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The response of benthic foraminifera to various pollution sources: A study from Nellore Coast, East Coast of India

N. Jayaraju · B. C. Sundara Raja Reddy · K. R. Reddy

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Abstract A study of benthic foraminiferal species was carried out along Nellore Coast of South India. Analysis of surfacial sediment samples from the study area shows enrichment in heavy metals (Cr, Cu, Pb and Zn). The environment has become so lethal to foraminifera that minimal species number (4–7) can currently preserved in living condition in a depth less than 5-fth contour from coast. Samples from outfalls which receive only agricultural and aquacultural drainage water show heavy metal concentrations slightly higher to natural baseline levels, and yielding, living foraminifera (10–15). The frequent occurrence of deformed and abnormal specimens in Industrial outfalls, comparable to aquacultural and agricultural outlets reveal that (a) benthic foraminifera are more sensitive to industrial wastes containing heavy metals, (b) agricultural and aquacultural wastes do not significantly harm benthic foraminifera, and (c) morphological abnormalities of the foraminiferal tests depend upon the nature of the pollutant.

Keywords Pollution outfalls · Heavy metals · Coastal pollution · Benthic foraminifera · Test deformation

N. Jayaraju (✉) · B. C. Sundara Raja Reddy · K. R. Reddy
Department of Geology, Sri Venkateswara University, Tirupati 517 502, India
e-mail: naddimi_raju@rediffmail.com

N. Jayaraju
Department of Geoinformatics, Y. V. University, Kadapa 516003, India

Introduction

Benthic foraminifera have been demonstrated their utility for stratigraphy and paleoecological studies. Not long ago, their application has been extended to pollution studies to the marine environment. Although there are numerous publications on the densities and diversities of foraminifera in unpolluted, modern environments there remains meager detailed understanding of the precise controls on distribution and on niche of each species (Alve 1995; Divrikli et al. 2003; Soylak et al. 2004). Marine pollution studies using benthic foraminifera as proxy indicators were initiated by (Resig 1996) and (Watkins 1961). Since then, lot of work has been carried out on the effects of various kinds of pollution sources in a wide range of marginal marine environments.

Despite the number of authors discussed on foraminiferal ecological dynamics in polluted environments, we are still far from understanding foraminiferal ecological dynamics in polluted environments and there are several reasons for this (Alve 1995).

1. The highly polluted areas are often naturally stressed marginal marine environments where the natural environmental conditions change over small distances.
2. Several pollutants are being discharged into the various marine environments and
3. The same kind of pollution can affect various environments differently. These earlier studies have inferred that foraminiferal taxon are sensitive to

pollution and show morphological deformities in polluted zones. Few studies thus far have addressed the relationship between modes of deformities and environmental variables (Bhalla and Nigam 1986; Alve 1991; Jayaraju and Reddy 1996).

The aim of this paper is to evaluate the response of benthic foraminifera to heavy metal pollution along the Nellore Coastal fringe with in the depth range of 5-fth contour.

To asses the impact of different types of pollutants on the biota, a comparison of different areas would be useful if they have the same faunal assemblage and comparable hydrographic and physical characteristics, but are exposed to different types of pollution.

The present investigations have focused on three different areas:

1. A zone which receives mainly untreated industrial wastes that contain high concentrations of heavy metals (sample stations 1, 2, 4, 5, 11 and 17).
2. A zone which receive only agricultural and aquacultural drainage water with pesticides (sample stations 7, 9, 12, 13, 15 and 16) and
3. A zone which is pollution free (sample stations 3, 6, 8, 10, 14 and 18) all these zones have imaginary demarcation along the Nellore Coast of India.

Area descriptions

The area studied in represented in the Survey of India topo sheet No. 66B in the scale of 1 in to 4 mi and is located between 14^0 00^1 and 15^0 00^1 E and $80^0.00^1$ and 80^030^1 N (Fig. 1). The study area covers about 110 km. The present investigations are considered to be first detailed research work ever carried out on benthic foraminifera under various pollution outfalls and its implications pertaining to the Nellore Coast with reference to heavy metals. Such studies are exclusively confined to the sedimentary material of shore with in a depth of 5-fth contour.

The area under investigation enjoys a tropical sub humid type of climate with an annual mean temperature of 29°C. The mercury goes up to 32°C in summer and to 28°in winter months. The humidity varies from 71 to 73% during summer and 88 to 90% during winter seasons and consequently the rate of evaporation is fairly high. The coast line of the study area is not straight but rather undulated. This is due to the paucity of development of sand bars and is of crenulated appearance due to marine action (Srinivas 1991). The sedimentation along the coast is controlled by geomorphological features especially by the virtue of coast line and estuaries. Deep cracks, low level laterite capings, sand mixed low level secondary laterites, formed by residual weathering of Archean gneisses are an interesting geomorphological features. The coastal fringes comprise of sediments of Pleistocene. Recent origin resting over the Precambrian basement gneiss and schist's. The recent sediments consists of alluvial deposits along the river banks, estuarine (back water) deposits and brown sands along the coast including muddy sand, silty sand, sandy silt and clays (Srinivas 1991).

Materials and methods

A total of 18 surficial bottom sediment samples were collected using Peterson grab. Out of 18 samples, six from each environment viz., unpolluted (stations 3, 6, 8, 10, 14 and 18), area away from the discharge point; industrially polluted zone (1, 2, 4, 5, 11 and 17) and aquaculture and agricultural drainage outlets (7, 9, 12, l3, 15 and 16) (Fig. 1).

A constant volume (50 mL) was taken from the upper 0–2 cm of undisturbed bottom sediments of each grab sample and preserved in 30% ethyl alcohol in the field. Wet samples were seived on a 63 μm screen and treated with Rose Bengal following the technique used by Walton (1952) for differentiating living from the dead species. Sediments were then oven-dried at 60°C; at this temperature, the probability for the loss of volatile metals (As and Hg) is at a minimum. Heavy metal concentrations were measured (Samir 2000) in different sediments using flame atomic absorption spectrophotometer.

Results and discussion

Heavy metals are unlikely to favour any particular species of benthic foraminifera. In practice, however, it is often difficult to separate effects caused by heavy metals from those caused by organic material because most polluted areas are subjected to some kind of

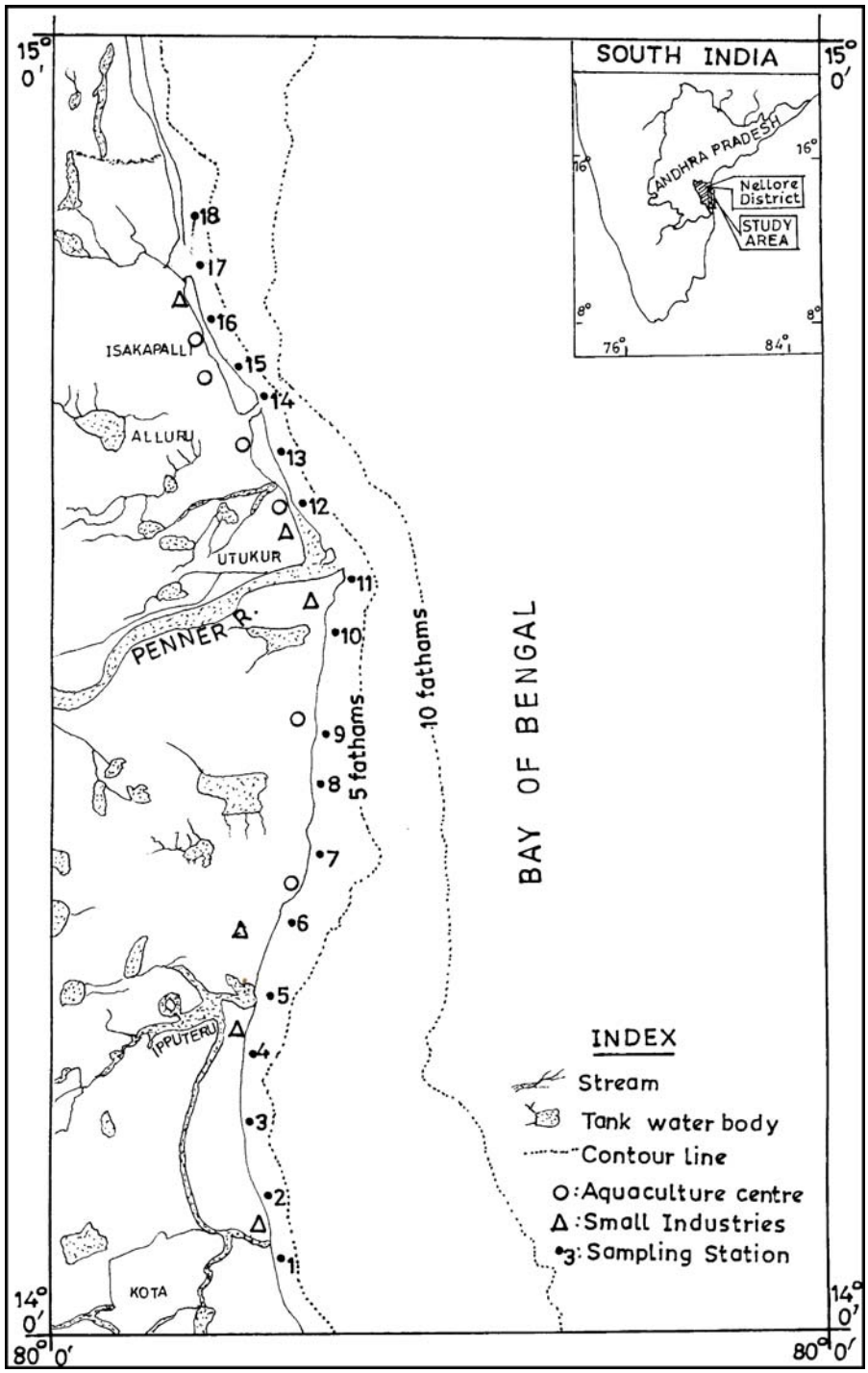

Fig. 1 Area map

organic enrichment (Alve 1995). Heavy metal pollution in Southampton coastal water, England, affected the foraminiferal distribution and caused test deformities (Sharifi et al. 1991). In the present study fewer number of living individuals (4–7) were recorded in samples 1,2,4,5,11 and 17 than in samples 3,6,8,10,14 and 18 (25–38). In samples 7, 9,12,13,15 and 16 a moderate number (10–15) was recorded. The low

numbers in aforementioned samples could be attributed to the high level of water pollution (Samir 2000). The Nellore Coast has been contaminated by numerous trace metals, but geochemical analysis shows that Cr, Cu, Pb and Zn are the most significant pollutants (Table 1). In general, heavy metals are enriched in the area affected by the industrial outfalls compared with the rest of the coast. Abnormal test shapes (deformed tests) have been reported from areas subjected to natural environmental concentrations (Bhalla and Nigam 1986). Heavy metals certainly have a deleterious effect on benthic fauna in general (Aschan and Skullernd 1990) and to foraminifera in particular (Yanko et al. 1998). Higher proportions of abnormal specimens near polluted area were noted by Siegel (1975). (Sharifi et al. 1991) suggested a relationship between test deformation and heavy metal concentration of Cu and Zn than non-deformed ones. (Yanko et al. 1998) described that increased concentrations of Cr and Cu produce a significant deformation in Cibicides. In some cases, test deformation is so extreme that taxonomic identification becomes very difficult. The maximum values (15–28%) of deformed tests were recorded from samples 1, 2, 4, 5, 11 and 17. In this part, as discussed earlier, the sediment in which foraminifera were recorded exhibited high concentrations of trace metals (Table 1). The uptake of these trace metals by foraminifera can explain the high percentage of test abnormalities. The number of deformed specimens decreased at relatively less polluted sites (7, 9, 12, 13, 15 and 16). The effects of heavy metal contamination in Southampton coast, England (Sharifi et al. 1991) and in Sorfjord, Western Norway (Alve 1991) revealed the same type of test deformation.

Table 1 Concentration of selected heavy metals (ppm) with in the sediments of Nellore Coast

Station	Cr	Cu	Pb	Zn
1	185.4	116.3	96.7	189.0
2	210.3	128.4	102.5	138.2
3	8.6	4.5	7.8	10.5
4	194.5	103.5	116.4	164.0
5	225.3	108.5	121.5	196.0
6	6.4	2.5	3.8	4.9
7	48.9	10.5	32.1	15.6
8	5.8	3.4	4.1	5.2
9	25.8	16.4	25.6	10.8
10	4.8	3.1	6.1	4.3
11	203.5	96.8	98.6	175.5
12	30.5	25.3	30.4	18.6
13	26.8	10.2	26.5	32.5
14	11.0	3.5	4.8	10.2
15	85.6	25.4	27.5	29.5
16	73.4	36.4	30.4	30.4
17	175.6	114.3	110.0	168.3
18	7.6	2.1	5.1	6.5

The percentage of deformed tests was less in sample numbers 3, 6, 8, 10, 14 and 18. At unpolluted and minimally polluted sites the values of deformed test are moderate (0.2–5%). These small percentages of abnormal individuals do not seem excessive i.e., abnormalities are too infrequent to indicate environmental stress caused by pollution. Alve (1991) distinguished seven modes of deformation viz., double apertures, reduction in size of one or more chambers, protuberances on one or more chambers, twisted or distorted chamber arrangement, enlarged aperture, aberrant chamber tape, and twinned forms. In the present study, the degree of deformation managed from mild to extreme. The types of deformities recorded have a wider range of anomalies than those reported by Alve (1991). Additional modes of test deformation were detected, represented by cavities, compressed tests, and the formation of a bulla like chamber covering the umbilicus.

It is noticed that, in the present study, the majority of deformed tests in samples 1, 2, 4, 5, 11 and 17 have developed cavities, reduction in size of chamber, broken peripheries, corrosion and poor overall growth of the chamber. In samples 7, 9, 12, 13, 15 and 16 where aquacultural and agricultural untreated sewage is released, the faunal tests are compressed, twisted and reduced in size of the chambers. Samples 3, 6, 8, 10, 14 and 18 on the other hand, located away from direct pollution suggesting that these types of deformation represent the lowest response of benthic foraminifera to pollution.

Although the results of the present study shed some light on the response of the benthic foraminifera to human induced changes of the natural environment, it is still a speculative subject and future investigations including both field studies and culture experiments under controlled conditions may provide a new insight into the coastal pollution.

Conclusions

A detailed study of foraminiferal species was carried out along Nellore Coast of South India. Analysis of surface sediment samples, which are currently receiving industrial wastes, indicates heavy metal enrichment in Cr, Cu, Pb and Zn. On the other hand sediment samples which receive only agricultural and aquacultural drainage water, have heavy metal concentrations slightly higher than normal levels. Based on faunal analysis, the following conclusions could be inferred.

1. Heavy metal pollution has a more deleterious effect upon the foraminiferal test morphology than agricultural and aquacultural wastes.
2. The mode of deformation depends upon the nature of the pollutant. Forms having, corrosion, cavity development, broken peripheries and reduction in the overall growth are associated with high trace metal levels. Twinned and reduced chamber size forms, which represent the minimal response of benthic foraminifera to pollution, occur largely in sites subjected to agricultural and aquacultural runoff drainage water.

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