Effect of the Environmental Parameters on the Distribution of Foraminifera in the Coastal Area of Ras Al Khaimah, U.A.E.

Naama Obaid Saif Al-Kaabi

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EFFECT OF THE ENVIRONMENTAL PARAMETERS ON THE DISTRIBUTION OF FORAMINIFERA IN THE COASTAL AREA OF RAS AL KHAIMAH, U.A.E.

Thesis submitted for the degree of M. Sc. in Environmental Science

By

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1999
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United Arab Emirates University 1999
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ABSTRACT

Twenty samples of sea water and twenty samples of sediment were collected from the off shore area of Ras Al-Khaimah to find out the relationships between environmental parameters, abundance of foraminifera, and ratio of living to dead foraminifera.

Analysis of sea water for the environmental parameters includes, temperature, salinity and nutrient salts (nitrate, nitrite, silicate, phosphate and amonia). Organic matter, and total carbonate were measured in the bottom sediments. Grain size analysis of the bottom sediments was done using sieving method. The foraminiferal species were picked, counted and photographed using the SEM. The ratio of dead to living forams was calculated. Rose Bengal dys was used to differentiate between dead and living foraminiferal tests.

The maximum grain size value was found at station 20, while the minimum was at station 4. The average grain size is 1.24 φ. Relationships were observed between mean size and the other parameters. The standard deviation (sorting) ranged between moderately sorted to poorly sorted. Skewness ranges between 0.22 and -0.46.

Complete linkage cluster analysis shows that the study area can be clustered into three groups. Group I includes stations numbers 20, 13, 5, 14, 11 and 3, group II contains stations numbers 7, 4, 16, 17, 18, 12 and 2, while group III contains stations numbers 15, 19, 9, 8 and 6. Grain size parameters indicates no indication about the similarities or dissimilarities between different stations.

The highest water temperature was recorded at station 20 (27.4°C) salinity ranges between 34.95 and 35.86.

For the organic matter station 7 shows the maximum content of organic matter, while station 17 has the minimum. For the nutrient salts, station 9 shows the maximum value for PO4 while station 4 has the lowest. For SiO3, station 1 presents the maximum value. On the other hand station 14 presents the lowest value in SiO3. Station 2 shows the lowest value for NO3 while stations 16 and 17 have the maximum values. The maximum value of NO2 is found at stations 11 while the minimum value is found at station number 7 and 20.

The high phosphate concentrations that have been recorded is a response to the decay of phytoplankton and excretion of considerable amounts of phosphate by aquatic organisms. On the other hand, the decrease in phosphate concentrations can be related to the decrease in the internal influx of phosphate, with an increase in consumption by phytoplankton. The high silicate values that have been found in the extreme east and off the Al-Khor opening is probably due to increase of the dissolution rate of diatom frustules and their fragments in the bottom sediments. The low values for nitrite may be attributed to the increase of nitrite oxidation to nitrate and its reduction to ammonia.

Station 8 shows the maximum foraminiferal individuals (391 individuals) while the minimum number (25 individuals) is found at station 2.

The must common foraminifera are the agglutinated forams, porcellaneous forams are the second in abundance; while the hyaline shells are less common.
The maximum number of dead foraminiferal individuals is 277 (station 13), while the minimum number is 5 individuals (station 2).

*Peneropolis* plantus, *Quinqueloculina neastrictula*, *Quinqueloculina cooki*, *Triloculina* sp., *Ammonia beccarii*, *Elphidium crispum* and *Texularia* sp. are the main foraminifera assemblages found in the study area. Other *Milliolina*, *Textularina* and Rotallina also occur.

The differences in the percentage of living foraminiferal tests may be a response to the nature of the bottom with the low values occurring in areas covered with seagrasses and halophytes. On the other hand, high percentages of living forams occur where algae, seagrasses and other plants disappear. Another possibility may be caused by the short lifespan of the benthic foraminifera. Another possible reason is the fact that some dead foraminiferal tests may be either recent deceased where the red color may be caused by the effect of Rose Bengal on the protoplasm.

Temperature and salinity have little influence on the distribution of the foraminiferal tests. Except for silicate, no relationship can be noticed. With the decreasing of the silicate, both living and total foraminiferal species slightly decrease.

Most of the foraminiferal assemblages fall within the normal marine to hypersaline marine marshes.

During the present study, some stations contain high percentages of blackened foraminifera that could be attributed to the decomposition of organic matter as well as to the effect of pollution. It also may be due the reducing conditions beneath the sediment surface.
Chapter 1
INTRODUCTION

The coastal area of UAE is now under forceful stress. This is due to the rapid expansion and the wide variations in coastal related activities (e.g. industries, oil and gas exploration, tourist activities, communications and harbors, etc.) during the last decade. This rapid expansion certainly has effected the coastal environments. The composition of living communities of the coastal area will generally be affected by this environmental stress. Foraminifera, which are considered the one of the most important of fossils, are generally controlled by a series of environmental parameters that include salinity, temperature, dissolved oxygen, nutrient salts and pH. Consequently foraminiferal assemblages will also be affected by variations in the environmental conditions. The relative abundance of the living foraminiferal tests to the non-living ones is a function of the environmental stress.

Foraminifera are unicellular organisms (Figure 1) belonging to the Rhizopod Protozoa (Protista). Their protoplasm is differentiated into endoplasm and ectoplasm, and is emitted in the form of retractile pseudopodia, which are granula, anastomosing filaments. These are used in catching prey, in locomotion and in the creation of the skeleton (Bignot, 1982).

The feature that distinguishes foraminifera is the possession of a mineralized, intra-ectoplasmic skeleton or test formed from chambers that are interconnected by openings or foramina. The interior of the test is lined with a
Figure 1: The morphology of the foraminiferal test (after Brasier, 1980)
basal organic ‘chitinoid’ layer. This description should not prejudge its chemical nature which, though close to chitin, remains unknown (Kennett, 1982).

The foraminifera (Class, Sarcodina; Order, Foraminiferida) are an extremely diverse group of marine, shell-bearing protozoans with several benthonic families and few planktonic families. They normally range in size from 50 to 400 μm, but they may grow larger. Although the benthonic forms are taxonomically more diverse than planktonic forms, there are fewer individuals per species. The tests of foraminifera are constructed of calcium carbonate except in one major suborder (Textularinae) of benthonic foraminifera, which construct their tests of cemented grains of sand and; in one small group; aragonite.

Foraminifera are considered marine. The benthonic foraminifera live at or near the sediment-water interface. Most are mobile, while sessile forms may be attached temporarily by pseudopodia or permanently by cementation. Benthonic foraminifera are easily differentiated from planktonic foraminifera in deep-sea sediments by differences in shape and wall-surface texture. The benthonic foraminifera occur in brackish to normal marine habitats and live at all depths. They are found at all latitudes, although the biogeographic provinciality is, in part, latitudinally determined and highest diversities are found in tropical areas. The diversity gradient between polar and tropical regions can be complicated by local environmental variations. Antarctic faunas
are much more diverse than Arctic faunas and similarities between polar faunas are small, particularly at the species level (Kennett, 1982).

The ecology of foraminifera is restricted to warm, clear, shallow water. They are confined to the tropics largely within the 25°C surface-water (Haynes, 1981).

1.1. Previous study:

Previous studies dealing with benthic foraminifera, recent sedimentation and environmental parameters along the coast of U.A.E. and nearby were dated back to almost 35 years ago. Murray (1965) studied the foraminifera assemblage in the Arabian Gulf and in the U.A.E. He gave almost full information about the foraminifera in the U.A.E., starting with the Arabian Gulf, Abu-Dhabi, and Khor Al Bazam. In 1966 the same author presented a series of paper on the foraminiferal assemblage of the Arabian Gulf, Halat Al Bahrani, and the shelf off the Trucial Coast (Murray, 1966, a, b and c). Murray (1970) published his last research paper on the foraminifera of the hypersaline lagoon, Abu Dhabi. Purser (1973) studied the Holocene carbonate sedimentation and diagenesis in a shallow epicontinental sea of the Arabian Gulf. He discussed the environmental parameters that seem to influence the nature of the Arabian Gulf. He also offered some information on the living foraminifera in the Arabian Gulf and around the U.A.E. Wefer, et al., (1981) studied the composition of the stable isotopes in recent larger benthic foraminifera from Bermuda, the Arabian Gulf, and the Philippines. Bahafzallah
and El-Askary (1981) studied the types of foraminifera that can be found in Saudi Arabia, where they showed the exestation of Miliolina, Rotalina, and Textularia sp. Post-Nappes, early Tertiary foraminiferal paleoecology of the northern Hafit area, south of Al-Ain City (United Arab Emirates) was achieved by Cherif, et al., (1992). They presented a good information about the small benthic and planktic foraminiferal fauna. They studied the vertical variations in its constitution in two sections. They recognized four bathymetrically significant groups of foraminiferal assemblages. Hamdan and Bahr (1992) studied also the lithostratigraphy of the Paleogene succession of northern Jabal Hafit, in Al-Ain area. Juma (1995) did a recent study on Dibba and Kalba in the eastern coast of the United Arab Emirates. She studied the heavy minerals and metals content of the coastal sediments. Hassan, et al. (1995) performed a study on systematic evaluation of selected nutrients, heavy metals and microbial pollution along the east coast of the U.A.E. Massoud, et al., (1996) studied the trace metal contents as indicators of pollution and implications for the effect and fate of the Kuwait oil slick. A recent study on the Arabian Gulf was done in 1996 by Massoud, et al. on TPH and TOC contents as indicators of oil pollution and implications for the effect and fate of the Kuwait oil slick.

Abou Ouf (1992) studied the benthic foraminifera in carbonate facies of a coastal sabkha, Red Sea, Saudi Arabia. He subdivided the foraminifera that he found into three groups according to the wall composition of their tests and these groups are porcellaneous foraminifera (70-98%), represented by five
genera, hyaline foraminifera (3-30%), including two genera, and agglutinated foraminifera (1-2%), comprising only one genus.

1.2. Aim of the present study:

The present study aims to find out the relationships between environmental parameters from one hand and the abundance of Foraminifera, ratio of living to dead foraminifera, and the diversity of foraminiferal tests in the coastal area of Ras Al-Kheima region from the other hand. It is expected that this research will give an idea about the state of the marine environment from the pollution point of view. It also will throw light on the relation of the distribution of different foraminiferal species and the environmental stress.

1.3. Area of study:

Ras Al Khaimah region is considered as a coastal marine environment, characterized by lagoons with coastal sabkhas extending inland for several kilometers along the coastline. In the same time, it represents a desert environment, since it is located near the Oman Mountains where sand dunes and ancient fluvial fan interact (Nasr & Yehia, 1993). These mountains rise between 400 and 1000 meters above sea level and exhibit folded structural forms of parallel ridges of high tilted beds. Due to differential erosion, resistant beds (caused by tectonic compression) stand out and lead to narrowing of wadis, while in some localities led to the development of interment basins. The
base of some of the mountain ridges exhibits wave-cut platforms, which
developed during the last post-glacial sea, rise (Nasr & Yehia, 1993).

Ras Al Khaimah is a part of The United Arab Emirates, which has the
same features in many different places. Most of the U. A. E. geological features
came from the geological features of Oman because it shares Oman in many
mountains and places. Also they share the same seawater of the Arabian Gulf.
According to Purser & Evans (1973) the northeastern region of the U.A.E.
coast consists of beaches backed by coastal dunes composed essentially of
skeletal carbonate sands. In the extreme NE near Sharajah, Umm al Qaiwain,
Hamra and Ras Al-Khaimah, a series of sub-parallel spits have prograded so
the coastline is some 5-10 km to seaward (Figure 2). The evolution of the
extreme NE part of the Trucial coast has been revealed by seven cored holes
drilled across this coastal plain to an average depth of 50 m in the vicinity of
Ras Al-Khaimah (Figure 3). Purser & Evans (1973) mentioned that these wells
passed through a Quaternary sequence ranging from wadi gravels and aeolian
sand at the base, to marine skeletal sands and carbonate muds at the surface.
The marine part of the sequence, approximately 10 m in thickness, is probably
the only part which is of Holocene age. The sequence is essentially a
transgressive one and is most probably the result of a post-glacial rise in sea
level; however, the presence of northerly-tilted terraces on the flanks of the
nearby Oman Mountains suggests that this transgressive sequence could be
related partly to tectonic movement Purser & Evans (1973)
Figure 2: Location map of United Arab Emirates.
**Figure 3:** Coastal morphology and geometry of the principal sediment units, NE extremity of the Trucial Coast (Ras Al Khaimah). (After Purser and Evans, 1973).
The climate of the area is typical of the high arid tropical zone. In such climatic conditions, evaporation (1460 mm/yr.) exceeds total precipitation (100 mm/yr.). The salinity of the shallow coastal water (42-50%) is highly variable and strongly influenced by the weather conditions, particularly winds. Offshore water temperature ranges from 18 to 32°C. The tides are semidiurnal but their heights differ considerably. Tidal and wind-driven currents and waves are locally strong (Abu-Hilal & Khordagui, 1992). The arid, sub-tropical climate has summer temperatures attaining 50°C, and frequent winds, that stimulate the formation of evaporitic minerals and the delivery of aeolian dust to the basin. Fluvial influx is limited to the Tigris-Euphrates-Karun delta and to the mountainous Iranian coast where terrigenous sediments contrast with the relatively pure carbonates forming in the shallow seas in front of the low deserts of Arabia (Purser, 1973).

1.4. Collection of samples:

The selection of the sampling stations was on the basis of a regular grid. Twenty stations were collected from the offshore area in front of Ras Al-Khaimah Harbor (Figure 4). Sediment samples were collected either by grab or by free diving. Water samples were collected from the same station from the surface layer directly in precleaned Polyethylene bottles. Water temperature and salinity were measured in situ. Sediment samples were then stored in clean plastic bags. Water and sediment samples were kept frozen until lab measurements were made.
Figure 4: Area of study showing the sampling stations.
1.5. Methods of analysis:

1.5.1 Foraminifera:

The sediment samples were divided into two parts. The first was kept frozen, while the second part have dried and sieved separately. Each grain size was checked under the microscope to observe the size in which Foraminifera are more common. The 2.0 μ was used, as it contains most of the foraminiferal speacies. Foraminifera were picked under binocular microscope. The picked foraminifera were photographed using a Scanning Electron Microscope (SEM).

The second part of the twenty sediments samples, that has been kept frozen, had been washed several times to get rid of the salt. Rose Bengal were added to that part of the samples to distinguish between the living foraminifera in order to calculate the ratio between the living and the deceased foraminifera. For the preparation of Rose Bengal solution, 20 grams of Rose Bengal powder were dissolved in 1 liter of ethanol alcohol. Samples were soaked in covered beakers with Rose Bengal solution for 2 weeks in order to stain the living foraminifera. The samples were then dried and sieved. Both stained (living) and non-stained (dead) foraminifera were then picked and counted to find the ratio between the living and the dead foraminifera.

1.5.2 Grain size analysis:

A detailed granulometric analysis was done using standard sieving methods. The sieves were arranged at one (φ) interval. 100 grams has been taken from each sample to be sieved. Shaking was done for 15 minutes. The
fractions that were retained on each sieve were weighed and recorded. The
graphical methods proposed by Folk & Ward (1957) were used in calculating
the grain size parameters. Cumulative curves were constructed on arithmetic
probability paper. The Graphical mean (Mz); Inclusive graphical standard
deviation (σI); Inclusive Graphical Skewness (SkI); and Graphic Kurtosis (KG)
were calculated.

1.5.2.1. The graphical mean (Mz):

The graphical mean (Mz) represents the average of size readings. Folk
and Ward (1957) had suggested the following formula be used for calculating
the graphical mean.

\[ Mz(\phi) = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3} \]

\( \phi_{16} \) represent the average of the coarsest third of the sample. The \( \phi_{84} \)
represent the average size of the finest third; while the \( \phi_{50} \) is the average value
of the middle size.

1.5.2.2. Standard deviation (Sorting σ I):

Folk and Ward (1957) proposed the inclusive graphical standard
deviation as a sorting measurement. The degree of sorting of a sample is
essentially a measure of dispersion. The formula for calculating the sorting of
the sediments is

\[ \sigma = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_{5}}{6.6} \]
The result of this formula shows the degree of sorting of the sediments (Table 1).

1.5.2.3. Skewness (SKI):

Skewness is the deviation of the frequency curve from the symmetry of a normal distribution. If the mean and the medium coincide in a symmetrical distribution, the skewness is zero. Folk and Ward (1957) developed a modification for the two formulas of skewness of Inman (1952) and combined them in one formula called the inclusive graphic skewness (SKI).

\[
SK_I = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_{5} + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_{5})}
\]

Folk and Ward (1957) have suggested the numerical limits for describing the symmetry of the curve; where the negative values indicate the coarse grains; while the positive values indicate the fine grains (Table 1).

1.5.2.4. Kurtosis (KG):

The measure of the peakness is expressed as Kurtosis. It is a measurement of relative sorting between the tails and the central part of cumulative frequency curve. It is considered to be valuable test to the normality of the sample distribution. Folk and Ward (1957) suggested the formula to find the Kurtosis as following

\[
KG = \frac{\phi_{95} - \phi_{5}}{2.44(\phi_{75} - \phi_{25})}
\]

The verbal limits suggested by Folk and Ward (1957) are shown in (Table 1).
Table 1: Verbal descriptions of the grain size statistical parameters.

<table>
<thead>
<tr>
<th>SORTING (σ_i)</th>
<th>SKEWNESS (SK_i)</th>
<th>KURTOSIS (KG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.35 μ</td>
<td>-1.0 to -0.3</td>
<td>&lt;0.67</td>
</tr>
<tr>
<td>0.35 - 0.5 μ</td>
<td>-0.3 to -0.1</td>
<td>0.69 - 0.90</td>
</tr>
<tr>
<td>0.5 - 1.0 μ</td>
<td>-0.1 to +0.1</td>
<td>0.90 - 1.11</td>
</tr>
<tr>
<td>1.0 - 2.0 μ</td>
<td>+0.1 to +0.3</td>
<td>1.11 - 1.50</td>
</tr>
<tr>
<td>2.0 - 4.0 μ</td>
<td>+0.3 to +1.0</td>
<td>1.50 - 3.00</td>
</tr>
<tr>
<td>&gt; 4.0 μ</td>
<td></td>
<td>&gt;3.00</td>
</tr>
</tbody>
</table>

1.6. Environmental Parameters:

1.6.1. Nutrient salts:

The amount of the Nutrient salts was analyzed using the method described by Parsons, et al (1985).

1.6.1.1. Nitrate:

Nitrate in seawater is reduced almost quantitatively to nitrite when a sample is run through a column containing cadmium filings coated with metallic cooper. The nitrite produced is determined by diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediamine to form a highly colored azo dye which can be measured spectrophotometrically. Any nitrite initially presented in the sample must be corrected for.
The equipment that has been used in this analysis is a reduction column (Figure 5). 2.0 ml of concentrated ammonium chloride was added to the sample in the Erlenmeyer flask. The solution was mixed and 5 ml was poured onto the top of the column to pass through. The remainder of the sample was added to the column and the drained Erlenmeyer flask was placed under the collection tube. About 40 ml were collected and discarded. The 50 ml were collected in a graduated cylinder and this was dispensed into a Erlenmeyer flask which contained the original sample. The column was allowed to drain before adding the next 5 ml sample. 1.0 ml of sulfanilamide solution was added to the 50 ml sample from an automatic pipette, mixed and allowed to react with the reagent for a period greater than 2 minutes but not exceeding 8 minutes. 1 ml of naphthylethylene diamine solution was added and mixed immediately. Between 10 minutes and 2 hours afterwards, the extinction of the solution in a 1-cm cuvette were measured against distilled water using a wavelength of 543 nm. At last that of the reagent blank corrected the observed extinction and nitrate was calculated from the expression:

\[ \mu g-at N/1 = (\text{corrected extinction} \times F) - 0.95C \]

where C is the concentration of nitrite in the sample in \( \mu g-at N/1 \)

1.6.1.2. Nitrite:

Nitrite in seawater was allowed to react with sulfanilamide in an acid solution. The resulting diazo compound was reacted with N-(1naphthyl)-ethylenediamine and formed a highly colored azo dye.
**Figure 5:** Nitrate reduction column.
The glassware was rinsed with sampled water before using. 50 ml of seawater which was measured from a measuring cylinder into a 125-ml Erlenmeyer flask and analyzed within a few hours and processed immediately.

In the experimental procedure 1.0 ml of sulfanilamide solution was added from an automatic pipette to each 50-ml sample, mixed, and the reagent was allowed to react for more than 2 minutes but less than 10 minutes to assure a complete reaction. 1.0 ml of naphthylethyl-enediamine reagent was added and mixed immediately. Between 10 minutes and 2 hours afterwards, the extinction of the solution in a 10-cm cuvette was measured at a wavelength of 543 nm. The measured extinction for the reagent (and turbidity, if necessary) blank was corrected and calculate the nitrite concentration as:

$$\mu g-at \text{ N/L} = (\text{corrected extinction} \times F)$$

1.6.1.3. Phosphate- Phosphorus:

For the Phosphate determination, the seawater sample was allowed to react with a composite reagent containing molybdic acid, ascorbic acid and trivalent antimony. The resulting complex was reduced to give a blue solution, which was measured at 885 nm.

The samples were warmed to room temperature (15-30°C). The turbidity of a sample was measured at 885 nm; if this value was greater than 0.01, a correction was applied to the final extinction value. To a 100 ml sample, 10 ml of mixed reagent was added using a syringe-type pipette and mixed at once.
After 5 minutes, and preferably within the first 2-3 hours, the extinction in a 10-cm cell was measured against distilled water at 885 nm.

The extinction was corrected with the reagent blank (and turbidity blank where necessary) and the phosphate concentration was calculated as:

\[ \mu\text{g-at P/l} = \text{corrected extinction} \times F \]

where \( F \) is a factor.

1.6.1.4. Silicate:

Silicate was determined in the seawater sample by allowing the sample to react with molybdate under conditions, which result in the formation of silicomolybdate, phosphomolybdate and arsenomolybdate complexes. A reducing solution, containing metol and oxalic acid, was then added which reduced the silicomolybdate complex to give a blue color and simultaneously decomposes any phosphomolybdate or arsenomolybdate. The resulting extinction was measured using a 1- or 10-cm cuvette, depending on concentrations encountered.

In the experimental procedure the samples temperatures were at room temperature (18-25°C). 10 ml of molybdate solution was added to a dry 50-ml graduated cylinder fitted with a glass stopper. 25 ml of the seawater sample were pipetted into the cylinder, stoppered, and mixed by inverting; allowed to stand for 10 minutes, but not for more than 30 minutes. The reducing reagent was added rapidly to make 50 ml and mixed immediately. The solution was allowed to stand for 2-3 hours to complete the reduction. The extinction was
measured at 810 nm using a 1-cm cell for concentrations > 15 μg-at/l and a 10-
cm cell for concentrations of < 15 μg-at/l.

At the end the measured extinction was corrected for the blank (1- or 10-
cm cell length) and reactive silicate was calculated as:

\[ \text{μg-at Si/l} = \text{corrected extinction} \times F \]

where \( F \) is the factor for a 1- or 10-cm cell length.

1.6.1.5. Ammonia:

Ammonia in seawater samples was oxidized to nitrite with hypochlorite in alkali using a large excess of potassium bromide as a catalyst. The precipitation of metal hydroxide in saline water in an alkaline medium was prevented by the addition of a complexing reagent prior to the oxidation step.

In the experimental procedure 50 ml of sample was added to an Erlenmeyer flask from a 50-ml measuring cylinder. 2 ml of complexing reagent was added from a pipette and the solution was swirled. 2 ml of alkaline potassium bromide solution was added from a pipette, the solution was swirled, and the flask was allowed to stand at a temperature of between 35°C and 45°C.

2 ml of 0.05N sodium hypochlorite solution was added, swirled vigorously, and the flask was allowed to stand for 2 minutes at 35-45°C. 2 ml of 1% sodium meta-arsenite solution was added, the solution was swirled, and the flask was allowed to stand at room temperature (20-25°C) for 2 minutes.
2ml of sulfanilamide solution were added and the solution was swirled, and the flask was allowed to stand at room temperature for 2 minutes.

2ml of sulfanilamide solution were added and the solution was swirled. The reagent was allowed to react for a period greater than 2 minutes but not exceeding 8 minutes. 2.0 ml of N-(1-naphthyl)-ethylenediamine solution was added and mixed immediately. Between 10 minutes and 2 hours afterwards, the extinction of the solution in a 1- or 5-cm cell was measured against de-ionized water at a wavelength of 543 nm. The measured extinction was corrected by that of the reagent blank and the ammonium nitrogen concentration was calculated from the expression:

\[ \mu \text{g-at N/l} = F \times \left( E - \frac{0.838 \times c}{F'} \right) \]

where \( E \) is the corrected extinction from which the reagent blank has been subtracted, \( F' \) is the nitrite factor, and \( c \) is the concentration of nitrite in \( \mu \text{g-at/l} \). The numeral 0.838 represents the dilution factor between ammonia and nitrite. \( F \) is the factor obtained.

1.6.2. Organic carbon and organic matter:

The readily oxidixzable organic carbon were determined according to the methods described by Gaudette et al. (1974). This method is a modification for the classic Walkley-Black method. This methods utilizes exothermic heating and oxidation with potassium dichromate and concentrated \( \text{H}_2\text{SO}_4 \), of 0.2 to 0.5 gram of the air-dried sediment, and the titration of the excess dichromate
with 0.5 N ferrous ammonium sulfate solution to a sharp 1 drop end point. The results of the analysis are calculated by the following equation:

$$\% \text{Organic Matter} = 10 \left(1 - \frac{T}{S}\right) \left[1.0N(0.003)\left(\frac{100}{W}\right)\right]$$

Organic matter contents were calculated from Organic carbon where:

$$\text{Organic Matter} = 1.8 \text{ Organic Carbon}.$$  

For each sample the following procedure was followed:

A 0.2 to 0.5 gram dried sediment sample is placed in a 500 Erlenmeyer flask. Exactly 10 ml of 1 N $\text{K}_2\text{Cr}_2\text{O}_7$ solution is added (by burette) to the sediment and the two are mixed by swirling the flask. Twenty ml of concentrated $\text{H}_2\text{SO}_4$ are added (by burette) and are mixed by gentle rotation of the flask for about one minute. This should be done carefully to insure complete mixing of the reagents with the sediment, while avoiding throwing the sediments onto the sides of the flask out of contact with reagents. The mixture is allowed to stand for 30 minutes. A standardization blank without sediment is run with each new batch of samples. After 30 minutes, the solution is diluted to 200 ml volume with distilled water, and 10 ml 80% $\text{H}_3\text{PO}_4$, 0.2 g NaF, and 15 drops of diphenylamine indicator are added to the sample flask. The solution is back titrated with 0.5 N ferrous ammonium sulfate solution. The color progressed from an opaque green-brown, to green upon the addition of approximately 10 ml of ferrous solution. The color continued to shift upon titration to a bluish-black-grey; at this point the addition of a 20–30 drops of ferrous solution
shifted the color to a brilliant green giving a one-drop end point. For precision and accuracy, up to five replicate analyses were carried out on the same sample (3 samples were selected). The standard deviation was less than ± 0.25%.

1.6.3. Inorganic Carbon “Total carbonate”

Determination of total carbonate was performed according to the method described by Molnia, (1974). Standard weight-loss determination method, entailed placing a weighted quantity of sediment containing calcium carbonate in a beaker, adding HCl until the bubbling is complete, filtering the residue in a folded paper filter cone, drying and weighing residue in the folded paper, and finally calculating the percent of the non-carbonate remaining. Molnia (1974) improved this standard method by using a filter disc and 0.47 mm diameter filter paper.
Chapter II
Foraminiferal identification

This chapter includes the identified microfossils including smaller benthonic foraminiferal species. They include eighteen genus and sixty six species as shown in table (2). The classification of Loeblich and Tappan (1988) has been applied. The microfossils were photographed using a Scanning Electron Microscope (SEM). Their systemetic description, occurrence and distribution in the study area have been mentioned and shown in plates from (1-12).
Table (2): Showing the taxonomy of the identified foraminiferal species recognized in the study area.

<table>
<thead>
<tr>
<th>Suborder</th>
<th>Superfamily</th>
<th>Family</th>
<th>Genera and species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textulariina</td>
<td>Textulariacea</td>
<td>Textularidae</td>
<td>Sahulia barkeri</td>
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<td></td>
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<td></td>
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<td>Textularia gramen</td>
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<td>Textularia sp.</td>
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<td>Valvulinidae</td>
<td>Goesella sp.</td>
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<tr>
<td>Miliolina</td>
<td>Miliolacea</td>
<td>Spiroloculinidae</td>
<td>Adelosina cf. honghensis</td>
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<td></td>
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<td>Adelosina crassicarinata</td>
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<td>Adelosina sp.</td>
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<td>Spiroloculina communis</td>
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<td>Hauerinidae</td>
<td>Agglutinella laticollis</td>
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<td>Nummulitidae</td>
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<td></td>
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RESULTS AND DISCUSSION OF ENVIRONMENTAL PARAMETERS

3.1 Grain size statistical parameters: (Table 3)

Figure (6) represents the commutative probability curves for different samples. It is obvious that most of the samples exhibit normal distribution patterns.

3.1.1 Mean Size (Mz):

Table 3 shows the values of the mean size at the different studied stations. 10 samples of which represents 50% the total samples are in the coarse sand range i.e. 0-1ϕ, 9 samples of which represents 45% of the total samples are in the medium sand that ranges between 1-2ϕ, and only one sample is in the range of fine sand i.e. 2-3ϕ, which represents 5% only. The maximum grain size value is found to be 2.87ϕ (station 20), while the minimum grain size i.e. 0.53ϕ is observed at station 4. On the other hand the average grain size is 1.24ϕ ±0.58 (Table 4). No relationships are observed between Mean size (ϕ) and the other measured and calculated parameters.

3.1.2 Inclusive graphic standard deviation (sorting σ_j):

The standard deviation ranges between moderately sorted to poorly sorted. The samples were divided equally into two groups. 10 samples are in the first group, which is moderately sorted, and 10 samples are poorly sorted sediment. The average sorting value calculated for the present study is 1.08ϕ ±0.37 and
### Table 3: Results of grain size analysis.

<table>
<thead>
<tr>
<th>STATION</th>
<th>MEAN SIZE (ϕ)</th>
<th>SORTING (ϕ)</th>
<th>SKEWNESS</th>
<th>KURTOSIS</th>
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<tr>
<td>1</td>
<td>1.06</td>
<td>M.S.</td>
<td>1.31</td>
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<td>2</td>
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<td>C.S.</td>
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<td>M.W.S</td>
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<td>0.61</td>
<td>M.W.S</td>
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<td>2.87</td>
<td>F.S.</td>
<td>0.61</td>
<td>M.W.S</td>
</tr>
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</table>

M.S.: medium sand.  
C.S.: coarse sand.  
F.S.: fine sand.  
P.S.: poorly sorted.  
M.W.S.: moderately well sorted.  
N.S.: negative skewed.  
F.S.: fine skewed.  
V.L.K.: very leptokurtic.  
L.K.: leptokurtic.  
M.K.: mesokurtic.  
P.K.: platykurtic.
Figure 6: Cumulative probability curves for different samples.
Table 4: Maximum, minimum and average ± standard deviation for the grain size statistical parameters as well as the environmental parameters.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± St.Dt.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
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<td>DEPTH</td>
<td>6.05 ± 1.99</td>
<td>4.00</td>
<td>9.00</td>
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<tr>
<td>S%0</td>
<td>35.47 ± 0.33</td>
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<td>35.86</td>
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<td>TEMP.</td>
<td>26.85 ± 0.35</td>
<td>25.80</td>
<td>27.40</td>
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<td>Mz</td>
<td>1.24 ± 0.58</td>
<td>0.53</td>
<td>2.87</td>
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<td>SORTING</td>
<td>1.08 ± 0.37</td>
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<td>SKEWNESS</td>
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</tr>
<tr>
<td>KURTOSIS</td>
<td>1.09 ± 0.22</td>
<td>0.61</td>
<td>1.56</td>
</tr>
<tr>
<td>O.M.</td>
<td>0.20 ± 0.06</td>
<td>0.11</td>
<td>0.32</td>
</tr>
<tr>
<td>PO4</td>
<td>0.5 ± 0.15</td>
<td>0.26</td>
<td>0.92</td>
</tr>
<tr>
<td>SiO3</td>
<td>2.21 ± 1.21</td>
<td>1.30</td>
<td>5.98</td>
</tr>
<tr>
<td>NO2</td>
<td>0.26 ± 0.09</td>
<td>0.07</td>
<td>0.40</td>
</tr>
<tr>
<td>NO3</td>
<td>4.37 ± 0.21</td>
<td>3.95</td>
<td>4.70</td>
</tr>
<tr>
<td>NH4</td>
<td>0.23 ± 0.23</td>
<td>0.02</td>
<td>1.05</td>
</tr>
</tbody>
</table>
the range of $\sigma_1$ is 1.90\(\phi\) and 0.61\(\phi\). No relationship is found between sorting and the other parameters.

### 3.1.3 Inclusive graphic Skewness (SkI):

Skewness varies from station to another. 5 samples (25%) are very negatively skewed, 3 samples are negatively skewed (15%), 7 samples represent 35% from the total samples are nearly symmetrical, and only 5 samples are positively skewed representing 25% of the total samples. The skewness ranges between 0.22 and -0.46 and averaging -0.074 ±0.195.

### 3.1.4 Kurtosis (KG):

Kurtosis which measures the peakedness of the grain size distribution curve, arranges as follows: 1 sample is very platy kurtic that represents 5% of the total samples, 3 samples (15% of the total samples) are platy kurtic, 6 samples (30%) are meso kurtic, 9 samples (45% of the total samples) are lepto kurtic, and only 1 sample is very lepto kurtic, representing 5% of the total samples. The maximum kurtic value is 1.56 and the minimum is 0.61. The average value of the kurtosis is 1.09±0.22.

### 3.1.5. Discussion of the grain size statistical data:

Figure (7) shows the histograms for each station. The histogram provides a quick and easy pictorial method for representing grain size distributions. This is because the approximate average grain size and the sorting, the spread of grain...
Figure 7: Histograms showing the distribution of different grade size at different samples.
size values around the average, can be seen at a glance.

It is obvious from the different histograms that most of the samples have almost a log-normal distribution with the exception of stations 6, 7, 9, 13 and 20. These log-normal distribution patterns may indicate that a normal condition of sedimentation could prevail. However, the histograms have limited applications. In fact the shape of the histogram is affected by the sieve interval used (Boggs, 1995).

Plots of various statistical parameters against each other may also depict trends or clustering of samples that can be used in other ways (Lewis & McConchie, 1994). Sedimentologists for many years had used the scatter-diagrams of grain size parameters to distinguish between different depositional environments. The physical processes assumption in the discrimination of different depositional setting using bivariant plots is that these statistical parameters reflect differences in the transporting and depositing mechanisms of fluid flow (Sutherland & Lee, 1994). Figure (8) shows the relation between sorting of the sediments and the mean grain size. It seems that no relationship can be found between sorting and the size of the sediments. Tucker (1988) found that, there are covariation of mean size and sorting. Griffiths (1967), showed how both mean size and sorting were hydraulically controlled, so that in all environments the best sorted sediments had their mean size in the fine sand category. This energy related universal relationship has been confirmed by many subsequent studies (Tucker, 1988).
Figure 8: Scattered plots, showing the relations between different grain size statistical parameters
The second scattered plot used in the present study is skewness and sorting. Moiola & Weiser (1968) used the scatter plot of sorting and skewness to provide discrimination between river and beach sand. Applying Moiola & Weiser to the present study, except for five sediment samples the rest can be described as river sand (figure 8b). However, Bjorlykke, (1983), draw an approximate fields for sands from different environments, in term of skewness and standard deviation. It seems that the number of beach sediments in the present study increased and some of the river-identified samples are said to be turbidite sediments.

The scatter plot of mean size (φ) versus skewness were also contrived in order to distinguished between the beach and dune sand. According to Tucker (1988) the relatively fine-grained unimodal sediments deposited from many parts of the world yielding similar characteristics: beach sands were well sorted and negatively skewed, whereas river sands were less well sorted and usually positively skewed. Dune sand also had positive skewness but was finer than beach sands. Figure (8c) illustrates that except for one sample (station 20) the rest are characterized as beach sand.

The scatter plot of kurtosis vs. skewness provides that no relationship can be retrieved from these two parameters.

In order to measure the similarities between different stations in term of texture characters, the complete linkage cluster analysis is performed (Figure 9). In this statistical multivariate analysis, a dendrogram is the final output. Dendrograms are an appealing method of displaying relationships between
Figure 9: Tree diagram showing the similarities between different stations based on the grain size statistical data.
multivariate objects. Closest relationships are between objects nearest together (Rock, 1988). It is obvious that stations in the study area are clustered in three groups. Stations numbers 20, 13, 5, 14, 11 and 3 comprise group I. Group II, contains samples numbers 7, 4, 16, 17, 18, 12 and 2. On the other hand, stations 15, 19, 9, 8 and 6 distinguish group III. As a matter of fact, these 3 groups indicate that grain size parameters give no indications about the similarities or dissimilarities in the sediments of the study area.

3.2 Environmental parameters: Table 5

3.2.1 Water Temperature:

The highest water temperature recorded in situ (27.4°C) is found to be at station 20 (Table 5). On the other hand station 1 has the minimum-recorded temperature (i.e. 25.8°C). The average temperature is 26.85°C ± 0.35 (Table 3). According to El-Gindy and Hegazi (1996), the study area lies within a zone of active water exchange. The area which they mentioned is locates off the study area and has a temperature range during winter equal to 22°C and 24°C in the surface water layer and reaches about 30-32°C during September to November.

3.2.2. Salinity:

Salinity measured during field work ranges between 34.95%0 and 35.86%0 with an average of 35.47%0 ± 0.331. Salinity shows positive correlation with some of the environmental parameters i.e. NO₂, NO₃. It has negative correlation with organic matter. El-Gindy and Hegazi, (1996) indicated that salinity in the
Table 5: Results of the measured environmental parameters.

<table>
<thead>
<tr>
<th>STATION</th>
<th>DEPTH (m)</th>
<th>SALINITY (%)</th>
<th>TEMP. (°C)</th>
<th>O.M. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>34.84</td>
<td>25.8</td>
<td>0.27</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>34.95</td>
<td>26.7</td>
<td>0.23</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>34.95</td>
<td>26.6</td>
<td>0.18</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>35.18</td>
<td>27.2</td>
<td>0.18</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>35.29</td>
<td>27.1</td>
<td>0.23</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>35.75</td>
<td>26.8</td>
<td>0.22</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>35.29</td>
<td>26.8</td>
<td>0.32</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>35.52</td>
<td>26.6</td>
<td>0.31</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>34.95</td>
<td>27.0</td>
<td>0.27</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>35.63</td>
<td>26.5</td>
<td>0.18</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>35.63</td>
<td>26.8</td>
<td>0.18</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>35.75</td>
<td>27.0</td>
<td>0.17</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>35.86</td>
<td>26.8</td>
<td>0.22</td>
</tr>
<tr>
<td>14</td>
<td>9</td>
<td>35.63</td>
<td>27.1</td>
<td>0.14</td>
</tr>
<tr>
<td>15</td>
<td>9</td>
<td>35.75</td>
<td>26.5</td>
<td>0.18</td>
</tr>
<tr>
<td>16</td>
<td>5</td>
<td>35.75</td>
<td>27.1</td>
<td>0.17</td>
</tr>
<tr>
<td>17</td>
<td>4</td>
<td>35.75</td>
<td>27.1</td>
<td>0.11</td>
</tr>
<tr>
<td>18</td>
<td>4</td>
<td>35.63</td>
<td>27.2</td>
<td>0.16</td>
</tr>
<tr>
<td>19</td>
<td>4</td>
<td>35.52</td>
<td>26.9</td>
<td>0.17</td>
</tr>
<tr>
<td>20</td>
<td>4</td>
<td>35.75</td>
<td>27.4</td>
<td>0.13</td>
</tr>
</tbody>
</table>
region in front of the study area ranges between 37-39 % during September and November and 37-38 % during January and February period.

### 3.2.3 Organic matter

Figure (10) represents the spatial distribution pattern of the organic matter in the study area. In general organic matter increases in a westward direction. The average organic matter is 0.2%±0.06. Station 7 shows the maximum content of organic matter, i.e. 0.32%. On the other hand the minimum contents of organic matter (0.11%) is shown at station 17. In general most of the sediments have an organic matter content less than 0.2%. This value is similar to the normal shallow marine values for organic matter. No relationships can be observed between organic matter and the other measured environmental parameters.

Table (6) compares the values of organic matter concentrations obtained during the present study with the previous values recorded at different areas with more or less similar conditions. It is obvious that organic matter contents for the Ras Al Kheimah coastal area is more or less similar to that recorded for the Dubai coastal area. However it is lower than from the other comparable sites, having roughly estimated similar conditions. Nonetheless, these values are almost considered as a normal shallow marine value for organic matter. The standard deviation of organic matter (i.e. 0.06) indicates that the variation within the sediments is very limited.
A) Organic Matter (%)

B) Phosphate-Phosphorus

C) Dissolved Silicates

Figure 10: Areal distribution of the different environmental parameters.
Table 6: Comparison between the organic matter detected during the present work and the previous results on the area or similar environments.

<table>
<thead>
<tr>
<th>Area</th>
<th>O.M. % range (average)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arab’s Bay, Egypt</td>
<td>0.414 – 0.918</td>
<td>Emelyanov, 1972</td>
</tr>
<tr>
<td>Abu Qir Bay, Egypt</td>
<td>0.072 – 3.37 (1.26)</td>
<td>Moussa, 1973</td>
</tr>
<tr>
<td>El-Mex Bay, Egypt</td>
<td>0.14 – 1.74% (0.57)</td>
<td>El-Sabrouit, et al., 1997</td>
</tr>
<tr>
<td>Miami Bay, U.S.A.</td>
<td>0.07 – 0.9% (0.39)</td>
<td>El-Sabrouit, et al., 1997</td>
</tr>
<tr>
<td>Montazah Bay, Egypt</td>
<td>0.726 – 2.5 1.0 ± 0.65</td>
<td>El Sammak, 1995</td>
</tr>
<tr>
<td>Dubai creak and Coastal U.A.E.</td>
<td>0.0052 – 0.4446 (0.152856)</td>
<td>El Sammak, 1998</td>
</tr>
<tr>
<td>Ras Al-Khaimah, U.A.E.</td>
<td>0.11 – 0.32 (0.2 ± 0.06)</td>
<td>Present study</td>
</tr>
</tbody>
</table>
3.3. Nutrient salts: Table 7

3.3.1 Phosphate phosphorus (PO₄):

As shown in Table 4 the maximum value for PO₄ is found to be at station number 9 i.e. 0.92 µg at/l. This value is very high, when compared to the other values from different stations. Stations 1 and 4 have the lowest value i.e. 0.26 µg at/l. The mean PO₄ concentration is 0.5 µg at/l ± 0.15. Phosphate phosphorous shows a negative correlation with SiO₃. Fig (10) shows the distribution of PO₄ in the surface water of the study area. Most of the stations having the maximum value of PO₄ locate in the northern part of the study area i.e. around the stations 9, 8, and 10. On the other hand, at the southern area the minimum value exists.

3.3.2 Silicate (SiO₃):

Table (7) represents SiO₃ concentration. SiO₃ shows the maximum value at station 1, i.e. 5.98 µg at/l. On the other hand, station 14 has the lowest value for SiO₃ (1.3 µg at/l). The average SiO₃ concentration is 2.21 µg at/l ±1.21. The areal distribution of SiO₃ is shown in Fig (10), which reveals that the maximum values; notice are around the station 16 and in the middle area between 1 and 10.

3.3.3. Nitrate NO₃:

Station 2 shows that the lowest value of NO₃ i.e. 3.95 µg at/l is found to be at station 2, while the maximum value i.e. 4.70 µg at/l is found at stations 16 and
Table 7: Concentration (μg at/l) of different nutrient salts at different stations.

<table>
<thead>
<tr>
<th>Station</th>
<th>PO₄</th>
<th>SiO₃</th>
<th>NO₂</th>
<th>NO₃</th>
<th>NH₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.26</td>
<td>5.98</td>
<td>0.18</td>
<td>4.22</td>
<td>0.58</td>
</tr>
<tr>
<td>2</td>
<td>0.36</td>
<td>1.82</td>
<td>0.07</td>
<td>3.95</td>
<td>0.09</td>
</tr>
<tr>
<td>3</td>
<td>0.46</td>
<td>1.92</td>
<td>0.22</td>
<td>4.31</td>
<td>0.23</td>
</tr>
<tr>
<td>4</td>
<td>0.26</td>
<td>1.82</td>
<td>0.11</td>
<td>4.28</td>
<td>0.09</td>
</tr>
<tr>
<td>5</td>
<td>0.56</td>
<td>1.51</td>
<td>0.14</td>
<td>4.66</td>
<td>0.05</td>
</tr>
<tr>
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<td>4.56</td>
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<tr>
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<td>2.44</td>
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<td>1.87</td>
<td>0.29</td>
<td>4.49</td>
<td>0.23</td>
</tr>
<tr>
<td>9</td>
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<td>1.51</td>
<td>0.25</td>
<td>4.26</td>
<td>0.18</td>
</tr>
<tr>
<td>10</td>
<td>0.53</td>
<td>2.24</td>
<td>0.36</td>
<td>4.14</td>
<td>0.21</td>
</tr>
<tr>
<td>11</td>
<td>0.46</td>
<td>1.82</td>
<td>0.32</td>
<td>4.37</td>
<td>1.05</td>
</tr>
<tr>
<td>12</td>
<td>0.36</td>
<td>1.61</td>
<td>0.32</td>
<td>4.18</td>
<td>0.16</td>
</tr>
<tr>
<td>13</td>
<td>0.46</td>
<td>2.70</td>
<td>0.32</td>
<td>4.58</td>
<td>0.18</td>
</tr>
<tr>
<td>14</td>
<td>0.69</td>
<td>1.30</td>
<td>0.29</td>
<td>4.24</td>
<td>0.02</td>
</tr>
<tr>
<td>15</td>
<td>0.56</td>
<td>1.77</td>
<td>0.29</td>
<td>4.39</td>
<td>0.02</td>
</tr>
<tr>
<td>16</td>
<td>0.33</td>
<td>5.15</td>
<td>0.25</td>
<td>4.70</td>
<td>0.23</td>
</tr>
<tr>
<td>17</td>
<td>0.59</td>
<td>1.40</td>
<td>0.32</td>
<td>4.70</td>
<td>0.28</td>
</tr>
<tr>
<td>18</td>
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<td>1.35</td>
<td>0.22</td>
<td>4.22</td>
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</tr>
<tr>
<td>19</td>
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<td>0.25</td>
<td>4.18</td>
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</tr>
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<td>2.18</td>
<td>0.40</td>
<td>4.49</td>
<td>0.30</td>
</tr>
</tbody>
</table>
17. The average NO₃ values is 4.37 µg at/l ±0.21. Fig (11) shows the iso-
concentration values of NO₃ in the surface water of the area where the 
maximum values are concentrated in the eastern and in the western sector of the 
area.

3.3.4. Nitrite NO₂:

NO₂ concentration in the upper layer of the water column ranges between a 
maximum value of 0.4 µg at/l (stations 7 and 20) and a minimum value of 0.07 
µg at/l (station 2). The average NO₂ concentration is 0.26 µg at/l ±0.09. Figure 
(11) represents the distribution of NO₂ in the surface water of the study area. It 
is obvious that the maximum NO₂ value exists i.e. around station 7. The rest of 
the stations have medium values.

3.3.5 Ammonium/Nitrogen NH₄:

The minimum value recorded for NH₄ is found to be at stations 14 and 15. 
The maximum value i.e. 1.05 µg at/l occurs at station 11. On the other hand, the 
average value is 0.23 µg at/l ±0.23. No correlation between NH₄ and any other 
parameters is found. The distribution of NH₄ in the surface water of the study 
area is shown in figure (11) with the maximum values concentrated around the 
area between stations 11 to 20.

3.3.6. Discussion of the environmental parameter:

Marine phytoplankton require certain trace elements for growth. These
Figure 11: Areal distribution of the different environmental parameters in the surface water of the study area.
nutrients are used until they become limiting and further growth is inhibited. The most important micronutrients are nitrogen and phosphorus. Some organisms have siliceous frustules and require silica (Millero and Sohn, 1991). Some reconnaissance measurements of the water nutrients of the U.A.E. coast, near Abu Dhabi, show that the coastal and lagoonal waters are generally low in phosphate and nitrate (Evans et al., 1973). Similarly there is no observable trend in the nitrate content of the waters during winter, although it does appear to decrease when traced from the open sea to the back of the lagoon during the summer (Evans et al., 1973). The silicate content is higher in the waters of the inner lagoon than in those of the open sea both in winter and in summer (Evans et al., 1973). Evans et al. (1973) also mentioned that, when the measurement for various seasons are compared, the waters of the nearshore zone, outer lagoon and inner lagoon all show higher phosphate content in winter than in summer; the nitrate content is very variable and shows no preferential enrichment in either seasons, while the silicate is noticeably higher in summer.

The importance of phosphate in natural waters has been stressed by many authors (Kramer et al., 1972, Saad and Fahmy, 1984). The average phosphate values in the open sea water off Jeddah in the Red Sea, ranged from 0.12 – 0.6 μg at P/l during March and from 0.18 – 0.49 μg at P/l in April (Saad and Fahmy, 1984). These values are more or less similar to the values obtained during this study. The high phosphate concentrations recorded in Ras Al Khaimah towards the offshore area are probably to the decay of phytoplankton and excretion of considerable amounts of phosphate by aquatic organisms.
(Kramer, *et al.*, 1972, Saad and Fahmy, 1984) as well as release of phosphate from the bottom sediments. On the other hand, the decrease in phosphate concentrations however can be related to the decrease in the internal influx of phosphate, with an increase in the consumption by phytoplankton.

The silicate values in the surface waters of the study area is almost similar to that obtained for the coastal water north of Jeddah, where Saad and Fahmy (1984) detected dissolved silicate values ranged between 1.3 – 5.22 µg at Si/l. The high silicate value found in the extreme east and off the Al-Khor opening is probably due to the increase of the dissolution rate of diatom frustules and their fragments in the bottom sediments. The decrease in silicate concentrations however could be attributed to the uptake by diatoms. Evans, *et al.*, (1973) attributed the comparatively high silicate content found in the waters near Abu Dhabi at the back of the lagoon to the seepage of water from the adjacent rocks or from the coastal plain, as the ground waters of this plain are usually rich in this component.

Nitrogen is one of the biologically important elements in aquatic habitats. In addition to dissolved molecular nitrogen, seawater contains low, but extremely important, concentration of inorganic and organic nitrogen (Abou-Kassim, 1987). The most important forms of inorganic nitrogen in seawater are nitrate (NO₃), nitrite (NO₂) and ammonia (NH₄). The concentrations of these forms usually lie in the range < 0.1 – 35 µg at NO₃-N/l, 0.01 – 3 35 µg at NO₂-N/l and 0.15 – 3 35 µg at NH₄-N/l in oxygenated waters (Riley and Chester, 1971).
Nitrate is the final oxidation product of nitrogen compounds in seawaters. It is generally considered the only thermodynamically stable species of nitrogen in the presence of oxygen in seawater (Aboul-Kassim, 1987). The nitrate concentration in the water of Ras Al Khaimah coastal area seems to be more or less uniform throughout the area, with a mean value of $4.37 \pm 0.35 \mu g$ at NO$_3$-N/l. The standard deviation from the arithmetic mean represents only about 4.6%. This reveals that no obvious variations in the utilization, regeneration or nitrate assimilation by phytoplankton in the investigated area.

Nitrite could hardly be a nitrogen source for phytoplankton since it is rarely present in measurable quantities (Wafar, et al., 1986). Nitrite is an intermediate species between ammonia and nitrate. The average NO$_2$ concentrations determined in the surface water of the study area (i.e. $0.26 \pm 0.09 \mu g$ at NO$_2$-N/l) is slightly lower than that values obtained for the different sectors of the Egyptian Mediterranean coast (Aboul-Kassim, 1987). The values for the eastern harbour, Alexandria Egypt was ranged between $0.062 - 3.318 \mu g$ at NO$_2$-N/l with a mean value of $0.949 \mu g$ at NO$_2$-N/l. The low values for nitrite in the surface water of the study area may be attributed to the increase of nitrite oxidation to nitrate and probably its reduction to ammonia, as well as nitrite uptake by phytoplankton. In fact the area off Al-Khor opening is highly depleted with nitrite compared with the other sites.

The occurrence of ammonia in the seawater depends mainly on the intermittent relationships between the different biological and chemical processes operating in
the re-generation of organic nitrogenous materials and also being a chief nitrogenous excretory products of many aquatic organisms especially zooplankton (Aboul-Kassim, 1987). He also mentioned that ammonia might be used as a good indicator for the degree of pollution. Ammonia in the study area is very low, if we compared its concentrations with that from the eastern harbour, Alexandria, Egypt (Aboul-Kassim, 1987).

3.4 Results of foraminifera:

Table (8) presents the result of the foraminiferal analysis at different stations. At each station living/dead foraminiferal species were counted. The sum of living and dead foraminiferal represents the total foraminiferal shells in the samples. For each of these categories (i.e. living, dead and total) the number of porcellaneous (Miliolidae), agglutinated (Textulariidae) and hyaline (Rotaliina) shells were counted.

3.4.1 Total foraminiferal species:

The maximum foraminiferal species is 319 individuals found at station 8, while the minimum number is 25 individuals found at station 2. The average number foraminiferal shells is $\approx 163.0\pm85$ (Table 9). The most common foraminifera is the agglutinated foraminifera constitutes about $59.4\% \pm 11.1$. The maximum number of agglutinated foraminiferal shells is 211, while the minimum number is 12 individuals. The second in abundant of the three categories is the porcellaneous foraminifera ($26.4\% \pm 8.15$, maximum number is
Table 8: Results of the foraminiferal studies.

| Station | LA | LP | LH | TL | LDA | LDP | LDH | T/L | DA | DP | DH | T/D | LA% | LP% | LH% | LDA% | LDP% | LDH% | DA% | DP% | DH% | %L |
|---------|----|----|----|----|-----|-----|-----|-----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| #1      | 24 | 5  | 16 | 45 | 57  | 26  | 19  | 102 | 33 | 21 | 3  | 57  | 53.33| 11.11| 35.56| 55.88| 25.49| 18.63| 57.89| 36.84| 5.26| 44.11|
| #2      | 11 | 7  | 2  | 20 | 12  | 11  | 2   | 25  | 1  | 4  | 0  | 5   | 55.00| 35.00| 10.00| 48.00| 44.00| 8.00 | 20.00| 80.00| 0.00| 80    |
| #3      | 11 | 9  | 19 | 39 | 59  | 25  | 29  | 113 | 42 | 16 | 10 | 68  | 28.21| 23.08| 48.72| 52.21| 22.12| 25.66| 61.76| 23.53| 14.71| 34.51|
| #4      | 12 | 11 | 2  | 25 | 33  | 17  | 2   | 52  | 21 | 6  | 0  | 27  | 48.00| 44.00| 8.00 | 63.46| 32.69| 3.85 | 77.78| 22.22| 0.00| 48.07|
| #5      | 23 | 7  | 6  | 36 | 144 | 19  | 18  | 181 | 121| 12 | 12 | 145 | 63.89| 19.44| 16.67| 79.56| 10.50| 9.94 | 83.45| 8.28 | 8.28 | 19.89|
| #6      | 43 | 20 | 6  | 69 | 88  | 48  | 30  | 166 | 45 | 28 | 24 | 97  | 62.32| 28.99| 8.70 | 53.01| 28.92| 18.07| 46.39| 28.87| 24.74| 41.56|
| #7      | 41 | 31 | 17 | 89 | 120 | 48  | 53  | 221 | 79 | 17 | 36 | 132 | 46.07| 34.83| 19.10| 54.30| 21.72| 23.98| 59.85| 12.88| 27.27| 40.27|
| #8      | 32 | 38 | 22 | 92 | 167 | 72  | 80  | 319 | 135| 34 | 58 | 227 | 34.78| 41.30| 23.91| 52.35| 22.57| 25.08| 59.47| 14.98| 25.55| 28.84|
| #9      | 37 | 30 | 14 | 81 | 177 | 41  | 27  | 245 | 140| 11 | 13 | 164 | 45.68| 37.04| 17.28| 72.24| 16.73| 11.02| 85.37| 6.71 | 7.93 | 33.06|
| #10     | 21 | 2  | 21 | 44 | 75  | 43  | 24  | 142 | 54 | 41 | 3  | 98  | 47.73| 45.55| 47.73| 52.82| 30.28| 16.90| 55.10| 41.84| 3.06| 30.985|
| #11     | 12 | 13 | 10 | 35 | 69  | 32  | 39  | 140 | 57 | 19 | 29 | 105 | 34.29| 37.14| 28.57| 49.29| 22.86| 27.86| 54.29| 18.10| 27.62| 25     |
| #12     | 7  | 4  | 4  | 15 | 69  | 19  | 11  | 99  | 62 | 15 | 7  | 84  | 46.67| 26.67| 26.67| 69.70| 19.19| 11.11| 73.81| 17.86| 8.33 | 15.15|
| #13     | 17 | 5  | 6  | 28 | 187 | 42  | 28  | 257 | 170| 35 | 22 | 227 | 60.71| 17.86| 21.43| 72.76| 16.34| 10.89| 74.89| 15.42| 9.69 | 10.89|
| #14     | 21 | 4  | 12 | 37 | 172 | 84  | 58  | 314 | 151| 80 | 46 | 277 | 56.76| 10.81| 32.43| 54.78| 26.75| 18.47| 54.51| 28.88| 16.61| 17.88|
| #15     | 14 | 6  | 3  | 23 | 211 | 41  | 7   | 259 | 197| 35 | 4  | 236 | 60.87| 26.09| 13.04| 81.47| 15.83| 2.70 | 93.47| 14.83| 1.69 | 8.88|
| #16     | 16 | 9  | 2  | 27 | 77  | 60  | 13  | 150 | 61 | 51 | 11 | 123 | 59.26| 33.33| 7.41 | 51.33| 40.00| 8.67 | 49.59| 41.46| 8.94 | 18     |
| #17     | 7  | 4  | 4  | 15 | 92  | 50  | 9   | 151 | 85 | 46 | 5  | 136 | 46.67| 26.67| 26.67| 60.93| 33.11| 9.56 | 62.50| 33.82| 3.68| 9.93|
| #18     | 15 | 4  | 2  | 21 | 124 | 48  | 9   | 181 | 109| 44 | 7  | 160 | 71.43| 19.05| 9.52 | 68.51| 26.52| 4.97 | 68.13| 27.50| 4.38| 11.60|
| #19     | 1  | 1  | 0  | 2  | 33  | 15  | 12  | 60  | 32 | 14 | 12 | 58  | 50.00| 50.00| 0.00 | 55.00| 25.00| 20.00| 55.17| 24.14| 20.69| 3.33|
| #20     | 2  | 3  | 3  | 8  | 30  | 20  | 23  | 73  | 28 | 17 | 20 | 65  | 25.00| 37.50| 37.50| 41.10| 27.40| 31.51| 43.08| 26.15| 30.77| 10.95|

LA: living agglutinated
LH: living hyaline
LDA: living and dead agglutinated
LDH: living and dead hyaline
LP: living porcelaneous
TL: total living
LDP: living and dead porcelaneous
TD: total dead
Table 9: Description statistics for the Results of Foraminiferal study.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard Deviation</th>
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<tr>
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<td>197.00</td>
<td>54.79</td>
</tr>
<tr>
<td>DP</td>
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<td>4.00</td>
<td>80.00</td>
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<tr>
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<td>%L</td>
<td>26.34</td>
<td>3.33</td>
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</tr>
</tbody>
</table>

LA: living agglutinated
LP: living porcelain
e
LH: living hyaline
TL: total living
LDA: living and dead agglutinated
LDP: living and dead porcelain
LDH: living and dead hyaline
TD: total dead
48 individuals and minimum number is 4 individuals), while the hyaline shells is less common representing about 15.17\% \pm 8.6 from the total shell counted (maximum is 80 and minimum is 25 shells).

Figure (12) shows that the total living and dead foraminiferal species increases northward (station 8) and eastward (station 4). On the other hand, the inshore stations in general have the lowest numbers of foraminiferal species. It is also clear that agglutinated foraminifera increases offshore as well as to the extreme east (Figure 12). Evidently, Hyaline and Porcellaneous foraminiferal species increases in number offshore and in the extreme east, while the area east to Al-Khor opening and inshore stations are characterized by the lowest number of these types of foraminifera (Figure 12).

Figure (13) shows the variations of porcellaneous, agglutinated and hyaline species at different stations. It is obvious that the 20 samples can be divided into 2 groups. Group 1 is mainly containing samples from the off shore stations located toward west as well as inshore station infront of Al-Khor opening (station 1, 3, 6, 7, 8, 9, 11, 14, 19 &20). Group 1 is discriminating by approximate equal proportions of porcellaneous, agglutinated and hyaline, with a shift towards more Hyaline than the other two types. Group 2 is mainly including the samples from the eastern part and the inshore extreme western stations. This group is discriminated by the high percentage of Agglutinated, and a lesser percentage of Hyaline and porcellaneous forms.
Figure 12: Areal distribution of the total number of Foraminiferal individuals in the sediments of study area.
Figure 13: Ternary plot of total foraminiferal assemblages.
3.4.2 Living foraminiferal species:

The maximum number of living foraminiferal species is 92 individuals found at station 8, while the minimum number is 2 individuals found at station 19. On the other hand the average number of foraminiferal tests is $\approx 38.0 \pm 26$ (Figure 14).

The average of the agglutinated is $49.8\% \pm 12.24$. On the other hand the maximum number is 43 individuals found at station 6, while the minimum number is only 1 individual found at station 19 (Figure 14).

For the porcellaneous species the maximum number is 38 individuals found to be at station number 8, while the minimum number of porcellaneous forams is 1 shells (station 19). The average number of the porcellaneous forams $28.2\% \pm 11.95$ (Figure 14).

The maximum number of the Hyaline species is 22 species (station number 8). The average is $21.95\% \pm 13.58$. No hyaline species is found at station number 19 (Figure 14).

Figure (15), represents the relationship between the living agglutinated, Hyaline and Porcellaneous species. It is clear that the stations can be divided into three groups. Group (I) includes samples numbers 1, 10, 13 and 14. This group discriminates by the equal percentages of the hyaline and agglutinated individuals. Group (II) on the other hand comprises samples numbers 2, 4, 5, 6, 15, 18 and 19. It distinguishes on the basis of the agglutinated numbers with minor percentage of procellaneous and a trace percentage of the hyaline forams. Group (III) has an equal numbers of the three components. This group includes samples numbers 3, 7, 9, 11, 12, 17 and 20.
**A) Total**

**B) Agglutinated**

**C) Hyaline**

**D) Procellaneous**

**Figure 14**: Areal distribution of the total number of living Foraminiferal individuals in the sediments of study area.
Figure 15: Ternary plot of total living foraminiferal assemblages.
3.4.3 Dead foraminiferal species:

The maximum number of dead foraminiferal species is 277 (station 13), while the minimum number of dead foraminifera (5 species) is found to be at station 2. The average foraminiferal shells is about 125±74 (Table 8, Figure 16). The most common foraminifera is the Agglutinated forams, which form about 61.3%±15.9 from the total dead foraminifera. The maximum number of Agglutinated forams is 197 individuals (station 15), while the minimum, which is 1 individuals, determined in the station 2 (Figure 16).

The second common foraminifera is porcellaneous that has an average about 26.2%±16.17, while the maximum is 80 individuals (station 14) and the minimum is 4 individuals (station 2) (Figure 16).

Hyaline forams have an average of 12.46%±10.21, and a maximum 58 shells found in Station 8. No hyaline forams can be observed at stations 2 and 4 (Figure 16).

Figure (17) shows the triangle diagram for the dead foraminifera. It is obvious that the samples can be divided into two groups. Group I is containing stations 1, 4, 5, 9, 10, 12, 13, 15, 16, 17, 18, and it shifts toward the agglutinated species. On the other hand, group II consists of stations 3, 6, 7, 8, 11, 14, 19, 20 which have roughly estimated equal proportions of agglutinated, porcellaneous and hyaline. Station 2 has more porcellaneous than agglutinated with zero proportion of hyaline.
**Figure 16:** Areal distribution of the total number of dead foraminiferal individuals in the sediments of study area.
Figure 17: Ternary plot of total dead foraminiferal assemblages.
3.4.4. Discussion of the foraminiferal results:

Studied dealing with modern benthic foraminifera are reported in term of living, dead or living plus dead (i.e. total) assemblages (Murray, 1991). It is commonly observed that the living and dead assemblage form the same sediment samples are different to a greater or lesser extent. This is due to the fact that the living assemblage represents only the time of sampling, whereas the dead assemblage represents many generations added over a long period of time (Staff, et al., 1986, Murray, 1991). According to Murray (1991), a living assemblage, through life processes such as production gives rise to an ideal dead assemblage and this, in turn, is invariably altered through post marten changes to give dead assemblage presented in the sediments.

In the present study, the living, dead and total assemblages were used. Figure (18) shows both total living (including, agglutinated, porcellaneous and hyaline forams) and total dead assemblages have the same pattern of distribution, where the increasing of living assemblage will lead to an increase in the total dead assemblage. However, it seems that dead assemblage comprises most of the total assemblage. This is clear due to the fact that the dead assemblage represents many generations.

According to Murray (1991), although dead benthic foraminifera are abundantly present in the sediments of the extensive lagoon complex along the coast of the United Arab Emirates, the standing crop of the living assemblage is low. He observed that the majority of living forms are found living epiphytically and only on death are their tests contributed to the sediments.
**Figure 18:** Line plots showing the variations of both total living and total dead assemblages in the sediments at different stations.
In the present study, the principle associations are those of *Penerolips plantus*, *Quinqueloculina neastrictula*, *Quinqueloculina cooki*, *Triloculina sp.*, *Ammonia beccarii*, *Elphidium crispum* and *Texularia sp*. Other Milliolina, *Texularina* and *Rotallina* are also noticed (Table 2). The same principle associations were reported by several authors working either on the coastal area of United Arab Emirates, Arabian Gulf and Red Sea coastal area ([Murray, 1965, 1966a, b & c, 1970, 1991; Bahafallah & El-Askary, 1981; Bahafallah, 1984; Abou-Ouf & El-Shater, 1993; Al-Zamel, *et al.*, 1997; Cheirif, *et al.* 1997:]).

According to Cheirif, *et al.*, (1997), many authors considered that the total dead shells in a marine thanatocenose represents a stable averaging of the effects of environmental conditions prevailing over a given area, particularly if this area covers an extensive surface and if the samples represent the accumulation of tests during a sufficient period of time. In fact the differences in the percentage of living foraminiferal tests (range between 3.3% and 80%) may be revealed to the nature of the bottom, where the low values occur in areas covered with seagrasses, and halophytes. On the other hand, high percentage of living forams occur where algae, seagrasses and other plants disappear. Other possible causes could be the low lifespan of the benthic foraminifera. The lifespan of a benthic foraminiferal generation is only known for few species, it varies between 0.3 month and two years depending on the species ([Steinsund & Hald, 1994]). Other possible reason is the fact that some dead foraminiferal tests could be either recent dead forams or the red colour
caused due to the effect of Rose Bengal on the protoplasm and other organic materials could be caused by clusters of benthic or other organisms using the test as a refuge (Murray, 1991).

Figure (19) reveals that the percentage of the total dead foraminiferal species increases eastward. It seems that Al-Khor opening divides the area into western part with high percentages of living forams and eastern region with low percentages of the living forams. Obviously, the water from Al Khor causes this distinction division. According to Shriadah (1998), pollutants from many sources such as municipal and industrial waste-water from many outlets as well as from fishing and cargo boats appears to contribute strongly to the metal and other pollutants accumulates in the sediments. Figure (20) shows the relation between organic matter contents in the sediments and the number of the living forams. It is obvious that both variables obey each other in their distribution. Organic matter is measure of pollution effect in the coastal sediments. Corner et al., (1996) found no correlation between percentages of living foraminifera and total organic matter. However the relationship between pollution and foraminifers is very complicated, not only because the pollutants are very different, but also because their effect on different species are also very different (Boltovskoy, et al, 1991).

To study the effect of temperature and salinity on the distribution of foraminifera, bivariate plots between the number of total dead, total living and total living & dead foraminifera with both salinity and temperature were preformed with a 95% confidante limit (Figure 21). It is obvious that at least
Figure 19: Ratio between total living and total dead foraminiferal assemblage at different stations.
Figure 20: Line plot showing the relation between the number of total living foraminiferal species and organic matter concentration at different stations.
Figure 21: Relation between Temperature and Salinity with the numbers of living, dead and total (living and dead) Foraminiferal assemblages.
50% of the stations fall outside the 95% confidence limit. This may indicate that temperature and salinity have a low influence on the distribution of the foraminiferal tests, both living and dead. According to Coles & McCain (1990), among all the environmental factors, salinity has the strongest high significant relationships with the numbers of benthic infaunal species in both seagrass and sand/silt in the western Arabian gulf. However, the absence of Sorites sp. may indicate the extreme high salinity and temperature. Murray (1991) mentioned that, with the exception of peneroplids and local occurrence of Sorites marginalis in the Halat al Bahrani lagoon (to the west of Abu Dhabi) larger foraminifera are conspicuously absent. He attributed this to the extreme salinity and temperature ranges experienced in this area.

Figure (22) shows the relationships of the percentage of total living foraminifera with both mean grain size and organic matter contents. It is visible that the percentage of the total living foraminiferal species increases slightly with increasing sediment size. However, it should be noted that the analysis of foraminifera were only done on the medium to fine sand fractions. Murray (1966c), during his study on the foraminifera of the shelf off the Trucial coast, Abu Dhabi region, implicated the numerical importance of the foraminifera in the size of 0.066 – 0.124 mm as shown from the cumulative curve for the counted foraminiferal tests at different grade size. He mentioned also the importance of the few large foraminiferids in the 0.124 – 1.003 mm in terms of weight. Cloes & McCain (1990) observed that both species diversity and number of benthic species increased with finer grain sediments. On the other
Figure 22: Relation between percentage of living Foraminiferal with both organic matter and mean grain size $\phi$. 
hand Murray (1966b) noticed that coarser sediments from the Shelf off Abu Dhabi, contained larger foraminifera, while fine-grained, muddy sediments contained astronomical numbers of tiny foraminiferids, many of which may be juveniles.

Figure (23a) explains the relationships between the number of the total living foraminiferal species and the nutrients salts, while figure (23b) represents the relation between the number to total foraminifera species (living plus dead) and the nutrients salts. It is apparent that except for silicate, no relations can be noticed. For silicate, there are slightly decreases in the number of both living and total foraminiferal species with the decreasing of the silicate content of water. The no relationships between the other nutrient salts and the number of living and total foraminifera may cause the diversities in the number of benthic forams. Cheirf *et al.*, (1997) suggested that the high diversities observed in the northern part of the Arabian Gulf are a reflection of the higher productivity of this water body as compared to the Gulf of Suez and the northern Red Sea.

In the 1964 classification of foraminifera (Loeblich & Tappan, 1964b) all modern forams with hard tests fell into three suborders – Texulariina, Miliolina and Rotaliina – which correspond to agglutinated, procellaneous and hyaline wall structures respectively (Murray, 1991). Using the ternary diagrams for the living, dead and total (living & dead) performed during the present study, it seems that procellaneous and agglutinated are the dominant foraminiferal species in the area. Comparing the results with the triangular plot of foraminifera with the boundary of Murray (1973) based on the wall
Figure 23: Scatter plot showing the relationships between A: percentage of living Foraminiferal individuals; B: total number of Foraminifera; with different nutrient salts.
composition (Figure 2-1). It is clear that most of the foraminiferal assemblages fall within the normal marine to hypersaline marine marshes. Comparing the present ternary plots with those of Murray (1965, 1966, 1970 and 1991) for Abu Dhabi region, it is evident that the present samples are more shifted towards the agglutinated forms rather than the hyaline apex. However, the present results are similar to the study carried out by Abou Ouf (1992) on the coastal sabkha, Red Sea coast, Saudi Arabia, where most of the samples fall close to the procellaneous apex and thus indicating a hypersaline environment.

According to Cheirf et al., (1997), assemblage with highest proportions of agglutinated foraminifera are found in the deep part of the central and western basin of the Arabian Gulf. Highest proportions of porcellaneous forams (with frequencies of $>45\%$) are found in the central, but relatively shallow waters of the gulf ($<60m$). The highest proportions of hyaline forams are found in the Arabian homoclone ($>60\%$). Murray (1991) indicated that the porcellaneous taxa are more abundant in the dead assemblage especially in those from close to shores, Abu Dhabi, United Arab Emirates. Hyaline on the other hand is more predominant in the living assemblage. Reiss and Hottinger (1984) indicated that the rotalliiids (hyaline) are presented as a very minor component of the benthic foraminiferal assemblage in the Gulf of Aqaba region. They also observed some unidentified species of *Ammonia* occur frequently in the shallowest environments around mangroves area in the Gulf of Aqaba. Murray (1965) stated that the most important features of the distribution of living foraminiferids in the shallow water carbonate complex is that they are not
Figure 24: Summary of wall structure environmental fields for living assemblages (After Murray, 1991).
uniformly distributed but like macrofauna (e.g. corals, gastropods, bivalves) they have restricted area of occurrence. However, the dead foraminiferal assemblages are not alike those of living (Murray, 1970).

According to Murray (1991), in the majority of cases the difference between the living assemblage and the ideal dead assemblages drawn from it are not very great. However postmortem processes influences modify the ideal dead assemblages to give the dead assemblages observed in the sediments. The processes involved are transport, mixing and destruction of tests. Transport as bed-load must be common in shallow-water area, and it is prevalent in sediments of sand grade and coarse. It leads to abrasion of the test, which may cause breakage of chambers, a dull or polished texture (Murray, 1991). Plate (12. figure 5) represents this type of postmortem changes, where part of the test is broken. This is mostly due to the bed load transport prevalent in this coastal area. Destruction of tests through transportation and abrasion has already been mentioned (Murray, 1991). Agglutinated tests, which are weakly, held together by organic materials do not survive long after death. However, the high percentage of agglutinated forams in the present study is mainly due to the fact that the destruction of this type of foraminifera is more common on fine-grained substrate (Douglas, et al., 1980). Noted that the area of study is covered with medium to coarse sand (Mz is ranging between 0.53–2.87 φ and averaging 1.24 ± 0.58φ).

Dissolution is another type of postmortem changes. Dissolution of calcareous foraminiferal tests in the present study is observed (Plate 4, figure
According to Murray (1991), dissolution of calcareous tests take places in waters undersaturated with respect to calcium carbonate. Such waters may be in contact with sea floor or interstitial within the sediments. Hyaline tests undergo a progressive series of changes when subject to dissolution (Murray & Wright, 1970, Corliss & Honjo, 1981). Initially, the surface acquires a dull texture and becomes opaque through etching; this then becomes pitted and the last chamber breaks: further breakage takes place and layers of wall are removed from unbroken chamber; this is followed by extensive chamber breakage and finally, total destruction. Some of these stages can be observed during the present study (Plate 12, figure 5). Nonetheless, some of these stages could be similar to the effect of boring organisms (Plate 9, figure 8). Mageau & Walker (1976) observed the same effect caused by predators feeding on foraminifera.

During the present study, some stations contain high percentages of blackened foraminifera. Murray (1991) indicated that, in the nearshore area off United Arab Emirates, the dead assemblages contain blackened foraminiferal tests, and off Abu Dhabi, these form up to 44% of the whole. He perceived that they have a lower diversity and a greater proportion of broken test than the unblackened assemblages. He attributed the blackened foraminiferal tests to older sources or they are relict. Abou-Ouf & El-Shater (1993) study the black benthic foraminifera in carbonate facies of the coastal sabkha, Saudi Arabia Red Sea coast. They assumed that the blackening may be due to impregnation of the sediments by dissolved or finely particulate iron sulphides (pyrite). Murray (1966) studied the black foraminifera in the shelf off the U.A.E. coast,
Abou Dhabi. Black foraminifera are known also to occur off Qatar (Houbolt, 1957). The blackened foraminiferal tests observed in the study area could be attributed to the decomposition of organic matter as well as to the effect of pollution. The black color of the present foraminiferal tests may also take places under reducing conditions beneath the sediment surface. Erosion and bioturbation return these shells to the surface. The black forams observed in the shallow carbonate shelf sediments from southeast of Borneo, western margin of the Pacific ocean, appear to be coated with a chlorite clay mineral and they occur at depth >35m. This mineral may form in reducing condition some centimeres below the sediment surface (Bouchard, et al., 1985)

To demonstrate the similarities between stations based on the foraminiferal results, complete linkage cluster analysis is preformed (Figure 25). It is evident from the resulted dendrogram that two groups of stations can be identified. Group 1, comprise station 1, 10, 14, 3, 7, 8, 11 and 20. Group 2, on the other hand contains station 19, 16, 6, 18, 15, 13, 17, 12, 9 and 4. Station 2 differs from the other stations. This discrimination confirms the distinction of different groups based on the ternary diagrams deduced from the percentages of the three foraminiferal assemblages of the wall composition (Hyaline, Agglutinated and Procellaneous) for the total (living & dead), dead and living counted foraminiferal shells. These two groups are also comparable to the division of the area into western and eastern regions from Al-Khor opening.
**Figure 25:** Tree diagram showing the similarity between different station based on the Results of Foraminifera.
Chapter IV
SUMMARY AND CONCLUSIONS

The present study aimed to find out the relationships between environmental parameters and the abundance of foraminifera, ratio of living to dead foraminifera and the diversity of foraminiferal tests in the coastal area of Ras Al Khaimah region from the other hand.

Twenty stations were selected for collection of samples. Collection of the samples was done during April 1997. Sediment samples were collected using either grab sampler or free diving. At each station, surface water was collected in precleaned plastic bottles. Temperature and salinity were measured *in situ*. In the laboratory, nutrient salts were analyzed in the water samples. Grain size analysis, organic matter and total carbonates were determined. Rose Bengal dye was used in order to distinguish between living and dead foraminiferal species. Foraminiferal species in the sediments at each station were counted and photographed using scanning electron microscope. Identification of the foraminiferal species was also made.

The maximum grain size value is found to be $2.87\phi$ (station 20), while the minimum grain size, i.e. $0.53\phi$ is observed at station 4. On the other hand, the average grain size is $1.24\phi \pm 0.58$. No relationship is observed between mean size ($\phi$) and the other measured and calculated parameters. The standard deviation ranges between moderately sorted to poorly sorted. Skewness varies from station to another. The skewness ranges between 0.22 and $-0.46$ and averaging $-0.07 \pm 0.195$. The maximum kurtic value is 1.56 and the minimum is 0.16. The average value of the kurtosis is $1.09 \pm 0.22$. In order to measure the
similarities between different stations in term of texture characters, the complete linkage cluster analysis is performed. It is obvious that stations in the study area are clustered in three groups. Stations 20, 13, 5, 14, 11 and 3 comprise group I. Group II, contains stations 7, 4, 16, 17, 18, 12 and 2. On the other hand, stations 15, 19, 9, 8 and 6 distinguish group III. As a matter of fact, these 3 groups indicate that grain size parameters give no indications about the similarities or dissimilarities in the sediments of the study area.

The highest water temperature recorded in situ (27.4°C) is found to be at station number 20. Salinity measured during field work ranged between 34.95‰ and 35.86‰ with an average of 35.47‰±0.331.

The average organic matter contents is 0.2%±0.06. Station 7 shows the maximum content of organic matter, i.e. 0.32%. On the other hand the minimum contents of organic matter (0.11%) is shown at station 17.

The maximum value for PO₄ is found to be at station 9 i.e. 0.92 µg at/l. This value is very high comparing to the other values at different stations. Stations 1 and 4 have the lowest i.e. 0.26 µg at/l. The mean PO₄ concentration is 0.5 µg at/l. SiO₃ shows the maximum value at station 1, i.e. 5.98 µg at/l. On the other hand station 14 has the lowest value for SiO₃ (1.3 µg at/l). The average SiO₃ concentration is 2.21 µg at/l±1.21. Station 2 shows the lowest value of NO₃ i.e. 3.95 µg at/l, while the maximum value i.e. 4.70 µg at/l is found at stations 16 and 17. The average NO₃ value is 4.37 µg at/l±0.21. NO₂ concentration is the upper layer of the water column is ranging between a maximum value of 0.4 µg at/l (station 7 and 20) and a minimum value of 0.07
μg at/l (Station 2). The average NO₃ concentration is 0.26 μg at/l ±0.09. The minimum value recorded for NH₄ is found to be at stations 14 and 15. The maximum value i.e. 1.05 μg at/l is shown at station 11. On the other hand, the average value is 0.23 μg at/l ±0.23.

The high phosphate concentrations recorded in Ras Al Khaimah towards the offshore area probably to the decay of phytoplankton and excretion of considerable amounts of phosphate by aquatic organisms, as well as release of phosphate from the bottom sediments. On the other hand, the decrease in phosphate concentrations; however can be related to the decrease in the internal influx of phosphate, with an increase in the consumption by phytoplankton. The silicate values in the surface waters of the study area are almost similar to that obtained for the coastal water north of Jeddah. The high silicate value that found to be in the extreme east and off the A-Khor opening is probably due to the increase of the dissolution rate of diatom frustules and their fragments in the bottom sediments.

The nitrate concentration in the water of Ras Al Khaimah coastal area is seems to be more or less uniform through out the area, with a mean values of 4.37±0.35 μg at NO₃-N/l. The standard deviation from the arithmetic mean represents only about 4.6%. This reveals that no obvious variations in the utilization, regeneration or nitrate assimilation by phytoplankton in the investigated area.
The low values for nitrite in the surface water of the study area may be attributed to the increase of nitrite oxidation to nitrate and probably its reduction to ammonia, as well as nitrite uptake by phytoplankton.

The maximum foraminiferal species is 319 species found at station 8, while the minimum number is 25 species found at station 2. The average number foraminiferal species is $\approx 163.0\pm 85$.

The most common foraminifera is the agglutinated foraminifera that constitutes about 59.43% $\pm 11.1$. The second in abundant of the three categories is the porcellaneous forams; while the hyaline shells is less common representing about 15.17% $\pm 8.6$ from the total shell counted.

The maximum number of living foraminiferal species is 92 species, while the minimum number is 2 species. On the other hand the average number of foraminiferal species is $\approx 38.0\pm 26$.

The maximum number of dead foraminiferal species is 277 (station number 13), while the minimum number of dead forams (5 species) is found to be at station number 2. The average number of the dead foraminiferal species is about $125\pm 74$.

Total dead assemblages have the same pattern of distribution, where the increased of living assemblage will lead to an increased in the total dead assemblage. However, it seems that dead assemblage comprises most of the total assemblage.

In the present study, the principle associations are those of *Peneroplis plantus*, *Quinqueloculina neastrictula*, *Quinqueloculina cooki*, *Triloculina* sp.,
Ammonia beccarii, Elphidium crispum and Texularia sp. Other Millilina, TeXtularina and Rotallina are also noticed.

The differences in the percentage of living foraminiferal tests (range between 3.3% and 80%) may be revealed to the nature of the bottom, where the low values occur in areas covered with seagrasses, and halophytes. On the other hand, high percentage of living forams occurs where algae, seagrasses and other plants disappear. Other possible causes could be the low lifespan of the benthic foraminifera. Other possible reason is the fact that some dead foraminiferal tests could be either recent dead forams or the red color caused due to the effect of Rose Bengal on the protoplasm and other organic materials could be caused by clusters of benthic or other organisms using the test as a refuge.

Temperature and salinity have a low influence on the distribution of the foraminiferal tests, both living and dead.

The percentage of the total living foraminiferal species increases slightly with increasing sediment size.

Except for silicate, no relations can be noticed. For silicate, there are slightly decreases in the number of both living and total foraminiferal species with the decreasing of the silicate content of water. The no relationships between the other nutrient salts and the number of living and total foraminifera may cause the diversities in the number of benthic forams.

Most of the foraminiferal assemblages fall within the normal marine to hypersaline marine marshes.
The high percentage of agglutinated forms in the present study is mainly due to the fact that the destruction of this type of foraminifera is more common on fine-grained substrate. Noted that the area of study is covered with medium to coarse sand (Mz is ranging between 0.53-2.87φ and averaging 1.24±0.58φ).

Dissolution of calcareous foraminiferal tests in the present study is observed.

During the present study, some stations contain high percentages of blackened foraminifera. The blackened foraminifera tests observed in the study area could be attributed to the decomposition of organic matter as well as to the effect of pollution. The black color of the present foraminiferal tests may also take places under reducing conditions beneath the sediment surface. Erosion and bioturbation return these shells to the surface.

Cluster analysis based on the results of foraminifera shows that the stations can be divided into two groups. This discrimination confirms the distinction of different groups based on the ternary diagrams deduced from the percentages of the three foraminiferal assemblages of the wall composition (Hyaline, Agglutinated and Porcellaneous) for the total (living and dead), dead and living counted foraminiferal species. These two groups are also comparable to the division of the area into western and eastern regions.
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Arabic Summary
حسن

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