

Dispersion and retrievability of water quality indicators during tidal cycles in coastal Salaya, Gulf of Kachchh (West coast of India).

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Abstract

Bacterial indicators in relation to tidal variations were studied at 5 locations for over two days covering three tidal cycles in the southwestern region of Gulf of Kachchh, India. Tidal flow here is predominantly in the east west direction and can transport particles up to 32 km. Tidal amplitude appears to play a prominent role in abundance, distribution and dispersal of coliform bacteria examined during this study. Shallow depths, clayey sediments, strong currents and higher tidal amplitudes appear to rise by an order of magnitude in total bacterial abundance up to $2.4 \times 10^4 \text{ ml}^{-1}$ due to their resuspension from the churned up sediments. Dispersal of allochthonous microflora far into coastal marine regions appears to be governed by the strong tidal amplitude in this region.

Keywords: Gulf of Kachchh, tidal movements, MIKE 21, bacterial dispersion.

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Introduction

Tides serve various biological functions. They aid transportation of larval stages of many invertebrates (Cronin et al.1979; Brookings et al. 1985), affect ambient nutrient concentrations as well as water quality. Understanding their influence is critical to both basic ecology of tidal creeks and for evolving sampling protocols and pollutant-mitigation advisories. Lindquist (1990) observed dispersal of soil bacteria from their habitats of origins due to passive and active water movements. Such dispersion may vary with the influence of external factors like sewage outfall or riverine inputs apart from tidal movements.

The Gulf of Kachchh (GOK) is a semi-enclosed embayment in the northeastern Arabian Sea. It is a very complex marine water body, encompassing several tidal inlets, creeks, small islands, shoals, coral reefs, tidal flats and rocky regions (Babu et al.2005). The tides here are predominantly semidiurnal and, surface currents vary from 0.75-1.25 ms⁻¹ at the mouth to 1.5-2.0 ms⁻¹ at the head, sometimes reaching a maximum of 2.5 ms⁻¹ (Desa et al.2005). There are reports of acute sedimentation at some packets due to capital and maintenance dredging. Dredging and the prevalent strong tidal currents have altered this ecosystem by transporting the sediment to other parts (Babu et al. 2005). Since the tidal amplitudes are so large in GOK, it is an ideal site for an understanding of dispersal of allochthonous microbial populations. Relative amount of suspended sediment at the study locations at different times in the tidal cycles would have been better support to this work but we did not collected samples due to various reasons. Thus, this study was undertaken to monitor the variations in bacterial abundance including those of water quality indicators over tidal cycles and their dispersion in the coastal stations in the mid region of the Gulf.

Material and Methods

Study area and sampling

As a part of developing the coastal zone management plan for the GOK, several short cruises were organized onboard CRV Sagar Paschmi to collect oceanographic and other environmental data. A cruise was conducted during 7-9 November 2002 (Cruise no: PAS-28-2002-2003) specifically to collect samples for studying the dispersal of bacteria with respect to tidal phases. Sampling was fixed off-Salaya keeping a current-meter mooring site (spot C in Fig. 1) for reference. From there, other stations N1, N2 north of C and S1, S2 south of C were sampled. Samples were collected during the ebbing and flooding tides by maintaining the requisite time intervals of two hours. A total of 49 water samples, ~10 during each tidal cycle, were collected covering 3 high- and two low- tides.

Flow pattern

The flow pattern during the period of sampling was obtained from the MIKE 21 model (Danish Hydraulic Institute, Denmark). The simulated current values were validated with the measured current vectors extracted from the current meter mooring off Salaya. This model has been earlier used to study the tidal driven currents, eddies and residual currents in the Gulf of Kachchh. Many details of this study are available in (Vethamony et al, (2005); Babu et al, (2005).

Water quality indicators

Water samples were collected using a Niskin sampler. About 200 ml sub- samples were transferred to pre sterilized polythene bottles, stored on ice immediately following collection and, transported to onshore laboratory for analysis within 2 hrs of collection. Samples were analyzed for total viable counts (TVC), total coliforms (TC) and fecal coliforms (TFC). Selective media viz., Hi-chrome coliform agar for TC, Rapid Enterococcus Agar for TFC and Nutrient Agar (prepared with 50% seawater) for TVC were used for enumeration of above bacterial groups. All the media were procured from Hi-Media, Mumbai. Standard microbiological methods (APHA, 1985) were followed for all microbiological analyses. Water samples were filtered through pre-sterilized 0.22 μ m pore sized cellulose acetate membrane filters (Whatman; Japan) and placed on the respective media. Plates were incubated for 48 hours or more before the final counts were recorded.

Physico chemical parameters

A Conductivity - Temperature –Depth (CTD; Sea-Bird SBE 25) profiler was operated at each station immediately after the water sampling to get the salinity and temperature profiles. The meteorological parameters such as barometric pressure, wind speed and direction and solar radiation were measured using Automatic weather station (AWS) available onboard.

Results and Discussions

Water temperature ($28 \pm 0.5^\circ$ C), salinity (37 ± 0.5 PSU) and dissolved oxygen concentrations (4.41 ± 0.5 ml l⁻¹) showed minor variations than those of wind speed, solar radiations and all the bacterial numbers (Table 1). The maximum counts of bacteria, of both heterotrophic and enteric groups, were from the coastal stations; TVC: 2.44×10^4 ml⁻¹, coliforms: 92 ml⁻¹ and fecal coliforms: 7.02×10^2 ml⁻¹ Table 1. Variations of bacterial population with respect to tide height are depicted in fig 2,3 and 4 explains the retrieval rates among the samples(49) analyzed, large number of samples were shown positive indication for total coliform bacteria, this reveals a fresh input of sewage and anthropogenic perturbation in the sampling area.

Bacterial dispersion with Tides

Bacterial distribution varied greatly over tidal cycles. Samples collected from the sites during different tidal phases at various time (Fig 2, 3 & 4) showed that the heterotrophic bacterial population estimated from the first sample during flood tide (tide elevation of 2.3m) is of the order of $4.6 \times 10^3 \text{ ml}^{-1}$. Subsequently, during the ebbing, this population receded to $2.9 \times 10^2 \text{ ml}^{-1}$. Such synchronous reductions in most of the bacterial populations were noticed at almost all the collection. The counts remained in the order of 10^2 ml^{-1} until the flood tide (tide height: 2.4 m). TVC counts were back to 10^3 orders when the tide receded. Among the 49 samples analyzed, the maximum numbers of heterotrophic counts in the order of 10^4 ml^{-1} was recorded during flood tide, when tide height in the region exceeded 3 m. The TC counts were in the range of 77- 92 ml^{-1} when the tide was > 2.0 m high and reduced to non-detectable levels when it was < 1.0 m in height. Usually, the TFC were more whenever the TVC were high suggesting that the TFC is an important component of viable fractions in the region.

Our observations are quite similar to those of Goyal et al, 1977 and Davies et al, (1995), who suggested that fecal coliform bacteria are often concentrated in sediments and their subsequent re-introduction to the water column by tidal stirring (tidal re -suspension) can increase their concentrations in the water column. Our results further confirm high heterotrophic and coliform counts whenever the tidal elevations were high (Fig 2, 3 & 4).

Wilson et al, 1980 found no significant change in total bacterial abundance over a tidal cycle but did observe a significant fluctuation in the abundance of bacteria attached to particles, which appears to be due to re-suspension of sediment particles; However, Wright et al, 1983 reported highest bacterioplankton abundance at low tide in the lower portion of the Essex estuary.

Flood tides create strong currents in the Gulf. These currents re-suspend the sediments and elevate bacterial population in the water column. The Gulf of Kachchh is known for very high-suspended load (0.11 to 3.60 g l^{-1}) especially during post monsoon season (Vethamony et al., 2005). Our results also imply that variation in the bacterial abundance might be possible in the tidal estuaries due to high-suspended load, which was as high as 3.60 g l^{-1} in GOK mostly during high tide time.

Harder, 2005 in his article, bacteria in most of the sites during spring tides ; those associated with full and new moons significantly elevated enterococci concentrations .Further he has quoted Boehm and Weisberg work, saying negative effect on water quality was greatest when a spring tide was going out. This explains the important of bacterial role during tidal cycle on water quality.

Tidal current modeling

Tidal flow pattern observed through MIKE 21 models were not plotted here to avoid large number of graphs (5 models for the five stations) .It can be referred through Fig1 which is displayed with distance and depth. The uppermost station in the northern side (N2), the flow is in the east west direction, which is in tune with the flow pattern in the central gulf from mouth to head. Due to the diversion of flow around an island west of C, the flow pattern for N1 to S1 is in northwest – southeast. Therefore, the bacterial populations are expected to disperse up to 15-20 km from these stations (Fig 1). Flow pattern in station S2 is partly north-south in direction along with eddy like structure. From the extent of the flow pattern observed from the model for all the stations, the extent of bacterial dispersion is expected to be around 23km in the direction along the gulf and about 13km across the Gulf (Fig 1). Considering the bacterial cells to be non-decaying and inert particles, it can be inferred that the organisms present at station N2 are likely to be transported in the east west direction and their populations from stations N1, C and S1 are transported in the northwest – southeast direction. At station S2, the organisms are likely to be mostly present in the same region due to circular flow pattern and the net movement would be towards the coast.

The model study explains that the movement of particles is observed towards south from N1 onwards. The exchange of materials may be possible between C and S1. At N1 the particle movement was towards station C. Since station C is not showing any southward movements, the probability of particle movement is meager from C to S2 due to the circulation pattern.

Conclusion

Average variation of different bacterial population explained at Fig 6 station wise i.e.,TVC ($6.4 \times 10^3 \text{ m}^{-1}$)(C),TC (20ml^{-1}) (S1) during high tide and FC (10ml^{-1})at (S1) during low tide. Even though the data is of one time observation the number of samples reflect 6 during high tide and 4 during low tides at each station. This results suggests that the fresh inputs received from the land were not dispersed much towards northern side. Further rocky offshore in the northern side do not support to add bacterial populations from the suspended matter or sediment. Therefore their abundance does not show much variation in the north. Thus influences over other coastal process like sedimentation and bacterial settlement are also minimal in the northern side. From this study it can be summarized that high tide in the GOK increases bacterial numbers. Attributable to sediment re-suspension, tidal elevations of greater than 3 m during flood tides resulted in maximum bacterial retrieval in these coastal waters.

Acknowledgements

The authors thank the Director, National Institute of Oceanography, Goa for providing the facilities to carry out the work. Ms. Celina Rodrigues, Ms. Eveline Alvares, Ms. Rahila Bi Mallahi Baksh, and Ms. P. Suja Jayan are duly acknowledged for their help in microbiological analyses. This work was partly funded by the ICMAM, Dept. of Ocean Development, Govt. of India.

References

- APHA-AWWA-WPCF., 1985. *Standard methods for the examination of water and wastewater*, 16th edition. American public health Association (APHA), Washington DC, pp1628.
- Babu. M.T., Vethamony, P., Desa Ehrlich., 2005, Modelling tide driven currents and residual eddies in the Gulf of Kachchh and their seasonal variability A marine environmental planning perspective, *Ecol. Model.* 184, 299-312.
- Brookings, K. G., Epifanio, C. E., 1985. Abundance of brachyuran larvae in a small coastal inlet over six consecutive tidal cycles. *Estu.* 8, 60-67.
- Cronin, T. W., Forward R. B., Jr 1979. Tidal vertical migration an endogenous rhythm in estuarine crab larvae. *Sci.* 205, 1020-1022.
- Davies, C. M., Long, J .A., Donald, M., Ashbolt, N. J.,1995. Survival of fecal microorganism in marine and freshwater sediments. *Appl. Environ. Microbiol.* 61(5)1888-1896.
- Desa, E.,Zingde, M.D.,Vethamony, P.,Babu M.T.,D'Souza, S.N.,Verlecar X.N., 2005. Dissolved oxygen- a target indicator in determining use of the Gulf of Kachchh waters. *Mar. Pollut. Bull.* 50, 73-79.
- Goyal, S.M., Gerba, C.P., Melnik, J. L., 1977. Occurrence and distribution of bacterial indicators and pathogens in canal communities along the Texas coast. *Appl. Environ. Microbiol.* 34(2), 139-149.
- Harder, B (2005). Bacteria ride the tide: moon`s phases predict water quality at beaches. *Science News*, July2, 2005.
- MIKE21., 2001, User Guide and Reference Manual Reference manual, Danish Hydraulic Institute, Agern Alle, Horsholm, Denmark, 70pp.
- Roland Lindquist., 1993, Dispersal of bacteria in ground water-mechanism, kinetics and consequences for facilitated transport, <http://www.kem.ekol.lu.se/theses.html>
- Vethamony, P., Reddy, G. S., Babu, M. T., Desa, E., Sudheesh, K., 2005, Tidal eddies in a semi-enclosed basin: a model study, *Mar. Environ. Res.* 59, 519-532.
- Wilson, C.A., Stevenson L.H., 1980. The dynamics of bacterial populations associated with a salt Marsh. *J. Exp. Mar. Biol. Ecol.* 48,126-127
- Wright, R. T., Coffin, R.B., 1984. Measuring microzooplankton grazing on planktonic marine bacteria by its impact on bacterial production. *Micro. Ecol.* 10, 137-149.

Table 1 Various meteorological and microbial parameters recorded during November 2002 from the gulf of Kachchh

Parameters	Minimum	Maximum
Temperature ° C	27.9	28.4
Salinity (psu)	37.12	37.80
Oxygen saturation (ml l ⁻¹)	4.39	4.43
Water depth (m)	9.0	24.0
Wind speed (m/s)	1.85	8.35
Solar radiation μM/m ²	ND	4.52E+06
TVC (cfu ml ⁻¹)	135	24400
TC (cfu ml ⁻¹)	ND	92
TFC (cfu ml ⁻¹)	ND	702

TVC – Total viable counts; TC – Total coliforms; TFC – Total fecal coliforms
ND-non detectable levels; cfu – colony-forming units.

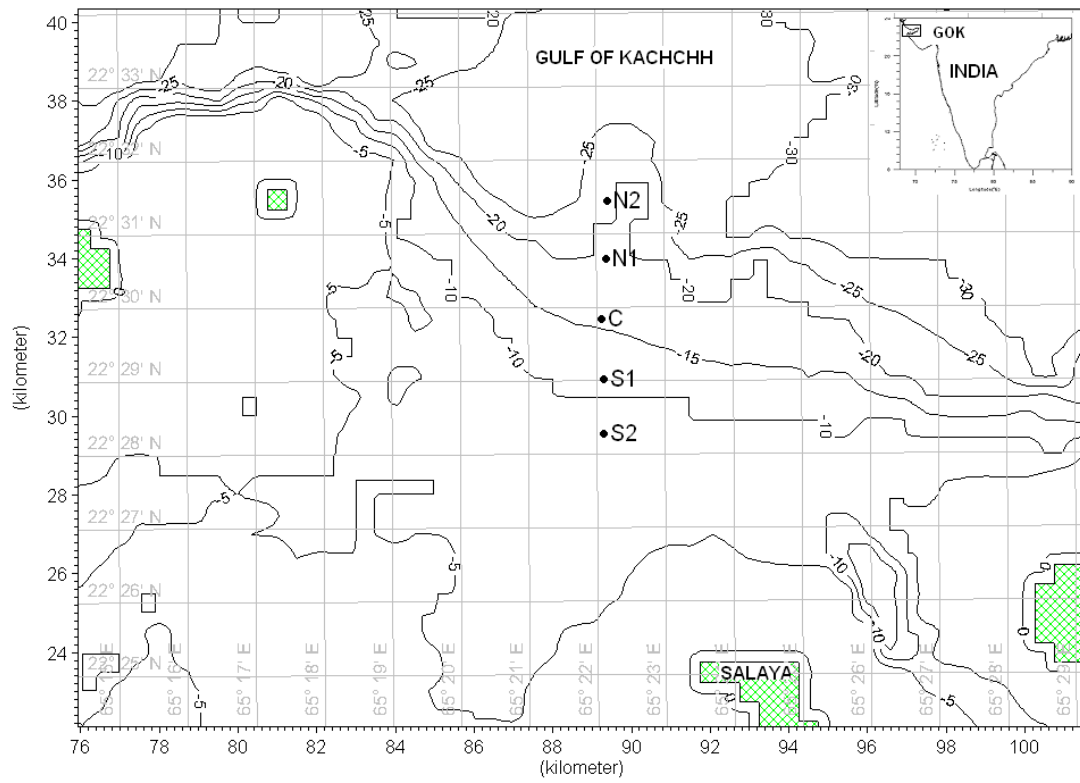


Fig. 1 Sampling locations in the Gulf of Kachchh

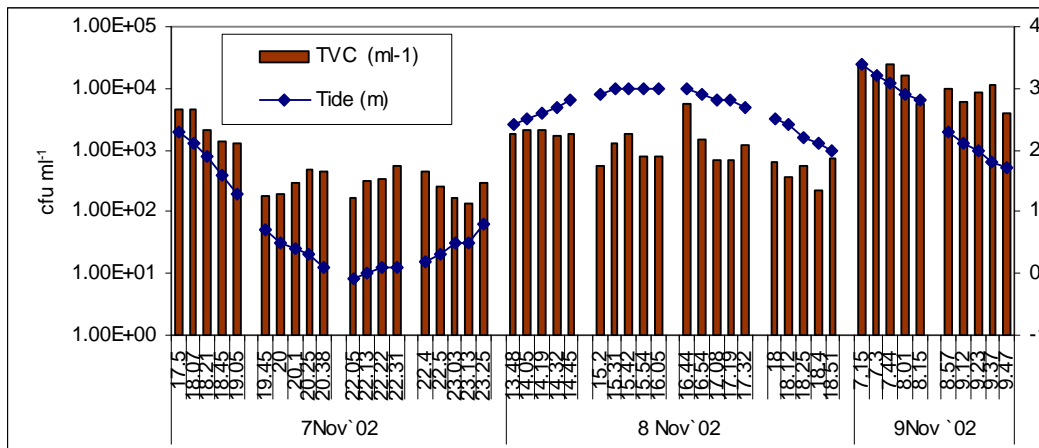


Fig. 2 Retrieval of Total viable counts in relation to tide at various time intervals during 7-9th November 2002

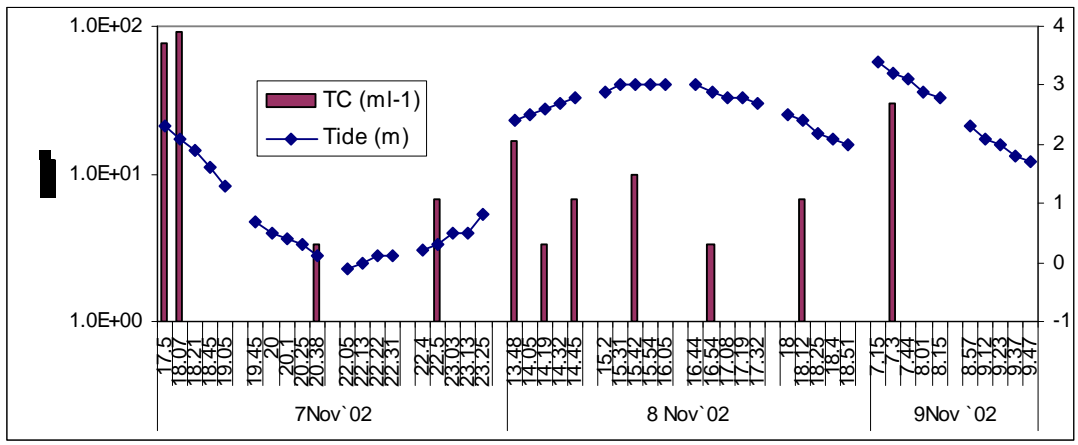


Fig. 3 Retrieval of Total coliforms in relation to tide at various time intervals during 7-9th November 2002

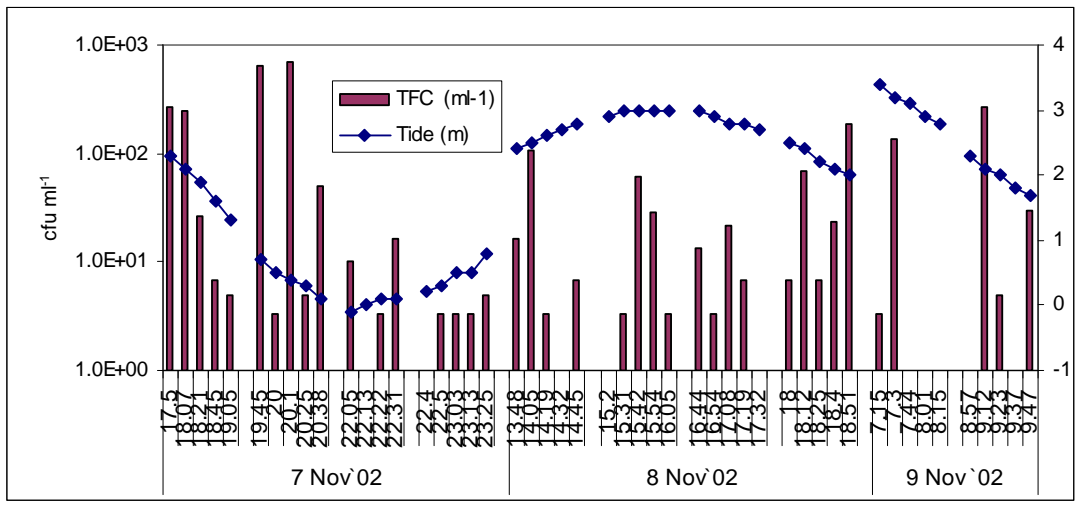


Fig. 4 Retrieval of Total Fecal Coliforms in relation to tide at various time intervals during 7 -9th November 2002

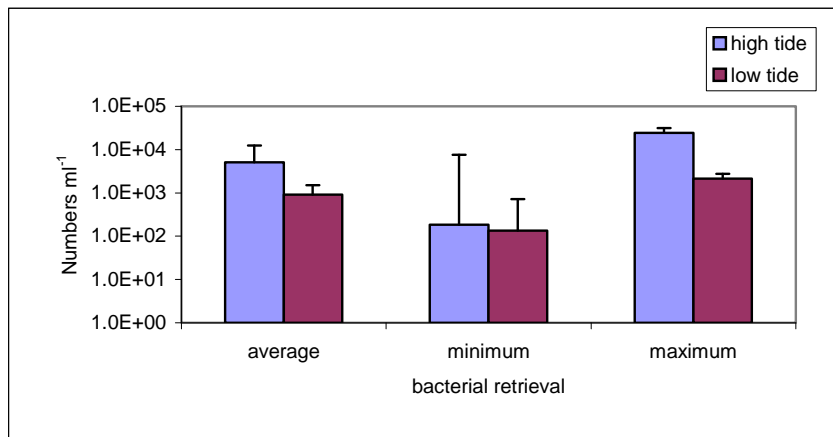


Fig. 5 Average counts of heterotrophic bacteria during high and low tides in the Gulf of Kachchh. Bars indicate standard deviation

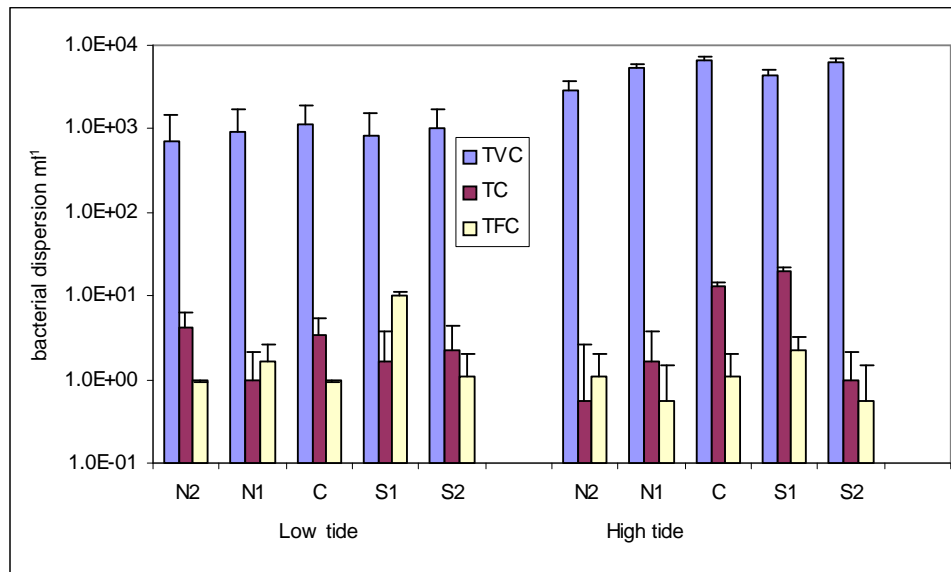


Fig. 6 Station wise variations of heterotrophic(TVC), Total(TC) and Fecal coliforms(TFC) (mean±SD) at sampling sites in the Gulf of Kachchh during low and high tides.