

Ecological Response of Foraminiferal Component in the Sediments of Kharo Creek, Kachchh (Gujarat), West Coast of India

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ABSTRACT

A total of seven surface sediment samples collected within 4.4m to 13.9 m water depth (below chart datum) from Kharo Creek were studied for their foraminiferal content. The study reveals forty seven foraminiferal species of which forty four are benthic and three are planktic. It is observed that distribution of foraminifera is mainly controlled by organic carbon, suspended load, substrate nature and tidal influences. The observations of this study further suggest that on the basis of total foraminiferal number, living and reworked foraminiferal specimens and other ecological variables, creek environments can be divided into three biotopes, viz., *upstream biotope*, *transition biotope* and *lower stream (marginal marine) biotope*. The study further emphasize on the possibility of the detailed foraminiferal study in the creek on seasonal basis as such study will form the base line data to asses the future impact of industrial pollution (if any) as ajetty for offloading cement is being constructed in Kharo Creek for proposed cement plant which is coming up in this area.

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INTRODUCTION

A detailed review of the foraminiferal studies from East and West Coast of India has revealed that foraminiferal components of various creeks of Indian coast have received meager attention. The review further highlighted that except Rao and Rao (1976a) who studied the living foraminifera from a tidal creek at Pudimadaka near Visakhapattanam, Rao and Rao (1976b) of Dummulapeta Creek, of East Coast of India, Setty (1982) and Setty and Nigam (1984) who studied foraminifera for pollution effect in Thane Creek, Bombay and Nigam and Chaturvedi (2000) of Kharo Creek of Kachchh, no other attempt has so far been made to study foraminifera from other creeks of east and west coasts of India. In view of this, out of many creeks in this region, an attempt has been made to study the Kharo Creek of Kachchh for their foraminiferal components.

This study assumes significance as a cement factory is coming up along the eastern bank of Kharo Creek and the creek will be used to transport the cement through sea after a construction of a proposed jetty. The foraminiferal data generated will be useful as a base line data to assess the future impact of industrial pollution.

ENVIRONMENTAL CONDITIONS WITHIN THE CREEK

According to coastline division of Gujarat, the study area falls under Jakhau-Kandla segment of coastline and is classified into high wave energy with moderate to high tide (3-8m) (Merh, 1995). This

area is categorized into semiarid regions of subtropical climatic zone with low rain fall (annual rainfall <300 mm). The creek is trending into NE-SW direction. Average dissolved oxygen of bottom water layer varies from 4.52 ml/l to 4.77 ml/l, salinity from 37.13‰ to 38.04 ‰ suspended load from 71.93 mg/l to 104.281 mg/l, and Organic Carbon (%C) of sediments from 0.166 to 0.299 (Anon, 1996).

MATERIALS AND METHODS

A total of seven sediment samples, collected from the Kharo Creek at depth of 4.4 m to 13.4 m (Fig. 5) were utilized in the present study. The samples were collected with a Van Veen grab, the top 1-centimeter was separated from each sample and fauna was preserved in a 10% buffered formaline solution and stained with rose bengal for recognition of living individuals. In the laboratory, all samples were washed and oven dried at 60°C. From the washed and weighed residue, around 100 - 250 specimens of foraminifera were obtained due to low specimen densities. The total foraminiferal numbers were then standardized to 1 gram to study relative abundance. The foraminifera from each samples were classified into two group, viz., planktic and benthic foraminifera. Following the morphological criteria (Severin, 1983; Nigam and Khare, 1994a; 1999 and Jayaraju and Reddi, 1997) benthic foraminifera were classified into angular-asymmetrical and rounded-symmetrical morphogroups and their percentages were computed for each sample. In order to have record of occurrences, all the specimens were identified upto species level. Number of reworked and living specimens were also counted in each samples (Table 1). Each sediment sample was analyzed for grain size (Table 2) using standard method provided by Shepard (1954). Unpublished data of salinity, temperature, organic carbon, suspended load and dissolved oxygen were provided by A.C. Anil (personal communication) for four stations (Table 3). Of the seven samples analyzed for

sediment grain size from the Kharo Creek, five samples are sand while one each is silty sand and sand-silt-clay.

RESULTS AND DISCUSSION

In order to understand the relative abundance of foraminifera in the study area, the total foraminiferal number (TFN) in one gram (>63µm size fraction) of dry sediments were calculated. The TFN in the creek fluctuated between 69 (sample 24) and 289 (sample 21) specimens (Table 1). Foraminiferal population within the creek is mainly composed of benthic foraminifera (94-100%). The study also recorded the presence of reworked fauna. The study revealed the presence of forty seven species of which forty four are benthic and three are planktic. Out of these, seven species are found in living state. The forty seven species of foraminifera recorded in the creek belong to twenty eight genera and ten families (Appendix-1). To study the relationship of foraminifera with substrate, size analysis of the sediment samples were performed and results are presented in Table 2. Most of the stations have sandy substrate. Sample 23 shows silty sand and sample 22 as sand-silt-clay textures.

To study the ecology of foraminifera, average half-yearly data of salinity, temperature, suspended load, dissolved oxygen for bottom water, and organic carbon of sediments for selected stations are taken from the report (Anon, 1996) and presented in Table 3.

Living Foraminifera

In general, living foraminifera are few in number. The highest percentage (Table 1) was noticed in sample no. 22 where clay percentage is found to be maximum (20.2%) (Table 2) and completely absent in sample no. 25 where sand fraction is highest (94.1 %). Boltovskoy and Wright (1976) after examining many (some time contradictory) reports on relationship between

Table 1. Distribution of Foraminifera in the Creek

Sample no.	Total no. of Foraminifera in One Gram	% of Total Benthic Foraminifera	% of Angular-Asymmetrical Forms of Benthic Foraminifera	% of Reworked Foraminifera	% of Living Foraminifera
21	289	98.85	Q.87	0	1.53
22	115	94.2	5.2	0	5
23	82	98.7	2.5	12	0.63
24	69	97.2	1.9	1.8	1.83
25	77	100	0	8.6	0
26	128	98.6	2.7	2.7	2.03
27	89	98.6	2.16	61	1.36

Table 2. Distribution of Sediment Texture in the Creek

Sample No.	Depth (m)	Sand %	Silt %	Clay %	Sediment texture
21	4.7	91.7	4.2	4.1	Sand
22	9.6	42.2	37.6	20.2	Sand-silt-clay
23	13.9	54.4	30.4	15.2	Silty sand
24	4.4	90.7	5.8	3.5	Sand
25	7.8	94.1	4.3	1.6	Sand
26	10.2	87.3	9.4	3.3	Sand
27	10.7	79.8	12.3	7.9	Sand

Table 3. Environmental Parameters in the Creek

Sample no.	Salinity %	Temperature °C	Suspended Load mg/l	Organic Carbon (%C) in sediments	Dissolved Oxygen ml/l
21	38.04	22.80	71.930	0.299	4.62
23	37.50	23.20	104.281	0.224	4.52
25	37.13	23.70	86.510	0.276	4.70
27	37.37	24.66	92.690	0.166	4.77

substrate and foraminifera stated "Although the correlation are not very good, the bulk of the observations suggest that fine sand mixed with some shelly fragments and silt or clay support the richest standing crop of foraminifera". Our results are in

agreement with this observation.

Out of total fortyseven species of foraminifera, seven are found to be in living state (Appendix-1). None of the living species (like

species belonging to Textulariidae) is agglutinated which shows the absence of hyposaline condition. Salinity reported in this area is $>37\text{‰}$ (Table 3). Murray (1991), reported the substrate preference of various species and according to him *Ammonia* prefers muddy sand, *Bolivina* and *Bulimina* mud to fine sand and *Nonion* mud and silt. These observations on preferences of substrate of various fauna, coupled with higher salinity conditions, explain for the occurrence of most of the living species in the study area. The high concentration of suspended matter and high tidal water influx are the factors responsible for the poor assemblage of living foraminiferal fauna in study area.

Reworked Foraminifera

In the study area, reworked foraminifera are also recorded. The reworked specimens are found more in samples 23, 25 and 27, less in 24 and 26 and absent in samples 21 and 22. The reworked specimens mostly belong to *Pararotalia*, *Quinqueloculina*, *Triloculina*, *Amphistegina*, *Elphidium*, *Textularia* and *Ammonia*. These reworked foraminifera are earthy colored, highly polished, badly abraded and typical of high-energy environment. These reworked specimens, similar to modern assemblages, are indicative of transport from near shore shallow depths and/or mixing due to winnowing associated with high-energy environment.

Boltovskoy and Wright (1976) have reported that the quantity of living specimen is adversely affected in the area of rapid water movement (tidal zone). In general the high concentration of living foraminifera and complete absence of reworked specimens in narrow upper reaches of the creek may be attributed due to low turbidity. Less living fauna and highest concentration of reworked specimens in broad middle, and their moderate presence in lower reaches of the creek may be due to high turbid and inhospitable conditions along with other ecological variables like sediment texture.

Total Foraminiferal Number (TFN)

The relatively higher abundance of foraminifera is found in samples 21, 22 and 26, whereas lower abundance is found in samples 23, 24, and 25 (Table 1). When the total foraminiferal population was further separated into benthic and planktic communities, it was noticed that benthic form varied from 94.2 to 100 %. The highest abundance of total foraminifera in sample 21 may be attributed due to various factors like higher salinity value and less tidal influence, as this part of the creek mostly remains cut off from the sea water influx and the stagnant sea water is exposed to evaporation leading to increasing salinity (38.04 ‰).

It seems, that the tidal influence is an important factor in the distribution of overall foraminiferal population. The high tide (~5 m) in the creek may be one of the reasons for gradual decreasing trend in foraminiferal population from upstream to marginal marine side. The upstream area (i.e., stations 21 and 22) are least affected by sea water influx whereas the middle part of the creek is directly under the influence of rapid tides causing intense agitation of sea water and make the area highly turbulent and force the foraminifera to uproot from their inhabitant resulting inhospitable place for their population. The lower stream seems to merely act as a passage for the tidal water flow in the creek and therefore less affected as compared to middle stream. The effect of tides on foraminifera have also been reported by other workers in vicinity of this region (Nigam, 1984). Earlier researchers have explained that turbulence controls the distribution of various morphogroups of foraminifera in modern sediments (Severin, 1983; Nigam and Khare, 1994a; 1994b and, Jayaraju and Reddi, 1997). These studies indicate that the angular-asymmetrical form could be taken as an indicator of quiescent environment whereas rounded symmetrical form may be considered as indicator of turbulent environment. In the study area, the overall abundance of rounded-symmetrical form (Table 1) confirms the above observations.

Generic Distribution

Among the total foraminifera, dominant families are Rotaliidae and Anomaliniidae. The distribution patterns of dominant and common genera are shown in Fig. 1. The most abundant genera are *Cibicides*, *Rotalidium* and *Eponides* (maximum abundance > 10%). *Ammonia*, *Pararotalia*, *Nonion*, *Elphidium* and *Quinqueloculina* are the common (maximum abundance ~ 15%) genera occur in many sample. Among all these genera the distribution pattern of *Rotalidium*, *Ammonia* and *Pararotalia* shows an increasing trend from upstream to down stream while *Cibicides* and *Eponides* show reverse trend. *Quinqueloculina* is insignificant in many samples except in sample 25 where its maximum abundance (~9%) is recorded. *Elphidium* and *Nonion* do not show any clear trend (Fig. 1).

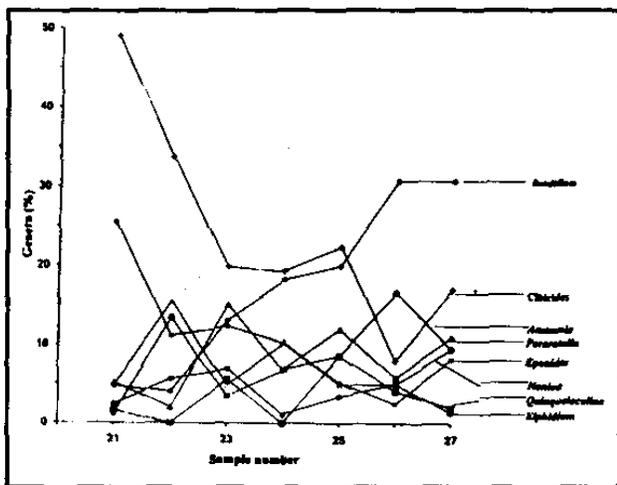


Fig. 1. Distribution pattern of dominant and common foraminiferal genera in creek.

All these genera belong to the rounded symmetrical morphogroup and represent the overall high-energy environment as they could withstand the high-energy environment due to their low surface area. However, within this high-energy environment their ecological preference of each species is different.

FORAMINIFERAL ECOLOGY

The ecological data for certain parameters

of few stations are available (Table 3) (Anon, 1996). Therefore, an attempt is made here to study the relationship of total organic carbon (TOC) in bottom sediments, the nature of substrate (texture) and suspended load (Table 3) with total benthic foraminiferal population.

Organic Carbon

The study reveals that total organic carbon of the bottom sediments is directly proportional to the total benthic foraminifera (Fig. 2). Increased foraminiferal population in the region of high organic carbon contents were also reported by Setty and Nigam (1982) from the Gulf of Kachchh and Lehmann (1957) from Metagrada Bay (Texas). These observations are also in agreement with Phleger (1960) who noted a bloom in the foraminiferal population in sediment containing a great quantity of organic material. Similarly, Seiglie (1970) while studying the foraminifera in Yabcreoa Bay (Puerto Rico), noticed that wherever the organic content of the substrate was higher, an increased population of foraminifera was recovered.

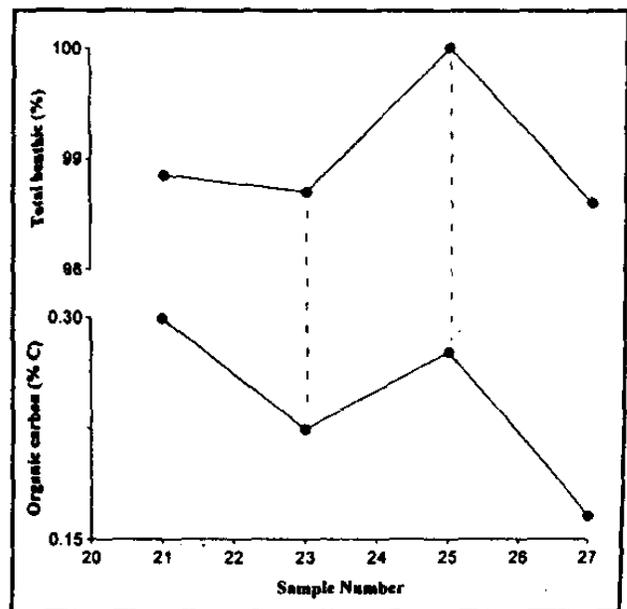


Fig. 2. Relationship between total benthic foraminifera and organic carbon.

Suspended Load

Fig. 3 shows that the distribution of suspended load is inversely proportional to the distribution of total benthic foraminifera. This observation is in concurrence with Nigam (1984) who after studying the Gulf of Khambhat has reported that the high concentration of suspended matter is one of the major factors responsible for the poor assemblage of foraminiferal fauna. Frerichs (1970), after examining the Andaman Sea, found that the water in the Gulf of Martaban is extremely turbid that affects the faunal composition significantly. He suggested that low to absent foraminiferal specimen at the mouth of the gulf is due to intense turbidity that makes the condition intolerable for foraminifers. Anomalous benthic foraminiferal distribution pattern of the Cameron Coast (Africa) was attributed to the influence of turbid river water which increased the amount of suspended material in water (Berthois et al, 1968).

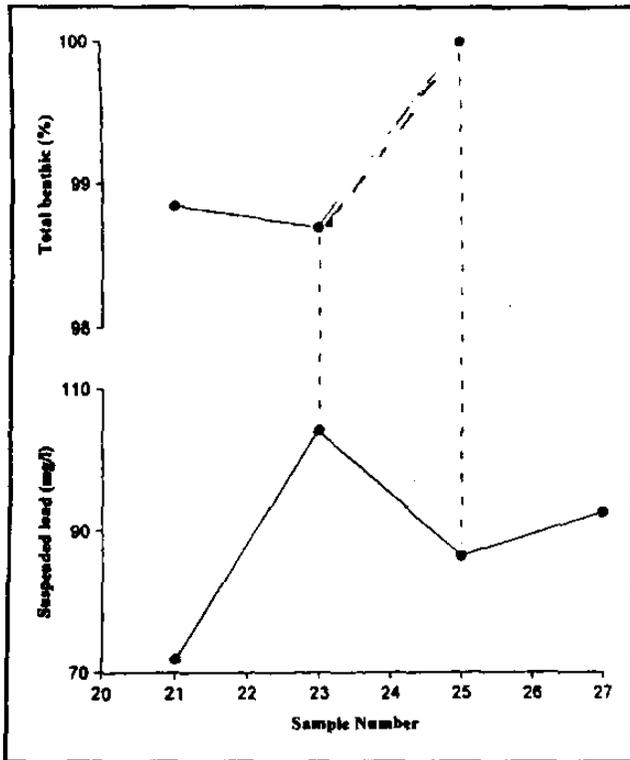


Fig. 3. Relationship between suspended load and total benthic foraminifera percentage.

Nature of Substratum

The effect of substratum on foraminiferal population has been studied in detail by Nigam and Chaturvedi (2000). The results indicate that sandy substratum provides favourable condition for benthic foraminifera to increase the population (Fig. 4). Earlier studies have also noted that there is a direct relation between foraminiferal number and median diameter of the sediment of the Red Sea (Said, 1950).

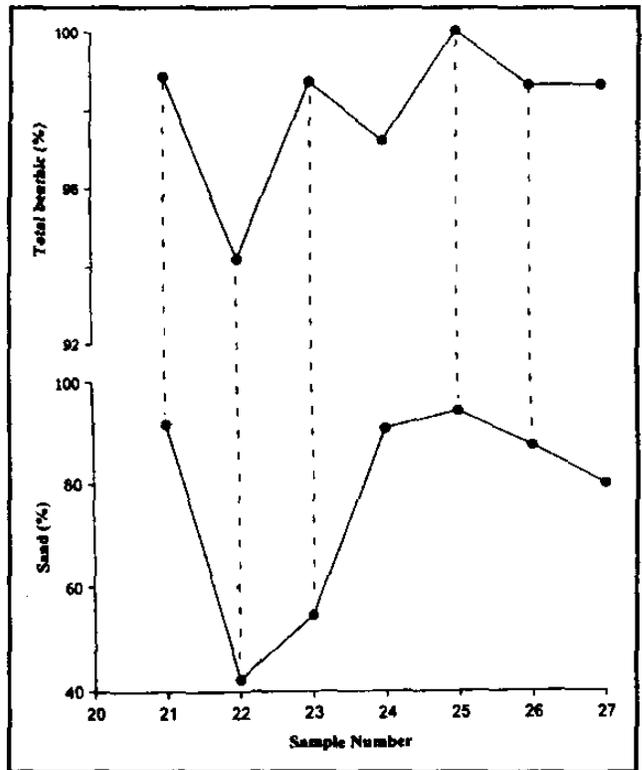


Fig. 4. Relationship between sand percentage and total benthic foraminifera percentage.

The other noticeable point observed in the creek is a clear relationship between sediment nature and the morphology of foraminifera (Tables 1 and 2). Results showed a positive correlation value between angular-asymmetrical morphogroup and clay percentage in sediments [$r = +0.82$, which is above the level of significance ($r = 0.7887$) at 98% confidence level]. The presence of relatively high angular-asymmetrical tests at some stations in creek indicates localized quiescent environment within the

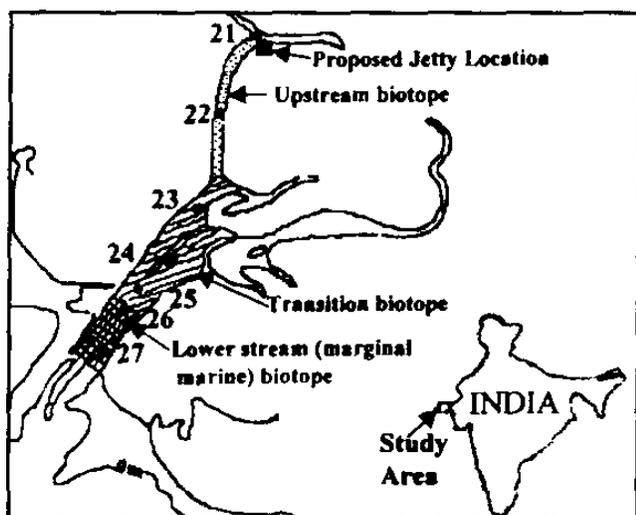


Fig. 5. Sample location and biotopes in the creek.

general high environmental setup. At these stations increased clay percentage alongwith high living specimens and low reworked foraminifera also indicate similar environment

SUMMARY OF SPATIAL DISTRIBUTION OF FORAMINIFERA IN THE CREEK

On the basis of foraminiferal components (such as total foraminiferal number, living foraminifera and reworked foraminiferal specimen) and ecological variables (like salinity, temperature,

suspended load and dissolved oxygen of bottom water and organic carbon of sediments) at different stations, creek environment can be divided into three biotopes, viz., *upstream biotope*; *lower stream (marginal marine) biotope* and *transition biotope* (Table 4, Fig. 5). Similar observations have been made in the Marianichi estuary, New Burnswick where the mean total foraminiferal population was most abundant in upper estuarine the next most productive area was the marginal marine biotope and least abundant in the transitional biotope (Schafer et al., 1977).

IMPLICATIONS IN POLLUTION MONITORING

Pollution is a phenomenon that is always associated with more and more industrilization to attain fast economic growth. Sea is the ultimate home for waste of most industries in general and coastal area in particular. The massive pollution causes the fall in live product of sea (like fishes) and thus negatively compensates some of the benefits of industrilization. Therefore, there is a worldwide awareness to control pollution for which detection/monitoring is the first step. Foraminifera cannot remain insensitive to environmental deterioration.

Table 4. Three Biotopes in the Creek

Biotope	Foraminiferal Characteristics	Ecological Characteristics
Upper stream	High total foraminiferal number, absent reworked specimens, highest living specimens and abundant genera of <i>Cibicides</i> and <i>Eponides</i> .	High salinity, low suspended load, high organic carbon and moderate dissolved oxygen.
Transitional	Low total foraminiferal number, highest reworked specimens, low living specimens and abundant genera of <i>Ammonia</i> , and <i>Pararotalia</i> .	Low salinity, high suspended load, moderate organic carbon (except station 25) and moderate dissolved oxygen.
Lower stream (marginal marine)	Moderate total foraminiferal number, high reworked specimens, moderate living specimens and abundant genera of <i>Rotalidium</i> and <i>Ammonia</i> .	High salinity, low suspended load, lowest organic carbon and high dissolved oxygen.

Appendix 1. List of Total Foraminiferal Species Recorded in Kharo Creek, Kachchh. Species Found in Living State are Markd With*

1. * <i>Ammonia sobrina</i> (Shupack)	24. <i>Lagena punctulata</i> Sidebottom
2. * <i>Ammonia tepida</i> (Cushman)	25. <i>Noniom depressulum</i> (Walker and Jacob)
3. <i>Asterorotalia dentata</i> (Parker and Jones)	26. <i>Nonion incisum</i> (Cushman)
4. <i>Asterorotalia inflata</i> (Millet)	27. " <i>Nonionoides elongatum</i> (d' Orbigny)
5. <i>Bolivina kuriani</i> Seibold,	28. <i>Pararotalia calcar</i> (d' Orbigny)
6. <i>Bolivina limbatum</i> Brady	29. <i>Poroeponides lateralis</i> (Terquem)
7. <i>Bolivina variabilis</i> Williamson	30. <i>Pseudoeponides equatoriana</i> Leroy
8. * <i>Brizalina siriatala</i> (Cushman)	31. <i>Quinqueloculina laevigata</i> d' Orbigny
9. * <i>Bulimina exilis</i> (Brady)	32. <i>Quinqueloculina seminulum</i> (Linne)
10. * <i>Bulimina marginata</i> d' Orbigny	33. <i>Quinqueloculina aff. Q. undulosa costata</i> (Terquem)
11. <i>Cancris auaricula</i> (Fichtel and Moll)	34. <i>Quinqueloculina venusta</i> Karrer
12. <i>Cibicides lobatulus</i> (Walker and Jacob)	35. <i>Rotalidium annectens</i> (Parker and Jones)
13. <i>Cibicides refulgens</i> Montfort	36. <i>Reuse!la pacifica</i> Cushman and MuCulloch
14. <i>Elphidium advenum</i> (Cushman)	37. <i>Rosalina bradyi</i> (Cushman)
15. <i>Elphidium articulatum</i> (d'Orbigny)	38. " <i>Rosalinafloridana</i> (Cushman)
16. <i>Elphidium crispum</i> (Linne')	39. <i>Spiroloculina aequa</i> (Cushman)
17. <i>Elphidium discoideale</i> (d' Orbigny)	40. <i>Spiroloculina communis</i> Cushman and Todd
18. <i>Elphidium discoideale multiloculatum</i> (Cushman and Ellisor)	41. <i>Spiroloculina depressa</i> d' Orbigny
19. <i>Elphidium simplex</i> Cushman	42. <i>Textularia conica</i> d' Orbigny
20. <i>Eponides repandus</i> (Fichtel and Moll)	43. <i>Textularia earlandi</i> Parker
21. <i>Globigerina bulloids</i> d' Orbigny	44. <i>Trifarina bradyi</i> Cushman
22. <i>Globigerinoides ruber</i> (d' Orbigny)	45. <i>Triloculina trigonula</i> (Lamarck)
23. <i>Globorotalia tumida</i> (Brady)	46. <i>Uvigerina auberiana</i> d' Orbigny
	47. <i>Virgulinema pertusa</i> Reuss

Because of the numerous merits, researchers have used benthic foraminifera as good indices in assessing the effect of pollution in the marine environment since last few decades (Schafer, 1970; Nagy and Alve, 1987; Sharifi et al., 1991 and Yanko et al., 1994). In India, many workers have published papers showing the utility of foraminifera in pollution studies (Banerjee, 1974; 1989; Setty, 1976; Setty and Nigam, 1984; Naidu et al., 1985; Bhalla and Nigam, 1986, Madabhusi, 1989; Jayaraju and Reddi, 1996, Rao and Rao, 1976b, etc.). However most of the

workers either used the known sites where pollution effects were established by other methods and foraminiferal studies were carried out to established utility of foraminifera also. Recently, Nigam et al. (1998) have shown that how foraminiferal distribution studies with time gap (~2 decades) from the same site can establish the existence of mining pollution. However, in many areas, previous records (pre pollution) are not available thus, limiting the application of this approach.

In Kharo Creek area, Sanghi Cement Industries is establishing its cement factory and they proposed to construct a jetty also on the bank of the creek which will be used to transport the cement through sea (Fig. 5). This industrial activity may (or may not) pollute the marine environment, which is hitherto very clean. If so, the data generated through present study will provide the base line data over which adverse effect of pollution can be assessed by comparing the present pre factory data with post factory data set after few years.

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