

Foraminiferal study from Kharo creek, Kachchh (Gujarat), north west coast of India

R Nigam & S K Chaturvedi

National Institute of Oceanography, Dona Paula, Goa - 403 004, India

Received 13 November 1998, revised 22 February 2000

A total of seven surface sediment samples collected within 4 to 13.5 m water depth below chart datum from Kharo creek were studied for their foraminiferal content. The study revealed 47 foraminiferal species of which 44 were benthic and 3 planktonic. Out of these, 7 benthic species were the living ones. The fauna showed a positive relationship between angular-asymmetrical form and clay fraction in the sediments. The dominant rounded-symmetrical form of benthic foraminifera exhibit high energy environment. However, relatively high clay, asymmetrical form, living foraminifera and absence of re-worked foraminifera at certain stations in the creek showed presence of quiescent microenvironment. This first report of foraminifera from any creek of Kachchh area will also serve as a baseline data to assess the future impact of industrial pollution (if any) as a jetty for offloading cement is being constructed in Kharo creek for proposed cement plant which is coming up in this area.

Creeks along with estuaries are integral part of marine environment and subjected to extensive faunal and floral studies. Recent foraminifera from creeks and estuaries along Indian coastline have been studied by several workers¹⁻⁶, but the northern part of west coast of India particularly Kachchh remained practically untouched. Even offshore area of Kachchh received meagre attention and covered by only two core top samples in studies by Rao⁷ on foraminifera from northern Arabian Sea.

The objective of the present study was to document the distribution of foraminiferal assemblages from the Kharo creek, Kachchh (Fig. 1). Out of many creeks in this region Kharo was selected because a cement factory is coming up along this bank and the creek will be used to transport the cement through sea after construction of a jetty. The data generated will be used as baseline study to monitor pollution (if any) through the adverse effect of same on foraminifera in this region.

Materials and Methods

The study area falls under Jakhau-Kandla segment of Gujarat coastline and characterized by high wave energy with moderate to high tide⁸ (3-8m). This area is categorized into arid region of subtropical climatic zone with low rain fall (< 250 mm/annum). The rivers are non-perennial and carry very little water even during the rainy season and over all does not affect the salinity in the creek. The Kharo creek is trending in NE-SW direction. Average particulate organic

content of bottom water layer varies from 1924 to 2557.16 µg/l, dissolved oxygen from 4.52 to 4.778 ml/l, salinity from 37.13 to 38.04‰, suspended load from 71.93 to 104.281 mg/l, and organic carbon (%C) of sediments⁹ from 0.166 to 0.299. In Kharo creek the tide is as high as over 5 m.

A total of seven sediment samples, collected in December 1994 from the Kharo creek within water

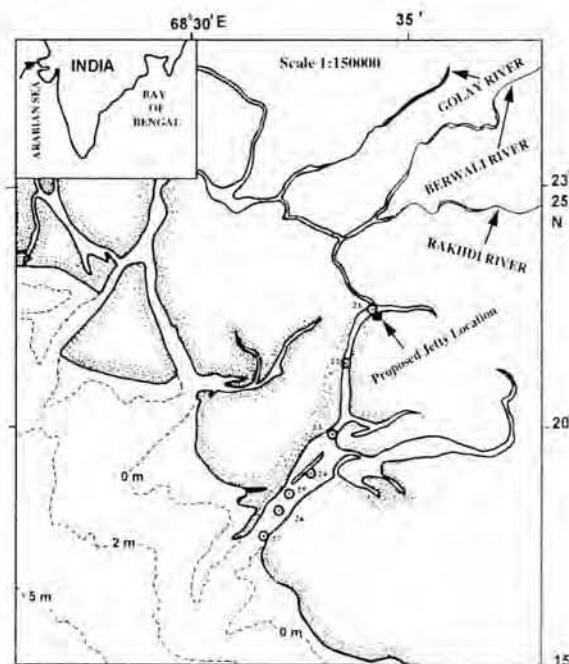


Fig. 1—Location of samples

depth of 4 to 13.5 m below chart datum (Fig. 1) were utilized in the present study. The samples were collected with a van Veen grab, the top 1 cm was separated from each sample and fauna were preserved in a 10% buffered formaline solution and stained with Rose Bengal for recognition of living individuals¹⁰. In the laboratory all samples were washed and oven dried at 60°C. From the washed and weighed residue about 300 foraminiferal specimens were picked and number of foraminiferal specimens per species per samples were calculated. The total foraminiferal number (TFN) were then standardized to 1 g to study relative abundance. The foraminifera from each sample were first separated into two groups viz. planktonic and benthic foraminifera. Following the morphological criteria¹¹⁻¹³ benthic foraminifera were classified into angular-asymmetrical and rounded-symmetrical morphogroup and their percentages were computed for each sample. In order to have record of occurrences all the specimen were identified up to species level. Number of reworked foraminifera and living foraminifera were also counted in each sample.

Each sediment sample was analyzed for grain size using standard method. Of the seven samples analyzed for sediment grain size from the Khari creek five samples were sand while other were silty sand and sand-silt-clay¹⁴. Correlation values were calculated through standard MSoffice of Microsoft excel program and level of significance was computed¹⁵.

Results and Discussion

Foraminiferal populations within the creek were mainly composed of benthic foraminifera (94-100%). The total foraminiferal number (TFN) in one gram of dry sediment (>63 µ) fluctuated between 69 (station 24) and 289 (station 21) specimen (Table 1). The

study revealed the presence of 47 species of which 44 were benthic and 3 planktic. The foraminiferal species recorded (in alphabetical order) were - *Ammonia sobrina*, *A. tepida*, *Asterorotalia dentata*, *A. inflata*, *Bolivina kuriani*, *B. limbatum*, *B. variabilis*, *Brizalina striatula*, *Bulimina exilis*, *B. marginata*, *Cancris auaricula*, *Cibicides lobatulus*, *C. refulgens*, *Elphidium advenum*, *E. craticulatum*, *E. crispum*, *E. discoidale*, *E. discoidale multiloculatum*, *E. simplex*, *Eponides* spp., *Globigerina bulloides*, *Globigerinoides ruber*, *Globorotalia menardii*, *Lagena* spp., *Nonion depressulum*, *N. incisum*, *Nonionoides elongatum*, *Pararotalia calcar*, *Poroeponides lateralis*, *Pseudoeponides equatoriana*, *Quinqueloculina laevigata*, *Q. seminulum*, *Quinqueloculina aff. Q. undulosa costata*, *Q. venusta*, *Rotalidium annectens*, *Reusella pacifica*, *Rosalina bradyi*, *R. leei*, *Spiroloculina aequa*, *S. communis*, *S. depressa*, *Textularia conica*, *T. earlandi*, *Trifarina bradyi*, *Triloculina* spp., *Uvigerina auheriana* and *Virgulinitella pertusa*. Out of these, 7 species were living. The percentage of angular-asymmetrical and rounded-symmetrical form of benthic foraminifera are given in Table 1. The results of sediment texture is given in Table 2.

Living foraminifera

In general living foraminifera were few in number (Table 1). The highest percentage was noticed in sample no. 22 where clay percentage was found to be maximum (20.2%) and completely absent in sample no. 25 where sand fraction was highest (94.1%). Thus our results are in agreement with Boltovskoy & Wright¹⁶ who after examining many (some time contradictory) reports on relationship between substrate and foraminifera stated that.—“Although the correlations are not very good, the bulk of the observations suggest that fine sand mixed with some

Table 1—Total foraminifera in one gram, percentage of rounded-symmetrical and angular-asymmetrical form of benthic foraminifera and reworked specimens of foraminifera in different samples

Sample no.	Depth (m)	Total foraminifera (no/1g)	Benthic foraminifera		Reworked Specimens in total fauna (%)	Living Specimens in total fauna (%)
			Rounded-symmetrical form (%)	Angular asymmetrical form (%)		
21	4.7	289			00	1.53
22	9.6	215			00	5
23	13.5	82			12	0.63
24	4.4	69	98.1	1.9	1.8	1.83
25	7.8	77	100	00	8.6	00
26	10.2	128	97.3	2.7	2.7	2.03
27	10.7	89	97.9	2.1	6.1	1.36

shelly fragments and silt or clay support the richest standing crop of foraminifera".

Out of total 47 species of foraminifera recorded 7 were found to be in living state viz. *Ammonia sobrina*, *A. tepida*, *Rosalina leei*, *Brizalina striatula*, *Bulimina exilis*, *B. marginata* and *Nonionoides elongatum*.

None of the living species (like Textulariidae) was agglutinated which indicates the absence of hyposaline condition. Salinity in this area⁹ was about 37‰. Murray¹⁷ 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 respectively. 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.

Reworked foraminifera

In the study area reworked foraminifera were also recorded (Table 1). The reworked specimens were found more in sample nos 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 were earthy coloured, highly polished and severely abraded and typical of high energy environment. These reworked specimens similar to modern assemblages were indicative of transport from nearshore shallow depths and/or mixing due to winnowing associated with high energy environment. It was noted that high tidal currents, high concentration of suspended matter and the high tidal water influx are the factors responsible for the poor assemblage of living foraminiferal fauna. In Nizamapatnam Bay also the reworked foraminifera in non depositional environment were encountered¹⁸. Boltvosky & Wright¹⁶ 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 low concentration of reworked specimen in narrow upper reaches of creek may be attributed due to low turbidity and, less living fauna and high concentration of reworked specimens in broad middle and lower reaches of the creek may be due to high turbidity and inhospitable conditions besides other ecological variables like sediment texture.

Total foraminifera

The study of foraminifera revealed a total number of 47 species belonging to 28 genera and 10 families.

Table 2—Percentage distribution of sediment grain size in different samples

Sample no.	Sand (%)	Silt (%)	Clay (%)	Sediment texture
21	91.7	4.2	4	Sand
22	42.2	37.6	20.2	Sand-silt-clay
23	54.4	30.4	15.2	Silty sand
24	90.7	5.8	3.5	Sand
25	94.1	4.3	1.6	Sand
26	87.3	9.4	3.3	Sand
27	79.8	12.3	7.9	Sand

Among the total foraminifera, dominant families were Rotaliidae and Anomaliniidae. The most abundant genera were *Cibicides*, *Rotalidium*, *Eponides*, *Ammonia*, *Pararotalia* and *Nonion*. *Elphidium* and *Quinqueloculina* were the common genera occur in many samples. Among all these genera *Rotalidium* showed an increasing trend from upstream to downstream while *Cibicides* and *Eponides* showed reverse trend. *Quinqueloculina* was insignificant in many samples except in sample no. 25 where its maximum abundance (~9%) was recorded. *Elphidium* was abundant in inner part of the 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 was different. For example, *Ammonia* is infaunal, free and prefers fine sediment in brackish to hypersaline environment., *Rotalidium*, a common species along the west coast of India, is epifaunal with thick shell and prefers sandy substratum with high salinity and high temperature., *Eponides* is free or clinging, epifaunal, prefers sediment or hard substratum, *Quinqueloculina* is epifaunal, free or clinging, occurs in shelf with marine to hypersaline water, while *Cibicides* is planoconvex, sessile epifaunal and prefers hard substratum to attach themselves besides other ecological conditions like many other species. The distribution pattern of abundant and common genera is shown in Fig. 2.

The noticeable thing observed was a clear relationship between sediment nature and the morphology of foraminifera (Tables 1,2). Figure 3 shows the direct relationship between angular-asymmetrical morphogroup and clay percentage in sediments. Results show a positive correlation value ($r=+0.82$) which is above the level of significance ($r= 0.7887$) at 98% confidence level. Severin¹¹ by

reanalyzing the Phleger's¹⁹ data observed that on the basis of the external test morphologies species count data can be classified into a few morphogroups. He explained that sediment turbulence controls the distribution of various morphogroups of foraminifera in modern sediments. Attempts were made to establish relationship between the external test morphology of foraminifera and energy condition, depth, monsoonal discharge etc.^{12,13,20-27}. 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 present study area the overall abundance of rounded-symmetrical form indicates a high energy condition. However within this general environmental setup, at some stations where angular asymmetrical tests are relatively high may indicate rather quiescent microenvironment. At these stations increased clay percentage also indicates the similar environment.

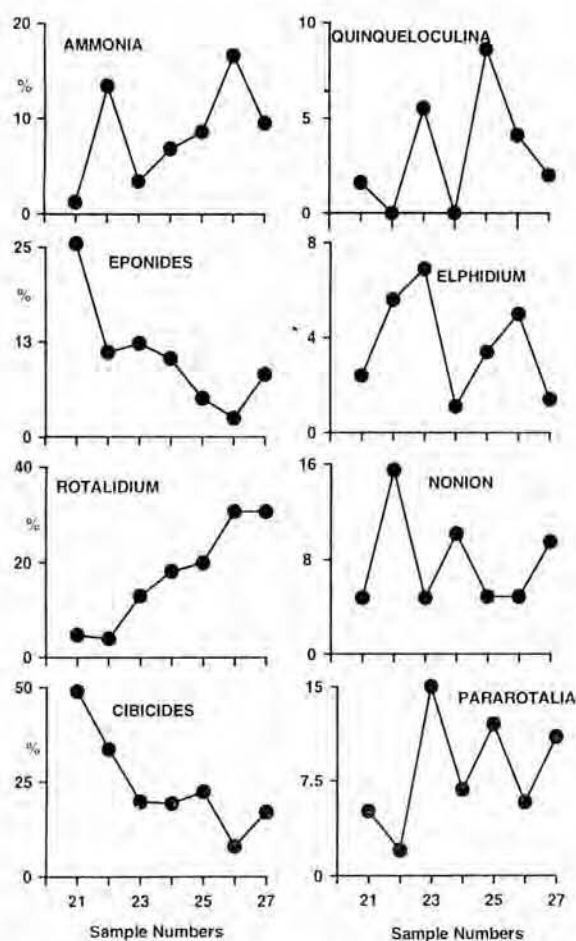


Fig. 2 - Distribution pattern of dominant and common foraminiferal genera in the creek.

The station marked by higher percentage of angular asymmetrical form also shows high living specimens and low reworked foraminifera. It is noticed by many workers that high energy conditions disrupt the sediment, which destroy the feeding [pseudopodial] net of foraminifera²⁸ and can adversely affect the quantity of living specimen in the area of rapid movement¹⁶. Nigam & Setty²⁹ reported 42 species of reworked foraminifera in Gulf of Khambhat where living foraminifera are absent³⁰.

In view of the foregoing it is summarized that overall abundance of rounded-symmetrical morphogroup indicates high energy condition in the study area. However, certain stations with high angular asymmetrical form, high living specimens and absence/rare presence of reworked specimens shows microenvironment with relatively quiescent conditions. It is also visualized that tidal movement (~5m) in Kharo creek may be one of the strong reasons for prevailing foraminiferal population. The upstream area is less affected with seawater influx whereas middle part of the creek is directly under the influence of rapid tide causing intense agitation of seawater that make the area highly turbulent and force the foraminifera to uproot from the 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 less affected compared to middle stream.

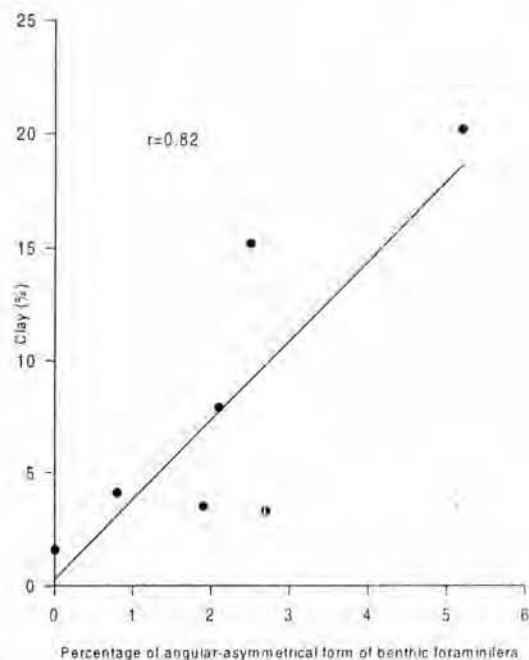


Fig. 3—Relationship between angular-asymmetrical form and clay percentage

Future significance of the study

Being very sensitive to environmental changes, foraminifera has been used to monitor marine pollution worldwide³¹. In India too number of reports showed the utility of foraminifera in pollution studies^{2,5,32-39}. 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 establish utility of foraminifera also. Recently, Naik³⁹ has shown that how foraminiferal distribution studies with time gap from the same site can establish the existence of pollution.

In Kharo creek area, M/s Sanghi Cement Industries is establishing its cement factory and they are constructing a jetty also (Fig. 1). This industrial activity may pollute the marine environment which is hitherto very clean. If so, present study will provide the baseline data over which adverse effect of pollution can be assessed by comparing the present pre industry data with post industry data set after few years.

Acknowledgement

The authors express their gratitude to Dr. E. Desa, Director, NIO, Goa for supporting this work. Thanks are due to Dr. A.C. Anil for providing the unpublished environmental data. The kind support of Dr. N.H. Hashimi, Dr. N. Khare, Mr. M. C. Pathak, Dr. A.K. Chaubey, Mr. K. L. Kotnala and other colleagues during field work is highly acknowledged. Samples for this study were collected as part of sponsored project for M/s Sanghi Cements. The financial assistance was provided by Department of Ocean Development vide their grant No. DOD/12-MMDP/2/95-OD-II.

References

- 1 Rao K K, Ecology of Mandovi and Zuari estuaries, Goa: Distribution of foraminiferal assemblages. *Indian J Mar Sci*, 3 (1974) 61-66.
- 2 Rao T V & Rao M S, The living foraminifera of Dummulpeta creek, east coast of India. *J Geol Soc India*, 17 (1976) 291-307.
- 3 Reddy A N & Reddy K R, Recent benthic foraminifera from the Araniar river estuary, Tamil Nadu, India. *Indian J Mar Sci*, 11 (1982) 249-250.
- 4 Setty M G A P, Pollution effects monitoring with foraminifera as indices in Thane creek, Bombay area. *Intern. J. Environmental Studies*, 18 (1982) 205-209.
- 5 Setty M G A P & Nigam R, Foraminifera as indicator of pollution in the marine environment on the west coast of India. *Revista Italiana de Paleontologia Milano*, 89 (1984) 421-436.
- 6 Naidu T Y, Kamalakaran S, Rao V B & Kaladhar R, Living foraminiferal diversity in marginal water bodies, east coast of India. *J Paleo Soc India*, 35 (1990) 33.
- 7 Rao K K, On some foraminifera from the north eastern part of the Arabian Sea. *Proc Indian Acad Sci*, 73 (1971) 155-178.
- 8 Merh S S, *Geology of Gujarat*, (Geol Soc India, Bangalore), 1995, pp.222.
- 9 Anon, Environmental baseline data and preliminary observations on marine corrosion and biofouling of Kharo creek. Kachchh, Project Report No. NIO/SP-3/96, (National Institute of Oceanography, Goa, India) 1996, pp.26.
- 10 Walton W R, Techniques for recognition of living foraminifera. *Cushman Found Foram Res*, 3 (1952) 56-60.
- 11 Severin K P, Test morphology of benthic foraminifera as a discriminator of bio facies. *Mar Micropal*, 8 (1983) 65-76.
- 12 Nigam R & Khare N, Effect of river discharge on the morphology of benthic foraminiferal test. *J Geol Soc India*, 43 (1994) 457-463.
- 13 Jayaraju N & Reddi K R, Effect of river discharge on the test morphology of benthic foraminifera, south east coast of India. *J Geol Soc India*, 50 (1997) 435-439.
- 14 Shepard F P, Nomenclature based on sand-silt-clay ratio. *J Sed Petrology*, 24 (1954) 151-158.
- 15 Fisher R A & Yates F, *Statistical tables for biological, agricultural and medical research*, (Oliver and Boyd, London) 1963, pp. 146.
- 16 Boltovskoy E & Wright R, *Recent foraminifera*, (Junk, The Hague) 1976, pp. 515.
- 17 Murray J W, *Ecology and paleoecology of benthic foraminifera*, (John Wiley & Sons, U.K.) 1991, pp. 397.
- 18 Rao P S, Naidu T Y & Satyanarayanan G, Distribution and factor analysis of benthic foraminifera in Nizamapattanam Bay, east coast of India. *J Geol Soc India*, 36 (1990) 163-172.
- 19 Phleger F B, Significance of living foraminiferal populations along the central Texas coast. *Contr Cushman Foram Res*, 7 (1956) 106-153.
- 20 Nigam R, Foraminifera and changing pattern of monsoon rainfall. *Curr Sci*, 64 (1993) 935-937.
- 21 Nigam R & Khare N, Oceanographic evidences of the great floods at 2000 & 1500 BC documented in archaeological records. in *New trend in Indian arts and archaeology*, Vol. 2, edited by N C Ghose & B U Nayak (Aditya Prakashan, Bangalore), 1992, pp. 517-522.
- 22 Nigam R & Khare N, Signals of change in monsoonal precipitation at around 2000 year BP in a sediment core off central west coast of India. *Curr Sci*, 66 (1994) 226-228.
- 23 Nigam R, Khare N & Borole D V, Can benthic foraminiferal morpho-groups be used as indicator of paleo monsoonal precipitation? *Estuar. Coast Shelf Sci*, 34 (1992) 533-542.
- 24 Raj R & Chamyal L S, Microfauna from a Middle Holocene terrace, lower Mahi valley, Western India. *J Paleo Soc India*, 43 (1998) 59-71.
- 25 Raj R & Chamyal L S, A note on foraminiferids from a new mahi formation, Rayaka mainland, Gujarat. *Geosci J.*, 18(1997) 123-129.
- 26 Nigam R, Khare N & Nair R R, Foraminiferal evidence of 77 year cyclicity of drought in India and its possible modulation by Gleissberg solar cycle. *J Coast Res*, 11 (1995) 1099-1107.
- 27 Khare N, Sinha R, Rai A K & Nigam R, Distributional pattern of benthic foraminifera morpho groups in the shelf region off Mangalore: Environmental implications. *Indian J Mar Sci*, 24 (1995) 162-165.
- 28 Richter G, Idem, II lebensraum und lebensweise von *Nonion depressulum* Elphidium excavatum und *E. selseyense*. *Natur u Museum* 11(1964) 421-430.
- 29 Nigam R & Setty M G A P, Paleogene reworked foraminifera in recent sediments off Daman, western India. in *Proc. 3rd*

- Indian Geological Cong.*, edited by K. B. Pawar (Indian Geological Congress, Roorkee) 1980, pp. 273-280.
- 30 Nigam R, Living benthic foraminifera in tidal environment: Gulf of Khambhat (India). *Mar Geol*, 58 (1984) 415-425.
 - 31 Schafer C T, Studies of benthic foraminifera in the Restigouche estuary: 1, Faunal distribution pattern near pollution sources. *Maritime Sediments*, 6 (1970) 121-134.
 - 32 Banerjee R K, benthic foraminifera as an aid to recognise the polluted environments. in *Proc IV Indian Colloq and Micropal Stratigr*, Dehradun edited by V. V. Sastry (ONGC, Dehradun) 1974, pp. 1-6.
 - 33 Banerjee R K, Heavy metals and benthic foraminiferal distribution along Bombay coast, India. *Studies in benthic foraminifera*, (Tokyo University Press, Tokyo) 1989, pp. 151-157.
 - 34 Setty M G A P, Relative sensitivity of benthic foraminifera in the polluted marine environment of Cola Bay, Goa. in *Proc VI Indian Colloq Micropal and Stratigr*, Varanasi, edited by M.S. Srinivasan (1976) pp. 225-234.
 - 35 Bhalla S N & Nigam R, Recent foraminifera from polluted marine environment of Velsao Island, South Goa, India. *Rev De Paleobiol*, 5 (1986) 43-46.
 - 36 Madabhushi S, Distribution of benthic foraminifera in the inner shelf off Cannanore - Calicut coast, Arabian Sea and its relation to marine pollution. in *Recent geoscientific studies in the Arabian Sea off India*, Spl Publ 24 (Geol Surv India, Calcutta) 1989, pp. 97-106.
 - 37 Naidu T Y, Rao D C & Rao M S, Foraminifera as pollution indicators in the Visakhapatnam Harbour Complex, east coast of India. *Bull Geol Mining Met Soc India*, 52 (1985) 88-96.
 - 38 Jayaraju N & Reddi K R, Impact of Pollution on coastal zone monitoring with benthic foraminifera of Tuticorin, south east coast of India. *Indian J Mar Sci*, 25 (1996) 376-378.
 - 39 Naik S S, Distribution, ecology and environmental significance of foraminifera in sediments of Mandovi estuary (Goa) with special reference to mining pollution, M.Sc. Dissertation, Goa University, India, 1998.