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ORIGINAL ARTICLE

APPLICATION OF BENTHIC FORAMINIFERA IN POLLUTION ASSESSMENT AT MISKAN ISLAND AND AL-KHIRAN COASTLINE, KUWAIT

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ABSTRACT

The biodiversity of benthic foraminifera around the coral communities and the concentration of heavy elements (e.g., Mn, Fe, Cr, Cu, Ni, Pb, Zn, Cd, and Co) in Miskan Island and Al-Khiran coastline of Kuwait are used as an ecological indicator for the environmental and anthropogenic stresses occurred from February 2018 to February 2019. The study resulted in identifying 19 families, 6 orders, 29 genera, and 94 species. Using R-mode cluster analysis results in four assemblages and using Q-mode principal component analysis (PCA) distinguished three groups depending on the deep. The three main assemblages refer to different depths, Group A from 20 cm to 1 m depth; Group B from 1.5 to 2 m depth, Group C from 6 to 8 m depth. Al-Khiran coastline is characterized by anoxic conditions, confirmed by the existence of pyrite. Additionally, high water turbidity because of anthropogenic effects. The low number of benthic foraminifera on Miskan Island is due to the dissolution and calcification of foraminifera shells. The Island characterized by freshwater runoff from Iraq meets saltwater in the gulf, affecting the salinity. The turbidity is caused by sediment runoff and eutrophication. Both sites were considered relatively unpolluted compared with the nearest Iranian coast. However, the relatively high potentially toxic elements in some locations are due to the semi-restricted geographic characteristic and high anthropogenic activity. There is no clear abnormality in the identified species showing normal aperture, coiling, shape, and size.

Keywords: Benthic Foraminifera, Biodiversity, Environment, Heavy Metals, Kuwait Pollution.

INTRODUCTION

Benthic foraminifera are abundant in the bottom sediments of coastal ecosystems and have a short reproductive cycle (Murray, 2006, 2014). Thus, they are highly sensitive to environmental changes (Koukousioura *et al*., 2011; El-Kahawy *et al*., 2018). Benthic foraminiferal assemblages are considered one of the principal and significant tools to understand the environmental changes, stressors, and conflicts recorded in marine environments (Bouchet *et al*., 2012, 2018, 2020), and used as indicators of climate change and global variability to monitor environmental changes (Charrieau *et al*., 2017; Sreenivasulu *et al*., 2019). A recent benthic foraminifer and its ecology in the Persian Gulf and the Kuwaiti Territories have been extensively studied by many authors (e.g., Cherif *et al*., 1997; Al-Zamel *et al*., 1998; Al-Zamel *et al*., 2009; Al-Enezi and Frontalini, 2015, Arslan *et al*., 2016; Amao *et al*., 2018a; Al-Enezi *et al*., 2019, 2020). Additionally, the composition of benthic populations, morphological characteristics, diversity, and distribution of species provide valuable data on water salinity, temperature, substrate characteristics, climate, changes in sea level, oxygen, and nutrient availability. In this regard, this work provides insight into the usefulness of benthic foraminifera for environmental regeneration. Benthic foraminifera are useful bio- indicators for potentially toxic elements (PTE) (e.g., Alve, 1995; Nigam *et al*., 2006). In contaminated areas, the benthic foraminifera can exhibit a variety of morphological distortions and changes in population composition and species richness (Kurbjeweit *et al*., 2000; du Chatelet *et al*., 2004).

Sedimentation rates of bottom sediments in the Arabian Gulf showed marked regional differences depending on offshore morphology and sediment type. Bay bottom sediments vary from natural limestone fragments of biological origin and rock fragments derived from beach rocks and submerged coral reefs to allochthonous terrigenous debris brought to the area mainly by storm dust and river deltas in the remote northern regions and along eastern Iran (Khalaf *et al*., 1984). The Miskan Island and Al-Khiran coastlines are part of the Arabian Gulf, which is considered a semi-restricted area and allows the precipitation of pollution in some areas. Therefore, the distribution and characteristics of the benthic foraminifera and the heavy metal geochemistry from these localities can be used to trace the environmental and climate changes in this part of the world.

The main objectives of this study are to (a) study the distribution of foraminifera assemblages and diversity in two localities (Miskan Island and Al-Kiran coastline), (b) identify the benthic foraminiferal assemblage to the species level, (c) distribution of monitor, major and trace (Fe, Mn, Cr, Cu, Ni, Pb, Zn, Co, and Cd) in the study areas, and (d) interpret the environmental factors controlling the distribution and species richness of benthic foraminifera.

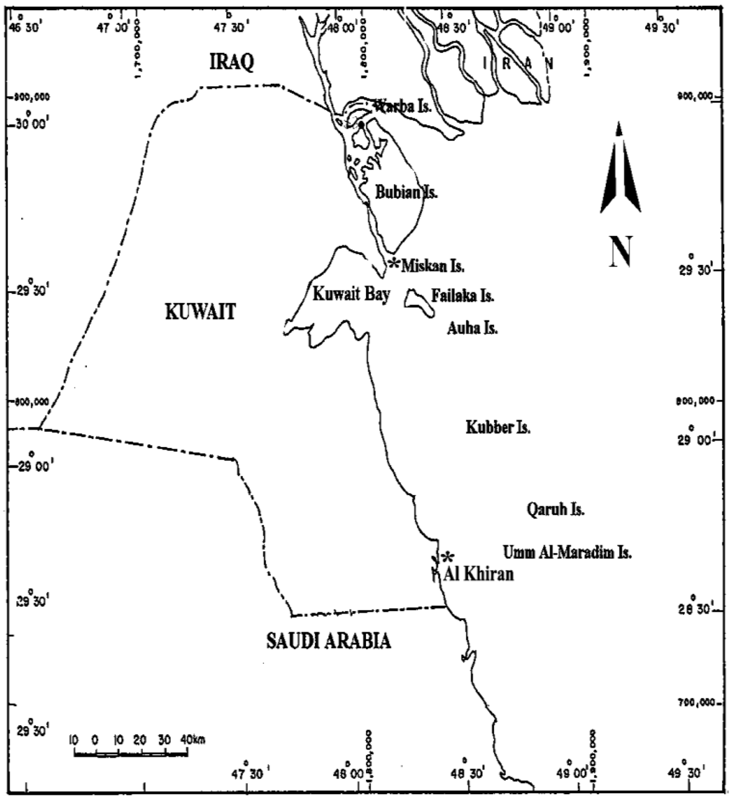
MATERIALS AND METHODS

Two localities, including 8 stations and 35 samples at Miskan Island to the north and the Al-Khiran coastline to the south have been studied (Map 1) to achieve the objective of this work.

Miskan Island: Miskan is a small-uninhabited island in the Persian (Arabian) Gulf (Kuwait territorial waters). It is located south of Bubiyan Island (Map 1). It is about 1.2 km long and 800 meters in width (about 0.75 km² area). The study area is bounded by latitude 29° 29′ 9″ N and longitude 48° 15′ 5″ E, about 3.2 km from Failaka Island. It contains medium to coarse coastal sand with coral reefs at specific depths of about 7-13 m in some places around the island. The northwestern part of the bay is considered a low salinity zone because most of the river's flow into the bay occurs at the northern end, mainly on the Iranian side. The Gulf receives freshwater inflows from the Euphrates and Tigris rivers in Iraq as well as numerous small seasonal streams flowing through Mount Zagros in Iran (Alsharhan and Kendall, 2003).

The Shatt Al-Arab Plain forms the northwest coast and many rivers along the Zagros Mountains. Many terrigenous sediments greatly influence the sediments of the Gulf (Alsharhan and Kendall 2003). Several rivers originating in the Zagros Mountains flow into the bay and are characterized by frequent flash floods, among them the Shatt Al- Arab, which pours mud and fine sand. Salinity values gradually increase southward and decrease at Shatt Al-Arab due to dilution from freshwater input (Sheppard *et al*., 2010; Riegel *et al*., 2013).

Al-Khiran coastline: The Al-Khiran area is in the southern part of Kuwait, about 100 km south of Kuwait City, on the coast of the Persian Gulf, which is part of a shallow plateau in Western Mesopotamia. It is bounded by latitudes 28°32'05" to 28°45'N and longitudes 48°15'00" to 48°26'06" E (Map 1). Al-Khiran has a great ecological significance and potential for environmental monitoring and analysis in highly variable environments.



Map (1): Location map for study stations (*).

Field work: Foraminiferal species at bottom sediments and around some coral reefs were collected during several field trips in February 2018 and 2019 from the Miskan Island and Al-Khiran coastlines from the tidal and intertidal zones at depths between 20 cm and 8 m away from turbidity. A grape sampler was used for the sampling of bottom sediments (sand or silt). Each sample was divided into two parts, one for the foraminifera analysis and the other for the sediment analysis. Samples have been transferred into plastic bags and frozen at -4 ^{O}C immediately after the sampling to avoid contamination, ecological variables changing, and chemical volatiles.

The number of living foraminifera at each locality was used to calculate the indices of species richness (S), dominance (D), Shannon-Wiener (H′) and homogeneity (e^H/S) using the PAST v3.12 software package (Hammer *et al*., 2001). Principal component analysis (PCA) using single value decomposition and hierarchical clustering (HCPC) using Ward's agglomeration and Euclidean distance have been applied to the sample station’s data.

Laboratory Analyses: To separate the different foraminiferal taxa, the top 10 cm^3 of the first split from the collected sediments were socked in a rose Bengal solution (2 g/l ethanol) for 2 days to distinguish live from dead foraminifera, then washed and sieved using a 63-µm mesh. The dry residue was divided by an Otto-Micro-splitter into fractions of which one part (1/4 or 1/8) was fully counted. Sediment samples were placed under normal tap water for one hour for cleaning using a 63-µm sieve. Part of the samples was dried at 50˚C in an oven for this group analysis. Sand fractions were weighed to assess the foraminifera assemblage. The members of this taxon were separated from the top 2 cm of twenty grams of dry-cleaned sediments using a reflected light microscope with magnifications between 40X and 180X. Separated foraminifera taxa were preserved in 70 % Rose Bengal ethanol solution to prevent the degradation of protoplasm and to facilitate the separation of a live (stained) and dead (unstained) cells.

Geochemistry of the Sediments: Bulk sediments (5 g) from the Miskan Island and Al-Khiran coastlines were dried under a light bulb at low temperatures to avoid heavy metal evaporation. The samples were pulverized to a size of 64µm and analyzed by the Research Field Project Unit (RSPU) of the University of Kuwait for the potentially toxic elements (PTEs) content (23 elements, particularly As, Al, Fe Cd, Co, Cr, Cu, V, Ni, Hg, Pb and Zn) by inductive plasma optical emission spectrometry (ICP-OES) using a modified US EPA 3050 preparation protocol. The distribution of heavy metals in the studied samples was influenced by texture, clay minerals, organic matter, iron oxyhydroxide, manganese, and calcium carbonate (Salmons and Forshtner, 1984).

Grain-Size Analysis: Grain-size analysis was performed using dry and wet sieving techniques (Poppe *et al*., 2000). Approximately 20 g of each sample was carefully weighed and sieved with 1 liter of distilled water on a 63-µm grid. The filtrate was added to 1-liter decanting tubes, and 20 ml (50 g/l) sodium hexametaphosphate was used as the dispersant for each tube to determine the sludge and clay fractions. The residue was then dried and sieved by different mesh sizes. The filtrate was then analyzed for mud and clay contents using the method of Poppe *et al*. (2000). GRADISTAT software was used to determine the grain size distribution and predominant sediment types (Blott and Pye, 2001). Dried samples were sieved using 63 µm, 100 µm, 125 µm, 150 µm, 200 µm, 225 µm, and 250 µm mesh sieves to separate different sizes. Samples were separated into a mud fraction (< 63 µm) and a sand fraction (> 63 µm).

Statistical Studies: Three hundred living specimens of foraminifera from 10 cm^3 sediments were picked out of the > 125-micron fraction. Samples were divided, and counts have been calculated for all samples. For quantitative analysis, the number of benthic foraminifera was calculated per individual (>125 µm) in the dry sediment to determine diversity. Diversity was determined using the Shannon-Wiener information equation (Buzas and Gibson, 1969). The Shannon diversity measures the order (or disorder) observed within a particular system (Hayek and Buzas, 1997). The first set of analyses determined groups of sample sites based on their similarity to foraminifera assemblages.

$$H (S) = -1 \Sigma pi \ln pi \quad (1)$$

H(S) represents diversity, S is the number of species observed, and pi is the species ratio. The classification concept in this study is mainly based on Abbachar and Kuhnt (1994), Shannon index rule, H (Shannon and Weaver, 1949) and Fisher's alpha index (Fisher *et al*., 1943) were used to determine species number (richness).

$S=\propto \ln (1 + n/\propto)$
S= the number of Taxa
N= total number of individuals
$\propto$= total number of individuals
Evenness E as eH′/S calculated after Buzas and Gibson (1969).
E= evenness/uniformity index
H= index of Shannon- Wiener
S= the number of taxa
Taxon dominance was determined using the dominance index (D). The dominance index was calculated according to the Simpson (1949) equation.
$D= \Sigma \left(\frac{ni}{n}\right)^2$
D= Dominance Index
ni= number of individual species I
n= total number of individuals

All calculations were made and performed using PAST4 v.1.0.0. (Hammer *et al*., 2001) and Statistical Package (SPSS, 22) and repeated twice for accuracy and to minimize bias (Hammer *et al*., 2001). All data were tested for normality using the Kolomogorvo-Smirnov test. The adopted significance level was 95% ($\alpha=0.05$). Clustering and principal component analyses (PCA) are based on the ward methods, and Euclidean analysis was used as an exploratory analysis to investigate the relationships between foraminifera groups and to investigate the community of the foraminifera assemblage using multiple variables prior to data analysis. The Euclidean method was used to construct the square root transform similarity matrices. This variation underestimates the importance of species being so abundant that similarities depend not only on their values but also on the values of "average" species. Based on this similarity matrix, Q-mode cluster analysis and histograms were constructed.

Systematic Classification of the Foraminifera: To identify and classify the foraminifera, the sand fractions (> 63 µm) were investigated by the microscope to check the presence of foraminifera (Hallock *et al*., 2003). Then, each sample was examined under the conventional stereo microscope, and the probe was removed with a fine artist's brush moistened with water. Individual specimens were placed on a wildlife cardboard microbiology slide, coated with a thin layer of water-soluble glue. The taxonomic identification of foraminifera was carried out following the monographs of Cimerman and Langer (1991), Hottinger *et al*. (1993), Loeblich and Tappan (1988, 1994), Cherif *et al*. (1997), Hayward *et al*. (2004), Parker (2009), and Amao *et al*. (2016; 2018 a, b; 2019).

RESULTS AND DISCUSSION

Statistical Data Analysis

Ninety-four species of foraminifera belonging to 19 families, 6 orders, and 29 genera were identified from the superficial sediments (upper 2-10 cm) of the Miskan Island and Al-Khiran coastline. There is no coastlines clear abnormality in our study species. Most of the species show normal aperture, coiling, shape, and size (Diags. 1-6). The wall types, with decreasing abundance, are transparent (61%), porcelain (32%), and agglomerate (7%). The most abundant genera are *Quinqueloculina*, (6.2%), *Adelosina* (6 %), *Spiroloculina* (5.8. %), *Asterorotalia* (4.1%), *Triloculina* (3.2 %), *Elphidium* (2.9%), *Ammonia* (2.1%), *Textularia* (1.9%). Richness (S) reached a maximum of 97 genera on SW Miskan Island and a minimum of 71 genera on the Al-Khiran coastline (Tab. 1). Evenness ranged from 0.83 at Miskan to 0.68 at the Alkhiran coastline.

Table (1): Diversity indices.

	Miskan Stations	**Al-Khiran Stations**						
	Southwest Miskn (SM1)	(M) Eat Miskan	Miskan Low Tide (LT-M-3)	S4a-Kh	(S4b-Kh)	(S5a-Kh)	S5b-Kh	Al-Khiran Beach S6
Symbols Used in PCA	B	C	D	E	F	G	H	I
Depth (m)	6	8	1.75	2	1.5	1	0.5	0.2
Taxa_S	97	95	87	86	84	77	78	71
Individuals	1868	2175	1326	868	763	426	472	318
Dominance_D	0.01348	0.01407	0.01424	0.01487	0.01627	0.02116	0.02154	0.02646
Simpson_1-D	0.9865	0.9859	0.9858	0.9851	0.9837	0.9788	0.9785	0.9735
Shannon_H	4.389	4.345	4.329	4.304	4.249	4.071	4.062	3.888
Evenness_e^H /S	0.8307	0.8114	0.8723	0.8605	0.8338	0.7615	0.7445	0.6875

Equitability_J	0.9595	0.9541	0.9694	0.9663	0.959	0.9373	0.9323	0.9121
Fisher_alpha	21.72	20.28	20.88	23.71	24.09	27.46	26.62	28.38

R-mode clustering analysis of the most abundant species revealed three groups related to depth (Diag. 1). Principal Component Analysis (PCA) suggested that 85.94% of the total variability among the dataset, 76.5% (axis 1-PC1), and 9.3% (axis 2-PC2) on the variability (Diag. 2), indicating a clear separation between the groups (Tabs. 2, 3). A high number of foraminifera have been observed in the sandy fractions of the investigated sediments. In contrast, a low number was associated with the silt fractions of the investigated sediments, which is consistent with the observations of Barbosa *et al*. (2009).

Table (2): PC Score showing eigenvalue and variance.

PC	Eigenvalue	% Variance
1	388.639	76.555
2	47.6935	9.3947
3	30.1968	5.9482
4	13.9465	2.7472
5	10.1134	1.9922
6	6.98167	1.3753
7	5.89753	1.1617
8	4.19359	0.82606

Table (3): Final PC score.

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
B	0.52554	0.014051	-0.18153	0.20312	-0.74075	0.078751	-0.30552	0.033735
C	0.66561	-0.29537	-0.44665	-0.18886	0.45525	-0.005383	0.16464	-0.012529
D	0.37845	-0.020806	0.60764	0.47361	0.29543	-0.33605	-0.21343	-0.13057
E	0.24031	-0.1435	0.51626	-0.12875	-0.22272	0.35639	0.66286	0.15018
F	0.21896	0.37013	0.30979	-0.68219	0.10139	0.21379	-0.44098	-0.057106
G	0.12343	0.44896	-0.046626	-0.16829	-0.093845	-0.65325	0.26293	0.49802
H	0.11337	0.60556	-0.14713	0.13707	-0.007216	0.045436	0.35648.	-0.67143
I	0.061318	0.43159	-0.10956	0.41195	0.29667	0.5285	-0.062773	0.50695

Relative Abundances of the Foraminifera: The absolute number of foraminifera per gram of graded bulk sediments was used in this work. Generate multiple statistics for each genus that contribute to >90% similarity within each group or differences between groups. The results included mean abundance, mean similarity and standard deviation similarity ratio, percent contribution, and cumulative percentage contribution of each genus. Miliolida and Rotaliida are the major recorded orders in the studied localities (Tab. 4, Diag. 3). The recorded species and lower number of benthic foraminifers (Tab. 5), was indicated that the Al-Khiran coastline is characterized by anoxic conditions. The relative abundance of framboidal pyrite in the Miskan Island also indicates these low oxygen conditions. The *Rotalina* is the most abundant suborder on the Al-Khiran coastline, whereas the *Textulariina* has the lowest percentage. The low number of foraminifera in the Miskan Island is due to the dissolution of shells. Freshwater runoff from Iraq meets saltwater in the Gulf, which causes or affects the salinity and calcite materials of the shells.

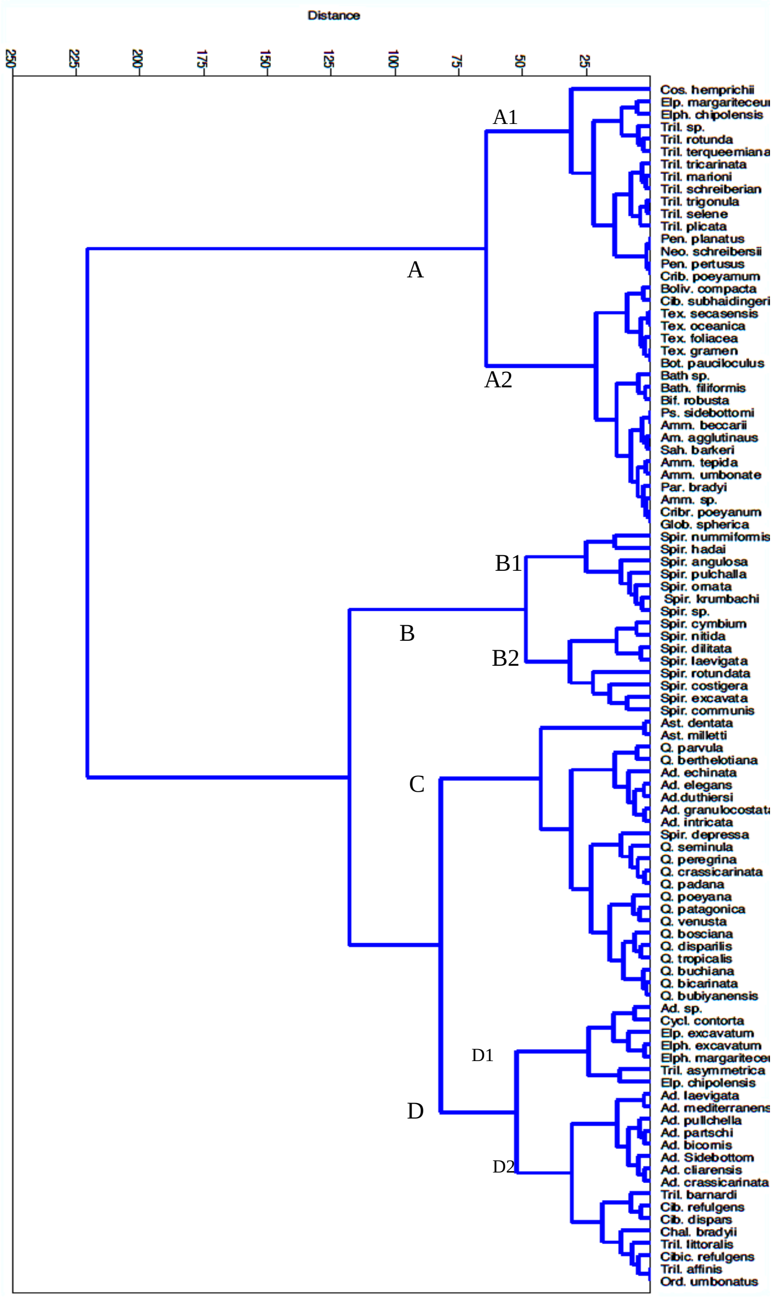


Diagram (1): Hierarchical of R-mode cluster analysis (Ward's method, Euclidean distances as a similarity index) based on the total abundance of the recorded foraminifera species higher than 5%.

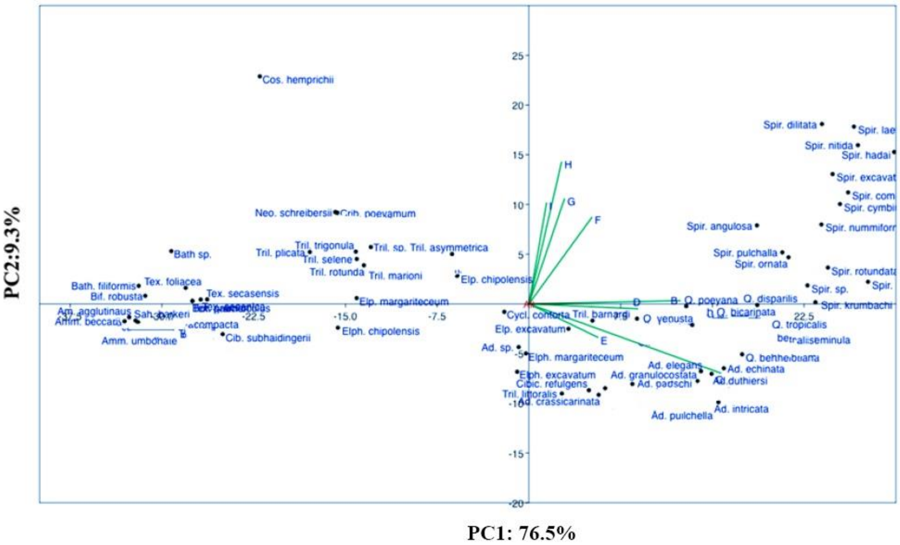


Diagram (2): PCA factor plan, variables Component (PC1 vs PC2).

Table (4): Identified benthic foraminifera taxa (Order, Family, Genus, and Species) distribution.

Order	Family	Genus	Species
Astrohizida	Rhabdamminidae	*Bathysiphon*	*Bathysiphon* sp. *Bathysiphon filiformis* Sars, 1872
Lituolida	Litiolidae	*Ammobaculites*	*Ammobaculites agglutinans* (d'Orbigny, 1826)
Miliolida	Cornuspiridae	*Cornouspira*	*Cornuspira planorbis* (Schultze, 1854)
	Cribrolinoididae	*Adelosina*	*Adeloisina echinate* (d'Orbigny, 1826) *A. elegans* (Williamson, 1858) *A. duthiersi* (Schlumberger, 1886) *A. granulocostata* (Germeraad, 1946) *A. intricate* (Terquem, 1878) *A. laevigata* (d'Orbigny, 1826) *A. mediterranensis* (Le Calvez & Le Calvez, 1958) *A. partschi* (d'Orbigny, 1846) *A. pullchella* (d'Orbigny, 1846) *A. bicornis* (Walker & Jacob, 1798) *A. cliarensis* (Heron-Allen & Earland, 1930) *A. sidebottomi* (Rasheed, 1971) *A. crassicarinata* (Collins, 1958) *Adelosina* sp.

		Cycloforina	*Cycloforina contorta* (d'Orbigny,1846)
		Parrina	*Parrina bradyi* (Millett, 1898)
		Pseudotriloculina	*Pseudotriloculina sidebottomi* (Martinotti, 1921)
		Quinqueloculina	*Quinqueloculina disparilis* (d'Orbigny, 1826) *Q. tropicalis* (Cushman, 1924) *Q. bosciana* (d'Orbigny,1846) *Q. bicarinate* (d'Orbigny, 1878) *Q. bubiyanensis* (Shublank, 1977) *Q. buchiana* (d'Orbigny, 1846) *Q. crassicarinata* (Collins, 1958) *Q. padana* (Perconig, 1954) *Q. patagonica* (d'Orbigny, 1839) *Q. peregrina* (d'Orbigny, 1878) *Q. poeyana* (d'Orbigny, 1846) *Q. berthelotiana* (d'Orbigny11839) *Q.parvula* Schlumberger, 1894 *Q. seminula* (Linnaeus, 1758) *Q. venusta* (Karrer, 1868)
	Hauerinidae	*Triloculina*	*Triloculina affinis* d'Orbigny, 1852 *T. barnardi* Rasheed, 1977 *T. littoralis* Collins, 1958 *T. asymmetrica* Said, 1949 *T. rotundata* d'Orbigny, 1826 *T. marioni* Shlumerger, 1893 *T. schreiberiena* d'Orbigny, 1839 *T. tricarinata* d'Orbigny, 1826 *T. trigonula* (Lamark, 1804) *T. terquemiana* (Brady, 1884) *T. plicata* Terquem, 1878 *Triloculina* sp. *Triloculinella selene* (Karrer, 1868)
	Peneroplidiae	*Peneroplis* *Cosinospira*	*Peneroplis Planatus* (Fishtel& Moll, 1798) *P. pertusus* (Forskal, 1775) *Cosinospira hemprichii* (Ehrenberg, 1839)

	Spiroloculinidae	*Spiroloculina*	*Spiroloculina angulosa* (Cushman, 1917) *S. depressa* (d'Orbigny, 1826) *S.hadai* (Thalmann, 1933) *S. ornata* (d'Orbigny, 1839) *S. pulchalla* (d'Orbigny, 1848) *S. nummiformis* (Said, 1949) *S. costigera* (Terquem, 1882) *S. communis* (Cushman and Todd 1944) *S. cymbium* (d'Orbigny, 1839) *S. dilitata* (d'Orbigny, 1846) *S. excavat* (d'Orbigny, 1846) *S. krumbachi* (Wiesner, 1911) *S. laevigata* (Cushman & Todd 1944) *S. nitida* (d'Orbigny, 1826) *S. rotundata* (Williamson 1858) *Spiroloculina* sp.
Nodosariida	Nodosariidae	*Botuloides*	*Botuloides pauciloculus* (Zheng, 1979)
Rotaliida	Alabaminidae	*Oridorsalis*	*Oridorsalis umbonatus* (Reuss, 1851)
	Ammoniidae	*Ammonia*	*Ammonia beccarii* (Linnaeus, 1758) *A.tepida* (Cushman, 1926) *A. umbonate* (Leroy, 1944) *Ammonia* sp.
		Asterorotalia	*Asterorotalia dentata* (Parker and Jones,1865) *A. milletti* (Bill *et al*.,1980)
		Challengerella	*Challengerella bradyi* (Billmannm Hottingerand Oesterle, 1980)
	Bolivinitidae	*Bolivina*	*Bolivina compacta* (Sidebottom, 1905)
	Cassidulinidae	*Globocassiidulina*	*Globocassidulina spherica* (Eade, 1967)
	Cibicididae	*Cibicides*	*Cibicides refulgens* (Montfort 1808) *C. dispars* (d'Orbigny, 1839)
		Cibicidoides	*Cibicidoides subhaidingerii* (Parr, 1950)
	Discorbidae	*Neoeponides*	*Neoeponides schreibersii* (d'Orbigny, 1846)
	Elphidiidae	*Cribroelphidium*	*Cribroelphidium poeyanum* (d'Orbigny, 1839)
		Elphidium	*Elphidium excavatum* (Terquem, 1875) *E. chipolensis* (Cushman, 1920) *E. margariteceum* (Cushman, 1930)
	Pavoninidae	*Bifarinella*	*Bifarinella robusta* (Sidebottom, 1918)
	Uvigerinidae	*Siphouvigerina*	*Siphouvigerina proboscidea* (Schwager, 186)
Textulariida	Textulariidae	*Sahulia*	*Sahulia barkeri* (Hofker, 1978)
		Textularia	*Textularia foliacea* (Heron-Allen and Earland, 1915) *T. secasensis* (Lalicker and McCulloch, 1940) *T. oceanica* (Cushman, 1932) *T. gramen* (d'Orbigny, 1846)

Table (5): Number and percentage of species in each order

Order	Astrohizida	Lituolida	Miliolida	Nodosariida	Rotaliida	Textulariida	Total
No. of species	2	1	65	1	20	5	94
Percentage (%)	2.1	1.06	69.14	1.06	21.27	5.31	100%

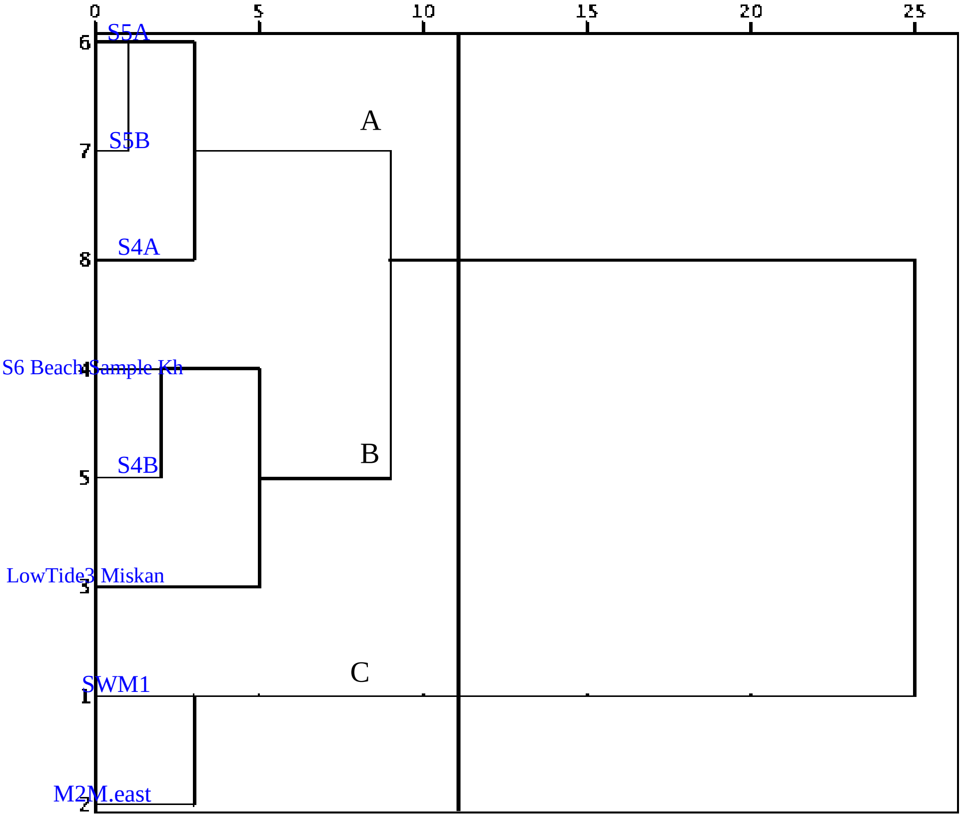


Diagram (3): Q-mode cluster analysis of the studied samples. Dendrogram using Ward Linkage Rescaled Distance Cluster Combine

Increased sediment runoff and eutrophication have increased the turbidity of the water in the Miskan to the point that benthic primary production has halted in some areas. Additionally, eutrophication has enhanced water turbidity in Al-Khiran coastline because of the anthropogenic effects of human life in this area.

The total number of foraminifera around Miskan Island in the northern part of the Arabian Gulf is higher than that reported by Gischler and Lomando (2005) and Parker and Gischler (2015). This might be due to sampling duration, seawater circulation, coral reef distribution, and physiochemical parameters around the island, as well as the transported foraminifera from other environments (e.g., Frontailini *et al*., 2017; Al-Enezi *et al*., 2019). Miskan foraminifera also showed badly preserved dead fauna, indicating a transportation habitat.

Diversity Indices: Relative abundance, species diversity, and the number of individuals has been recorded and shown in Table (4) and Table (5). 97 and 95 species were recorded on SWM1-Miskan and East Miskan-M2, respectively and 71 species was recorded on the S6 sample in the Al-Khiran coastline. All the studied localities showed a high Shannon-H index and evenness. Dominance (D) taxon values were nearly zero in all investigated stations.

Cluster Analysis: To identify genera that tend to coexist (i.e., R-mode analysis), a similarity matrix is constructed based on untransformed row-standardized generic data for all taxa present in greater than 5% of the samples (Tab. 3 and Appendices). The same percentage procedure examines the contribution of individual genera to group segregation, for the observed clustering pattern, or for the difference between a sample set (Clarke and Warwick, 2001). The same matrix-based cluster analysis plots were used to identify foraminifera assemblages. Multivariate and Euclidean-Distance analyses were conducted using Past programs and SPSS. 22 packages to explain relationships between genera. The dendrogram obtained from the R-mode HCA represents the grouping of samples according to the abundance of benthic foraminifera (Diag. 2). Distinct and high hierarchical level four major clusters (A, B, C and D) have been recognized using the R-mode clustering analysis (Diag. 2). Each of these groups was subdivided into two subgroups (i.e., A1, A2, B1, B2, C and D1, D2) that included very similar samples. The dominant species characterizing the four clusters were recognized using the species distribution index of the Arabian Gulf area and worldwide.

Cluster A: Cluster A includes two subclusters, namely, A1 and A2. Assemblage A1 is dominance by *Cosinospira hemprichii*, *Elphidium margariteceum*, *E. chipolensis*, *Triloculina* sp., *T. Rotunda*, *T. tricarinata*, *T. terqueemiana*, *T. marioni*, *T. schreiberiana*, *T. selene*, *T. plicata*, *Peneroplis planatus*, *Neoeponides schreibersii*, *Cribroelphidium poeyamum.* Assemblage A2 is dominated by *Bolivina compacta*, *Cibicidoides subhreibersii*, *Textularia secasensis, T. oceanica, T. foliacea*, *T. gramen*, *Botuloides pauciloculus, Bathysiphon* sp., *B. filiformis*, *Bifarinella robusta*, *Pseudotriloculina sidebottomi*, *Ammonia beccarii*, *A. tepida*, *Ammonia* sp., *A. umbonate*, *Ammobaculites agglutinaus*, *Sahulia barkeri*, *Parrina bradyi*, *Cribroelphidium* sp., *Cibicidoides* sp. and *Globocassidulina spherica* These species were reported to be intolerant of environmental stress, especially bottom oxygen deficiency (van der Zwaan, 1983). *Bolivina* species have shallow microhabitats in the fauna and are adapted to live in low oxygen-depleted environments in the bottom and interstitial waters, and with moderate eutrophication (Murray, 1991; Schmiedl *et al*., 2003).

Cluster B: Assemblage B1 of this cluster includes *Spiroloculina nummiformis*, *S. hadai*, *S. angulosa*, *S. pulchalla*, *S. ornate*, *S. krumbachi*, while assemblage B2 consists of *S. cymbium, S. nitida*, *S dilitata*, *S. laevigata*, *S. rotundata*, *S. costigera, S. excavata*, and *S. communis.*

Cluster C: The association of this cluster consists of *Asterorotalia dentata*, *A. milletti*, *Quinqueloculina parvula*, *Q. berthelotiana*, *Q. seminula*, *Q. peregrina*, *Q. crassicarinata*, *Q. padana*, *Q. poeyana*, *Q. patagonica*, *Q. venusta*, *Q. bosciana*, *Q. disparilis*, *Q. tropicalis*, *Q. buchiana*, *Q. bicarinata*, *Q. bubiyanensis*. *Adelosina echinate*, *A. elegans*, *A. duthiersi*, *A. granulocostat*, *A. intricate*, and *Spiroloculina depressa*. These taxa prefer shallower aquatic microhabitats (Murray, 1991).

Cluster D: The D1 cluster association is dominated by *Adelosina* sp., *Cycloforina contorta*, *E. excavatum*, *E. margariteceum*, *T. asymmetrica*, *E. Chipolensis*. Whereas the D2 cluster consists of *A. laevigata*, *A. mediterranensis*, *A. pullchella*, *A. partschi*, *A. bicornis*, *A. sidebottom*, *A. cliarensis*, *A. crassicarinata*, *T. barnardi*, *Cibicides refulgens*, *C. dispars*, *Challengerella bradyii*, *T. littoralis*, *Cibicides* sp., *T. affinis*, and *Ordiosalis umbonatus.*

Principal Component Analysis and Bivariate Correlation: The first two axes of the principal component analysis (PCA) explain 85.94% of the total variation in the data set (Tab. 6). This percentage is relatively high, and therefore, the foreground will represent the variability of the data. In PCA, the first axis (76.5%) is positively related to Miskan West B (SW-M1), F (S4b-Kh) and negatively related to the low tide pattern from Miskan D (Low Tide-3) (-1) M2 Miskan East C (-7.5), E (-3) (S4a-Kh).

The first axis is positively related to the distribution of *Quinquloculina disparilis*, *Spiroloculina krumbachi*, *S. costigera*, *S. rotundata*, *S. cornata*, *S. pulchalla*, *S. Costigera*, *Bathysiphon* sp., *B. filiforuis*, *Elphidium chipolensis*, *E. margariteceum*, *Textularia*, *foliacea*, *T. secasensis*, *Bifarinella robusta*, *Botuloides pouciloculus*, *Triloculina plicata*, *Q. poeyana*, *Elphidium margariteceum*, *E. excavatum*, *Textularia foliacea*, *Bifarinella robusta.* While it is negatively related to *Cibicides dispars*, *C. refulgens*, *Adelosina echinate*, *A. elegans*, *Astrorotalia milletti*, *A. dentate*, *Chanllengerella baradyii*, *Quinquloculina berthelotiana*, *Q. seminula*, *Q. tropicalis*, *Spiroloculina* sp., *Eliphidium exacavatum*, *Elph. chipolensis*, *Triloculina barnardi*, *Cyclotorina contorta*, *Cibicidoides subhaidingerii*, *Ammonia beccarii*, *A. umbonate*, and *Ammonia* sp.

The second axis explains 9.3 % of the variance, which is positively related to the Al-Khiran coastline samples (S5b-Kh), and S6 and negatively related to S4akh and East Miskan samples (M2). This axis is also positively related to *Spiroloculina dilitata*, *S. laevigata*, *S. nitida*, *S. hadai*, *S. excavata*, *Coscinospira hemperichii*, *Neoeponides schreibersii*, *Cribroelphidium poeyamum* and negatively related to *Adelosina pullchella*, *A. crassicarinata*, and *Elphidium excavate* (Diag. 2).

Q-mode clustering analysis (Diag. 3) confirmed three predominant groups (A, B, and C). The three distinctive facies express the following: Group A, S5A, S5B, and S6 represent a shallow sea condition ranging from 20 cm to 1 m depth. Group B ranges from 1.5 m to 2 m showed gradient and slightly deeper conditions. Group C defined a deeper well-acquainted sample out of 6 in imitation of 10 m. The anoxic conditions and lower number of benthic foraminifers characterize the lowermost part of the Al-Khiran coastline (Diag. 4).

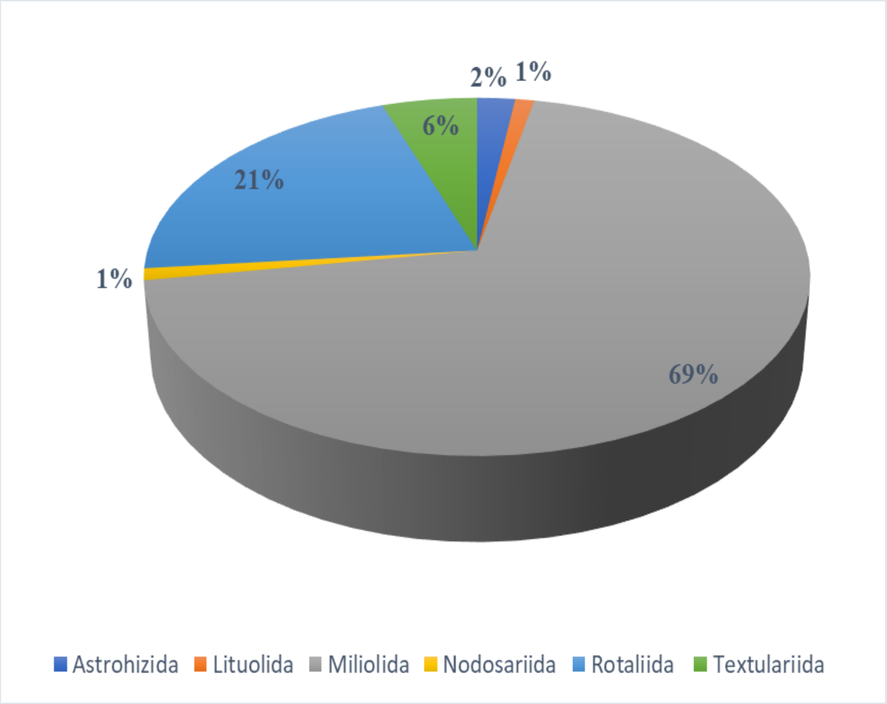


Diagram (4): Order Percentage %.

Heavy Metals: Heavy elements are introduced into the environment through various pathways such as fusion, fuel combustion, and industrialization. They find their way into the Arabian Gulf through atmospheric fallout, dumping, accidental leaks, earth system flows, anthropogenic activities, and geological changes (Al-Yousuf *et al*., 2000). Several studies have been conducted on the concentrations of heavy metals at different locations in the Arabian Gulf and Kuwait territorial water (Al-Arfaj and Alam, 1993; Fowler *et al*., 1993; Al-Abddali *et al*., 1996; Saeed *et al*., 1999; Nigam *et al*., 2006; Al-Enezi, 2002, 2015, 2020). Table (1) shows the distribution of Hg in the studied areas, while Table (6) shows the concentration values for Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, and Fe. Tables in the Appendices show the concentration values of K, Mg, Mn, Na, Ni, Pb, Sb, Se, Ti, V, and Zn in the sediments. These tables revealed that Hg showed a similar pattern in the investigated areas. High concentrations of Hg were recorded in SW-M1 and M-2 from the Miskan Island (Table 1). A high concentration pattern was recorded for arsenic (As) in samples S-6, S-5, B, and constant pattern of < 0.01 in the rest of the samples. High Cd, Pb, Se, V, Be, Cd, Co, Cr, Cu, Fe, Zn, Ni, Mg, K, Al, and Ba concentrations were reported in sample M-2 (Diag. 6). High Al, K, Mg, Mn, and Ni contents were recorded in stations M-2 and S-6. Low Cd, Cu, Pb, and V concentrations have been reported in stations SW-M1 and the Al-Khiran coastline (Diag. 6). Analyzed samples show similar Ca contents except sample S-5A which exhibits a relatively low Ca concentration (Diag. 7).

Table (6): Location, total organic matter, and percentage of size fraction studied sediment samples.

Locality	Sediment type	TOM (%)	> 500	500–250	250–125	125–63	< 63
SWM1	Muddy sand	1.765	8.23	40	39.49	8.91	2.37
East Miskan	Muddy sand	1.686	7.65	42.97	40.37	5.99	2.89
LT-M-3	Muddy sand	1.652	8.11	40.21	39.97	8.42	2.30
S4a-Kh	sand	0.455	60.38	20.8	10.54	7.10	1.68
S4b-Kh	sand	0.220	62.99	18.71	12.44	6.71	0.55
S5a-Kh	sand	0.306	61.19	18.44	12.21	7.11	0.70
S5b-Kh	sand	0.175	60.10	19.10	11.77	7.81	0.84
Al-Khiran Beach S6	Muddy sand	1.512	8.20	42.61	39.11	7.18	2.91

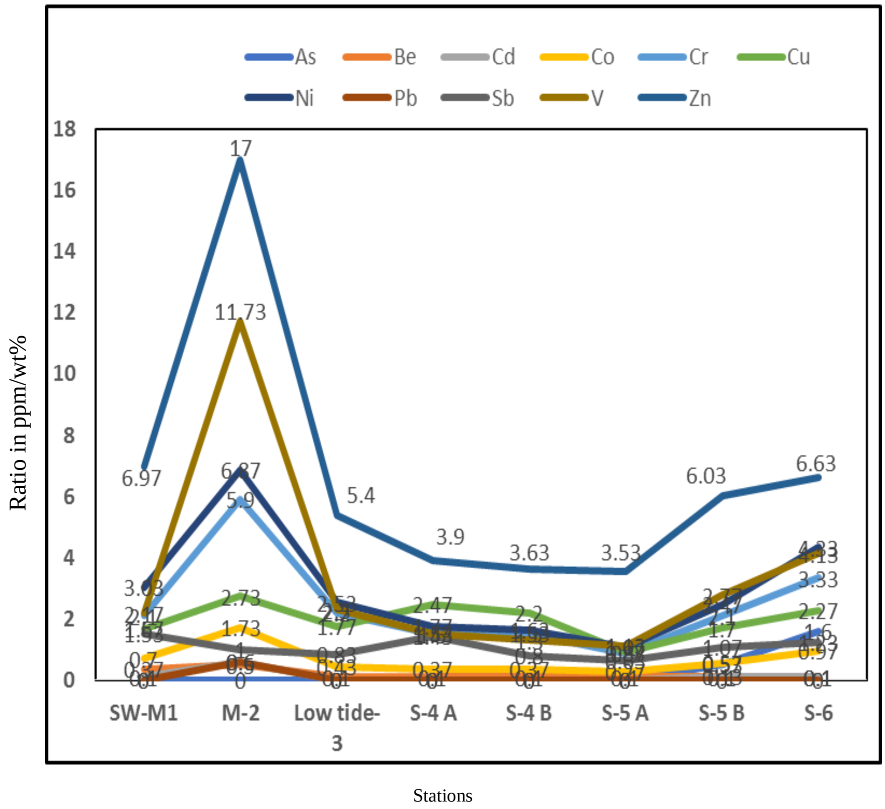


Diagram (5): As, Be, Cd, Co, Cr, Cu, Ni, Pb, Sb, V, and Zn profiles in studied stations. All trace elements are shown as ratios to ppm/wt% .

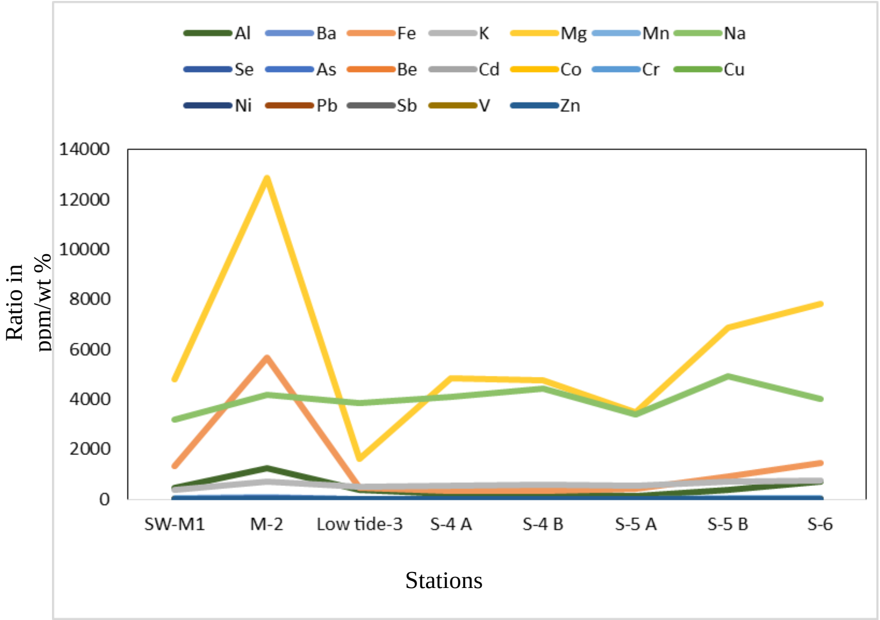


Diagram (6): Al, Ba, Fe, K, Mg, Mn, Na, Se, As, Be, Cd, Co, Cr, Ni, Pb, Sb, V and Zn profiles in studied stations. All trace elements are shown as ratios to ppm/wt%.

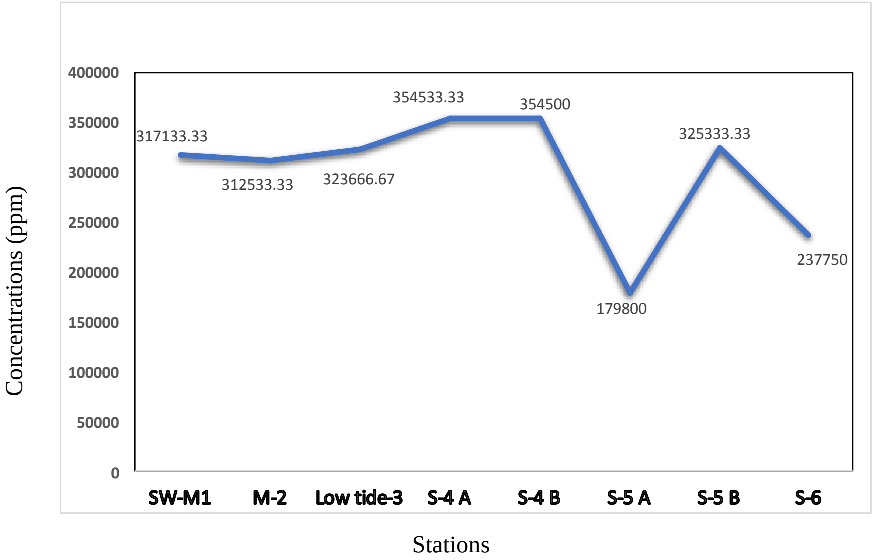


Diagram (7): Ca concentrations in ppm.

Grain-Size Distribution and Total Organic Matter: The grain size analysis showed a predominance of coarse sand, fine sand, silt, and clay. The studied sediments consist of about 70.75% sand in most of the studied area. Silt and clay compositions were recorded at average 25.25% and rare shell fragments at average 4%. The coarse sand part increased towards the sea in the Al Khiran samples; while the fine part (mud and clay) increases around the Miskan Island samples and decreases in the Al Khiran station (Tab. 6). The total organic matter (TOM) is higher in the Miskan samples with an average of 1.70 % compared to the Al Khiran samples (average of 0.54 %).

CONCLUSIONS

Sediment samples have been collected from the Miskan Island Al-Khiran coastline in Kuwait to examine the environmental factors controlling benthic foraminifera's distribution and species richness. Based on the quantitative analysis of the benthic foraminiferal assemblages in these sediments, 19 families, 6 orders, 29 genera, and 94 species were recorded. The quantitative distribution of the benthic foraminifera around the coral reefs varied from Miskan Island to Al-Khiran coastline suggesting strong environmental changes and productivity. The highest diversity of the benthic foraminiferal assemblages in the Miskan Island is due to the high nutrient quantity that comes from Shatt Al-Arab through the drainage system and the coral reefs around the island. Another indication of a slight increase in oxygen in the Miskan Island is the increased diversity and presence of benthic taxa such as *Eponides* sp. and *Laevidentalina* sp., which appear to be tolerant of bottom aquifer oxygen depletion and high organic matter flows.

The relative abundance of the framboidal pyrite in the Miskan Island also confirms this. The high foraminifera richness recorded at Miskan West may be the result of the presence of high-quality organic matter trapped in the sediments and derived from Shatt Al-Arab. Deformities and foraminifera preservation in the Miskan Island are due to the dilution from the influence of the freshwater of Shatt Al-Arab in the north. Q-mode clustering analysis of the studied samples pointed out that the different locations and depth gradients are the main factors that affected the differences in Foraminifera assemblages. The data indicates that heavy metals and PTE concentrations observed in the studied stations were within the range of normal standard values reported for unpolluted marine areas and with the sediment quality guidelines. In general, the studied stations revealed the high diversity, low turbidity, and good oxidation of the surface bottom sediments, and the PTE concentrations in the sediments are within the range of published background values for similarly uncontaminated areas west of the Arabian Gulf. There is no clear abnormality in the identified species, and most species show normal aperture, coiling, shape, and size.

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CONFLICT OFINTERESTSTATEMENT

"The authors have no conflicts of interest to declare".

LITERATURE CITED

Al-Yousuf, M. H., El-Shahawi, M. S. E. and Al-Ghais, S. M. 2000. Trace metals in liver, skin, and muscle of *Lethrinus lentjan* fish species in relation to body length and sex. *Science of the Total Environment*, 256(2-3):87-94. [CrossRef]

Al-Abdali, F., Massoud, M. and Al-Ghadban, A. 1996. Bottom sediments of the Arabian Gulf III: Trace metal contents as indicators of pollution and implication for the effect and fate of the Kuwait oil slick. *Environmental Pollution*, 9: 1-17. [CrossRef]

Al-Arfaj, A., A. and Alam, I., A. 1993. Chemical characterization of sediments from the gulf area after the 1991 oil spill. *Marine Pollution Bulletin*, 93: 85-301. [CrossRef]

Al-Enezi, E. and Frontalini, F. 2015. Benthic foraminifera and environmental quality: The case study of Sulaibikhat Bay (Kuwait). *Arabian Journal of Geosciences*, 8: 8527-8538. [Click here]

Al-Enezi, E., Al-Ghadban, A. N., Al-Refai, I., Pieretti, N. and Frontalini, F. 2019. Living benthic foraminifera around the unique Umm al Maradim Island (Kuwait). *Kuwait Journal of Science*, 46: 59-66.

Al-Enezi, E., Khader, S., Balassi, E. and Frontalin, F. 2020. Modern Benthic Foraminiferal Diversity: An initial insight into the total foraminiferal diversity along the Kuwait coastal water, 167 pp.

Alsharhan, A.S. and Kendall, C.G. 2003. Holocene coastal carbonates and evaporates of the southern Arabian Gulf and their ancient analogues. *Earth Science Reviews*, 61: 3-4, 191-243. [CrossRef]

Alve, E. 1995. Benthic foraminiferal responses to estuarine pollution: a review. *Journal of Foraminiferal Research*, 25(3): 190-203. [CrossRef]

Alve, E. and Murray, I. W. 1994. Ecology and taphonomy of benthic foraminifera in a temperate mesotidal inlet. *Journal of Foraminiferal Research*, 24:18-27. [CrossRef]

Al-Zamel, A., Cherif, O. and Al-Rifaiy, I. 1998. Subtidal foraminiferal assemblages of the western part of the Shatt Al-Arab delta, Kuwait, Arabian Gulf. *Journal of Foraminiferal Research*, 28: 327-344. [CrossRef]

Al-Zamel, A.Z., Al-Sarawi, M.A., Khader, S., R. and Al-Rifaiy, I., A. 2009. Benthic foraminifera from polluted marine environment of Sulaibikhat Bay (Kuwait). *Environmental Monitoring Assessment*, 149: 395-409. [Click here]

Amao, A. O., Kaminski, M. A. and Babalola, L. 2018 a. Benthic foraminifera in hypersaline Salwa Bay (Saudi Arabia): an insight into future climate change in the gulf region. *Journal Foraminifera Research*, 49: 366-371. [CrossRef]

Amao, A. O., Kaminski, M. A. and Setoyama, E. 2016. Diversity of foraminifera in a shallow restricted lagoon in Bahrain. *Micropalaeontology*, 62: 197-211. [CrossRef]

Amao, A. O., Kaminski, M. A., Rostami, M. A., Gharaie, M. H. M., Lak, R. and Frontalini, F. 2018 b. Distribution of benthic foraminifera along the Iranian coast. *Marine Biodiversity*, 13: 1-14. [CrossRef]

Amao, A. O., Qurban, M. A., Kaminski, M. A., Joydas, T. V., Manikandan, P. K. and Frontalini F. 2019. A baseline investigation of benthic foraminifera in relation to marine sediments parameters in western parts of the Arabian Gulf. *Marine Pollution Bulletin*, 146: 751-766. [CrossRef]

Arslan, M., Kaminski, M., Khalil, A., Ilyas, M. and Tawabini, B. S. 2017. Benthic foraminifera in Eastern Bahrain: Relationships with local pollution sources. *Polish Journal of Environmental Studies*, 26(3):969-984. [CrossRef]

Barbosa, C. F., Prazeres, M. F., Ferreira, B. P. and Seoane, J. C. S. 2009. Foraminiferal assemblage and reef check census in coral reef health monitoring of East Brazilian margin. *Marine Micropaleontology*, 73:62-69. [CrossRef]

Blott, S. J. and Pye, K. 2001. Gradistat: A grain size analysis distribution and statistics package for the analysis of unconsolidated sediments. *Earth Surface Processes and Landforms*, 26:1237-1248. [CrossRef]

Bouchet, V. M. P., Alve, E., Rygg, B. and Telford, R. J. 2012. Benthic foraminifera provide a promising tool for ecological quality assessment of marine waters. *Ecological Indicators*, 23: 66-75. [CrossRef]

Bouchet, V. M. P., Deldicq, N., Baux, N., Dauvin, J. C., Pezy, J.P., Seuront, L. and Méar, Y. 2020. Benthic foraminifera to assess ecological quality statuses: The case of salmon fish farming: *Ecological Indicators*, 117: 106607-106613. [CrossRef]

Bouchet, V. M. P., Goberville, E. and Frontalini, F. 2018. Benthic foraminifera to assess Ecological Quality Statuses in Italian transitional waters. *Ecological Indicators*, 84: 130-139. [CrossRef]

Buzas, M. A. and Gibson, T. G. 1969. Species diversity: benthonic foraminifera in western north Atlantic. *Science*, 163(3862): 72-75. [CrossRef]

Charrieau, L. M., Filipsson, H. L., Ljung, K., Chierici, M., Knudsen, K. L. and Kritzberg, E. 2017. The effects of multiple stressors on the distribution of coastal benthic foraminifera: A case study from the Skagerrak-Baltic Sea region. *Lundqua Thesis*, 2017: 57-8. [CrossRef]

Cherif, O. H., Al-Ghadban, A. and Al-Rigaiy, A. 1997. Distribution of foraminifera in the Arabian Gulf. *Micropaleontology*, 43: 253-280.

Cimerman, F. and Langer, M. 1991. Mediterranean Foraminifera. Slovenska Akademia Znanosti in Umetnosti. *Historia Naturalis*, 30: 1-118. [CrossRef]

Clarke, K. R. and Warwick, R. M. 2001. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. 2nd Edition, PRIMER-E, Plymouth, 172 pp.

Du Châtelet, E. A., Debenay, J. P. and Soulard, R. 2004. Foraminiferal proxies for pollution monitoring in moderately polluted harbors. *Environmental Pollution*, 127: 27-40. [CrossRef]

El-Kahawy, R., El-Shafeiy, M., Helal, S. A., Aboul-Ela, N. and Abd El-Wahab, M. 2018. Morphological deformities of benthic foraminifera in response to nearshore pollution of the Red Sea, Egypt: *Environmental Monitoring and Assessment*, 190: 1-22. [Click here]

Fisher, R. A., Steven, Corbert, A. and Williams, C. B. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology*, 12(1): 42-58. [CrossRef]

Fowler, C. W. 1999. Management of multi-species fisheries: from overfishing to sustainability. *ICES Journal of Marine Science*, 56: 927-932. [CrossRef]

Frontailini, F., Greco, M., Di Bella, l., Lejzerowicz, F., Reo, E., Caruso, A., Cosentino, C., Maccotta, A., Scopelliti, G., Nardelli, M. P., Losada, M. T., du Châtelet, E. A., Coccioni, R., Pawlowski, J. 2017. Assessing the effect of mercury pollution on cultured benthic foraminifera community using morphological and eDNA metabarcoding approaches. *Marine Pollution Bulletin*, 129(2): 512-524. [CrossRef]

Gischler, E. and Lomando, A. J. 2005. Offshore sedimentary facies of a modern carbonate ramp, Kuwait, northwestern Arabian-Persian Gulf. *Facies*, 50: 443-462. [CrossRef]

Hallock, P., Williams, D. E., Fisher, E. M. and Toler1, S. K. 2006. Bleaching in Foraminifera with algal symbionts: Implications for reef monitoring and risk assessment. *Anuário do Instituto de Geociências*, 29: 108-128. [CrossRef]

Hammer, O., Harper, D. A. T. and Ryan, P. D. 2001. Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, 4(1): 9-17. [Click here]

Hayek, L. A. C. and Buzas, M. A. 1997. Surveying natural populations. Columbia University Press, New York, 563 pp.

Hottinger, L., Halicz, E. and Reiss, Z. 1993. Recent foraminiferida, Gulf of Aqaba, Red Sea. Opera Academia Scientiarum et Artium Slovenica, Classis IV: Historia Naturalis, 33, Paleontological Institute “Ivan Rakovec”, 96 pp.

Khalaf, F., AL-Bakri, D. and Al-Ghadban, A. 1984. Sedimentological characteristics of the surficial sediments of the Kuwaiti marine environment, Northern Arabian Gulf. *Sedimentology*, 31(4):531-545. [CrossRef]

Koukousioura, O., Dimiza, M. D., Triantaphyllou, M. V. and Hallock, P. 2011. Living benthic foraminifera as an environmental proxy in coastal ecosystems: a case study from the Aegean Sea (Greece, NE Mediterranean): *Journal of Marine Systems*, 88: 489-506. [CrossRef]

Kurbjeweit, F., Schmiedl, G., Schiebel, R., Hemleben, C., Pfannkuche, O., Wallmann, K. and Schafer, P. 2000. Distribution, biomass, and diversity of benthic foraminifera in relation to sediment geochemistry in the Arabian Sea. *Deep-Sea Research II*, 47: 2913-2955. [CrossRef]

Loeblich, A. R. and Tappan, H. N. 1994. Foraminifera of the Sahul Shelf and Timor Sea. *Cushman Foundation for Foraminiferal Research Special Publication*, 31: 661-673.

Loeblich, A. R. and Tappan, H. N. 1988. Foraminiferal genera and their classification. 1. Van Nostrand Reinhold, 212 pp.

Ly, A. and Kuhnt, W. 1994. Late Cretaceous benthic foraminiferal assemblages of the Casamanca Shelf (Senegal, NW Africa): indication of a late Cretaceous oxygen minimum zone. *Revue de Micropaléontologie*, 37(1): 49-74. [CrossRef]

McCune, B. and Grace, J. B. 2002. Analysis of ecological communities. Mj M Software Design, Gleneden Beach, Oregon, 300 pp.

Murray, J. W. 1991. Ecology and Palaeoecology of Benthic Foraminifera.1st edition, Logman Scientific and Technical, London, 408pp. [CrossRef]

Murray, J. W. 2014. Ecology and Palaeoecology of Benthic Foraminifera: First edition Routledge, London, 408 pp. [CrossRef]

Nigam, R., Saraswat, R. and Kurtarkar, S. 2006a. Laboratory experiment to study the effect of salinity variations on benthic foraminiferal species- *Pararotalia nipponica* (Asano). *Journal Geological Society India*, 67: 41-46.

Nigam, R., Saraswat, R. and Panchang, R. 2006b. Application of foraminifers in ecotoxicology: Retrospect, prospect, and prospect. *Environment International*, 32: 273-283. [CrossRef]

Parker, J. H. 2009. Taxonomy of Foraminifera from Ningaloo Reef, Western Australia. *Memories Associated Australian Paleontology*, 36: 1-812.

Parker, J. H. and Gischler, E. 2015. Modern and relict foraminiferal biofacies from a carbonate ramp, offshore Kuwait, northwest Persian Gulf. *Facies*, 61: 10-16. [CrossRef]

Poppe, L. J., Eliason, A. H., Fredericks, J. J., Rendigs, R. R., Blackwood, D. and Polloni, C. F. 2000. Grain size analysis of marine sediments: methodology and data processing. *In*: Poppe, L. J. and Polloni, C. F. (Eds.), USGS East-coast sediment analysis: procedures, database, and georeferenced displays. US Geological Survey Open-File Report, 358 pp. [CrossRef]

Riegel, J. B., Bernhardt, E. S. and Swenson, J. 2013. Estimating aboveground carbon biomass in a newly restored coastal plain wetland using remote sensing. *PLoS One*, 8: 68251-68259.

Saeed, T., Al-Ghadban, A.N., Al-Shemmari, H., Al-Mutairi, M. and Al-Hashash, H. 1999. Preliminary assessment of the impact of draining of Iraqi Marshes on Kuwait's Northern Marine Environment. Part II. *Sediment Associated Pollutants Water Science and Technology*; *London*, 40: 89-98. [CrossRef]

Salmons, W. and Forstner, U. 1984. Metals in the Hydrocycle, Springer Verlag, Berlin, Heidelberg, New York, Tokyo, 198 pp.

Schmidt, C., Heinz, P., Kucera, M. and Uthicke, S. 2011. Temperature-induced stress leads to bleaching in larger benthic foraminifera endosymbiotic diatoms. *Limnology Oceanography*, 56(5): 1587-1602. [CrossRef]

Schmiedl, G., Mitschele, A., Beck, S., Emeis, K-Ch., Hemleben, Ch., Schulz, H., Sperling, M. and Weldeab, S. 2003. Benthic foraminiferal record ofecosystem variability in the eastern Mediterranean Sea during times of sapropel S_5 and S_6 deposition. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 190: 139-164. [CrossRef]

Shannon, C. E. and Weaver, W. 1949. The mathematical theory of communication. University of Illinois Press, Urbana, IL, 144 pp.

Sheppard, C., Al-Husiani, M., Al-Jamali, F., Al-Yamani, F., Baldwin, R. and Bishop, J. 2010. The gulf: a young sea in decline. *Marine Pollution Bulletin* 60 (1): 13-38. [CrossRef]

Simpson, E. 1949. Measurement of diversity. *Nature*, 163:688. [Click here]

Sreenivasulu, G., Praseetha, B. S., Daud, N. R., Varghese, T. I., Prakash, T. N., Jayaraju, N. 2019. Benthic foraminifera as potential ecological proxies for environmental monitoring in coastal regions: a study on the Beypore estuary, Southwest coast of India. *Marine Pollution Bulletin*, 138: 341-351. [Click here]

Van der Zwaan, G. J. 1983. Quantitative analyses and the reconstruction of benthic foraminiferal communities. *Utrecht Micropaleontological Bulletin*, 30: 49-69. [Click here]

APPENDICES

Appendix (1): Test results of Hg analysis. All the results are given in ppb.

Sample ID	**Hg in ppb**
SW-M1	0.0200
M-2	0.0217
S-4 A	0.0163
S-4 B	0.0120
S-5 B	0.0142
S-6	0.0119
Low tide-3	0.0135

Appendix (2): Test results of metal analysis. All the results are given in mg/kg (ppm).

Sample ID	**Ag**	**Al**	**As**	**Ba**	**Be**	**Ca**	**Cd**
SW-M1	<0.01	467.70	<0.01	8.60	0.37	317133.33	0.10
M-2	<0.01	1237.67	<0.01	22.07	0.50	312533.33	0.60
Low tide-3	<0.01	377.70	<0.01	14.20	0.10	323666.67	0.00
S-4 A	<0.01	239.40	<0.01	20.80	0.10	354533.33	0.00
S-4 B	<0.01	234.20	<0.01	20.60	0.10	354500.00	0.00
S-5 A	<0.01	140.10	<0.01	4.23	0.10	179800.00	0.00
S-5 B	<0.01	369.20	0.53	8.37	0.13	325333.33	0.10
S-6	<0.01	727.77	1.60	13.77	0.10	237750.00	0.10

Appendix (3): Test results of metal analysis. All the results are given in mg/kg (ppm).

Sample ID	**K**	**Mg**	**Mn**	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**Tl**	**V**	**Zn**
SW-M1	396.67	4796.67	40.00	3190.00	3.03	<0.01	1.53	16.43	<0.01	2.17	6.97
M-2	716.67	12873.33	110.	4183.33	6.87	0.60	1.00	51.83	<0.01	11.73	17.00
Low tide-3	506.67	1633.33	10.00	3866.67	2.53	<0.01	0.83	4.87	<0.01	2.30	5.40
S-4 A	530.00	4850.00	20.00	4103.33	1.77	<0.01	1.43	3.50	<0.01	1.50	3.90
S-4 B	606.67	4756.67	20.00	4420.00	1.63	<0.01	0.80	3.53	<0.01	1.30	3.63
S-5 A	536.67	3476.67	20.00	3383.33	1.07	<0.01	0.63	4.00	<0.01	1.13	3.53
S-5 B	696.67	6883.33	36.67	4930.00	2.47	<0.01	1.07	9.10	<0.01	2.77	6.03
S-6	756.67	7810.00	56.67	4020.00	4.33	<0.01	1.23	15.77	<0.01	4.13	6.63

Bull. Iraq nat. Hist. Mus.
(2023) 17(4): 629-653.

تطبيقات الفورامنيفرا القاعية لتقييم التلوث في جزيرة مسكان وساحل الخيران، الكويت

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الخلاصة

استخدم التنوع البيولوجي للفورامنيفرا القاعية وتركيز المعادن الثقيلة مثل Mn و Fe و Cr و Cu و Ni و Pb و Zn و Cd و Co حول الشعاب المرجانية حول جزيرة مسكان و ساحل الخيران في الكويت كمؤشرعلى الجهاد البيئي والذي ينتج من نشاط االنسان في الفترة بين فبراير 2018 الى فبراير .2019 تم التعرف على 19عائلة شملت 6 رتبة و29 جنسا و 94 نوعا.

نتج عن استخدام التحليل (R) للفورامنيفرا أربع مجموعات، بينما نتج عن استخدام التحليل (PCA) ثالث مجاميع رئيسية وقد استخد م عمق الماء كعامل للمقارنة. وكانت المجاميع كالتالي، مجموعة (أ) تمثل فورامنيفرا تعيش بعمق يتراوح بين 20 سم – 1 متر، و مجموعة (ب) تعيش بعمق بين 1.5– 2 متر . أما مجموعة (ج) تعيش بالمياه العميقة من -6 8 متر. يعاني ساحل الخيران من نقص في تركيز الأوكسجين بدليل وجود البيريت في الرواسب. وأيضا يعاني من التخثث بسبب المخلفات البشرية. أما في جزيرة مسكان فيرجع سبب قلة عدد الفورامينيفرا الى تكلس وتحلل هياكلها. حيث تتميز جزيرة مسكان باختلاط المياه العذبة من العراق مع المياه المالحة من الخليج مما يؤثر على ملوحة المياه وأيضا جرف الرواسب وتعكر المياه بسبب النشاط البشري. وتعتبر المنطقتين خاليتين من التلوث بالمعادن الثقيلة عند مقارنتها مع تركيز هذه المعادن في أقرب شاطئ لها في ايرن. ولكن األمر ال يخلو من وجود مواد عالية السمية في بعض المواقع و يعزي هذا الى أن المنطقة جغرافيا شبة مغلقة بالأضافة الى أثر النشاط البشري. لم تسجل أي تشوهات في الفورامنيفرا التي تم التعرف عليها، أغلبها كان له فتحة الفم، و الشكل و الحجم و اتجاه لفة هيكل طبيعي.