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Environmental Factors Controlling the Distribution of Sediment Infauna, Az-Zour Area, South of Kuwait

العاملات البيئية المتحكمة في توزيع الكائنات الحيوانية البينية في الرواسب - منطقة الزور - جنوب الكويت

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Abstract: The special distributions of meiofaunal and macrofaunal groups of Az-Zour area, south of Kuwait were investigated. Sediment samples were collected during July, 2004 at equilateral distances comprising eight parallel transects perpendicular to the shore. A total of 25 species of meiofauna were identified. Generally, nematodes, crustaceans and polychaetes dominated the samples with other groups forming only a minor part. 31 species of macrofauna groups were recorded. Annelida macrofauna dominated the samples with 14 species followed by Mollusca (11 species), followed by crustaceans (5 species) and Echinodermata was represented with one species and was considered very rare. The infaunal communities of the study area could be grouped into three main groups, the active borrowers, the scrapers and the filter feeders. The present investigation showed that high abundance and species diversity of the infaunal groups were recorded in the middle zone of the study area. This could be related to different sediment characteristics such as sediments grain size, total organic carbon, heavy metal and water temperature that could enable meiofaunal enrichment for the middle zone.

Keys word: *Meiofauna; Macrofauna; heavy metals; total organic carbon; total suspended sediments; Arabian Gulf; Kuwait.*

المستخلص: تمت دراسة توزيع مجموعات الكائنات الحيوانية البينية الصغيرة والكبيرة في رواسب منطقة الزور جنوب الكويت وقد تم جمع عينات الرواسب خلال شهر يوليو 2004 من ثماني قطاعات عمودية على الشاطئ. وقد تم تحديد عدد 25 نوع من الكائنات البينية الصغيرة وبشكل عام فقد سيطرت الديدان والقشريات والديدان متعددة الأشواك على عينات الكائنات البينية

الصغيرة مع بعض الكائنات الأخرى التي شكلت مجموعات صغيرة وقد تم تسجيل 31 نوعاً من الكائنات الحيوانية الكبيرة حيث سيطر الحلقيات على توزيع الكائنات وتمثلت بـ 14 نوعاً تليها الرخويات (11 نوعاً) والقشريات (5 أنواع) والجلد شوكيات (نوع واحد) ويمكن تقسيم الكائنات الحيوانية البينية في منطقة الدراسة إلى ثلاث مجموعات رئيسية وقد أظهرت الدراسة الحالية أن هناك وفر عالية وتنوع من الأنواع لمجموعات الكائنات البينية الحيوانية في المنطقة الوسطى ويمكن أن يعزى ذلك إلى خصائص الرواسب المختلفة مثل حجم الحبيبات والكربون العضوي الكلي وتراكيز المعادن الثقيلة ودرجة حرارة المياه التي يمكن أنا تساعد في زيادة الكائنات لحيوانية البينية في المنطقة الوسطى.

كلمات مدخلية : *الكائنات البينية الحيوانية، المعادن الثقيلة، الكربون العضوي الكلي، المواد العالقة الكلية، الخليج العربي، الكويت.*

INTRODUCTION

The marine environment of Kuwait receives continuous supply of nutrient salts from Shatt Al-Arab estuary that makes it one of the most productive areas of the Gulf (Al-Yamani, 1989). The marine environment of Kuwait is at higher risks of ecological damages than most of the other Gulf areas (Al-Ghadban and Salman, 1993, Sheppard, *et al*, 2010). The coastal waters of Kuwait are greatly affected by the increased human developments which include, industrialization, urbanization and recreation activities. Notwithstanding that, the southern area of Kuwait is less developed than the northern region including Kuwait Bay, the southern area of Kuwait at Az-Zour area is also impacted from the outflow of the already existing power and desalination plant, as well as the enhancement of recreational activities south (Khiran Area) and north to Az - Zour.

Biological components have traditionally been a preferred option for use as environmental monitoring tools for scrutinizing the environmental health (Goldberg *et al*, 1978; Bryan *et al*., 1985; Kennedy and Jacoby, 1999, Waldbusser and Marinelli, 2009). According to Kenndy and Jacoby (1999), accurate prediction of anthropogenic impacts on natural environment would be achieved by a clear understanding of the interaction between the *priori* census of human development and the surrounding ecological system. The term in-fauna refers to the assemblages of meiofauna and macrofauna. Meiofauna refers to the assemblage of marine benthic metazoan with dimensions smaller than the macrofauna (minimum size 1000 μm) and larger than the microfauna (maximum size 62 μm). Kuwait Institute for Scientific Research (KISR) had implemented a project aiming at assessing the impacts from the construction of a power plant at the southern coastal area. A major component of the study was the biological assessment of the offshore area, Az - Zour area (Al-Ghadban *et al*, 2004) This study is an integral part of this project and aiming at identifying the environmental factors affecting the distribution, abundance and diversity of the benthic infauna, in the Az - Zour area, south of Kuwait. The relationships between sediment quality, environmental parameters and the distribution of the different infaunal groups are considered.

MATERIALS AND METHODS

Eight equidistant transects perpendicular to the coast were collected during June 2004, from the area of Az-Zour (south of Kuwait, fig. 1). At each transect, sediment samples were collected from six stations corresponding to 100 m, 200 m, 400 m, 800 m, 1600 m and 3200 m distance from the coast. In addition to the 48 stations from the different transects, two reference stations were selected from the offshore area. Environmental parameters (pH, Dissolved Oxygen “DO”, Salinity “S‰”, and Water Temperature) for the subsurface water were measured in situ using the multi-parameters instrument (YSI 6600). For sediments samples, the Total Organic Carbon (TOC) and mean grain size (Mz) were measured according to the methods recommended by ROPME (MMOPAM, 1999).

Five metals were analyzed for their total metal- contents in - 50 sediment- samples (MMOPAM, 1999). These metals are Al, Fe, Cu, Ni and V. The Pollution load index (PLI) was at

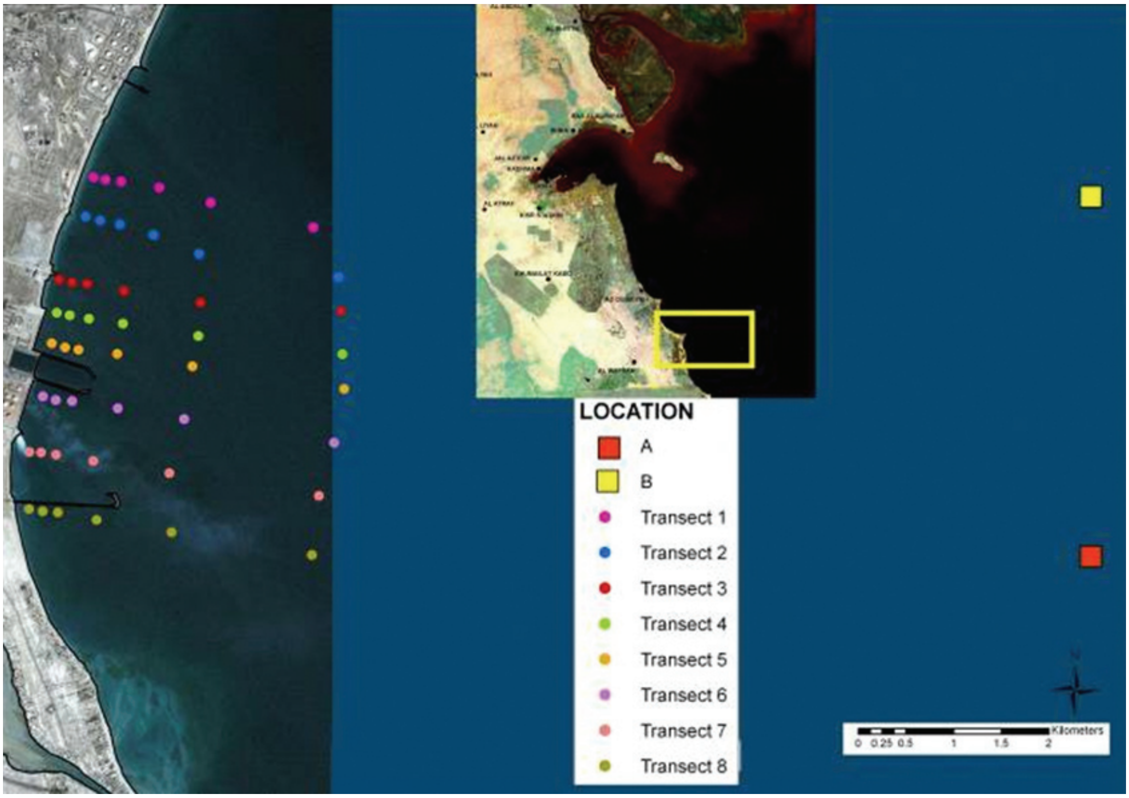

Fig.1. Locations of sampling transects along the coastal area of Az-Zour, south of Kuwait.

first determined by calculating the contamination factor for each metal. The Contamination Factor (CF) is the concentrations of metal divided by its background value. Back ground values used here are the shallow marine sediments (Solomons and Föstner, 1984).

Only six transects from the eight transects were used for the identification of macrobenthos and meiobenthos. The collections were made by Scuba diving, where a plastic bag was filled with about 2 kg of surface bottom sediments (down to about 5 cm of bottom sediments). The material was placed in large plastic jars and preserved in 5% formalin solution. Rose Bengal was added for staining the organic materials. Sub-samples of 200 g were used for identification and enumeration of macrofaunal and meiofaunal groups. 1mm and 0.63 mm mesh sieves were used for the separation of the macrofauna and meiofauna separation, respectively. Separations were repeated three times in order to ensure the complete isolation of different faunal groups.

The data were analyzed using species richness and species diversity indices. The richness was calculated according to Margalef's Diversity Index and Shannon Diversity Index (Magurran, 2004).

$$D = \frac{S - 1}{Ln\ N}$$

Where: D= Richness; S= the number of the species in the population.
N= total number of individuals in the population.

The diversity index was used to assess how widely dispersed species are in the samples (Magurran, 2004). The Shannon index of general diversity (H`) was calculated using the following equation:

$$H_{i=1} = \frac{ni}{N} \ x \ \frac{Ln \quad ni}{N}$$

Where:
ni= the number of species individuals; N= the total number of individuals.

STATISTICA 8 software was used for the statistical analysis, while Arc-GIS software and SURFER software were used for drawing the distribution of different parameters.

RESULTS AND DISCUSSION

Environmental Parameters

Table (1) illustrates the maximum, minimum and average values of the different environmental parameters as well as a comparison with the average values reported for Kuwait's water. All the measured parameters are within the range of Kuwait's water average values (Al-Yamani *et al*, 2004, Al-Rashidi *et al*, 2009).

The mean grain size (F) ranged between 4.800 F (coarse silt) and 0.366 F (coarse sand) with an average of 1.68 F ± 0.93 (i.e. medium sand). Most of the area is covered with coarse to medium sand (Fig. 2) while mud is found in the north-eastern corner of the study area. In general, the grain size of the sediment becomes finer offshore. Fine sand is observed in the area adjacent to the outfall facilities. These results are in accordance with Khalaf *et al*., 1984 and Marmoush *et al*., (2000) study, where they indicated that the offshore areas south of Kuwait are generally covered with coarse to fine sand.

The distribution of total organic carbon (%) in the study area is shown in Fig. (3). The TOC is ranging between maximum value of 2.16 (%) and a minimum concentration of 0.72 (%) with an average of 1.802 % ± 0.39).

The distribution of heavy metal concentrations in the study area is shown in Fig (4). Al and Fe had almost the same distribution pattern, where higher concentrations were almost found offshore and to the northern region. Ni and V showed high concentration offshore (Fig. 4). These high levels may be inferred to the hydrocarbon pollution. These two metals are well known as petroleum hydrocarbons indicators and they exhibit high concentrations when petroleum hydrocarbons levels are high (El Sammak *et al.,* 2004). The sources of these hydrocarbons can be expected from the offshore area, through illegal discharge of ballast water, natural seepage, and navigation as well as to the hydrodynamic conditions. El Sammak *et al*. (2005) mentioned that natural oil seepage occurred in the area between Umm Al-Mardem and Qaro islands that locate offshore from the study area.

Abou Seida (1988) indicated that burning fuel oil leaves a deposit in the power plant that is normally cleaned by acids, a process that produces an intermittent acidic discharge potentially containing strong concentrations of metals, notably copper. They also mentioned that Cu, Zn and Fe are also released because of pipe corrosion within plant. The distribution pattern of Cu (Fig. 4) indicating that Cu source is most likely from the discharged outfall water as proposed by Abu Seida (1988). Other factor is the association of Cu and other metals with fine fractions (i.e. grain size control the distribution of metals such as Cu).

Table (2) compares the concentrations of metals in the sediments of Az-Zour area with some similar areas. It was reported that both Ni and V were found to be at elevated levels. These elements are present at enriched levels in Kuwait crude oil, and they may therefore act as markers for oil contamination. It is also notable that both nickel and vanadium may persist in sediments over much longer period of time than the typical hydrocarbons. They may consequently provide longer lasting signatures of oil pollution in coastal environments.

Using PLI it is possible to divide the study area into different zones. The highest PLI indicates that this zone is more contaminated than the other zones. PLI is calculated according to following equation (Salmon and Forstner, 1984).

$$PL1 = \sqrt{CF^{v} \ x \ CF^{cu} \ x \ CF^{Ni}}$$

Fig.(5) illustrates the PLI calculated using three metals (Cu, Ni and V). As mentioned before, Cu is known to be associated with power stations while V and Ni are considered to be hydrocarbon indicators.

Table 1. Descriptive Statistics of environmental parameters.

Environmental parameter	Present Study			Average Kuwait's Water (Summer Season) (Al-Yamani *et al*, 2004)
	Minimum	Maximum	Average ± Standard Deviation	
pH	8.02	8.16	8.09 ± 0.032	8.2
DO (mg/l)	5.60	13.9	7.61 ± 2.34	6.1
Salinity (‰)	37.60	41.50	40.28 ± 1.04	39.6
Water Temperature (°C)	29.10	31.60	30.33 ± 0.50	30.5

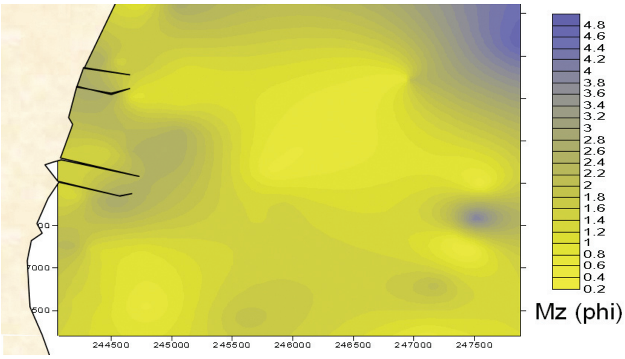

Fig.2. Distribution of mean grain size (Φ) at Az-Zour Area.

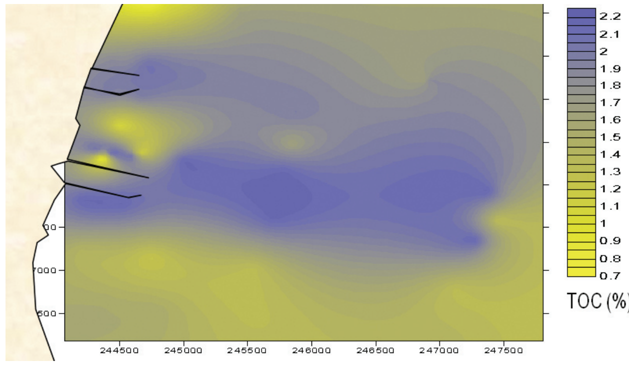

Fig.3. Distribution of TOC (%) in the sediments of Az-Zour Area.

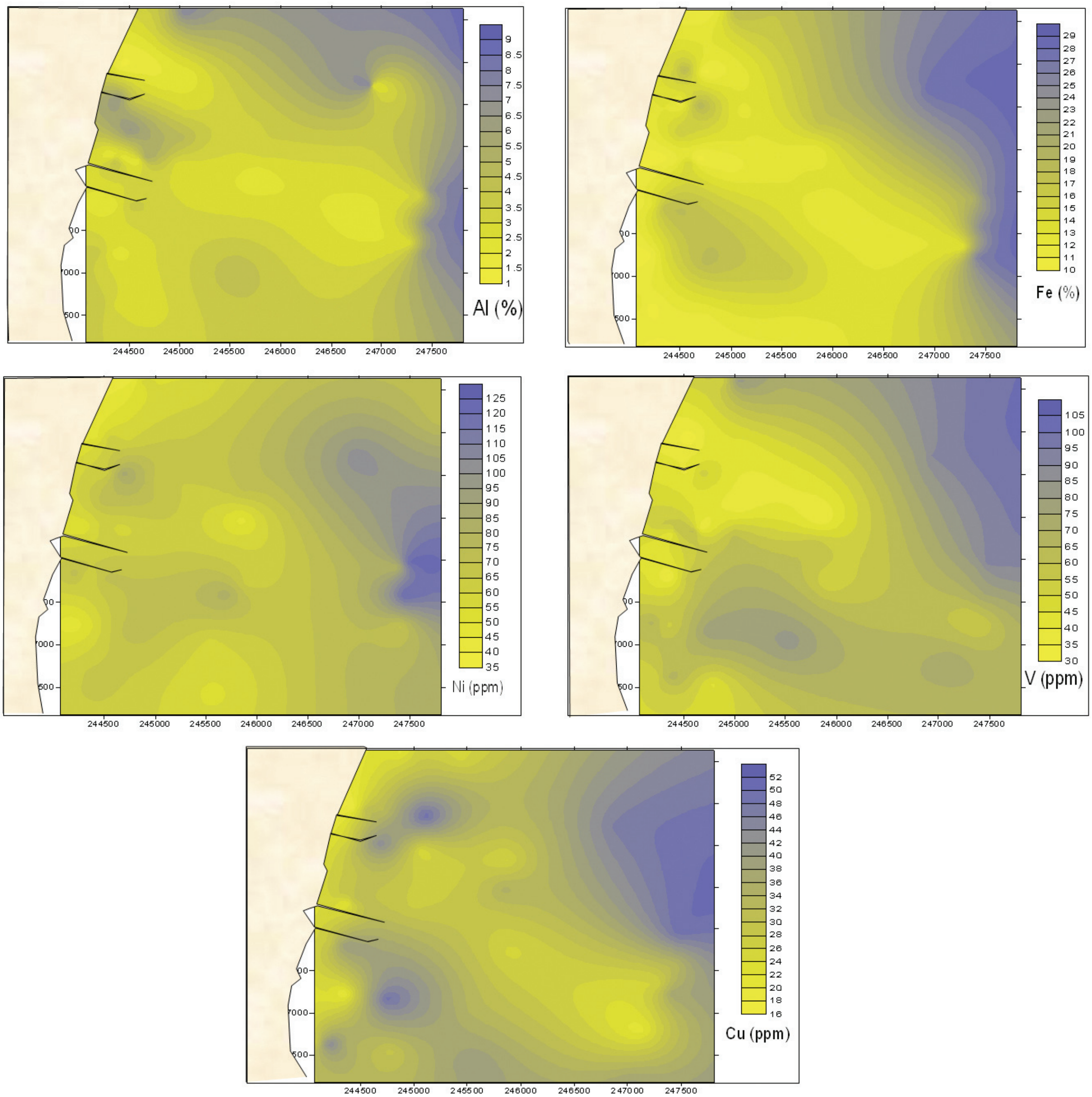

Fig.4. Distribution of heavy metals in the sediments (mg/l)) at Az-Zour Area.

Table 2. Comparison between the levels of heavy metals in the sediments of Az-Zour area with areas within the Arabian Gulf (1 = El-Sammak *et al*, 2004; 2 = Salmons and Förstner, 1984; 3 = Anderlini, *et al*, 1986, 4, 5, 6, 7 = Basaham and Lihaibi, 1993; 8 = Fowler, *et al*, 1993).

	Cu(ppm)	Ni(ppm)	V (ppm)	Fe(%)
1. Background value				
Limestone	5.1	7.0	45	1.7
Shallow Water sediments	56	35	145	6.5
2. Kuwait Territorial waters				
Range	13.0-1.0	17.0-3.0	30-6.0	0.65 - 0.14
Avg ±Sd.DV	5.56 ± 4.5	8.9±5.33	15.4 ± 8.88	0.36 ±0.2
3. Kuwait (1986)				
Range	30-15	120-86	50-30	20-12
Average	22.5	103	40	16
4.Kuwait (1993)				
Range	50-34	209-150	134-85	28-12
Average	42	179.5	109.5	20
5.Saudi Arabia				
Range	6-3	28-8		11-3.4
Average	4.5	18	19	7.2
6. NE Qatar				
Range	36-2.7	6.7-4.9	3.6-2.7	0.007- 0.004
Average	3.2	5.8	3.2	
7. Qatar/ Bahrain				
Range	4 - 3.8	12.8 - 0.2	7.4-2.7	0.01- 0.006
Average	3.9	6.5	4.6	0.008
8. UAE				
Range	7-13	25-12.8	36-7.3	6 -3.6
Average	4.2	18.9	20.7	4.8
9. Present study (Az-Zour)				
Range	18.35 – 49.6	42.2 – 121.5	31.09 – 106.9	1.02 – 2.81
Average	32.6	69.1	58.68	1.6

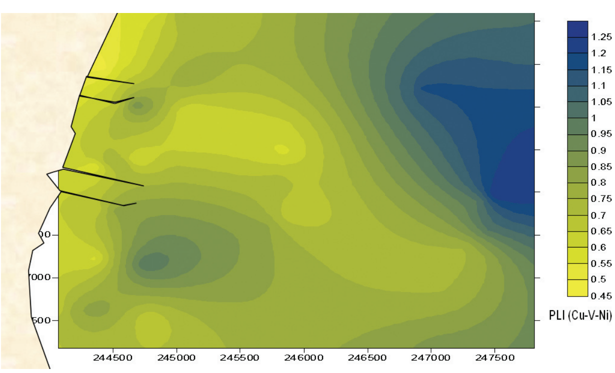

Fig.5. Distribution of Pollution Load Index in the sediment of Az-Zour Area.

Meiofauna and macrofauna distribution and diversity:

Fig 6, represents the meiofaunal groups at different transects (2-7). At transect 2, nematodes showed its highest percentage at 1600m (31.6%), polychaetes showed the maximum percentage at 3200 m (18.0%). The maximum percentage for ostracodes was 29.0% at 400 m and was 48.0% for harpacticoidae at both 400 and 800 m. At transect 3, the nematodes showed its highest percentage at 800 (52.5%), while polychaetes showed maximum percentage at 400 (15.8%). Ostracodes and harpacticoidae showed their

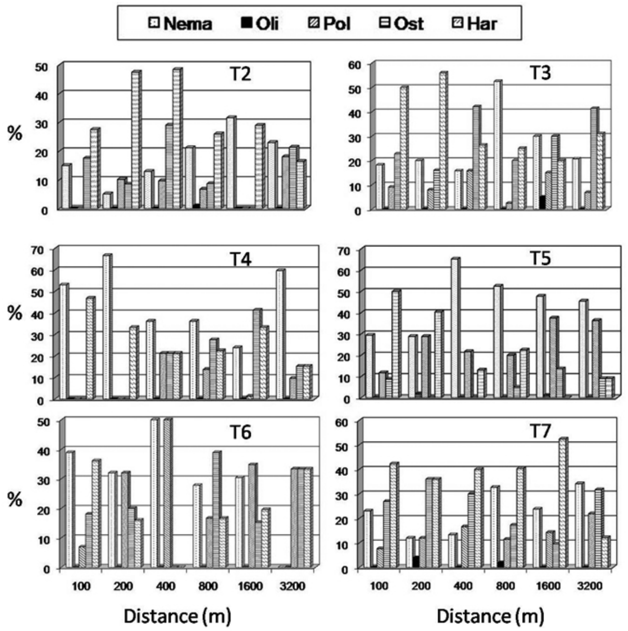

Fig.6. Distribution of heavy metals in the sediments (mg/l)) at Az-Zour Area.

maximum percentage at 400 m (42.1%) and at 200 m (56.0%) respectively. The maximum percentage of nematodes was 66.7% at 200 for transect 4. The polychaetes showed its maximum percentage at 400 (21.3%) (Fig. 6).

The maximum percentage for ostracodes was recorded at 1600 m (41.3%), while harpacticoidae showed it maximum percentage at 100 (46.9%). At transect 5, the maximum percentage of nematodes was recorded at 400 m (65.2%) and was 37.5% at 1600 m for polychaetes. The ostracodes and harpacticoides showed their maximum percentage at 1600 m (13.6%) and at 100 (50.0%) respectively. The maximum percentage of both nematodes and polychaetes at transect 6 was recorded at 400 m (50.0 % for each) (Fig. 6).

The maximum percentage of ostracodes and harpacticoides were recorded at 800 (38.9 %) and 100 (36.1%) respectively. The maximum percentage of both nematodes and polychaetes at transect 7 was recorded at 3200 m (34.1 % and 22.0%) respectively. The maximum percentage of ostracodes and harpacticoides were recorded at 200 (36.0 %) and 1600 (52.4%) respectively, (Fig. 6).

The mieofaunal groups showed the highest abundance in the middle zone, between 800m and 1600 m and also showed the highest species diversity in the inshore and the offshore zones of the study area. This could be most probably related to sediment characteristics such as sediment-grain size and total organic carbon as well as water temperature that could enable meiofaunal enrichment for the middle zone (Al-Abdul Razzaq *et al*., 1982). From the distribution of TOC (Figure 3), it could be clearly demonstrated that it is correlated with the distribution of the both the abundance and the species diversity of meiofaunal and macrofaunal groups, where high values were recorded in the middle and offshore areas.

The species richness, and the species diversity index of meiofaunal groups at different transects are given in table (3). The spatial distribution of meiofauna density and diversity in the study area are presented in Fig (7). 25 species were recorded for the meiofauna groups at different transects comprising 36 stations, ranging between 4 species to 14 species. In General, polychaete worms, nematodes, and crustaceans dominated the samples with other groups forming only a minor part. The species diversity for different transects showed maximum values at transects 2, 4 and 5 ranging between 12 and 14. (Juvenile gastropods and juvenile bivalves were not included).

The average maximum species diversity was recorded at 800 m (10.7) and the average minimum was recorded at 100 m (8.0). The number of individuals per sample volume showed its maximum value at transect 4 (1600 m from the shore) and its minimum value at transect 6 (3200 m). The average maximum abundance per sample was recorded at 1600 m (56 individuals per sample) and the average minimum was 29.5 individuals per sample at 400 m (Table 3 and Fig. 7).

The maximum abundance for meiofaunal groups (number of individuals per m^2) was recorded at transect 4 (662,400/m2) at 1600 m and the minimum value was recorded at transect 6 (14,400/m2) at 3200 m. The average maximum abundance per m^2 was recorded at 1600 m (272,133 individual /m^2) and the average minimal value was recorded at 400 m (141,600 individuals /m^2) (Fig. 7)

The meiofauna species richness showed more or less similar values at different transects. Transects 5, 6 and 7 showed the highest species

Table 3. The Species richness and diversity indices of meiofauna at different transects at Az-Zour area.

	Transect/ Distance (m)	100	200	400	800	1600	3200
Species richness	/T2	1.89	2.14	2.04	2.86	0.96	3.10
	T3	2.59	2.49	2.04	1.90	2.67	2.67
	T4	1.44	1.48	3.12	2.71	2.03	2.11
	T5	1.99	3.29	2.87	2.71	2.90	2.50
	T6	2.10	3.11	2.16	2.08	2.87	1.82
	T7	2.15	3.11	2.65	3.04	2.30	2.96
Diversity Index	/ T2	1.80	1.66	1.20	2.00	1.41	1.93
	T3	1.58	1.89	1.93	1.78	2.16	1.89
	T4	1.55	1.35	1.99	1.99	1.42	1.78
	T5	1.17	1.17	0.88	1.69	1.61	1.17
	T6	1.47	1.35	0.92	1.28	1.63	1.11
	T7	1.80	1.91	1.65	1.81	1.90	1.52

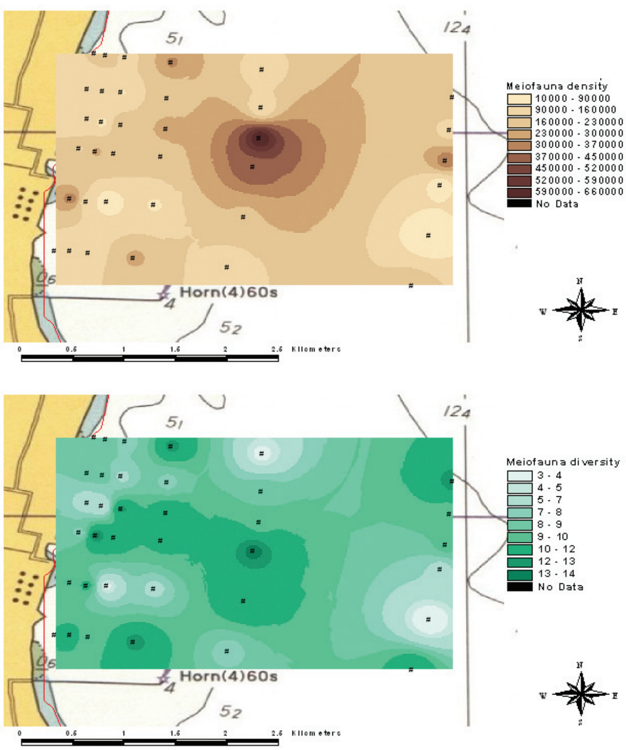

Fig.7. The distribution of species diversity and abundance of meiofauna at Az-Zour area, south of Kuwait.

richness values, while the lowest value was at 1600 m of transect 1 (table 3). The species diversity index showed the same trend as that of the species richness. The lowest values of the species diversity index were recorded at transect 5 and transect 6 at 400 m (table 3). The diversity index was much elaborated at transects 1, 2, 3 and 7 (table 3).

The macrofaunal groups are represented as percentages (Fig. 8). At transect 2, polychaetes showed the highest percentage at - 400m (55.6%) and 800 m (56.0%) respectively. Oligochaeta and other groups showed their maximum percentage at 200 m (13.3%) and at 400 m (15.8%). The maximum percentage for ostracodes was 30.0% at 1600 m. The bivalves and the gastropods were represented by maximum percentages of 59.1% at 1600 m and 50.0% at 100 m, respectively. At transect 3, the polychaetes showed its highest percentage at both 1600 and 3200 m (27.8% and 28.0% respectively, while other groups and ostracodes showed their maximum percentage at 1600 (27.8% and 30% respectively). Bivalves and gastropods showed their maximum percentage at 400 m (56.3%) and at 100 m (75.0%) respectively, (Fig. 8).

The maximum percentage of polychaetes was 42.9% at 1600 for transect 4. The other groups showed its maximum percentage at 400 (21.3%). The maximum percentage for ostracodes and harpacticoidae was recorded at 1600 m (30.0% and 20.0 %, respectively), while showed it maximum percentage at 400m (57.1% for bivalves) and 100 m for gastropods (50.0%). At transect 5, the maximum percentage of polychaetes was recorded at 100 m (63.6%) and was 15.8% at 400 m for other groups. The ostracodes and harpacticoides showed their maximum percentage at 1600 m (30.0% and 20.0% respectively). Bivalves and gastropods showed their maximum percentage at 800 m (50.0%) and at 1600 m (34.1%) respectively, (Fig. 8).

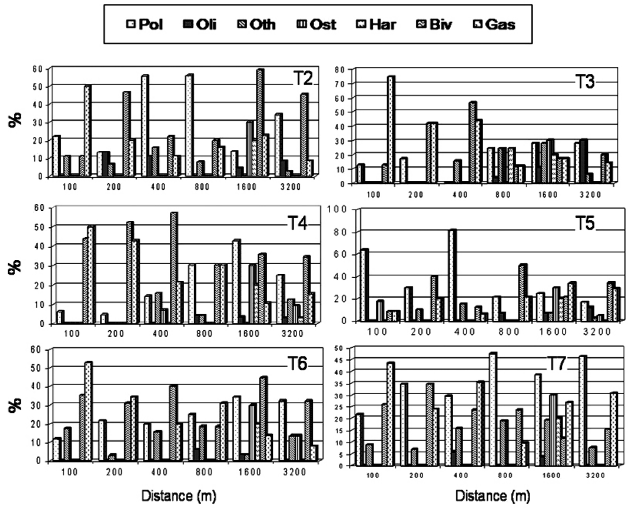

Fig.8. Distribution of different macrofaunal groups at different transects.

The maximum percentage of both polychaetes and other groups at transect 6 was recorded at 1600 m (34.5%) and at 800 m (18.8m), respectively. The maximum percentage of ostracodes and harpacticoides were recorded at 1600 (30.0% and 20 % respectively). Bivalves and gastropods showed their maximum percentage at 1600 m (44.8%) and at 100 m (52.9%) respectively. The maximum percentage of both polychaetes and other groups at transect 7 was recorded at 800 m (47.6 % and 19.0% respectively. The maximum percentage of ostracodes and harpacticoides were recorded at 1600 (30.0 % and 20.0% respectively). The maximum percentage of bivalves was recorded at 200m (34.5%) and at 100 m for gastropods (43.5%), (Fig. 8).

Table (4) shows species richness and species diversity indices of macrofauna groups at different transects. The maximum species richness was recorded at transect 4 and transect 7 (4.47 at 800 m and 4.46 at 200 m respectively). Thirty-one species were recorded for the macrofauna groups at different transects comprising 36 stations ranging between 6 species and 17 species. The Macrofauna Annelida group dominated the samples with 14 species followed by Mollusca (11 species), followed by crustaceans (5 species) and Echinodermata was represented with one species and was considered very rare.

Fig. (9) illustrates the spatial distribution of the macrofaunal species diversity. The average maximum species diversity was recorded at

Table 4. The Species richness and diversity indices of macrofauna at different transects at Az-Zour area.

	Transect/ Distance (m)	100	200	400	800	1600	3200
Species richness	T2	3.46	2.59	3.64	4.04	2.59	3.66
	T3	2.16	2.42	2.89	3.42	3.46	4.09
	T4	2.53	2.96	2.65	4.47	3.91	3.46
	T5	2.09	3.47	2.53	3.79	3.50	4.31
	T6	3.53	4.04	3.04	4.33	3.56	3.60
	T7	3.19	4.46	2.47	2.3	3.99	3.68
Diversity Index	T2	1.17	1.4	1.14	1.14	1.06	1.25
	T3	0.74	1.04	0.68	1.65	1.56	1.49
	T4	0.88	0.85	1.12	1.16	1.09	1.38
	T5	0.82	1.28	0.48	1.20	1.56	1.52
	T6	1.30	1.17	1.33	1.50	1.23	1.48
	T7	1.26	1.28	1.42	1.23	1.42	1.22

3200m (14.7) and the average minimum was recorded at 400 m (8.3). The number of individuals per sample volume showed its maximum value at transects 2 and 4 (50 and 41 individuals per sample respectively at 3200 m) and its minimum value was recorded at transect 1 (9 individuals per sample at 400 m). The average maximum abundance per sample was recorded at 3200 m (36.8 individuals per sample) and the average minimum was 13.7 individuals per sample at 400 m.

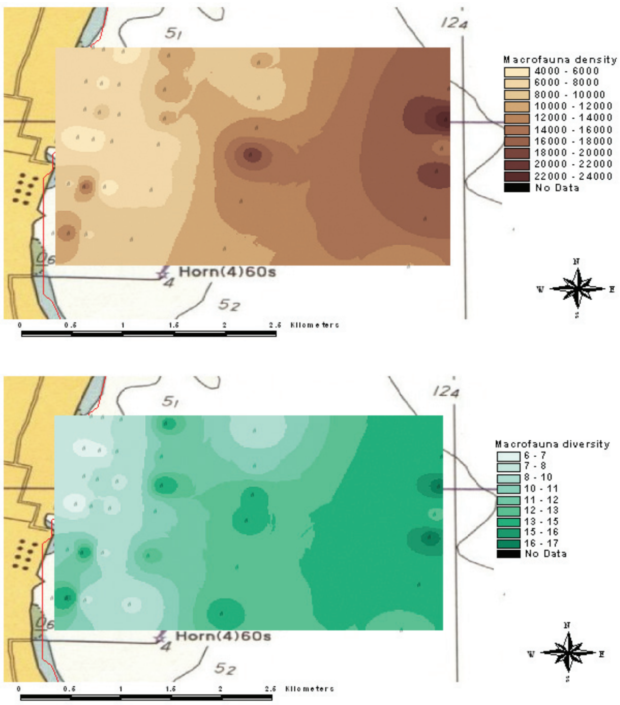

Fig.9. Tistribution of species diversity and abundances of macrofauna at Az-Zour area, south of Kuwait.

The maximum abundance for meiofaunal groups (number of individuals per m^2) was recorded at transect 2 (240,000/m2) at 3200 m and the minimum value was recorded at transect 1 (43,200/m2) at 400 m (Fig, 8). The average maximum abundance per m^2 was recorded at 3200 m (individual /176,800m^2) and the average minimal value was recorded at 400 m (65,600 individuals /m^2) (Fig. 9).

The species richness was much demonstrated at the 3200 m for all transects (table 4). The species diversity index of macrofauna showed that the stations at the 100 m to the 300 m had the lowest diversity; while on the other hand, the highest values of species diversity index were recorded at the deepest stations between 800m and 3200m. This result could be related to the present status of the coastal area relative to the outflow of the already existing power plant. The overall picture shows that coastal stations near the shore are under the impact of the outflow of the power plant. This is most probably related to different species indices and evenness values recorded among stations and among different transects.

In general, the meio and macrofaunal diversities and abundances are of the same trends, with few exceptions (Figs, 7 & 9 respectively). Trends are apparent from the samples with some stations showing high biodiversity and abundance. In contrast, low biodiversity in meiofauna correlates with highest abundances. The meiofauna showed low species diversity and high abundances of individual species. In macrofaunal groups, Annelida dominated the samples, followed by Mollusca and followed by crustaceans where Echinodermata was very rare.

The abundance values recorded during the present study showed similarities with some of the literature of the Indian Ocean, where meiofaunal abundances from subtidal sand showed values from 36,100 to 229,500 and for muddy sediments from 14,200 to 125,000/m^2 (McCain, 1984). The present values recorded for species diversity are in good comparison with the previous work done for the south Kuwait survey, where the species diversity recorded was between 5 to 24 species that were examined in 35 stations (El-Sammak *et al*, 2004).

STATISTICAL DISCRIMINATION OF THE RESULTS

In order to correlate the distribution of meio- and macro-fauna with different environmental factors, simple correlation matrix was conducted. Fig (10) graphically represents the significant correlated variables. It is obvious that TOC correlates negatively with the diversity and evenness of the meiofauna. Depth controls the meiofaual distribution negatively. On the other hand, DO correlates positively with the macrofaunal diversity.

It is important to mention that water temperature is considered one of the main factors

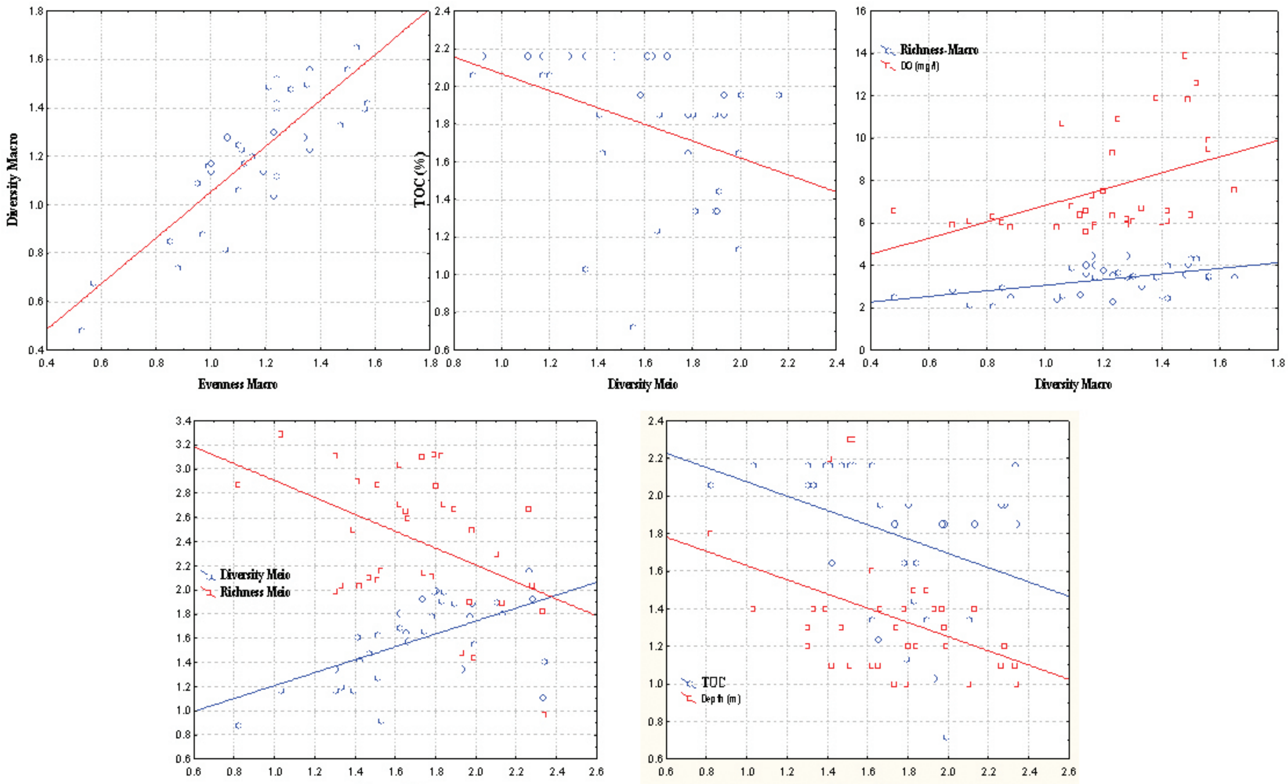

Fig.10. Correlations between significant variables.

that are possibly controlling the migration of a particular taxonomic group or groups of organisms up and down the beach to different depths within the sediment depending mostly on time of the day (Al Bakri and Kittaneh1998).

Factor analysis was used to confirm the statistical discrimination results of the bivariant plot. Factor analysis aims to explain observed relations among numerous variables in term of simpler relations. The simplification may consist of producing a set of classificatory categories, or creating a smaller number of hypothetical variables. The main applications of factor analytic techniques are: (1) to reduce the number of variables and (2) to detect structure in the relationships between variables, that is to classify variables. Therefore, factor analytic is applied as a data reduction or (exploratory) structure detection method (Davis, 1986).

R-mode factor analysis was performed from a data matrix comprises of 16 variables (Meio- and macro- benthos richness, and diversity, TOC, DO, S‰, Temperature, pH and metal concentrations). Factor 1, explains 27.1% of the total variations, while factor 2 and 3 explain 17.02% and 13.61% of the total variance among the variables. The bi-variant plots of the factors' loading (Fig, 11) indicate that TOC and DO are the main variables affecting the diversity and richness of the macrofauna. On the other hand sediment grain size and salinity are the main variables affecting meiofauna diversity and richness. The heavy metals contents have no impacts on the infaunal communities in the study area. Depth control the macro- and meio-fauna in more or less similar influence. Water temperature and pH have more impacts on the meiofauna than on the macrofauna.

Cluster analysis (complete linkage, 1-Pearson r) was also performed using the same data matrix. Cluster analysis was performed in order to verify the results obtained from the other statistical analyses. The resultant dendgram (Fig 12) confirms the results obtained using factor analysis and bi-variant plots. Three clusters can be observed. Cluster 1, includes heavy metals. This cluster shows a low similarity level with the other two clusters. This may inferred the weak influence of metal pollution on the distribution of infaunal species. Cluster 2, discriminates

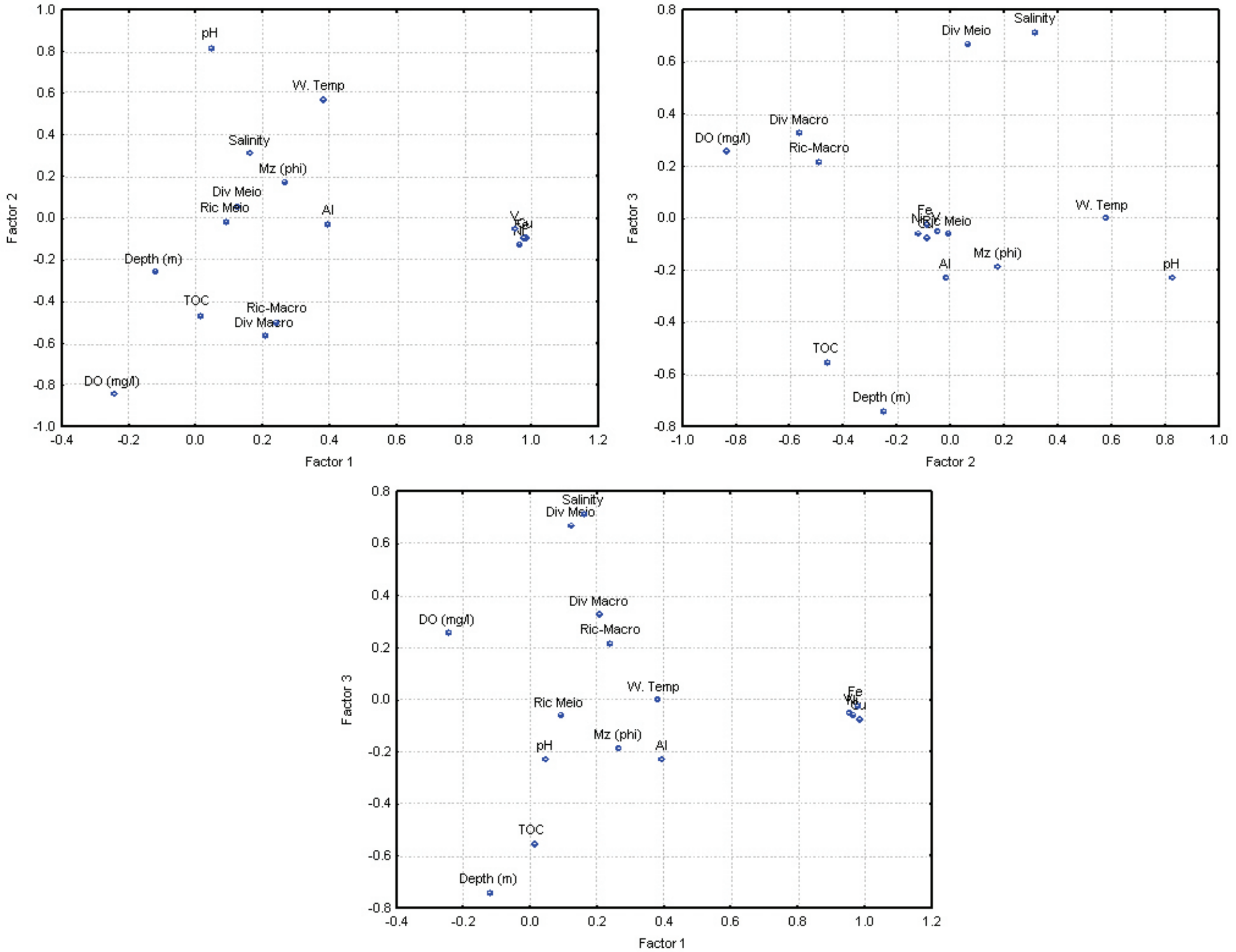

Fig.11. Sactter plots of the factor's loading.

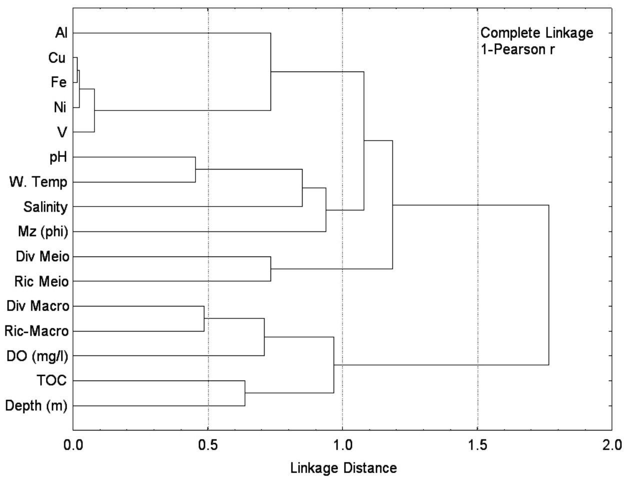

Fig.11. Dendrogram showing the statistical relation between variables.

the meiofauna species. It is clear that water parameters (pH, temperature and salinity) control the distribution of meiofauna in term of diversity and richness. On the hand, cluster 3, separates the macro-faunal diversity and richness with the controlling factors. The main controlling factors are sediments grain size, organic matter contents in the sediments, depth and dissolved oxygen.

CONCLUSIONS

The meiofauna of the study area were grouped into three main groups, the active borrowers including most of the worms and feeding on beach materials where they digest the organic portion and discharge the rest unchanged. The scrapers, including many small crustaceans (copepoda and ostracoda) and feeding on small organic particles by scraping the surface of sand grains, and the filter feeders. These include bivalve mollusks as they digest food from small organic particles (detritus and plankton) through filtration. The present preservation and staining techniques were chosen in an attempt to find a rapid method for storage, extraction and enumeration.

Generally, the meiofauna showed low species diversity and high abundances of individual species. In macrofaunal groups, Annelida dominated the samples, followed by Mollusca, followed by crustaceans and Echinodermata was very rare. The meiofauna and macrofauna communities showed similarities between different stations and among different transects. According to Bu-Olayan and Thomas (2005), low diversity indices correspondingly related to the increase in trace metals level in benthic species collected from four sites in Kuwait Bay.

Along the northern area of the Arabian Gulf off Saudi Arabia, the estimated density of the infauna in the sandy beaches exceeded 400,000 individuals/m^2 (McCain, 1984). During the present work, the maximum total average was recorded at 1600 m (350,000 individual/m^2). This number is relatively high compared to the above estimated densities of the infaunal groups along the northern area of the Arabian Gulf off Saudi Arabia. This implies the presence of healthy environment.

The evaluation of different parameters revealed correlation with meiofaunal and macrofaunal groups in different stations where the surface distribution of Pollution Load Index indicated that the offshore area exhibited the highest PLI, while the inshore area was considered to have the lowest PLI. However in general, PLI values were considered as low values where Cu, Ni and V did not have elevated values in the marine sediments of Az-Zour area.

Heavy metal concentrations showed slight effects on the distribution of different infaunal groups (Meio- and Macro-benthos) with trivial effects towards the meiofaunal distribution and abundance.

In general the distribution and abundance of meiofauna are controlled by water parameters such as salinity, temperature and pH, on the other hand, the sediments characteristics (grain size, TOC) control the macrofaunal species diversity, abundance and distribution. Depth controls mainly the macrofaunal distribution with less effect on the meiofauna distribution.

Mainly, this study provides meaningful information on the distribution of meio- and macro-fauna in the area. The results showed that this type of investigation is important as it provides background information for future assessment studies.

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