ISSN: 2277-9655
Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Distribution and Ecology of the Recent Benthic Foraminifera from the sediments of Adyar River, Chennai, Tamilnadu, India

M.Suresh Gandhi[*1], A.Solai[1], R.Kalaivanan[2]

[*1] Department of Geology, University of Madras, Guindy campus, Chennai -600 025, India

[2] Department of Applied Geology, University of Madras, Guindy campus, Chennai -600 025, India

surgan@yahoo.co.uk

Abstract

Micropalaeontological investigation has been carried out, for the first time to study the systematic of recent Benthic Foraminifera from the Adyar River, Chennai, Tamilnadu, India, Totally 20 sediment samples were collocted during March 2010. 46 benthic foraminiferal species belonging to 22 genus, 5 families and 3 sub orders are identified. Off which Miliolina (52%) occupies the dominant place followed by Rotallina (33%) Textularina (15%). From station no. 1 to 6 the foraminifeal species distribution shows decrease in order. The higher species are observed in the rivermouth area particularly in the sample no1. (254 species). The following species are abundantly distributed in this region namely Ammonia beccarii, Elpidiumcripsum, Spiroloculina communis and Textularia agglutinans followed by Ammobaculites exigus, Triloculina trigonula. In general the distribution of foraminifera is very low. The abundance of species in the river mount may be due to the mixing of marine and nearshore environment. All the species are illustrated with Scanning Electron Microscope Photographs. From the Zoogeographical distribution of the fauna of the study area, it is observed that the assemblage shows close affinity with the Indo- Pacific faunal Province

Keywords: Recent Benthic Foraminifera, Systematic Palaeontology, Distribution and Ecology, Adyar River, Chennai.

Introduction

Foraminifers, marine protists of mieofauna size, are extremely sensitive to the slightest change in marine environmental conditions. They have good preservation and fossilization potential and thus have been used extensively in pollution studies all over the world (Alve, 1995; Debenay et al., 2001; Geslin et al., 2002; Sharifi et al., 1991; Yanko et al., 1998), including India (Banerjee, 1974, 1989; Bhalla and Nigam, 1986; Jayaraju and Reddi, 1996; Madabhushi 1989; Naidu et al., 1985; Nigam et al., 2002; Rao and Rao, 1979; Setty, 1976; S and Nigam, 1984).

Foraminifera are found in all marine environments, they may be planktic or benthic in mode of life. Deformities in the tests of foraminifers from the polluted environments have been one of the important aspects of pollution monitoring studies utilizing foraminiferal characteristics. The effects of pollution on the foraminifers along the west coast of India is studied by Setty and Nigam (1984) who reported that the abnormalities included lower than normal ornamentation, deepening of grooves and sutural thickening, enlargement of pores, widening of apertures, erosion along peripheries and induced growth in last few chambers. In almost all the studies, dealing with this aspect of foraminifers, the variation in abundance of species and abnormalities in foraminiferal tests was attributed to the pollutants based on circumstantial evidences. This characteristic of foraminifers to incorporate the signatures of presence of pollutants and preserve them was proposed to be effective tool for temporal pollution monitoring studies. But one of the drawbacks of this work that hampered the effective application of foraminifers for pollution monitoring was the lack of availability of studies documenting presence of specific foraminiferal features from areas affected by specific pollutants and also the presence of similar foraminiferal characteristics from few naturally stressed areas (Boltovskoy et al., 1991). Therefore, the quest for more and more characteristic foraminiferal features, from polluted environments, continued with rigorous field based studies. The increasing human population along the coastal area, anthropogenic impacts on the coastal zone has become severe threat over the past few decades. Coral ecosystem also face many threats, of which some are of natural origin like storms and waves particularly

ISSN: 2277-9655
Impact Factor: 1.852

tropical storms and cyclones that cause major intermittent damage to reefs.

Study Area

The study area Adyar River (Fig.1, Table.1) is located in Chennai district, Tiruvallur distirct and Kanchipuram District. The drainage originating near Sattarai in Tiruvallur Taluk, Kanchipuram District.

The total length of the river is 65 km and nearly 50m wide it collects the surplus waters from 75 tanks of the Adyar group, which has a total catchment area of 138 km2. Due to the diversion into Chembarambakkam Lake, there is very little flow in the Adyar as it approaches Chennai City. The river takes a meandering course west to east for about 16 km within the city. It receives a good deal of the urban drainage as it travels along major areas of the city such as Arumbakkam, Aminjikarai, Chetput, Egmore, Pudupet, Chintadripet, and Island Grounds. It finally joins the Bay of Bengal near Napier Bridge. The Adyar is also connected with the north Buckingham Canal through the Stanley Duct.

Table.1. Geographical locations of Adyar River

Sa.Location	Longitude	Latitude
1	80° 26' 98.88"	13° 01'05.61"
2	80° 25' 36.97"	13°01' 17.69"
3	80°24' 37.89"	13° 01' 82.94"
4	80° 23' 29.14"	13° 01' 78.11"
5	80° 21' 79.31"	13° 01' 24.94"
6	80° 20' 68.15"	13°02' 14.35"
7	80° 19' 47.32"	13° 02' 57.85"
8	80° 18' 48.24"	13° 01' 75.69"
9	80° 17' 90.24"	13° 01' 75.69"
10	80° 17' 44.33"	12° 99' 96.86"
11	80° 16' 33.16"	13° 00' 28.28"
12	80° 15' 29.25"	12° 99' 36.45"
13	80° 13' 86.67"	12°99' 24.36"
14	80° 12' 75.51"	12° 98' 85.70"
15	80° 11' 64.35"	12° 98' 15.62"
16	80° 11' 37.76"	12° 97' 16.54"
17	80° 10' 58.02"	12° 96' 12.63"
18	80° 10' 00.02"	12° 95' 11.13"
19	80° 09' 56.52"	12° 94' 02.38"
20	80° 08' 33.27"	12◦ 92' 86.39"

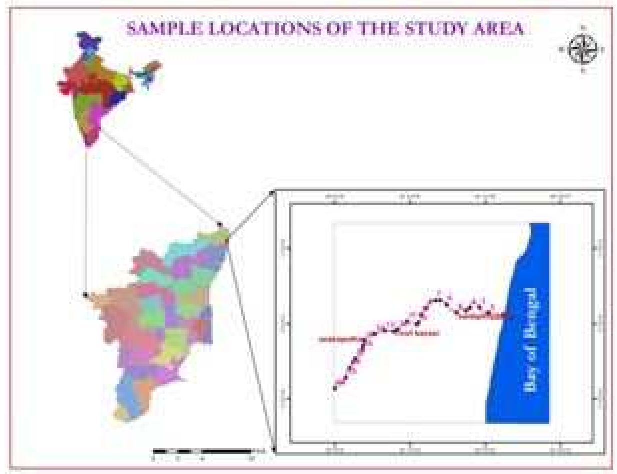


Fig.1.Sampling Locations of the Study Area – Adyar River

Geology

The Adyar River is an extremely polluted urban stream that flows through the heart of Chennai, India's fourth largest metropolis, into the Bay of Bengal. During the dry (non-monsoon) season, the upper reaches of the river are dry and flow in the river through the city may be attributed primarily to the production of sewage by the population. The river is essentially a foul-smelling open sewer. The geology of Chennai (Adyar river) comprises mostly clay, shale and sandstone. The city is classified into three regions based on geology, sandy areas, clayey areas and hard-rock areas. Sandy areas are found along the river banks and the coasts. Clayey regions cover most of the city. In sandy areas such as Tiruvanmiyur, Adyar, Kottivakkam, Santhome, George Town, Tondiarpet and the rest of coastal Chennai, rainwater run-off percolates very quickly. In clayey and hard rock areas, rainwater percolates slowly, but it is held by the soil for a longer time. The major part of the river Basin of Adyar is covered by alluvium soil with tertiary and Gondwana rocks at depth. The alluvium soil varies from 10 to 20 metres thickness and is mostly granular. In the down stream area of the river Basin coastal sand predominates while the middle part and upper parts are dominated by sand and silt. Charnockites are also found in some part of the basins.

Materials and Methods

The sampling design includes sediment samples (20 nos) from Adyar river at 2 km interval . All samples were collected on March 2010. (Fig.2-6.). A stratified, random sampling design was chosen and as many sites as possible were sampled to provide sufficient coverage of the study area. The aim of the study was to evaluate and characterize the distribution of water and soil contamination from the study area of Adyar river.

ISSN: 2277-9655
Impact Factor: 1.852

To obtain lucid illustrations, microphotographs of different views of all the Foraminifera species were taken using a Scanning Electron Microscope (JEOL JSM - 6360) of the Department (plate 1 -4)

Fig.2.Sediment samples collections at Adyar River

Fig.3.Contaminated water at the upper reaches of the Adyar River

Fig.4.Devoid of Fossils at Adyar River Middle Reaches

Fig. 5.Absence of Foraminifera at the highly contaminated upper part of the Adyar River

Fig.6. Highly polluted Adyar River due to dumping of garbage at middle reaches

Systematic Palaeontology

The widely utilised classification proposed by Loeblich and Tappan (1987) has been followed in the present study. A species has been regarded as the sum-total of specimens sharing all test characters, with such measurable, countable, or otherwise observable, variation in size and shape of some elements or of proportions between the latter in different ontogenic stages, which fits a pattern of normal distribution and whereby these specimens are separable from other similar groupings regarded as distinct species (Hottinger et al., 1993).The identification of the species recorded in this study is based on comparison with the Catalogue of Foraminifera by Ellis and Messina (1940 onwards), innumerable publications from several parts of the world and in the country (especially provided by Dr.Rajiv Nigam, National Institute of Oceanography,& Dr.Rajeswara Rao, Dept.of Applied Geology) and specimens reposited in the Departments of Geology, University of Madras, Madras 600 025, India.

 ISSN: 2277-9655
Impact Factor: 1.852

Checklist of Foraminifera

1.Ammobaculites exiguus
2.Trochammina inflata
3.Textularia agglutinans
4.Textularia candeiana
5.Textularia porrecta
6.Textularia bocki
7.Vertebralina striata
8.Spiroloculina communis
9.Spiroloculina costifera
10.Spiroloculina depressa
11.Spiroloculina henbesti
12.Spiroloculina nitida
13.Spiroloculina orbis
14.Spiroloculina affixa
15.Quinqueloculina agglutinans
16.Quinqueloculina costata
17.Quinqueloculina cristata
18.Quinqueloculina echinata
19.Quinqueloculina lamarckiana
20.Quinqueloculina parkeri
21.Quinqueloculina polygona
22.Quinqueloculina seminulum
23.Quinqueloculina tropicalis
24.Miliolinella circularis
25.Miliolinella pyrgoformis
26.Triloculina insignis
27.Triloculina terquemiana
28.Triloculina tricarinata
29.Triloculina trigonula
30.Rupertianella rupertiana
31.Bolivina hadai
32.Loxostomina durrandii
33.Rectobolivina raphanus
34.Cancris oblonga
35.Eponides repandus
36.Rosalina globularis
37.Discorbinella bertheloti
38.Cibicides labatulus
39.Amphistegina radiata
40.Pararotalia nipponica
41.Ammonia beccarii
42.Ammonia dentata
43.Ammonia tepida
44.Pseudorotalia schroeteriana
45.Elphidium crispum
46.Elphidium discoidale

Totally, 46 foraminiferal species belonging to 22 genus, 5 familes and 3 sub order are identified. Off which Miliolina (52%) occupies the dominant place followed by Rotallina (33%) Textularina (15%) (Fig.7 -9.).

From station no. 1 to 6 the foraminifeal species distribution shows decrease in order. The higher species are observed in the rivermouth area particularly in the sample no1. (254 species). The following species ae abundantly distributed in this region namely Ammonia beccarii, Elpidiumcripsum, Spiroloculina communis and Textularia agglutinans followed by Ammobaculites exigus, Triloculina trigonula. In general the distribution of foraminfera is vely low. The abundance of species in the river mouth may be due to the mixing of marine and nearshore environment.

Distribution of Foraminifera

The distribution of foraminifera clearly show a decreeing trend toeards the upper reaches of the river Adyar. The folling species are distributed in the river mouth of the Adyar river namely Ammonia beccarrii, Ammonia tepida, Elphidium crispum, Quinqueloculins Seminiulum, Spiroloculina, and Ammobaculites exigus.

Nigam et al (2002) explained the reduction in diversity and TFN due to pollution in estuary. The total recent benthic foraminifera shows decline trends towards the head of Adyarm river and leading to complete absent beyond the station Samples collected at inland Adyar river no 18 to 20 show the presence of speciems different in appearance form the normal recent benthic foraminifera. They are black to brown in colour. Si, Fe or Mn –oxide has replaced the calcareous tests. They have undergone transport which is evident by thie rounding, polysing, fracturing and at times absence of tests with only the sutures resistant to abrasion standing out. Similar findings also reported by Panchang et al (2005).Many of the stations show absence/rare presence of Recent foraminifera. The absence may be attributed to low salinity and pH conditions in the Adyar rive, as both factors are detrimental to the existence of foraminifera (Boltovskoy and Wright, 1976). Similar conditions were noticed elsewhere, and Murray (1991) summarized the status of foraminifera in estuaries and stated, ‘‘The extreme environment of the Purari River in Papua New Guinea (salinity 1‰, temperature 24 to 258C, pH 5.5 to 5.7) causes standing crop to be very low.Station 1 to 5, which yielded the maximum number of Recent foraminiferal specimens, is located at the lower reaches of the river Adyar. Many of the foraminiferal specimens encountered are broken, thus indicating an unstable substrate.

Distribution and Ecology of the Foraminifera

Sediment substrate

The sand percentage ranges from 49.40% to 79.20% with an average value of 64.17%. The lowest value of sand is recorded at the upper reaches of Adyar River. The silty sand is observed in the upper reaches. The study area is dominated by Sand and silty sand. Here the foraminifeal distribution is very rare in the silty sand substrate indicate the unfavorable environment with sediment conditions.

Calcium Carbonate

The calcium carbonate content was generally very low in the midddel and upper part of the river. Iit ranges from 0.40% to 3.20 % with an average value of 1.42%. The calcium carbonate content in rivermouth area is slight variations.

Higher organic matter and calcium carbonate were observed in the near shore region. Similar observation is aldo made from the inner shelf sediments of Kasargod, west coast of India (Reghunath and Murthy (1996). The calcium content is more in the river mouth reagion may be due to the duming of broken shell fragments tide actions.

In most of the Sampling stations, very low percentage of calcium carbonate is observed. This may due to the terrigenous material brought down from the landmass (Rao and Rao, 1975) and high rate of sedimentation. According to Reghunath and Murthy, 1996), high rate of sedimentation and fine nature of substratum, in general, do not support biogenic activity and hence low carbonate values. Carbonate sands occur in most of the outer continental shelves of the world, which are not covered by recent fine-grained sediments (Ginsberg and James, 1974). This may be due either to the strong current activity or long distance from river mouths (Milliman, 1974).

Organic Matter

The organic matter concentrations are higher at the lower reaches of the river. Low organic matter content in the upper reaches off the relict sediments may be due to existing high energy conditions, alongshore currents, high dissolved oxygen content and sandy texture of the sediment (Reddy 2003). Foraminifeal distributions are abundant in the rivermouth region where the organic matter also favor for thirving of foraminifeea in this region.

In sediments, the organic matter is mainly attached to the fine grained fraction. In general, a strong positive correlation is found between the organic matter concentration and the fraction of (mud) clay- and silt-sized sediments found, that organic matter is mainly attached to clay minerals, oxy-hydroxides and bioclasts such as diatoms, frustules etc. They also found that the organic matter is not evenly distributed over the grain surface, but is concentrated in patches, thus enervating the hypothesis that organic matter is preserved in a monolayer enveloping the individual sediment particles. However, it is clear that most of the organic matter is preserved in fine-grained sediments (Ransom et al., 1997, 1998).

Most of the organic matter is preserved in fine grained sediments. While studying the fate of the organic matter, it is essential to know the transport path of the fine grained sediments. From the review it becomes clear that > 95% of the primary produced organic matter is mineralized by biological and chemical processes in the alter column and in the upper few centimeters to decimeters of the sediment column. This coincides very well with the calculations of Emerson and Hedges (1988) who state that at most 4% of the particulate flux from the euphotic zone is buried in marine sediments.

The low percentage of the organic matter in the upper reaches samples are due to the nature of sedimentation and mixing processes at the sediment-water interface where the rate of delivery, as well as rates of degradation by microbially-medicated processes can be high (Canuel and Martens, 1993). According to Paropkari (1979) organic matter in the sediments of the northwestern continental shelf of India vary from 0.42 to 3.86% (avg. 1.64%), which is far below the world average of 2.5% for near shore sediments. It has also been recorded that around the 75m isobath the whole western continental shelf shows less amount of organic matter content that the near shore environments (Paropkari et al., 1987).

The abundant supply of organic matter in the water column in the relatively rapid rate of accumulation of fine-grained inorganic matter and low oxygen content of the water immediately above the sediments would favour higher organic matter in the bottom sediments (Sverdrup et al., 1942). Rajamanickam and Setty (1973) in their study on the near shore sediments of Goa, observed high percentage of organic matter is attributable to decreasing grain size, protective action of clay and other pollutants. The inner shelf is favourable for the preservation of organic matter, not only because of the fine sediments there, but also because of the rapid terrigenous sedimentation rate (Paropkari et al., 1987, 1992).

Salinity

In the study area the salinity values ranges from 35 to 37 ppm at the lower part near the river mouth. At the middle part of the Adyar River is ranging from 12.5 to 25 ppm is observed and in the upper reaches it is 2.5 to 9 ppm respectively. The salinity nd the distribution of foraminiferal species is directly related to each other.

Higher the salinity values in the lower reaches also favor for the foramifneal distribution with higher species, wheras in the upper and middle part of the Adyar River the salinity values are lesser in amount. The foraminaral distribution and salinity is also support this parameters.

Results and Discussion

Ecology Parmeters

Most of the samples in the lower reaches are sandy in nature and in the upper reaches it is dominated by silty sand. Coarser grain size and poor sorting indicate high energy environment (Bascom, 1953). Higher energy is expected to produce at the river mouth due to interaction of strong outflow of the river water and incoming wave and tidal currents. The high energy levels permit deposition of coarser sediments as well as transportation of a much wider range of finer sediments (Bryant, 1982). Turbidity currents may be the liable agent for the transportation of such silt rich sediments from the river mouth and from the shelves (Bagnold, 1962; Parker, 1982; Middleton and Southard, 1984; Fukushimo et al., 1985; Middleton, 1993 and Ramesh, 1997).

Low value of organic matter content was observed in the upper reaches of the surface sample is due to under water currents (Ramesh, 1998). Almost low percentage of CaCO3 is observed in middle of the Adyar river due to the terrigenous material brought down from the landmass (Rao and Rao, 1975) and high rate of sedimentation (Hema Achyuthan et al., 2002). According to Reghunath and Murthy, 1996), high rate of sedimentation and fine nature of substratum, in general, do not support biogenic activity and hence low carbonate values.

Low percentage of the organic matter were observed in the middle of the river are due to the nature of marine sedimentation and mixing processes at the sediment-water interface where the rate of delivery, as well as rates of degradation by microbially-medicated processes can be high (Canuel and Martens, 1993).

Foraminifera Discussion

Though initially most of the studies concentrated on the effect of sewage pollution on the foraminifers but later the industrial effluents also came under the purview. Setty (1976) observed that the deleterious effects of effluents from the fertilizer industry resulted in decreased abundance and increase in diversity of foraminifers. Rao and Rao (1979) reported solution effects and decreased species diversity as a result of effluents from metal industry, while reported the effects of pollutants emanating from pulp and paper mills. Setty and Nigam (1984) described the effect of acidic and alkaline effluents from fertilizer and metal processing industries while Bhalla and Nigam (1986) noted decline in foraminiferal species diversity and increase in abundance of deformed tests in response to the discharge of ammonia and arsenic from the fertilizer industries. Sharifi et al. (1991) concluded that the presence of heavy metals (Cu, Zn) caused abnormalities in the foraminifers and that deformed tests contained higher concentration of heavy metals than non-deformed specimens. Geslin et al. (1998) reported that presence of trace elements could lead to crystalline disorganizations. In a study aimed at deciphering the effect of heavy metals, Samir (2000) observed that benthic foraminifers are more sensitive to industrial waste containing heavy metals and also less tolerant to pollution as compared to ostracodes and molluscs. The same indicator can also be used for monitoring anthropogenic oil and gas slicks. Yanko et al. (1994) described the effects of coal andfuel ash on the benthic foraminiferal community. Mayer (1980) reported ill effect of oil spill on the benthic foraminiferal population and diversity

Since response of foraminifers from areas affected by almost all possible pollutants was being documented collectively, therefore the need to find the variation in response of foraminifers as per the type of pollutants was widely felt. In order to delineate the specific response of foraminifers to specific pollutants, few attempts were made to supplement the foraminiferal features with geochemical characteristics of the affected area. The physical parameters like salinity and temperature in the affected area were noted and reported along with the foraminiferal characteristics since the beginning of such studies (Watkins, 1961; Bandy et al., 1964b). In most of the cases, the supporting geochemical data was taken from the earlier published reports from the same region.

The geochemical analysis to draw specific conclusions from the foraminiferal features resulted in studies mentioning the effects of trace and heavy metals, emanating from various anthropogenic sources, on the foraminifers (Ellison et al., 1986). Banerji (1992) prepared a detailed report correlating the variation in amount of heavy metals and foraminiferal characteristics. He concluded that while higher concentrations of Fe–Mn–Zn resulted in higher foraminiferal diversity, the increased concentration of Co–Ni–Pb adversely affected the foraminiferal diversity.

He listed the foraminiferal genera as per their increasing vulnerability to heavy metals wherein Lagenids had least impact while Elphidium group of species were most severely affected.

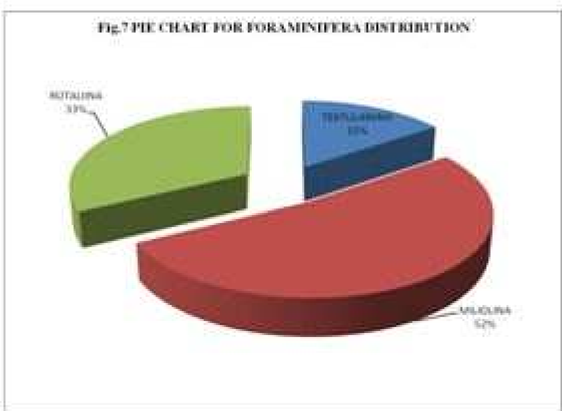
The Adyar River transported 11.87–120.06 t/d of suspended solids, 0.08–58.7 t/d of ammonia, 6.11–29.25 t/d of nitrate and 0.66–10.73 t/d of phosphate, 0.003–0.021 kg/d of cadmium, 0.02–0.44 kg/d of lead and 1.36–3.87 kg/d of zinc. The minimum and maximum discharge noted in the Adyar River between 266.45 and 709.34 × 106 litres/day. The low discharge by the Adyar River is due to the heavy silt deposition from storm water drains. This might also be due to the construction of Kesavaram, Aranvayalanicuts across the Adyar River that reduces the flow of the river in the

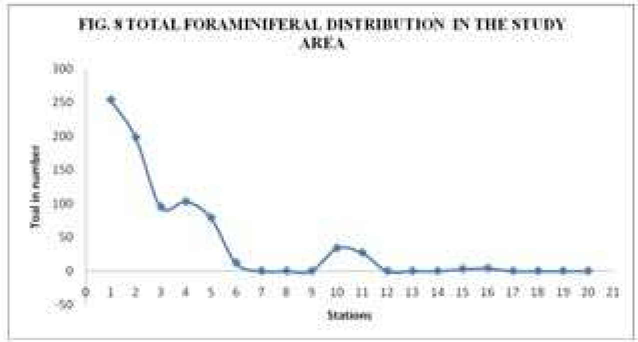
ISSN: 2277-9655
Impact Factor: 1.852

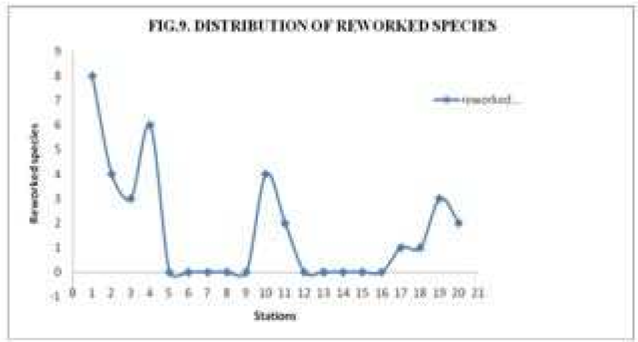
upstream. Moreover, the construction of the artificial Chennai harbour frequently closes the Adyar River mouth by sand bar formation. Further Lead, Cadmium and Zinc are more in the upper reaches and also highly polluted region which control the foraminifera distribution a is observed.

Depending upon the quantitative distribution of foraminifera the Adyar river can be divided in to three parts: the lower reaches of the river marked by gradual decrease in total foraminiferal number (TFN) away from the sea headwards. The middle reaches marked by low and absence of foraminifera and the upper reaches characterized by the absence of foraminifera.The decline trend in the total foraminiferal number from the sea moving upstreams follows the normal river pattern. Just near the mouth the TFN is high and it has fallen drastically at the station 6. The complete absence of foraminifera in the middle reaches indicates the truncation of Adyar River and weakening of tidal ingress of sea water.

The salinity data collected during sampling shows the salinity drops below 32 ppm in the upper reaches of the Adyar River. The absence of foraminifera at the upper reaches can be attributed to the fall in salinity hindrance to growth in the study area(Fig.7-9).







Conclusion

Totally, 46 foraminiferal species belonging to 22 genera, 5 familes and 3 sub order are identified. Off which MILIOLINA (52%) occupies the dominant place followed by ROTALLINA (33%) and TEXTULARINA (15%). The complete absence of foraminifera in the middle reaches indicates the truncation of Adyar River and weakening of tidal ingress of sea water. The salinity data collected during sampling shows the salinity drops below 32 ppm in the upper reaches of the Adyar River. The absence of foraminifera at the upper reaches can be attributed to the fall in salinity hindrance to growth in the study area. Overall, from the geochemical and micropaleontological studies it is inferred that the middle and upper reaches is contaminated by pollution and enter to the lower reaches of the Adyar River.

Acknowledgements

The authors are thankful to the UGC CONSIST Programme of the Department for SEM Facility. The Authors are grateful to Prof.S.P.Mohan, Head, and Department of Geology for his encouragement and also for providing facilities to carry out this work.

References

[1] Alve, E. (1995) Benthic foraminiferal responses to estuarine pollution: a review, J. Foram. Res., 25: 190–203.

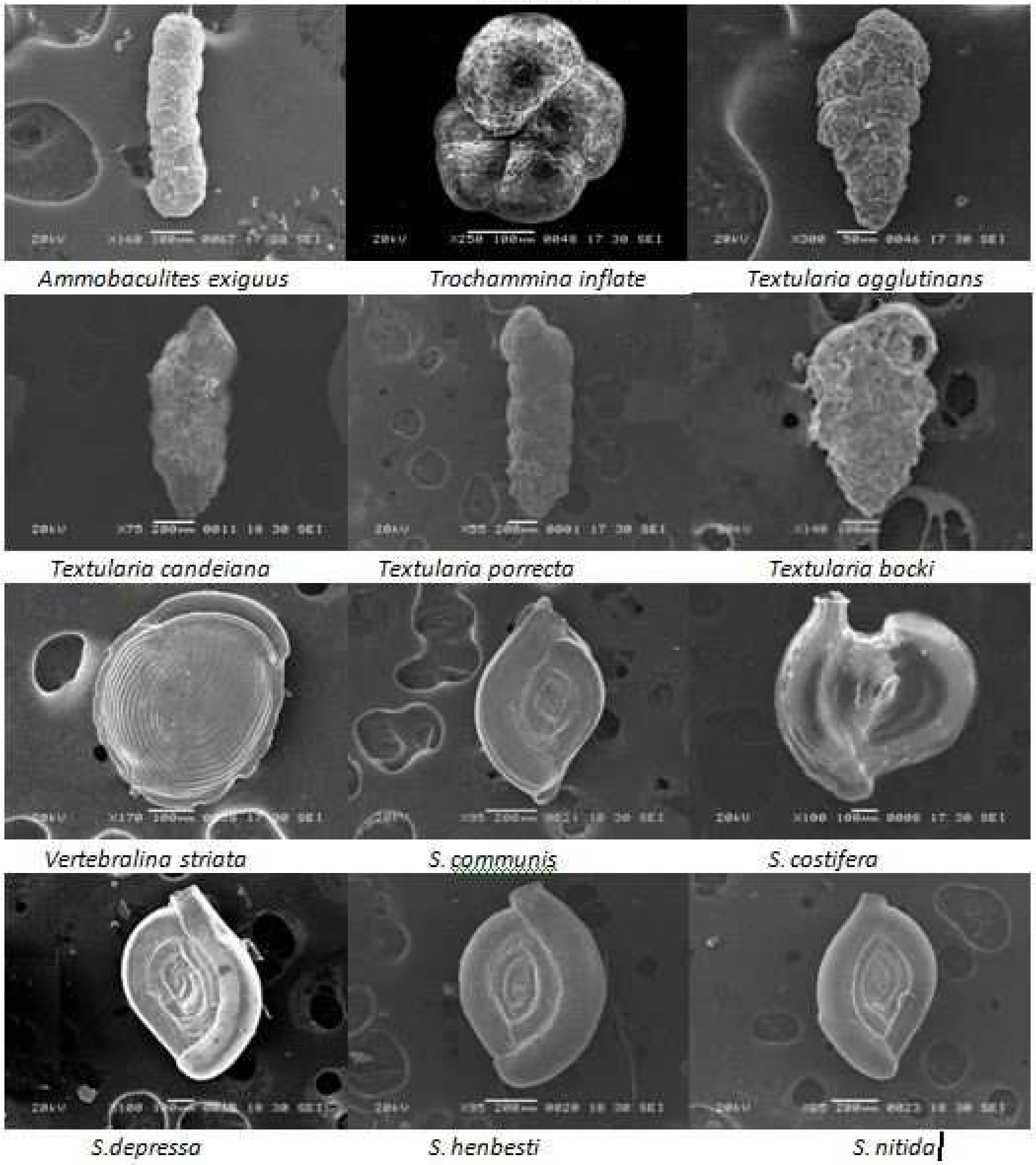
[2] Bagnold, R. A. (1962) Sedimentology of some flysch deposits. Elsevier, Amsterdam, 168p.
[3] Bandy, O.L., J.C. Ingle, and J.M. Resig. 1964b. Foraminiferal trends, Laguna Beach outfall area, California. Limnology and Oceanography 9:112¬123.
[4] Banerjee, P. K., Saha, B. K., Majumdar, S., Rakshit, S., Deb Roy, D. K., Sinha, J. K. and Bhattacharya, D. (1992) Nature and origin of anomalous base metal enrichment in the recent sediments around the Narcondam Island in the Andaman Sea. Geological Survey Special Publication, 29: 111-116
[5] Banerjee, R. K. (1974) Benthic foraminifera as an aid to recognize the polluted environments, Proc. IV Ind. Colloq. Micropal. Strat., pp.1-6.
[6] Banerjee, R. K. (1989) Foraminifera and discrimination of polluted environment along Bombay Coast, Proc. XII Ind. Colloq. Micropal. Strat., pp.1-18.
[7] Bascom, W. J. (1953) Trans A mer Geophy Uni, 32: 866.
[8] Bhalla, S. N. and Nigam, R. (1986) Recent foraminifera from polluted environment of Velsao Beach, South Goa, Revue de Paleobiologie, v. 5, pp.43-46.
[9] Boltovskoy, E. and Wright, R. (1976) Recent Foraminifera, Dr. W. Junk Publishers, The Hague, 515 p.
[10] Boltovskoy, E., Scott, D.B., Medioli, F.S., 1991. Morphological variations of benthic foraminiferal tests in response to changes in ecological parameters: a review. Journal of Paleontology 65 (2), 175– 185.
[11] Bryant, E. A. (1982) Journal of Sedimentary Petrology, 52: 431.
[12] Canuel, E. A. and Martens, C. S. (1993) Seasonal variations in the sources and alteration of organic matter associated with recently deposited sediments. Org. Geochem., 20(5): 563-577.
[13] Debenay, J.-P.; Tsakiridis, E.; Soulard, R.; Grossel, H. Factor determining the distribution of foraminiferal assemblages in port Joinville Harbour (Ile d'Yeu, France): the influence of pollution. Mar. Micropal. 43:75-118; 2001.
[14] Ellis, B. F. and Messina, A. R. (1940) et seq., A Catalogue of Foraminifera. Amer. Mus. Natl. Hist., 30 vols. and supplements.
[15] Ellison, R. L, Broome. R. and Ogilvie, R. (1986) Foraminiferal response to trace metal contamination in the Patapsco River and Baltimore Harbor, Maryland, Mar. Pollut. Bull., 17: 419–423.
[16] Emerson, S. and Hedges, J. I. (1988) Processes controlling the organic carbon content of open ocean sediments, Paleoceanogr., 3: 621-634.
[17] Fukushimo, Y., Parker, G. and Patin, H. M. (1985) Prediction of ignitive turbidity currents in Scripps submarine canyons. Marine Geology, 67: 89-114.
[18] Geslin, E.; Debenay, J.-P.; Duleba, W.; Bonetti, C. Morphological abnormalities of foraminiferal tests in Brazilian environment: comparison between polluted and non-polluted areas. Mar. Micropal. 45:151-168; 2002.
[19] Geslin, E.; Debenay, J.-P.; Lesourd, M. Abnormal wall textures and test deformation in Ammonia (hyaline foraminifer). J. Foram. Res. 28:148-156; 1998.
[20] Ginsberg, R. N. and James, N. P. (1974) Holocene carbonate sediments of continental shelves. In: Burk, C. A. and Drake, C. L. (eds) The Geology of Continental Margins. Berlin. Springer, p. 137-155.
[21] Hottinger, L., Halicz, E. and Reiss, Z. (1993) Recent Foraminiferida from the Gulf of Aqaba, Red Sea, Ljbubljana: Slovenska Akademija znanosti in unmetnisti, 179 p.
[22] Jayaraju, N. and Reddy, K. R. (1996) Factor analysis of benthic foraminifera from coastal and estuarine sediments of Kovalam-Tuticorin, South India, J. Geol. Soc. India, v.48, pp.309-318.
[23] Loeblich, A. R. and Tappan, H. (1964) Sarcodina, chiefly Thecamoebians and Foraminiferida, In: R. C. Moore (Ed.), Treatise on Invertebrate Palaeontology, Part C, Geol. Soc. Amer., New York, 900 p.
[24] Loeblich, A. R. and Tappan, H. (1987) Foraminiferal Genera and their Classification, Von Nostrand Reinhold, New York, 970 p.
[25] Madabhushi, S. (1989a) Distribution of benthonic foraminifera in the outer shelf-upper slope area off Cochin, Arabian Sea. Recent geoscientific studies in the Arabian Sea off India, Geol. Surv. India, Specl. Publn., 24, pp.89-96.
[26] Madabhushi, S. (1989b) Distribution of benthonic foraminifera in the inner shelf off Cannanore-Calicut Coast, Arabian Sea, and its relation to marine pollution. Recent studies in the Arabian Sea off India, Geol. Surv. India, Specl. Publn., 24, pp.97-106.
[27] Mayer, L. M. and Fink, L. K. Jr. (1980). Granulometric dependence of Chromium accumulation in estuarine sediments in Marine. Estuar. Coast. Mar. Sci., 11, 491-503.

[28] Middleton, G. V. and Southard, J. B. (1984) Mechanics of sediment transport, Soc. Econ. Pal. Miner., Short Course, 3: 34 p.
[29] Middleton, G. V. (1993) Sediment deposition from turbidity currents. Annual Review of Earth and Planetary Sciences, 21: 89-114.
[30] Milliman, J. D. (1974) Marine carbonates, Part I, Berlin: Springer, p. 375.
[31] Murray, J.W. 1991. Ecology and palaeoecology of benthic foraminifera. John Wiley & Sons Inc., New York, 397p. Nagy and Alve 1987
[32] Naidu, A. S. Mowatt, T. C., Fairbanks., Somayajulu, B. L. K. and Sree Ramachandra Rao, K. (1985) Characteristics of clay minerals in the bed loads of major rivers of India. Mitt. Geol-Pal. Inst., Univ. Hamburg, SCOPE/UNEP Sounderband, Heft, 58: 559-568.
[33] Nigam, R., Nayak, G. N. and Naik, S. (2002) Does mining pollution affect foraminiferal distribution in Mandovi Estuary, Goa, India? Revue de Paleobiol., Geneva, v.21 (2), pp.673-677.
[34] Panchang, R., Nigam, R., Baig, N. and Nayak, G. N. (2005) A foraminiferal testimony for the reduced adverse effects of mining in Zuari Estuary, Goa, Int. J. Environ. Stud., v.62 (5), pp.579-591.
[35] Parker, G. (1982) Conditions for the ignition of catastrophically erosive turbidity currents. Marine Geology, 46: 307-327.
[36] Paropkari, A. L. (1979) Distribution of organic carbon in sediments of the northwestern continental shelf of India. Indian J. Mar. Sci., 8: 127-129.
[37] Paropkari, A. L., Prakash Babu, C. and Mascarenhas, A. (1992) A critical evaluation of depositional parameters controlling the variability of organic carbon in Arabian Sea sediments. Marine Geology, 107: 213-226.
[38] Paropkari, A. L., Rao, Ch. M. and Murty, P. S. N. (1987) Environmental controls on the distribution of organic carbon in recent sediments of the western continental margin of India. In: Kumar and others (eds) Petroleum Geochemistry and Exploration in the Afro-Asian region. Rotterdam: Belakend Press, p. 347-361.
[39] Rajamanickam, G. V. and Setty, M. G. A. P. (1973) Distribution of phosphorus and organic carbon in the nearshore sediments of Goa, Ind. J. Mar. Sci., 2: 84-89.
[40] Ramesh, S. (1997) Sedimentation and paleoclimatic conditions of late Pliestocene-Holocene sediments of the eastern part of lower Bengal Fan, Northeast Indian Ocean. University of Madras, Ph.D Thesis, 133p.
[41] Rao, M. S., Vedantam, D. and Rao, J. N. (1979) Distribution and ecology of benthonic foraminifera in the sediments of the Visakhapatnam shelf, east coast of India, Paleogeogr., Paleoclimatol., Paleoecol., v.27, pp.349-369.
[42] Rao, M. S. S. and Rao, M. P. (1975) Distribution patterns of calcium carbonate and organic matter in the shelf sediments off the Mangalore coast, India. Proc. Symp. Sediment, Sedimentation and Sedimentary Environments, University of Delhi, Delhi, 149-157. Reddy, N. P. C. (2003) Organic matter distribution in the continental shelf sediments, off Kochi, west coast of India, Ind. J. Petrol. Geol., 12 (2): 41-47.
[43] Reghunath, R. and Sreedhara Murthy, T. R. (1996) Carbonate and organic matter studies of the shelf sediments off Kasargod, west coast of India. Indian J. Mar. Sci., 25: 355-357.
[44] Samir, A. M. (2000) The response of benthic foraminifera and ostracods to various pollution sources: a study from two lagoons in Egypt, J. Foram. Res., 30: 83–98.
[45] Setty, M. G. A. P. (1976) The relative sensitivity of benthonic foraminifera in the polluted marine environment of Cola Bay, Goa, Proc. VI Ind. Colloq. Micropal. Strat., pp.225-234.
[46] Setty, M. G. A. P. and Nigam, R. (1984) Benthic foraminifera as pollution indices in the marine environment of west coast of India, Revista Italiana di Paleontologia Strat., 89 (3): 421-436.
[47] Sharifi, A. R., Croudace, I. W. & Austin, R. L. 1991 Benthic foraminiferids as pollution indicators in Southampton Water, southern England, U.K. Journal of Micropalaeontology 10, 109– 113.
[48] Sverdrop, H. V., Johnson, M. W and Fleming, R. H. (1942) In: the Oceans, their physics, chemistry and general biology. Prentice-Hall, New York, 1087.
[49] Watkins, J.G., 1961. Foraminiferal ecology around the Orange County, California, ocean sewer outfall. Micropaleontology 7 (2), 199–206.
[50] Yanko, V.; Kronfeld, J.; Flexer, A. Response of benthic foraminifera to various pollution sources: implication for pollution monitoring. J. Foram. Res. 24:73-97; 1994.

ISSN: 2277-9655
Impact Factor: 1.852

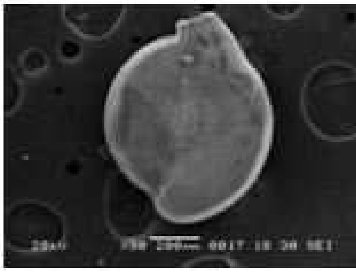
[51] Yanko, V.; Ahmad, M.; Kaminski, M. Morphological deformities of benthic foraminiferal tests in response to pollution by heavy metals: Implications for pollution monitoring. J. Foram. Res. 28:177-200; 1998.

PLATE –I



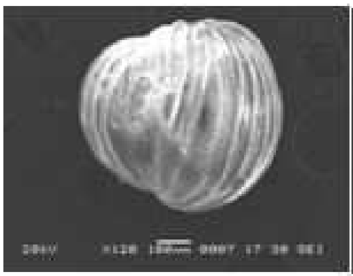
ISSN: 2277-9655
Impact Factor: 1.852

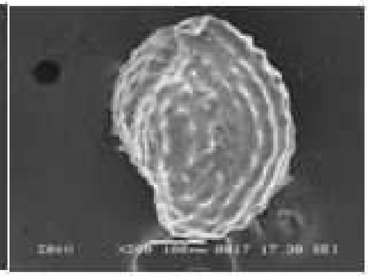
PLATE –II


S.orbis

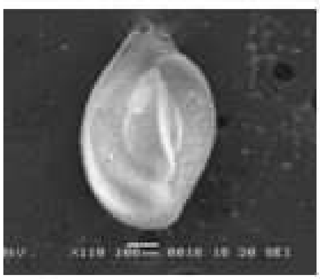

S.affiixa


Quinqueloculina agglutinans


Q.costata

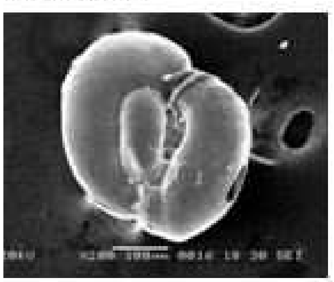

Q.Echinata

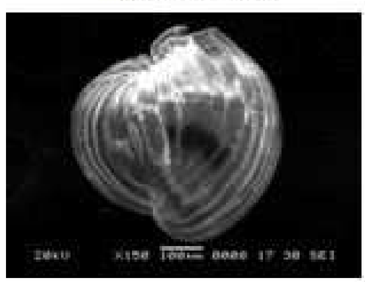

Q. lamarckiana


Q.polygona


Q.seminulum


Q. tropicalis

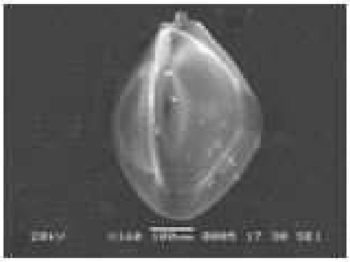

Miliolinella circularis

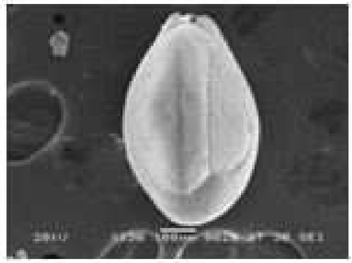

Triloculina insignis

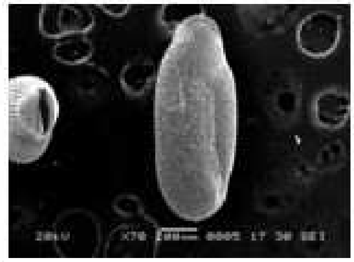

T. terquemiana

ISSN: 2277-9655
Impact Factor: 1.852

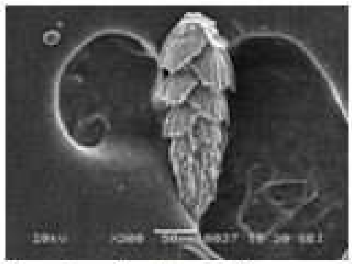
PLATE –III

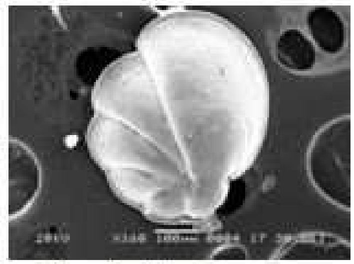

T. tricarinata

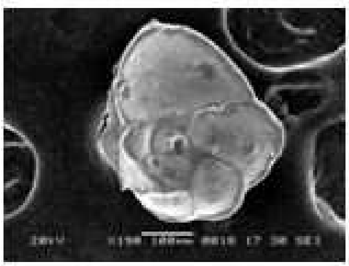

T. trigonula

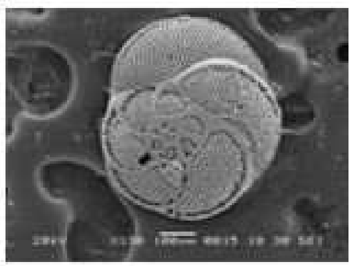

Rupertianella rupertiana

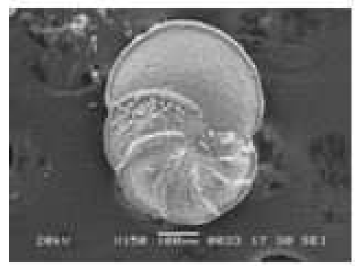

Bolivina hadai

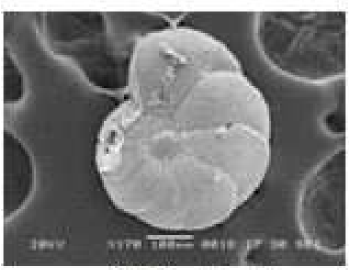

Loxostomina durrandii

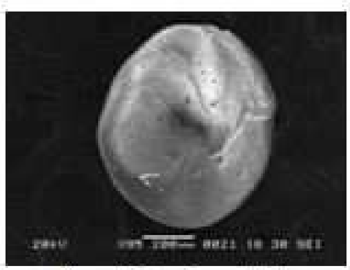

Cancris oblonga

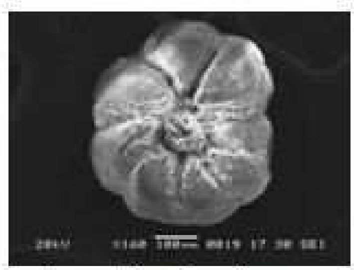

E. repandus


Rosalina globularis


Discorbinella bertheloti

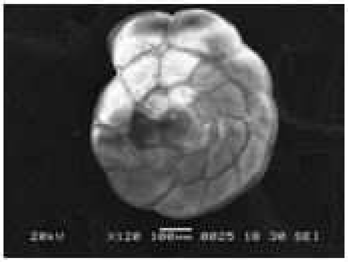

Cibicides lobatulus


Amphistegina radiate

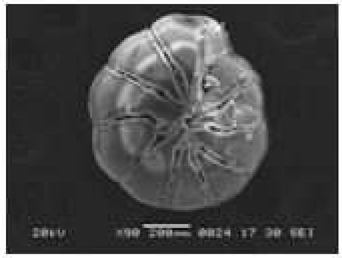

Pararotalia nipponica

ISSN: 2277-9655
Impact Factor: 1.852

PLATE – IV

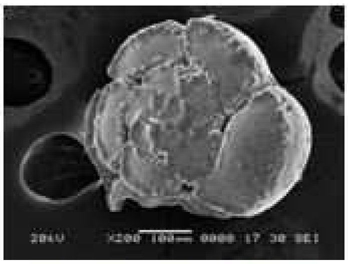


Ammonia beccarii

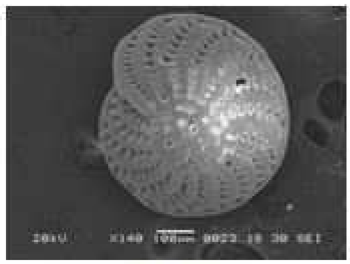


Ammonia dentata

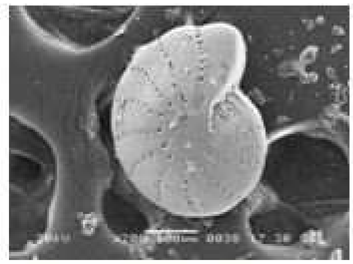
Ammonia tepida



Pseudorotalia schroterina



Elphidium crispum



Elphidium discoidale