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Sewage pollution in the coastal waters of Madras, east coast of India

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The extent of pollution over the coastal waters of Madras due to sewage inflow through the river Cooum was studied. Analyses were carried out at both low and high tides. Monitoring of estuarine and seawater opposite the mouth of the river at short intervals indicated a recovery in water quality with time from low to high tide and the effect appeared to be localized. Laboratory studies revealed that drastic reduction in faecal coliforms was aided by the native flora.

Sewage discharged by the river Cooum into the Bay of Bengal contains higher concentrations of ammonia, phosphate, faecal coliforms and organic matter relative to ambient seawater. It is hoped that measurement of various physico-chemical, biological and bacteriological parameters may provide a good indication of the spatial extent of pollution. This paper reports the result of such a study conducted at weekly intervals for 2 months during December 1989 and January 1990.

Materials and Methods

The coastal waters of Madras receive a large amount of untreated domestic sewage from the river Cooum through many open sewers which discharge it directly into the river. The bed slope of the river is very mild. This, together with the formation of a sand bar at the river mouth and a tidal range below 1.2 m prevent the effective flushing of the river during ebb tide. As a result, for periods other than monsoon, the stagnant river is anoxic and very rich in total organic matter. There is a periodical reversal of this trend only at the river mouth due to a weak tidal effect.

Samples of surface water were collected at 5 stations both at high and low tides (Fig. 1) at weekly intervals during December 1989 and January 1990. St I was located at Cooum estuary about 10 m upstream of the river mouth. Water samples were also collected at sts 1 and 2 at intervals of every 2 h one over tidal period during the above study period to document the recovery in water quality. Dissolved oxygen and nutrients such as nitrate, nitrite, ammonia, phosphate and silicate were measured[1]. Biochemical oxygen demand and faecal coliform estimations were done as outlined in APHA[2]. Water samples for bacteriological analyses were made in sterilized 300 ml bottles and all analyses were carried out immediately after collection.

To determine the survival period of faecal coliforms in seawater and to find the effect of native flora on the same, the following experiment was carried out. Surface seawater was collected from 1 km offshore and a portion of it was filtered using Whatmann GF/C 0.45 µm glass fibre filters. The filtered water was apportioned 1 l each into 2 sterile flasks. Native flora was introduced into one of these flasks such that there was a 10 fold increase in its population over the ambient seawater population. Raw seawater was also distributed 1 l each into 2 sterile flasks. Sewage water (10 ml) collected from one of the inputs into the river was inoculated into each of the flasks except the one containing raw seawater. Flask containing filtersterilized raw seawater with sewage inoculum was compared with flask containing added native phytoplankton.

Results and Discussion

Physico-chemical as well as bacterilogical parameters over the 9 weeks study period revealed that the impact of sewage was not felt beyond 250 m and in any case not beyond 500 m. The spatial extent of pollution based on data obtained on a particular

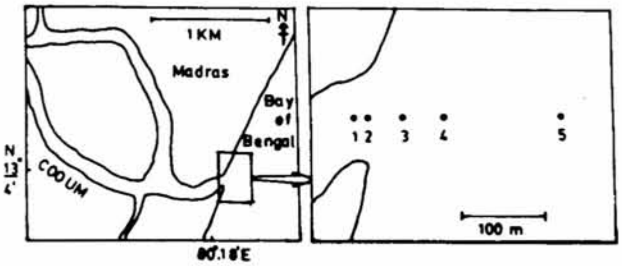

Fig. 1—Location of sampling stations

collection made on 30 December 1989 (high tide 0924 hrs; low tide 1524 hrs) and recovery in water quality based on data obtained on 31 December 1989 during 1600 to 2200 hrs only are presented due to similarity in the results and trends observed therefrom (Figs 2 and 3). Results show considerable variation between the high and low tide periods in dissolved oxygen, biochemical oxygen demand, ammonia and phosphate in the estuary and in the sea up to 100 m from the shore (Fig. 2). In contrast, at st 5 the variation was small. Generally at low tide there was a decrease in dissolved oxygen and an increase in BOD, NH_3-N and PO_4-P. However, st 5 when compared to other stations, showed an increase in dissolved oxygen and a reduction in NH_3-N levels during low tide suggesting that this reversal was partly due to photosynthetic processes and partly due to dilution as could be made out from BOD values.

At high tide, DO was greater than 4 $ml.l^{-1}$ at all stations, the maximum being 4.6 $ml.l^{-1}$ at st 4 while during low tide the maximum was at st 5 (4.96 $ml.l^{-1}$), st 4 registering a lower DO (2.43 $ml.l^{-1}$) and other stations recording no DO. A negative correlation between DO and BOD ($r = -0.6746$), DO and NH_3 - N ($r = -0.9762$, $P < 1\%$ level), DO and PO_4-P ($r = -0.8738$) as well as DO and faecal coliform ($r = -0.882$) was noticed at low tide which was to be expected as effluents are very rich in organic matter, NH_3 and PO_4. Further, BOD showed significant positive correlation with PO_4-P both at high ($r = 0.9691, P < 1\%$ level) and low tide ($r = 0.948, P < 1\%$ level). A positive correlation was also obtained between BOD and NH_3-N, BOD and faecal coliform and a negative correlation between BOD and salinity confirming the nature of the effluents. Nitrate, nitrite and silicate were so low as to be of any significance.

At high tide, faecal coliforms showed a maximum of 7900 at sts 1 and 2 and minimum of 13 at st 5. Corresponding numbers during low tide were 9.2×10^6 at st 1 and 5400 at st 5. As with NH_3 and PO_4, faecal coliforms showed maximum in the estuary and gradually decreased in number towards the sea. However, they showed a large decrease with progression from sts 3-4 during high tide and from sts 4-5 during low tide.

Sampling at short intervals within the tidal period revealed great recovery in water quality by way of increased oxygen and reduced BOD, NH_3-N, PO_4-P and faecal coliforms within 4 h after low tide. The recovery was more complete at high tide (Fig. 3).

Laboratory studies revealed a great reduction in faecal coliform population when raw sewage was introduced into seawater (Table 1). The reduction was more pronounced in the presence of native flora

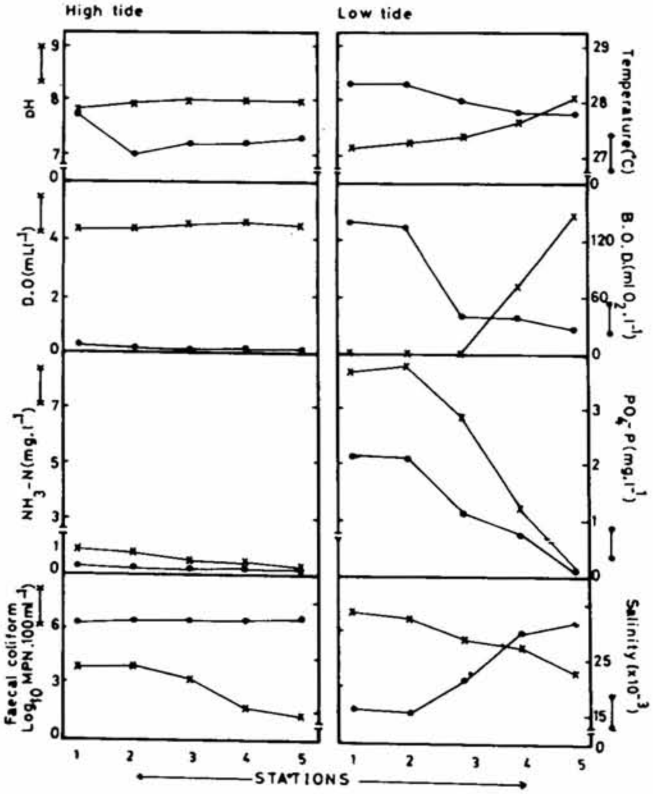

Fig. 2—Variations in pH, temperature, DO, BOD, NH_3-N, PO_4-P, faecal coliforms and salinity during high and low tides

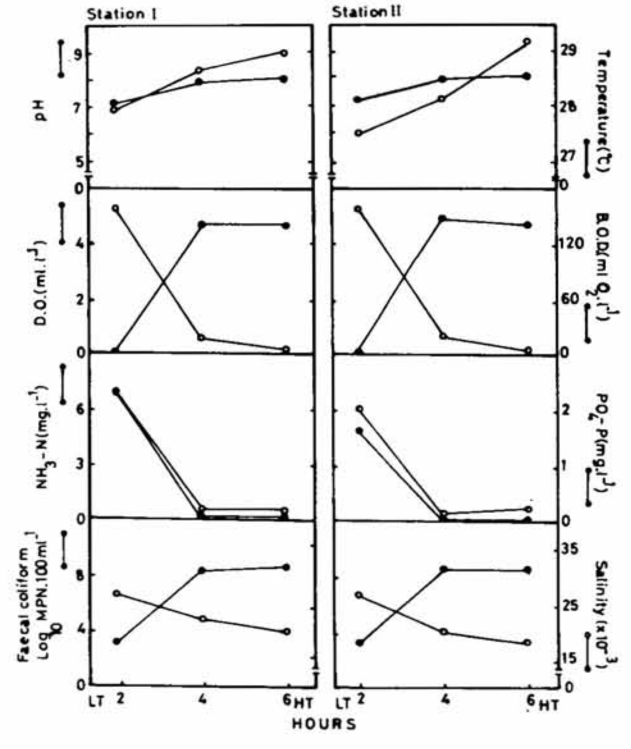

Fig. 3—Variations in pH, temperature, DO, BOD, NH_3-N, PO_4-P, faecal coliforms and salinity at intervals of every 2 h during one tidal period at sts 1 and 2

Table 1—Survival of faecal coliforms in treatments of seawater [Values in table refer to faecal coliforms MPN. 100 ml^{-1}, and values in parentheses indicate percentage survival]

Treatments	Time in hours			
	0	8	16	24
Raw seawater	79 (100)	11 (13.9)	0 (0)	0 (0)
Raw seawater + inoculum	540000 (100)	49000 (9.07)	3300 (0.6)	490 (0.09)
Filter sterilized seawater + inoculum	280000 (100)	23000 (8.21)	4000 (1.43)	350 (0.13)
Filter sterilized seawater + phytoplankton from 10 l seawater + inoculum	490000 (100)	20000 (4.08)	1300 (0.27)	230 (0.05)

which included phytoplankton (2.4 $\mu g.l^{-1}$ in terms of chl *a*) and other micro-organisms. Greater the number of native flora (24 µg chl $a.l^{-1}$) greater was the reduction in the number of faecal coliforms, thereby implicating the role of the former in contributing to the die off of *E. coli*. Algae are capable of antibiotic production[3-5] and bactericidal effect of seawater is impaired to a large extent by either autoclaving the seawater or allowing it to age[6]. Though nutrient enrichment and salinity[7] of seawater play a role, solar radiation and sedimentation have been implicated to account for bulk of the die off in the sea[8]. In the present study, relatively low density of bacteria in seawater when the tide progressed from low to high might be attributed, not just to factors such as antibacterial property of the native population, light, salinity, nutrients, predation and the initial concentration itself, but mainly to dispersion and dilution as was evident from decrease in BOD, NH_3-N, PO_4-P and increase in DO and salinity. Moreover when the tide changes from low to high the quantum of sewage discharged into the sea decreased as seen from the salinity values. That this stage was reached well before high tide was reflected in the recovery of water quality. Several field studies undertaken in different seas have shown[6] that 90% of coliform die (t_{90}), within 1 to 10 h. Present study showed that presence of native population helped in the rapid achievement of t_{90}.

In the present study no values of DO and very high values of BOD, PO_4-P, NH_3-N and faecal coliforms were recorded at low tide, not just in the estuary but even at nearshore stations in the sea. That the estuary is tide dominated[9] is clearly established by an earlier work[10], wherein very high values of BOD, PO_4-P, NH_3-N, faecal coliforms and heavy metals was reported at stations upstream of the river mouth. Obviously the slush is pushed up and down and oscillate with the tide without easily flowing out. The river Cooum to a good extent acts as a sink, trapping some of the excess nutrients and pollutants discharged into it. The load of pollution on a volume basis in the river is far greater than other similar estuaries of the east and west coast of India[11-14] and is on many occasions greater than that of Visakhapatnam harbour area[15-17]. That the load of pollution discharged into the sea at Madras is greater than that at Visakhapatnam is evident from the fact that sediments along the coast and continental shelf north of Madras show relatively high concentrations of organic carbon and trace metals such as Fe, Cu, Mn, Zn and Hg than north of Visakhapatnam[18].

Among the many inorganic substances released, ammonia has been reported to stimulate algal metabolism[19]. The present study, revealed the presence of high concentration of ammonia and absence of other forms of nitrogen which may mean the preponderance of anaerobic decomposition by facultative heterotrophs using sewage as carbon source. This virtual single source dependence on ammonia as nitrogen source may be of importance to phytoplankton as species composition is partly based on diversity of inorganic species of available nitrogen. Earlier studies[20] in the coastal waters off Madras showed that total cell number at the river mouth increased while species diversity decreased and there was also an increase in chlorophyll content and gross production. However, net production was least in this region due to intense microbial activity.

The effect of discharge of river Cooum is largely dependent on prevailing tides. Drastic pollution during low tide is seen up to a maximum of 100 m offshore. There is a swift recovery in water quality when tide changes from low to high and the recovery is complete even before onset of the highest tide. Faecal coliforms hitherto used as indicator of sewage pollution in estuaries may also be used as indicator in the sea as shown by the study here.

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