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ORIGINAL PAPER

Geochemical and foraminiferal analyses of the bottom sediments of Dammam coast, Arabian Gulf, Saudi Arabia

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Abstract Bottom sediment samples were collected from 17 locations of the Dammam coast, Dammam city, Saudi Arabia in April 2014. The concentrations of iron, chromium, manganese, nickel, zinc, cadmium, lead, and copper in the bottom sediments were measured by inductively coupled plasma-mass spectrometer (ICP-MS). The mean metal concentrations are Fe (372.4 μg/g), Mn (5.9 $\mu g\ g^{-1}$), Zn (5.1 $\mu g\ g^{-1}$), Cu (6.3 $\mu g\ g^{-1}$), Pb (2.1 $\mu g\ g^{-1}$), Ni (4.4 $\mu g\ g^{-1}$), Cr (6.5 $\mu g\ g^{-1}$), and Cd (0.1 $\mu g\ g^{-1}$). The distribution of benthic foraminifera in the collected samples was investigated. Twenty-nine species of 12 genera under nine families and three suborders were recorded. The most common genera are *Peneroplis* and *Quinqueloculina* which attain 39 and 38 % of the recorded fauna, respectively. The other common genera which were recorded in the study area are as follows: *Ammonia* (9 %), *Spiroloculina* (6 %), *Triloculina* (5 %), *Sorites* (1.1 %), and *Textularaia* (1 %). The other genera that have been recorded represent minor constituents. Some species exhibit abnormal test morphologies that may indicate environmental stress.

Keywords Benthic foraminifera · Heavy metals · Dammam coast · Saudi Arabia

Introduction

The Arabian Gulf is a shallow subtropical epicontinental sea. It is nearly closed and is about 1000 km long and 200–300 km wide covering an area of about 226, 000 km^2 (Abou-Ouf 1981). The average depth of the Arabian Gulf is only 35 m. The Arabian Gulf is characterized by the abnormal salinity, the surface salinities in the central parts of the Gulf is in average of 37–40 ‰; while the shallow parts on the Arabian side is at range of 40–50 ‰. The Saudi Arabian coastline of the Arabian Gulf extends for about 450 km. The coastline has an extensive system of bays and lagoons such as Tarut Bay. The sediments are dominantly carbonates and evaporites in the shallow waters off the Arabian coast.

Recent benthic foraminifera in the Arabian Gulf bottom sediments have attracted the attention of many workers since the first attempt of Fichtel and Moll (1798). This foraminiferal content have attracted more attention in the last 50 years (e.g., Henson 1950; Houbolt 1957; Murray 1970a, b, 1973; Anber 1974; Haake 1975; Abou-Ouf 1981; Darmoian and Al-Rubaee 1989; Elewi and Safawe 1989; Farahani 1998; Al Hitmi 2000; Issa et al. 2009; Mooraki et al. 2012).

The type of bottom sediments can play a fundamental role in the distribution of metal concentrations in marine environments. The Arabian Gulf bottom sediments

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consist principally of carbonates, evaporates, and terrigenous materials (Al-Ghadban et al. 1994; Basaham and El-Sayed 1998 and Maeda et al. 1998; Basaham 2010). The determination of the total metal content in the bulk sediments of coastal areas of the Arabian Gulf has been carried out in many studies (e.g., Sadiq and Zaidi 1985; Al-Arfaj and Alam 1993; Basaham and Al-Lihabi 1993; Al-Sayed et al. 1994; El Sayed et al. 2002; Samir et al. 2006; Basaham 2010; Biati et al. 2012; Elhabab and Adsani 2013).

The present work aimed to (1) study the concentrations and distribution heavy metals in the recent bottom sediments in the Dammam coast and (2) study the distribution of the benthic foraminiferal assemblages and their response to the environmental stress in the eastern coast of Saudi Arabia.

Materials and method

Seventeen bottom sediment samples were collected from the studied area (Fig. 1) in April 2014. For the heavy metal concentrations in the bottom sediment, the samples were prepared by accurately weighing around 50 mg of samples into a dry and clean Teflon digestion beaker; 2 ml of HNO_3, 6 ml HCl, and 2 ml HF were added to the Teflon beaker. Samples were digested on the hot plate at 120–150 °C for approximately 40 min. The resulting digest was not clear, so it was filtered through Whatman filtered paper no. 42. The filtered digest was transferred to 15-ml plastic tubes and made up to mark using deionized water. A blank digest was carried out in the same way. The analytical determination of trace metals was carried out by inductively coupled plasma-mass spectrometer (ICP-MS) NexION 300D (Perkin Elmer, USA) of King Saud University.

For foraminiferal analysis 50 g from the upper 2 cm of the bottom sediments of each dry sample was washed over a sieve of 0.063-mm opening size to remove salts and/or clay materials. A part of each sample was preserved in formalin (5 %) in the field, and then stained with rose bengal to differentiate between the dead and live foraminifera. The residue was then dried in drying oven at 70–80 °C. Each sample was subdivided into two fractions (250 and 125 μ) to pick the foraminiferal tests. If possible, 200 specimens were counted from the 250-μ fraction of each sample. The selected foraminiferal taxa were photographed using the scanning electron microscope (JSM-6380LA) of King Saud University.

Results and discussions

Benthic foraminiferal analysis

Twenty-nine species belonging to 12 genera and nine families under the Textularina, Rotalina, and Miliolina suborders (according to the scheme of Loeblich and Tappan 1987, and 1988) have been recorded in the study area. The most common genera are *Peneroplis* and *Quinqueloculina* which attain 39 and 38 % of the recorded fauna, respectively. The other common genera which recorded in the study area are as follows: *Ammonia* (9 %), *Spiroloculina* (6 %), *Triloculina*

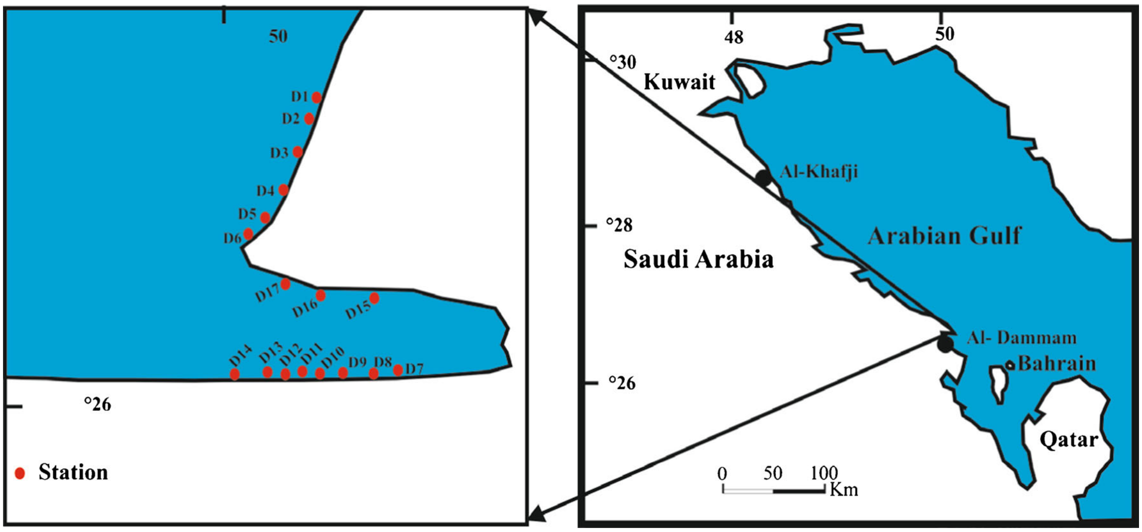

Fig. 1 Location map for the study area

Table 1 Frequency and distribution of recent benthic foraminifera in the study area

G. no.	Species no.	Family	Genus	Species	Sp. total	Sp. percent	Genus	Percent	Family	Percent	Order	Percent
1	1	Textulariidae	*Textularia*	*Textularia conica*	2	0.16	*Textularaia*	1.03	Textulariidae	1.03	Textularina	1.030111
	2			*Textularia foliacea*	3	0.24	*Spirolina*	0.95	Eliphidiidae	0.554675119	Rotalina	49.36609
	3			*Textularia agglutinaus*	7	0.55	Eliphidium	0.55	Spirolinidae	0.950871632	Miliolina	48.65293
	4			*Textularia* sp.	1	0.08	*Sorites*	1.11	Soritidae	1.109350238		
2	5	Spirolinidae	*Spirolina*	*Spirolina arietina*	12	0.95	*Peneroplis*	38.91	peneroplidae	38.90649762		
3	6	Eliphidiidae	*Eliphidum*	*Eliphidum crispium*	4	0.32	*Ammonia*	8.80	Rotaliidae	8.795562599		
	7			*Eliphidum advenum*	3	0.24	*Spiroloculina*	6.02	Spiroloculinidae	6.022187005		
4	8	Soritidae	*Sorites*	*Sorites marginalis*	14	1.11	Triloculina	4.91	Hauerinidae	42.55		
5	9	peneroplidae	*Peneroplis*	*Peneroplis planatus*	33	2.61	*Quinqueloculina*	37.48	Nubeculariidae	0.079239303		
	10			*Peneroplis pertusus*	330	26.15	*Articulina*	0.08				
	11			*Peneroplis proteus*	128	10.14	*Pseudomassilina*	0.08				
6	12	Rotaliidae	*Ammonia*	*Ammonia beccarii*	111	8.80	*Nodophthalmidium*	0.08				
7	13	Spiroloculinidae	*Spiroloculina*	*Spiroloculina laevigata*	45	3.57						
	14			*Spiroloculina hadai*	14	1.11						
	15			*Spiroloculina angulata*	13	1.03						
	16			*Spiroloculina* sp.	4	0.32						
8	17	Hauerinidae	*Triloculina*	*Triloculina affinis*	60	4.75						
	18			*Triloculina* sp.	2	0.16						
9	19		*Quinqueloculina*	*Quinqueloculina bidentata*	96	7.61						
	20			*Quinqueloculina agglutinous*	8	0.63						
	21			*Quinqueloculina elegans*	123	9.75						
	22			*Quinqueloculina oblonga*	19	1.51						
	23			*Quinqueloculina seminulum*	1	0.08						
	24			*Quinqueloculina angularis*	28	2.22						
				Quinqueloculina mosharafi	1	0.08						
	25			*Quinqueloculina* sp.	197	15.61						
10	26		*Articulina*	*Articulina* sp.	1	0.08						
11	27		*Pseudomassilina*	*Pseudomassilina pacificensis*	1	0.08						
12	28	Nubeculariidae	*Nodophthalmidium*	*Nodophthalmidium antillarum*	1	0.08						
Total					1262	100.00						

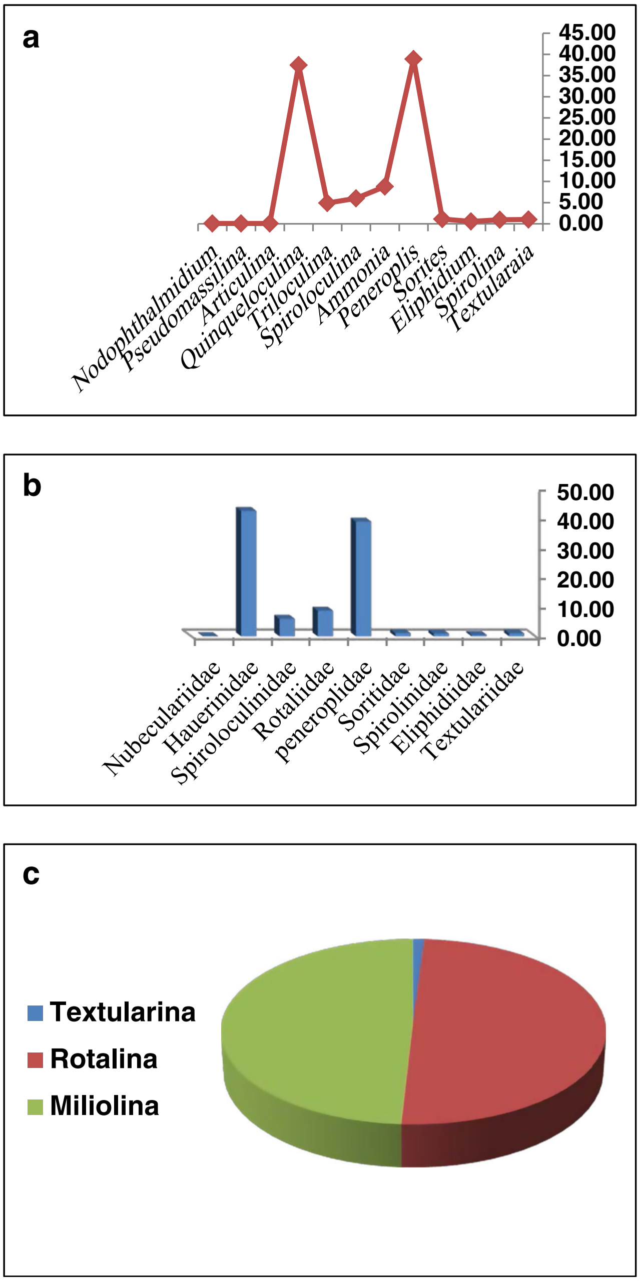

Fig. 2 The frequency of the benthic foraminifera in the studied area: **a** by genera, **b** by family, and **c** by suborder

(5 %), *Sorites* (1.1 %), and *Textularaia* (1 %). The other genera that have been recorded represent minor constituents such as: *Spirolina*, *Elphidium*, *Articulina*, *Pseudomassilina*, and *Nodophthalmidium* (Table 1).

Family Peneroplidae of suborder Miliolina is the most dominant foraminiferal family in the studied assemblage (Table 1 and Figs. 2, 3, and 4). Species of the recorded families live in association with sea grass, which is widely distributed through the coastal area (Mohamed et al. 2013). The abundance of genera of the family Hauerinidae of the same suborder, which comprises *Quinqueloculina*, *Triloculina*, and *Articulina*, characterize a shallow, sheltered, warm marine environment (Madkour 2013). This agrees with Abu-El Enein's (1979) findings that the study area is a sheltered bay with relatively weak wave action and agrees with the ecologic distribution of these taxa (Murray 1973).The reef lagoon had a high abundance of *Quinqueloculina* (Abou-Ouf 1981). The markedly greater abundance of these genera in the Arabian Gulf may be, furthermore, considered to be due to the warmer nature of this water body (20–40 °C). The Peneroplids are common in the south western part of

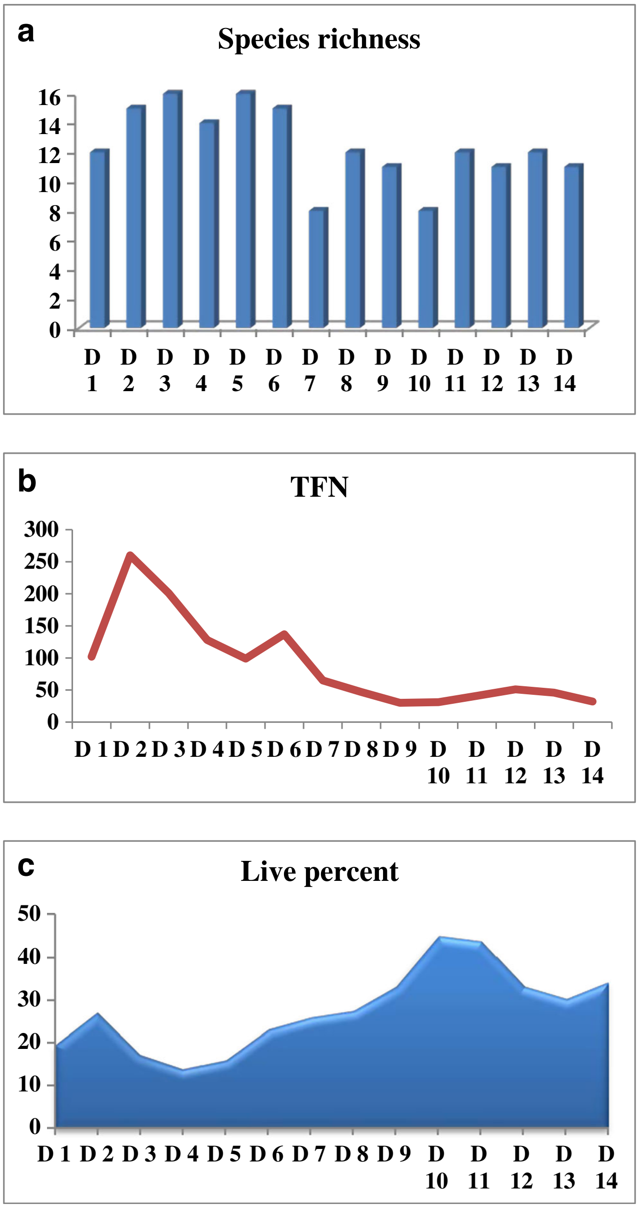

Fig. 3 Parameters of the benthic foraminifera in the studied area: **a** species richness, **b** total foraminiferal number in 100 g sediments, and **c** live percent

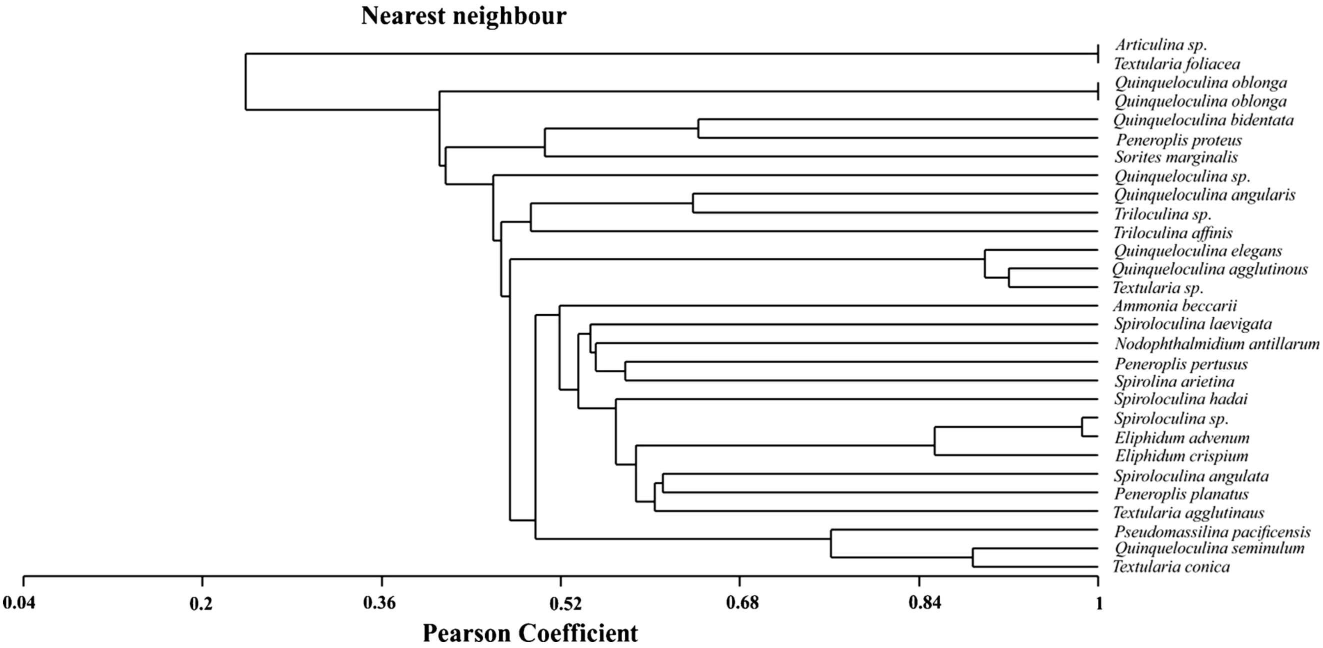

Fig. 4 Dendrogram of cluster analysis for the foraminiferal species

the Arabian Gulf (Tarut Bay) and becomes rare northwards and have not been recorded from the Iranian side of the Gulf (Abou-Ouf 1981). They were found to be very rare at Kuwait (Anber 1974).

The suborder Rotaliina is less abundant as it represents about 5.8 % (Fig. 2) of the studied foraminiferal assemblage. The most abundant family of the suborder Rotaliina is the family Rotaliidae which is represented by the genus *Ammonia*. The *Ammonia beccarii* is highly abundant in the studied area. It is increased under stressed environmental conditions such as abnormal salinity (Pokorny 1965). The high abundance of *Ammonia* characterizes the abnormal environmental conditions (Abou-Ouf 1981; Mohamed et al. 2013). The Arabian Gulf includes euhaline-hyperhaline waters. Its restriction can be used as an indicator of warm environments with euhaline-hyperhaline waters (Abou-Ouf 1981).

Test morphology abnormalities

Morphological abnormalities are a general feature occurring among all benthic foraminifera. The presence of abnormal tests suggests natural environmental stresses, e.g., changes in ecological parameters (Closs and Maderia 1968), extreme environmental conditions (Zaninetti 1982), or pollution. For a long time, it has been difficult to distinguish between abnormalities resulting from natural or anthropogenic stresses. Abnormal specimens contain much greater values of Cu and Zn than non-deformed specimens (Yanko et al. 1998). Foraminiferal tests with twisted, compressed, and abnormal growth are characterized by higher values of heavy metals than those forms with protuberances (Samir and El-Din 2001). The abnormalities in foraminiferal tests in the studied area include the following: abnormal growth, protuberances, or abnormal test shape (Plates 1 and 2, figs. 15, 16). Some foraminiferal species display a wide variety of abnormality caused by pathological morphogenesis including double aperture, aberrant chamber shape, and extreme compression. This record indicates that environmental pollution is preserved within the foraminiferal tests of some specimens.

Heavy metal concentration

Metal concentrations in sediment fraction are controlled by particle size, chemical and mineralogical composition, and degree of surface oxidation of the particles. Concentrations of Fe, Mn, Zn, Cu, Pb, Ni, Cr, and Cd in the study area are presented in Table 2.

Iron

Iron shows higher concentration in D-17 (710.5 μg g^{-1}) and decreased to 290.8 μg g^{-1} in D-10 (Fig. 5a). Iron is an essential element in the marine ecosystem and consequently one of the most abundant elements in marine sediments of Arabian Gulf.

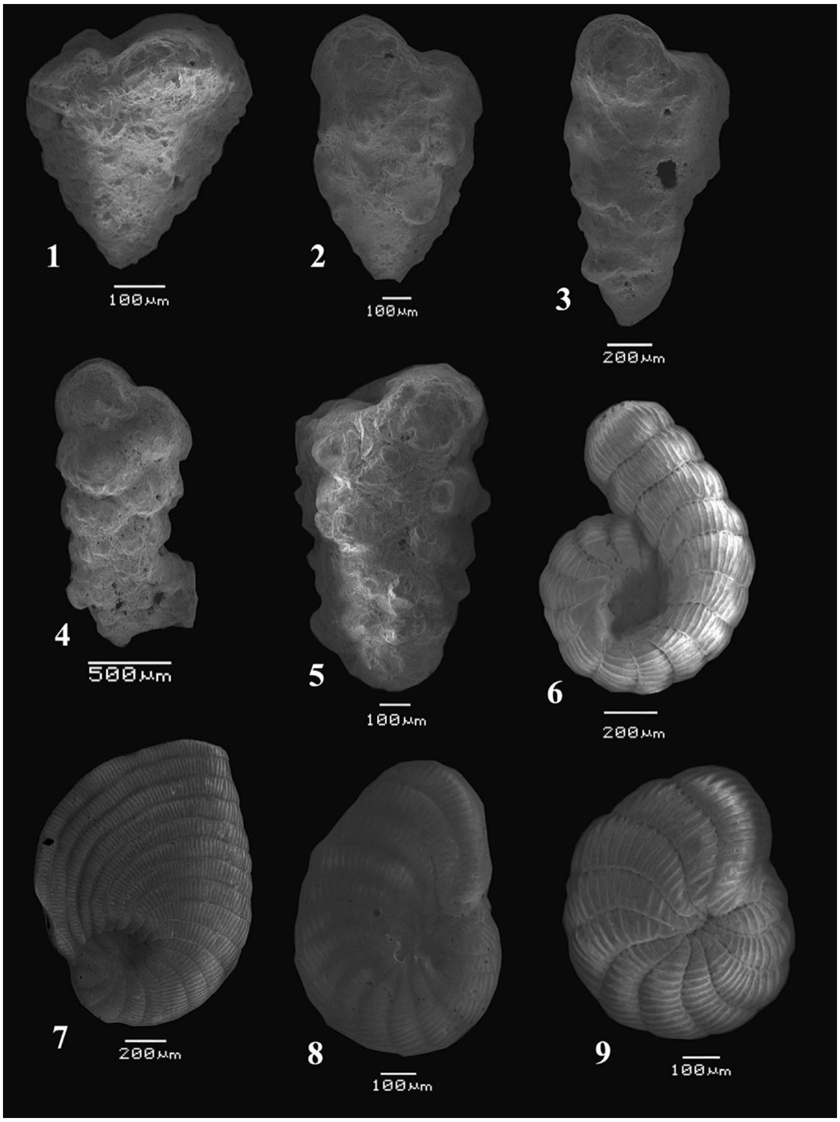

Plate 1 *1. Textularia conica*, D-5; *2. Textularia agglutinaus*, D-5; *3. Textularia foliacea*, D-6; *4. Textularia foliacea*, D-6; *5. Textularia* sp. D-11; *6. Spirolina arietina*, D-1; *7. Peneroplis planatus*, D-2; *8. Peneroplis pertusus*, D-4; *9. Peneroplis proteus*, D-5

Manganese

Mn is a low-toxic element and having considerable biological significance. It is one of the more biogeochemical and active transition metals in aquatic environment (Evans et al. 1977). The average contents of Mn range between 4.9 and 8.2 μg g^{-1} (Fig. 5b). The most prominent positive relations of manganese are with Pb (0.58). Mn shows a negative correlation with the Ni and Cu and positive correlation with Fe and Cr. Low concentrations of Mn indicate that dissolved Mn ions are easily removed from the pore of surface sediments to the upper water column through active diffusion and advection processes (Janaki-Raman et al. 2007).

Zinc

Zinc is a naturally abundant element present as a common contaminant in agriculture, food wastes, and manufacturing of pesticides as well as antifouling used to paint hulls of boats. The average distribution of Zn concentrations in the studied localities ranges from 1.9 μg g^{-1} in D-9 to 7.5 μg g^{-1} in D-3 (Fig. 5c). The most significant positive relation is that detected with Cd (0.83). The concentration of zinc is low in the sediment of the study area which is characterized by high temperature. Zinc is an essential element; therefore, its uptake by marine biota may be increased with high temperature (Attia et al. 2012).

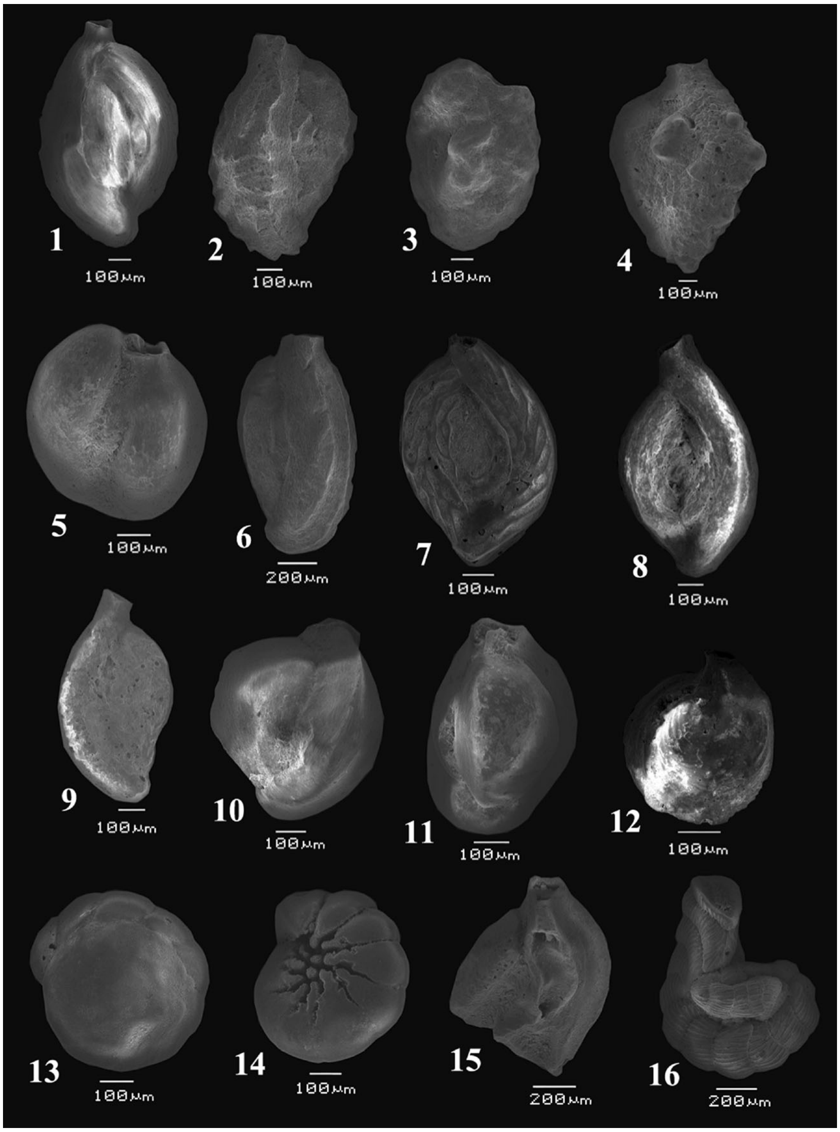

Plate 2 *1. Quinqueloculina, elegans*, D-1; *2. Quinqueloculina mosharafi*, D-8; *3. Quinqueloculina bidentata*, D-9; *4. Quinqueloculina agglutinans*, D-11; *5. Quinqueloculina oblonga*, D-9; *6. Quinqueloculina angularis*, D-11; *7. Spiroloculina hadai*, D-3; *8. Spiroloculina laevigata*, D-3; *9. Spiroloculina angulata*, D-3; *10. Triloculina affinis*, D-14; *11. Triloculina affinis*, D-13; *12. Pesudomassilina pacificensis*, D-4; *13. Ammonia beccari*, D-9; *14. Ammonia beccari*, D-7; *15.* Abnormal *Quinqueloculina elegans*, D-10; *16.* Abnormal *Spirolina arietina* deformed, D-2

Copper

Copper concentration in the area varies from 0.6 μg g^{-1} in D-9 to 13.4 μg g^{-1} in D-4 (Fig. 5d). This average is near to the average of copper content (15 ppm) of limestones (Wedepohl 1963) and agrees with the average copper content of the marine sediments of Arabian Gulf (Zyadah and Almoteiry 2013). The highest correlation coefficients for Cu are with Ni (0.87), Cd (0.84), and Zn (0.61). According to Atsdr 1990, the sediments of the study area are considered as clean sediments because the Cu content is <50 μg g^{-1}. This means that the addition of Cu to the marine sediments comes from limited sources as antifouling used to paint hulls of boats.

Lead

All lead compounds are potentially harmful or toxic (Jenkins 1981). Concentrations of Pb in the studied localities vary from 0.9 μg g^{-1} in D-10 to 3.6 μg g^{-1} in D-17 (Fig. 6a) which are considered as low values. Atmospheric input of Pb that is generated from the automobile exhaust emission can be attributed to the most significant source of Pb in the cities (Badr et al. 2009). The Cd, Pb, and Zn are mostly introduced to the marine environment through atmospheric input (Frignani et al. 1997).

Nickel

The average concentration of Ni in the investigated sediments ranges from 1.4 μg g^{-1} in D-9 to 11 μg g^{-1} in

Table 2 Trace metal concentrations from the studied samples (values = μg g^{-1})

	Cr	Fe	Mn	Ni	Zn	Cd	Pb	Cu
D1	5.9	346.5	5.4	10	7.8	0.1	3	13
D2	5.2	322.8	5	9.5	6.9	0.1	2.8	13
D3	6.1	335.2	5.5	11	7.5	0.1	2.5	12
D4	5.7	325.5	4.9	11	8	0.2	2.7	13
D5	5.9	340	5.4	9.6	7.3	0.1	3.1	13
D6	5.1	401.3	6.6	3.2	2.2	0	1.3	1.4
D7	4.4	319	6	1.9	6.3	0	1.3	1.3
D8	4.5	310.9	5.2	1.7	4.2	0	1.2	0.8
D9	3.6	315	4.9	1.4	1.9	0	1.1	0.6
D10	3.4	290.8	5.4	2.2	2.6	0	0.9	6.1
D11	3.8	301.5	5.6	1.9	2.8	0	1	7.8
D12	4.2	317.2	5	1.6	3.1	0	1.3	1.2
D13	4.4	312.5	5.2	1.9	5.5	0	1.1	1.3
D14	3.9	283.4	5.6	2.1	2.6	0	1	8.8
D15	16	545.6	7.8	2.1	6.3	0.1	3.9	4.8
D16	13	553.4	8	2.3	5.8	0.1	3.5	3.9
D17	15	710.5	8.2	2	5.7	0.1	3.6	4.6
Mean	6.5	372.4	5.9	4.4	5.1	0.1	2.1	6.3

D-3 (Fig. 6b). These values are more or less higher than that of the average of sedimentary rocks (2 ppm; Beus and Grigorian 1975). The most significant positive relation of nickel is that detected with Cd (0.94; Table 2). Nickel is quite abundant in the Earth's crust and enters surface waters from the dissolution of rocks and soils, from biological cycles, and atmospheric collapse, and especially from industrial processes and waste throw (Prego et al. 1999).

Chromium

Chromium concentration in the study area ranges from 3.4 to 15.5 μg g^{-1} (Fig. 6c). Cr is relatively mobile and migrates to the reduced zone deeper levels (Gaillard et al. 1989). Cr has strong significant positive correlation with Fe and Mn (0.95, 0.90), respectively. Chromium is also suggested to be co-precipitated with authigenic Mn-oxyhydroxide (Pattan et al. 1995).

Cadmium

Cadmium content of the marine environment is mainly from anthropogenic source through refining and use of

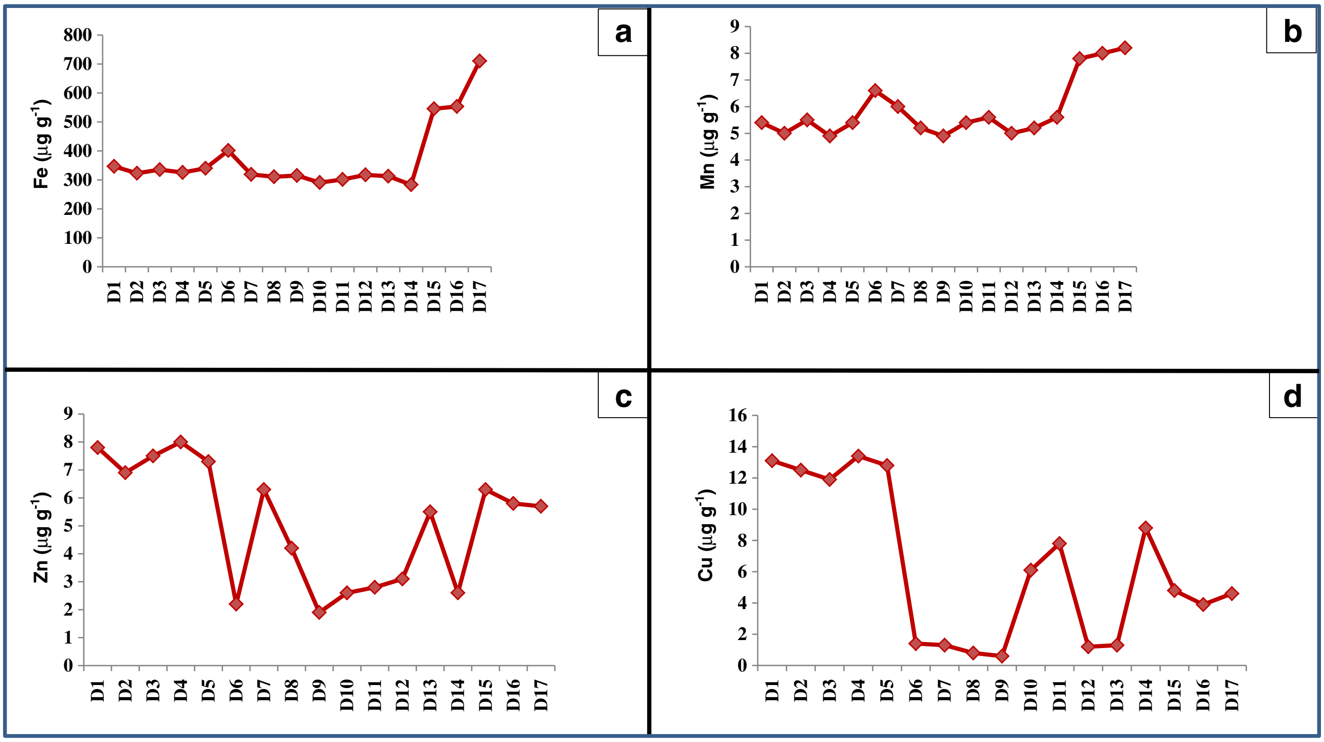

Fig. 5 The concentrations of heavy metals in bottom sediments samples collected from Dammam coast, **a** Fe, **b** Mn, **c** Zn, and **d** Cu

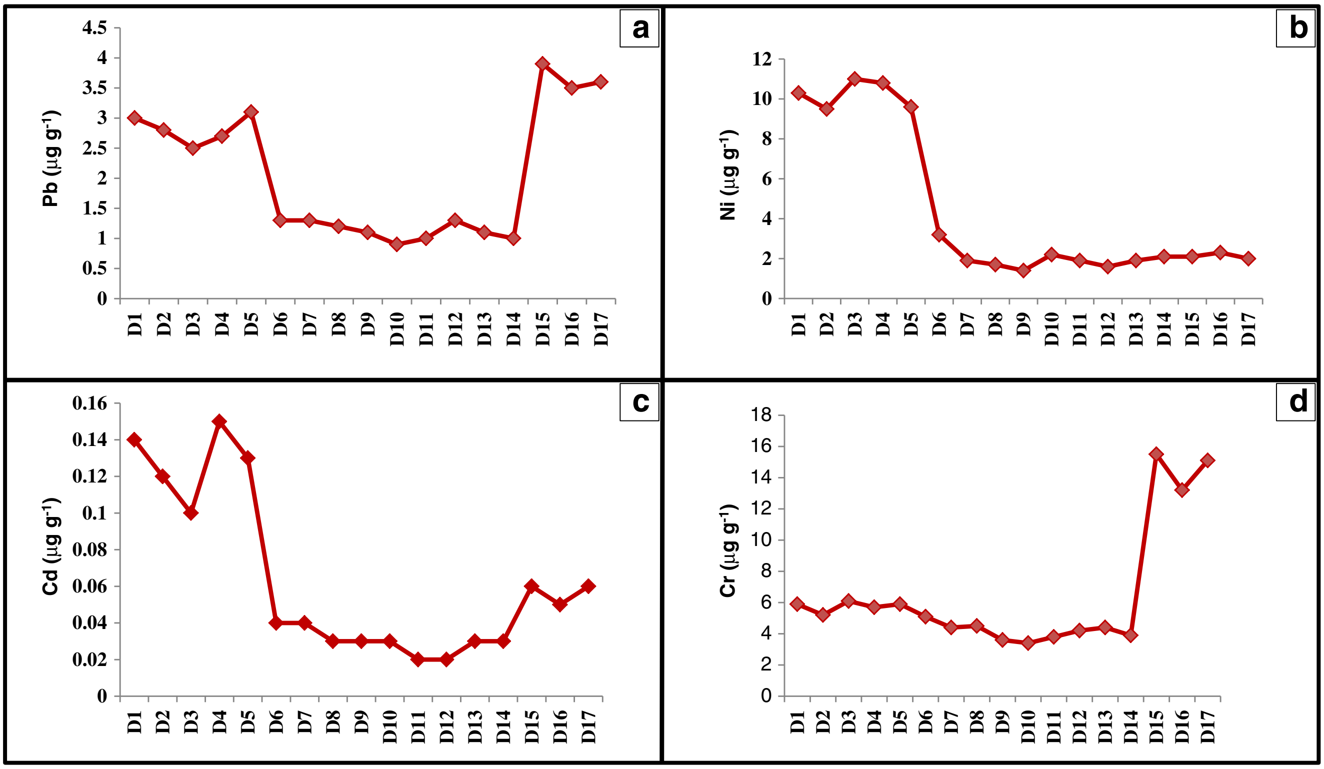

Fig. 6 The concentrations of heavy metals in bottom sediments samples collected from Dammam coast, **a** Pb, **b** Ni, **c** Cd, and **d** Cr

Cd, Cu, and Ni smelting and atmospheric loading (Kennish 1996) where most of them are deposited in bottom sediments (Clark et al. 1997). The average concentration of Cd levels in marine sediments of the studied localities is low and varies from 0.02 µg g^{-1} in D-12 to 0.2 µg g^{-1} in D-4 (Fig. 6, d). The recorded values are higher than the values 0.001–0.009 and 0.04 ppm quoted for sedimentary rocks (Beus and Grigorian 1975). There is a positive relation between cadmium and cooper (0.84) (Table 3, Fig. 7).

Heavy metal clusters

Statistical computations (cluster analysis) were performed with the program SPSS using a hierarchical cluster analysis (Ward's method). Based on the concentration of eight

Table 3 Pearson's coefficient correlations for analyzed metals

	Cr	Fe	Mn	Ni	Zn	Cd	Pb	Cu
Cr	1							
Fe	0.946**	1						
Mn	0.900**	0.923**	1					
Ni	−0.097	−0.192	−0.333	1				
Zn	0.354	0.209	0.087	0.739**	1			
Cd	0.114	0.014	−0.157	0.944**	0.826**	1		
Pb	0.818**	0.709**	0.581*	0.458	0.732**	0.641**	1	
Cu	−0.035	−0.155	−0.238	0.873**	0.607**	0.841**	0.446	1

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

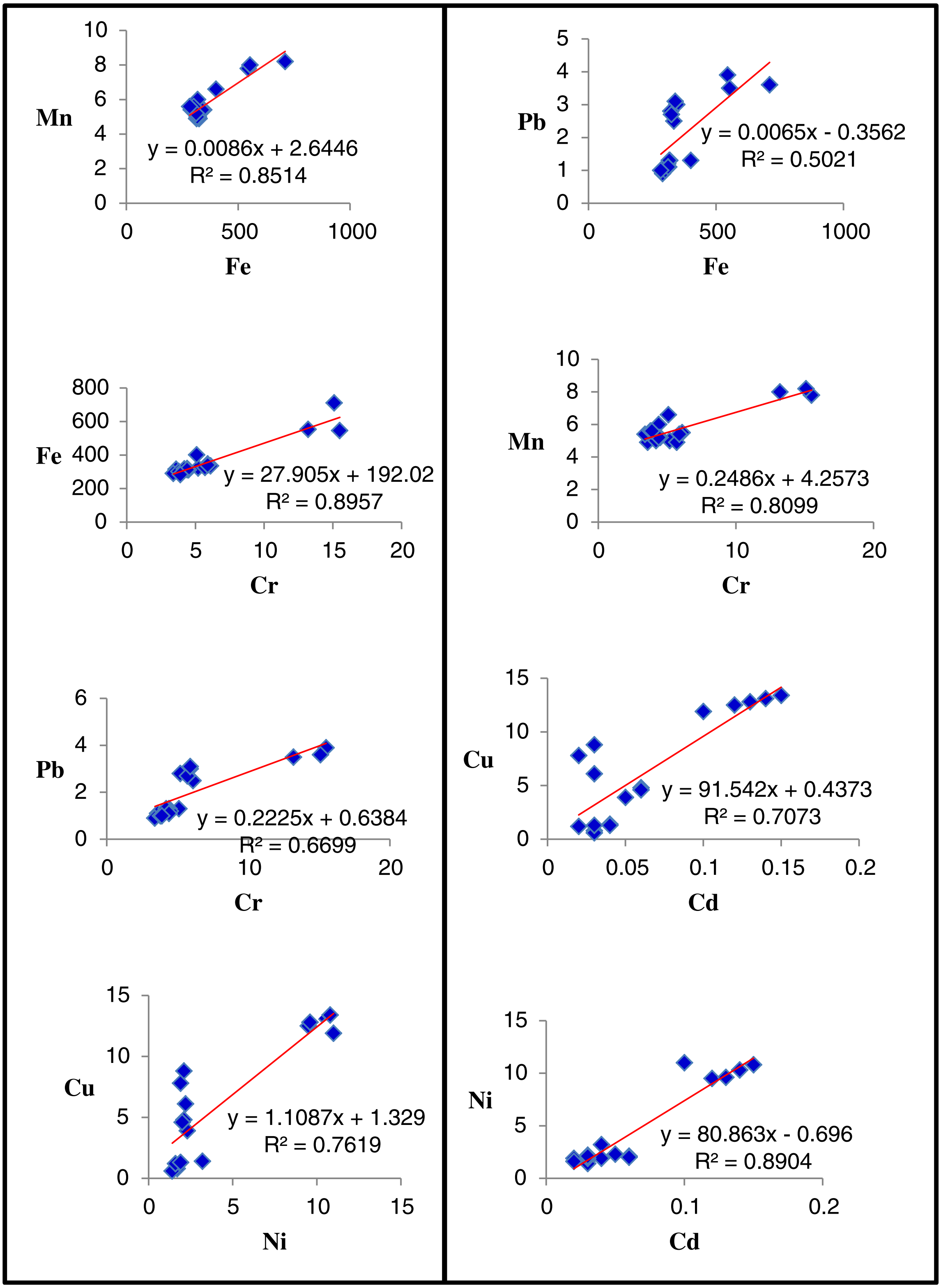

Fig. 7 Scatter plot of pairs of a significant correlation coefficient metals: Fe and Mn, Fe and Pb, Cr and Fe, Cr and Mn, Cr and Pb, Cd and Cu, Ni and Cu, and Cd and Ni

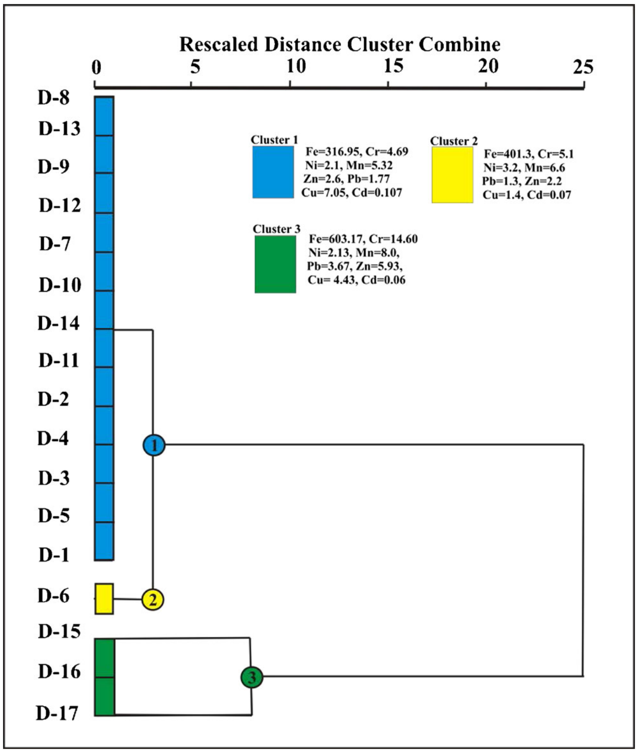

Fig. 8 Dendrogram from cluster analysis (Ward's method) of heavy metals in bottom sediments from Dammam coast

heavy metals (Fe, Mn, Zn, Cu, Pb, Ni, Cr, and Cd), the studied bottom samples from the studied area are divided into three main clusters (Fig. 8; Table 4). Cluster 1 contains 13 samples (76.5 % of the total samples) and is characterized by low concentrations of Fe (X = 316.95 μg g^{-1}, S = 18 μg g^{-1}) and Cr (X = 4.69 μg g^{-1}, S = 0.95 μg g^{-1}). Cluster 2 includes only one sample (sample D-6) with medium concentrations of Fe (X = 401.3 μg g^{-1}), Cr (X = 5.1 μg g^{-1}), and Ni (X = 3.2 μg g^{-1}). The three samples of cluster 3 (17.64 % of the total samples) are separated by high concentration of Fe (X = 603.17 μg g^{-1}, S = 93.04 μg g^{-1}), Cr (X = 14.60 μg g^{-1}, S = 1.23 μg g^{-1}). This cluster indicates that the general trends of lead contents are increasing southward. These three samples of cluster 3 were collected from the polluted area. Dredging and land filling, sewage, and oil pollution are the most important sources of pollution in the study area. Incomplete or no sewage treatment, increasing wastes from different human activities, oil spills, constructions, waste and trash materials, and tires are the chronic problems associated with heavy metal pollution (Fig. 9).

Table 4 Some statistical parameters of the heavy metals of the clusters computed by (Ward's method) cluster analysis based on eight variables of heavy metals in bottom sediments at the study area

	Cr	Fe	Mn	Ni	Zn	Cd	Pb	Cu
Cluster 1								
D1	5.9	346.5	5.4	10.3	7.8	0.14	3	13.1
D2	5.2	322.8	5	9.5	6.9	0.12	2.8	12.5
D3	6.1	335.2	5.5	11	7.5	0.1	2.5	11.9
D4	5.7	325.5	4.9	10.8	8	0.15	2.7	13.4
D5	5.9	340	5.4	9.6	7.3	0.13	3.1	12.8
D7	4.4	319	6	1.9	6.3	0.04	1.3	1.3
D8	4.5	310.9	5.2	1.7	4.2	0.03	1.2	0.8
D9	3.6	315	4.9	1.4	1.9	0.03	1.1	0.6
D10	3.4	290.8	5.4	2.2	2.6	0.03	0.9	6.1
D11	3.8	301.5	5.6	1.9	2.8	0.02	1	7.8
D12	4.2	317.2	5	1.6	3.1	0.02	1.3	1.2
D13	4.4	312.5	5.2	1.9	5.5	0.03	1.1	1.3
D14	3.9	283.4	5.6	2.1	2.6	0.03	1	8.8
S	0.95	18.16	0.32	4.28	2.31	0.05	0.88	5.39
Min	3.40	283.40	4.90	1.40	1.90	0.02	0.90	0.60
Max	6.10	346.50	6.00	11.00	8.00	0.15	3.10	13.40
X	4.69	316.95	5.32	5.07	5.12	0.07	1.77	7.05
Cluster 2								
D6	5.1	401.3	6.6	3.2	2.2	0.04	1.3	1.4
Cluster 3								
D15	15.5	545.6	7.8	2.1	6.3	0.06	3.9	4.8
D16	13.2	553.4	8	2.3	5.8	0.05	3.5	3.9
D17	15.1	710.5	8.2	2	5.7	0.06	3.6	4.6
S	1.23	93.04	0.20	0.15	0.32	0.01	0.21	0.47
Min	13.20	545.60	7.80	2.00	5.70	0.05	3.50	3.90
Max	15.50	710.50	8.20	2.30	6.30	0.06	3.90	4.80
X	14.60	603.17	8.00	2.13	5.93	0.06	3.67	4.43

Conclusions

- The concentrations of the metals iron, chromium, manganese, nickel, zinc, cadmium, lead, and copper in sediments were measured.
- The mean metal concentrations are Fe (372.4), Mn (5.9), Zn (5.1), Cu (6.3), Pb (2.1), Ni (4.4), Cr (6.5), and Cd (0.1).
- The distribution of benthic foraminifera in the collected samples was investigated. Thirty species of 12 genera under nine families and three suborders were recorded.
- The most common genera are *Peneroplis* and *Quinqueloculina* which attain 39 and 38 % of the recorded

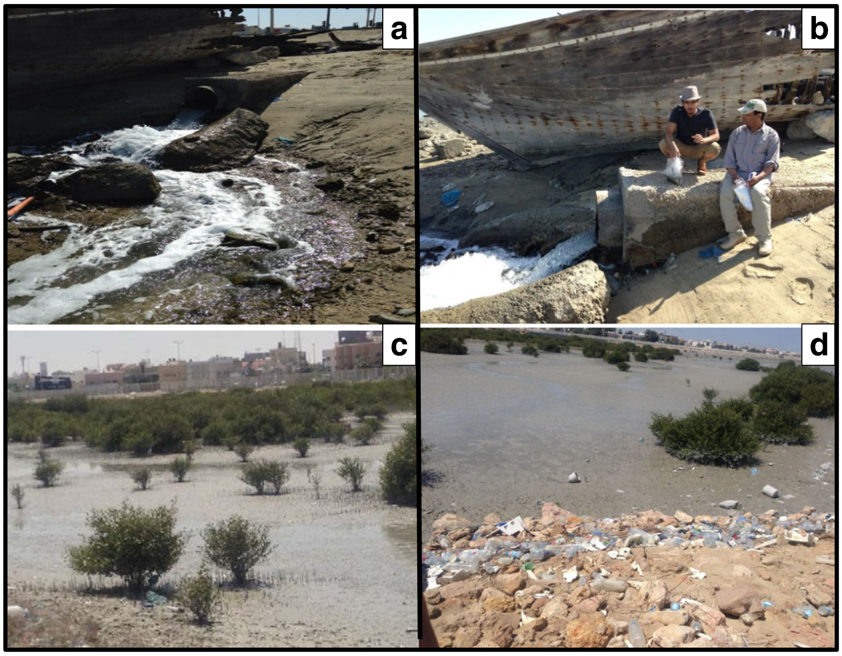

Fig. 9 Different anthropogenic sources of pollution in study area (**a**–**c**) drainage of reject sewages directly to the Tarut bay surrounding the island. **d** Close-up views of waste dumps of different waste materials directly on the coast in different locations

fauna, respectively. The other common genera which were recorded in the study area are as follows: *Ammonia* (9 %), *Spiroloculina* (6 %), *Triloculina* (5 %), *Sorites* (1.1 %), and *Textularaia* (1 %).

- The other genera recorded in the studied samples are represented by minor constituents.
- Some species exhibit abnormal tests that may indicate environmental stress.

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