspondence to: Department of Geology and Geophysics, College of Science, King Saud University, P.O. Box 2455, Riyadh 11451, Saudi Arabia. Tel.: +966 11 4699644; fax: +966 11 4676214.
*E-mail addresses:* mymohamed@ksu.edu.sa, myousefgeology@gmail.com.
Peer review under the responsibility of Institute of Oceanology of the Polish Academy of Sciences.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.oceano.2015.04.002

## 1. Introduction

The Red Sea is a marginal marine basin that is entirely enclosed by African continent and Arabian Peninsula. The extreme evaporation rates in these arid to semi-arid regions result in high salinity of surface water masses with maximum values above 40‰ in the northern Red Sea (Badawi et al., 2005). The Saudi Red Sea coast extends for nearly 1932 km with numerous coastal lagoons, some of them locally known as Sharms (Hariri, 2008). The dumping of wastewaters from Jeddah in the Al-Arbaeen and Al-Shabab inlets which occur in the middle of Jeddah coast led to the occurrence of an estuarine circulation pattern in the inlets and surrounding areas (Abu-Zied et al., 2012; Basaham et al., 2011; El-Rayis and Moammar, 1998).

Foraminifera are very useful to study marine environmental conditions, because of their highest diversity and abundance in the sediments (Narayan and Pandolfi, 2010). Their tests provide the most abundant sediment particles in most marine environment (Piller, 1994). They also play an important role in short-term carbon cycling in the Oxygen Minimum Zone (OMZ) (Enge et al., 2014). Foraminifera can display varieties of test deformation caused by pathological morphogenesis, including extreme compression, double apertures, twisted coiling, aberrant chamber shape, and protrusions (Alve, 1991; Samir, 2000; Samir and El-Din, 2001; Yanko et al., 1994). Moreover, malformation of benthic foraminifera may be related to natural environmental stresses such as hypersalinity, change in trophic resources, and rapidly changing in other environmental conditions (Albani et al., 2007; Almogi-Labin et al., 1992; Armynot du Châtelet et al., 2004; Debenay et al., 2001; Mojtahid et al., 2008; Murray, 1973; Romano et al., 2009; Scott et al., 2005). Deformed tests appear to increase significantly in areas subjected to different types of pollutants, e.g., oil slicks (Venec-Peyre, 1981), sewage discharge (Watkins, 1961), agrochemicals (Bhalla and Nigam, 1986), high organic matter content (Caralp, 1989), and heavy metals contamination (Alve, 1991; Yanko et al., 1994, 1998).

Many studies of benthic foraminifera on the Red Sea deal with taxonomy or distribution and diversity (e.g., Aref and Madkour, 1999, 2000; El-Deeb, 1978; Haunold et al., 1997; Madkour and Youssef, 2011; Mohamed, 1996; Obaidalla, 1988; Ouda and Obaidalla, 1998). The study of benthic foraminifera as a tool for monitoring of the Red Sea environment has been relatively neglected since little information was published on the levels of heavy metals in benthic foraminifera of the western Red Sea coast (e.g., Madkour, 2004; Madkour and Youssef, 2009; Mansour et al., 2005; Ziko et al., 2001).

In the eastern Red Sea coast, many studies have been carried out on benthic foraminiferal abundance, distribution and their relation to environmental conditions (Abou Ouf, 1992a,b; Abou Ouf et al., 1988; Abou Ouf and El-Shater, 1993; Abu-Zied et al., 2012; Bahafzalah, 1979; Bahafzalah and El Askary, 1981; Gheith and Abou Ouf, 1996; Hariri, 2008; Yusuf, 1984). The present study focuses on the impact of the natural inputs and anthropogenic activities on the coastal areas along the Red Sea coast in Jeddah through the following: (1) investigating the distribution and abundance of benthic foraminiferal species in the two studied locations and the relationship between this distribution to the environmental stress; (2) determinig heavy metals in the benthic foraminifera; and (3) detecting the malformation in the foraminiferal tests.

## 2. Study area

Jeddah is a major city with a population of over 2.6 million and an area of 1500 km$^2$. The considerable increase in population of Jeddah in addition to about two million visitors during the pilgrimage season each year and the increase in tourism activities have polluted its coastal sea water. The coastal water receives different pollutants: untreated domestic sewage wastes, oil pollution from oil refinery of the Petromin factory, fish wastes from the big fish market, and probably desalination plant effluents. The wastes resulting from several processes related to these sources added a considerable amount of organic and heavy metals load to the study area.

The study area is located along the Red Sea coast, Jeddah, Saudi Arabia. Two coastal sites (Salman Bay and south Jeddah area) were sampled. The locations of these coastal areas are as follows: Salman Bay (Khalig Salman): 21°51′33″N, 38°58′45″E and south Jeddah area (Bahar Al Ganoob): 21°15′88″N, 39°8′18″E (Fig. 1).

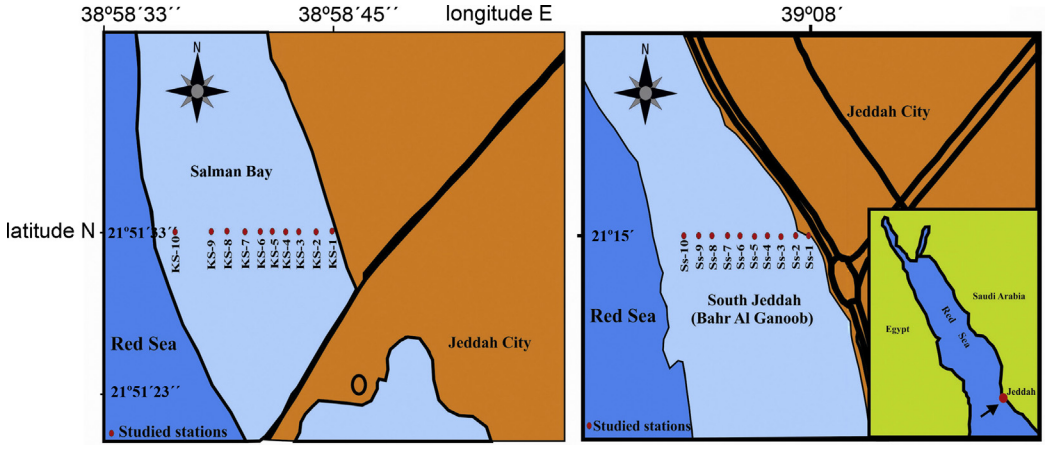


**Figure 1** Location map of Salman Bay (Khalig Salman), north of Jeddah, and south Jeddah area (Bahr Al Ganoob), south of Jeddah.