

POLLUTION EFFECTS MONITORING WITH FORAMINIFERA AS INDICES IN THE THANA CREEK, BOMBAY AREA

M. G. ANANTHA PADMANABHA SETTY

National Institute of Oceanography, Dona Paula 403 004, Goa (India)

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In the study area, the pollution effect on the foraminiferids is intense, hence highly reliable and measurable. The relative sensitivity of tolerance of the biota is sharply variable and dependent upon the nature of the pollutants discharged. The degree of pollution of this environment can be monitored through delineation of zones of effects of pollution.

INTRODUCTION

Thana Creek, a freshwater stream, flows into the Arabian Sea through Bombay and the mainland. It is highly polluted by the discharge of large quantities of effluents from the various factories located on either side of the creek. The various parameters like temperature, salinity, depth and tidal range are drastically affected by the heavy effluent discharge into the creek which has a very low fresh water inflow. Composite grab samples were collected at tide times to facilitate navigation, starting from the Colaba Light House point, through the harbour and up the creek to about 4 km north of the Bombay-Nova Sheva Bridge (Figure 1).

The main harbour area has a depth of 8 m (2 m more deeper than at the entrance to the Harbour), but the upper part of the Thana creek is of 4.6 m depth. This may be due to the influx of sediment from the open ocean at one end and the static (uneroded and not transported) sediment containing mostly solid wastes (contributed by the factories) at the other.

The temperature at the sediment-water interface is higher (26°C) than the surface temperature (23°C) all along the creek, and possibly with a minor fluctuation of 1-2°C inside the harbour area. This condition prevails throughout the year irrespective of all tidal movements into the creek.

PREVIOUS WORK

The relative sensitivity of benthonic foraminifera in the polluted marine environment caused by industrial effluents at Cola Bay, Goa, was studied

by Setty,¹ and at the inshore areas off Karwar, Karnataka, and Trivandrum, Kerala located along the west coast of India by Setty and Nigam.² Bandy and others³ studied the sewage outfall areas off Orange County, California, and Schaefer⁴ off Chaleur Bay, Canada. Setty¹ was able to show the variable responses of the benthonics to the dilution and dispersion gradient of the effluent from the proximal to distal zone from the point of discharge at Cola Bay, Goa. Bandy and others³ found foraminiferal abundance trends along the California coast and estimate the prominent types of living forms in the area affected by the sewage outfall.

SEDIMENT PATTERN

In the upstream region of the creek, up to station 3 near the BARC jetty point (see Figure 1), the sediment is very fine grained, mostly of clay character, dark to steel gray when wet, thick and very sticky. It becomes very hard on exposure to the atmosphere. The substrate pattern, however, changes further downstream, but remains clayish with admixtures of particles of coal, fine basaltic rock fragments and sand grains brought in from the open sea.

From the Elphanta island to the mouth of the creek at Colaba Light House point, the sediment is more of a mixed nature. It is composed of very fine particles of sand (up to 30 percent), and includes more abundantly (up to 50 percent) with, slag, grains of variously coloured particles, yellow element sulphur, and (up to 20 percent) highly decomposed calcareous shell debris including

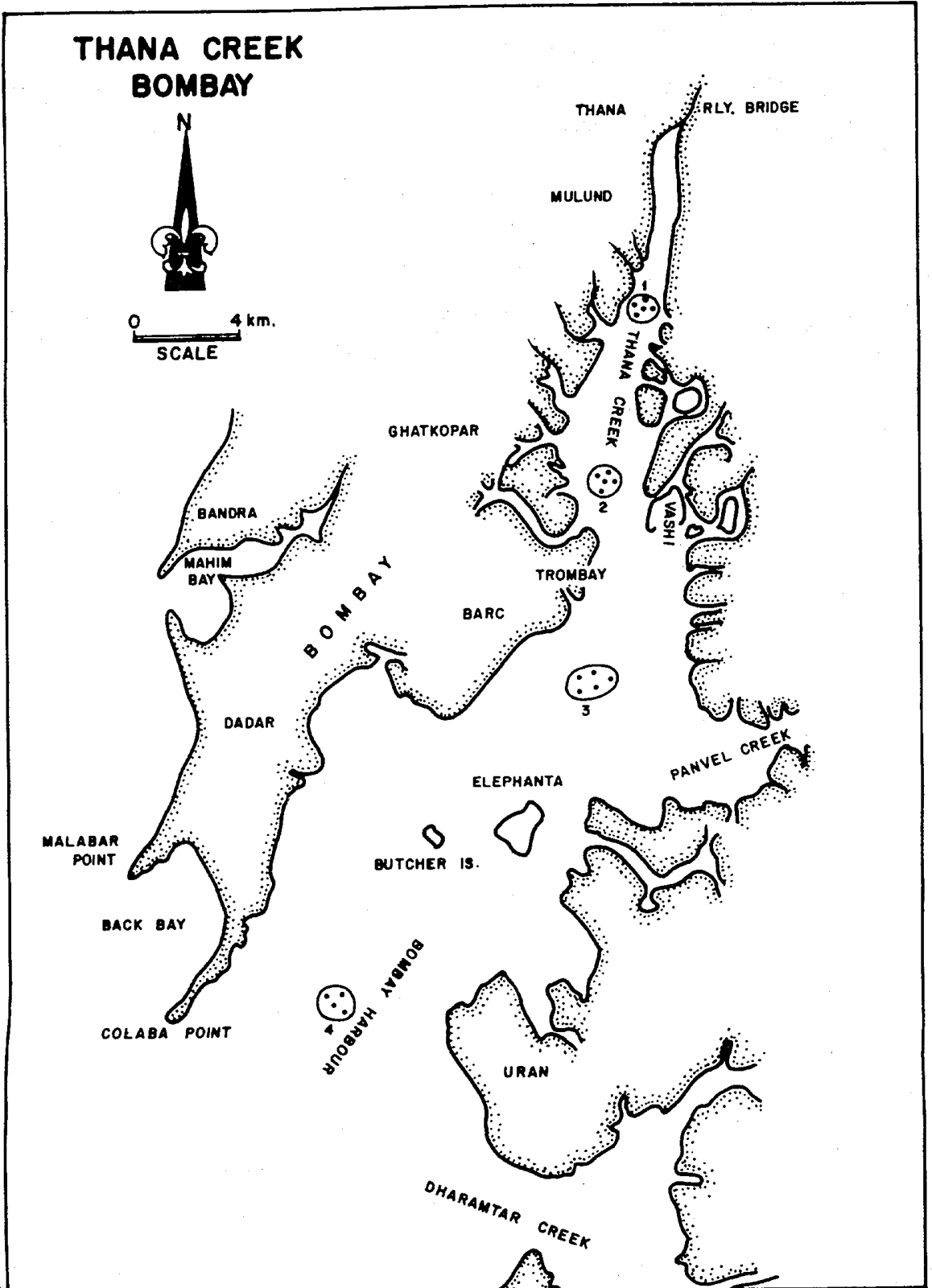


FIGURE 1 Station locations and physiographic setting of Thana Creek—Bombay harbour area.

| Station Number | Depth (m) | Temperature (°C) | | Salinity (‰) | pH | Tidal Range | Organic matter (organic carbon X 1.724 per dry weight) | Type of Substrate | Foraminifera (in 1 gram dry weight) | |
|----------------|-----------|------------------|-----------------------------------|--------------|------|-------------|--|-------------------|-------------------------------------|----------------------|
| | | Surface water | Sediment / bottom water interface | | | | | | Total Foraminiferal Number | Total species Number |
| 1 | 4.6 | 23 | 25.8 | 37.70 | 6.50 | 2.6 | 2.77 | Clay | 347 | 7 |
| 2 | 8 | 26 | 26 | 37.05 | 6.67 | 3.9 | 2.53 | —H— | 545 | 13 |
| 3 | 8 | 25 | 25.5 | 36.71 | 8.35 | 4.4 | 2.22 | Sandy-Clay | 1309 | 19 |
| 4 | 6 | 25.5 | 26 | 35.87 | 7.25 | 5.6 | 2.06 | —H— | 3049 | 28 |

FIGURE 2 Temperature, salinity, organic matter and foraminiferal distribution pattern in the study area.

foraminifera. Some particles of shell debris and foraminiferal tests are found to be encrusted and infilled by precipitates caused possibly by the highly saturated effluents present in the water (Figure 2).

The pH at stations 1 and 2 is more acidic, whereas it turns alkaline at station 3 and becomes normal at station 4. Similarly, it is somewhat hypersaline at stations 1 and 2, lower at 3, but normal at 4. The temperature of surface and the bottom water does not show any variation (Figure 2).

ORGANIC MATTER ESTIMATION

The organic matter is present in the form of fine particles of fragmentary wood and twigs which are mostly in a burnt, corroded, peeled, charred and decomposed condition. It is estimated by the El Wakeel and Riley method,⁵ wherein the organic matter present in a sample is oxidised with a known quantity of chromic acid and titrated against ferrous ammonium sulphate. The value thus obtained is multiplied by a factor of 1.724 (as recommended by soil chemists), which represents the amount of organic matter present in the sample. Figure 2 shows that it is high at station 1, but is reduced towards station 4. Some particles of unburnt coal is also encountered at station 4. However, the organic matter content present in the sediment is very high throughout, but analysis of samples (composites) at four stations (1 at 4 km north of Bombay-Nova Sheva bridge; 2 at 2 km south of the above bridge; 3 near the Bhabha

Atomic Research Centre, BARC, jetty; and 4 near the Colaba Light House point) showed that it is highest (2.77 percent) at station 1 and lowest (2.06 percent) at station 4. It is, however, high (2.53 percent) at station 2, but somewhat reduced (2.22 percent) at station 3 (Figures 1, 2).

This suggests that the small inflow of fresh water into the creek, coupled with the heavy discharge of pollutants together with high organic matter, raises the pH of the water and thereby turns the water more acidic. This condition, however, decreases gradually from stations 1 to 4. The dilution is mainly due to tidal effect and mixing with "fresh" sea water.

MICROFAUNAL DISTRIBUTION

Ostracoda are absent at station 1 but rare at station 2. They are, however, common at 3 and 4, and occur in various stages of preservation.

Foraminifera encountered at 1 and 2 are very small, embryonic and dull, and appear to be highly corroded having only a very low (5–10 taxa in 1 gram dry weight sediment) distribution. The preservation leading to identifiable forms are *Ammonia*, *Bolivina*, *Cibicides*, *Nonion* and *Quinqueloculina* sp. The agglutinated species like *Ammobaculites agglutinans*, *A. pensicus* and *Textularia* sp. occur in small numbers as dwarfed forms at station 2 only.

The species diversity (TSN) and the total foraminiferal number (TFN) is high at 3 (1:4) and 4 (but higher at 4 1:10), compared to stations 1 (1:1) and 2 (1:2), and include both

embryonic and adult forms, such as *Ammonia annectans*, *A. papillosus*, *Bolivina striatula*, *Elphidium advenum*, *E. discoideale*, *Eponides repandus*, *Florilus scaphum*, *Nonion boeneum*, *N. elongatum*, *Nonionella basispinata*, *Quinqueloculina lamarkiana*, *Q. seminulum*, *Triloculina tricarinata*, *Textularia agglutinans* and *Trochammina*. These are well developed and preserved, and also include transported, fragmented, pitted and dull looking embryonic forms. This indicates that only the dead foraminifera are transported in suspension by the tidal waters up into the Thana Creek through the harbour, and deposited on the way in the sediment. The dull looking forms suggest either reaction with the effluents, or mixing with the earlier types, or both.

DISCUSSION

The pollution effect on the foraminiferids is intense and marked, hence highly reliable in the estimation of the degree of pollution and thus measurable. The relative sensitivity of tolerance of the biota is sharply variable and directly dependent upon the nature of the toxicity of the pollutants discharged. The degree of pollution of the environment can be monitored through a delineation of zones of effects of pollution.

It is unfortunate that the high toxicity of the pollutants in the higher reaches of the creek does not permit any organism, including the foraminifera to survive and thus allow them to register the tolerance limit. It is obvious therefore that it is beyond the tolerance limitation, hence the living biota could not be established. Even the embryonic forms, which are brought in periodically through the high tidal waters, cannot remain alive because their survival under high toxic environment becomes nullified; hence this study was restricted to the microfossils only. Though conditions appear to improve at stations 3 and more particularly at 4, the comparison between the living and microfossils would be of an extreme nature, hence not attempted.

The absence of large-sized, well-preserved foraminifera and the presence of only small embryonic, thin walled, and digested forms (in various stages) in lesser abundance at stations 1 and 2 indicates that they are being destroyed very quickly in spite of the steady influx of tidal waters into the region. But the presence of a larger population, with high diversity and better preservation

at stations 3 and 4 suggests less damage owing to dilution, and dispersion due to mixing, and a periodically increased supply. The dilution is caused by the inflow of fresh water in the creek (no matter how negligible) and tidal effects, the dispersion due to mixing of these waters, and periodically increased supply of living as well as dead foraminiferal fauna through tidal waters. The toxicity of the *in situ* waters at stations 1 and 2 together with a continual discharge from the plants at various strengths from stations may kill the living forms as they ascend from stations 4 to 1 and further upstream. Hence the organic productivity in this estuary (?) is negative. The living foraminifera, if any (at the time of collection), take the pink stain of *rose bengal* when added to the sample at station 4. The diatom frustules (dead) are present throughout as they are not affected by the toxicity.

The corrosive effect on foraminifera at stations 1 and 2 is marked by pitting and thinning of the test wall of the specimens. The pH, high salinity and warmer temperature conditions prevalent at the substrate level appear to be inducing factors (Figure 2). Particularly in the central umbilical region of *Ammonia* sp., the ornamentation shows diminishing effects in such parts as knobs and pustules. In other specimens there is a deepening of grooves around the umbo and of earlier sutural thickenings, resulting in dull and porcellaneous appearance which is further augmented with increased pore size. Dissolution appears to be sharper and acute in the last and penultimate chambers through the widening of pores, as seen in *Nonion*, *Nonionella*, *Fursenkoina*, and *Florilus* sp. The widening of the aperture seems to be more marked in miliolids (*Quinqueloculina seminulum*, *Triloculina tricarinata*). Some miliolids have infillings and invariably their casts alone are present which is due to total removal of calcareous test wall. Further, pelicypod debris encrusted and foraminiferal tests having infillings by extraneous matter is suggestive of reducing and stagnant conditions.

These events suggest that the study area can be divided into three zones. They are characterised by (a) small, thin walled, highly corroded and digested forms of foraminifera occurring in various stages of dissolution, as noticed in the upper reaches of Thana creek, followed by (b) a transitional stage where mixed fauna with a few taxa of dwarfed and impoverished agglutinated species being present, and (c) well developed and well

preserved fauna dominating with an admixture of transported and fragmented fauna.

Therefore, it is observed that living foraminifera are not only totally absent but cannot also survive in the entire region of Thana creek and the harbour area, as the environment is too toxic, highly unfavourable and belligerently hostile for them to grow and proliferate. The organic matter values of the sediment are high throughout (2.06–2.77 percent) and are inversely proportional to the foraminiferal number. Also, they do not bear any correlation, as the area is devoid of living foraminiferal populations.

Further, the dead assemblage that is brought in through the tidal waters, shows a gradual decline from stations 4 to 1 in its abundance, quality diversity and state of preservation, but only results in a gradual increase in the rate of dissolution and destruction. This is a direct indication of the pollution effect of effluents discharged into the creek and a measure of the environmental stress undergone by the foraminifera. Thus foraminifera have proved to be good indicators of pollution in this environment.

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