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Prevalence of multiple pollutants in selected Tamil Nadu coastal waters, Southern India

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Abstract

The sea water samples from five different coastal cities (Chennai S1, Cuddalore S2, Nagappattinam S3, Tuticorin S4 and Kanyakumari S5) in Tamil Nadu were collected during premonsoon 2015 for physiochemical, microbiological and trace metal studies. The high bacterial load in the study sites indicated that which received enormous waste materials from different sources like land materials, municipal discharges, agricultural and industrial discharges, and more visits. The higher pollution index (PI) ratio (>1) were observed in all sampling sites which indicated the human fecal matters were responsible for sea water pollution. The statistical approach (correlation) explained that the physiochemical and trace metal parameters are not supporting the microbial growth in large extend. Based on the report, this study was suggesting that throughout impoundment is needed to protect fresh water sources.

Keywords: Pollution indicators, Physiochemical parameters, Tamil Nadu coast, Trace metals, Pollution index.

1. Introduction

Coastal waters have traditionally been considered as the ultimate sink for the by-products of human activities. In the recent past, expanding human population, industrialization, intensive agricultural practices and discharges of massive amount of wastewater into the ocean have resulted in deterioration of water quality. Estuarine water will be particularly vulnerable to pollution due to the enclosed nature of the system and the subsequent accumulation of pollutants. It has been estimated that 70–80% of marine debris comes from land-based sources [1]. Heavy rains can cause sewage overflows, thus, by passing sewage treatment facilities, increasing surface water runoff directly influencing microbiological water quality. Discharges may be regular, through long and short sea outfalls and irregular through storm water and overflow outfalls, and unregulated private discharges. Due to the severe anthropogenic activity, the nutrients / physiochemical and microbial load, and trace metals levels were drastically fluctuated.

Besides the marine microbiota, seawater and sediments can contain a significant nonindigenous microbiota composed by bacteria, virus and protozoan that are discharged to the environment from domestic sewage and urban drainage water [2]. The presence of such microorganisms in recreational seawater, sediments and beach sands affect the quality of these habitats, leading to high risk of beachgoer's health due to waterborne and other illness, as well as to the high resistance that can be showed by these microorganisms to several antimicrobial agents such as antibiotics [3].

Pollution of the natural environment by heavy metals is a worldwide problem as these metals are indestructible and have toxic effects on living organisms when they exceed a certain concentration limit [4]. Heavy metals in environment mostly come from lithogenic and anthropogenic sources. Through the natural process of biomagnifications, minute quantities of metals become part of the various food chains and concentrations become elevated to levels which can prove to be toxic to both human and other living organisms [5]. The aim of this present research was to determine the level of bacterial, physiochemical and trace metal parameters from five different water samples in the coastal cities and also find their sources of pollutions. Further, the statistical approach helps to understand the relationship between the parameters with respect to pollution.

2. Materials and methods

2.1 Sampling

The sea water samples from five different places in Tamil Nadu coast were collected during premonsoon 2015 for bacteriological (pollution indicators and pathogenic bacteria), physiochemical and heavy metal analysis. The sampling

sites were Chennai (S1), Cuddalore (S2), Nagappattinam (S3), Tuticorin (or) Thoothukudi (S4) and Kanyakumari (S5). The sampling sites were chosen based on the massive discharges of pollutants into coastal zone without any sort of treatment and those are an important coastal cities and harbors in the Tamil Nadu coastal line. The sea water samples were collected from 0 to 20 cm below the surface [6][7]. The 2000 mL of water samples were collected with a 2500 mL sterile container in each location and stored in ice box at 4 °C. The samples were transported into laboratory and processed within 10 hrs. The one liter of sea water sample was acidified immediately with concentrated nitric acid after the collection of sample in the field.

2.2 Physiochemical and trace metal analysis

The physiochemical parameters, i.e., pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured using field kit (Thermo Orion 5-Star pH Multi-Meter) on the site and the concentrations of soluble cations and anions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{-}, HCO_3^{-}, Cl^{-} and SO_4^{2-}) were determined according to the method described by APHA [7] and Vignesh *et al*[9][10]. For trace metal study, acidified sea water samples were filtered by Whatman No.1 filter paper and processed (APDC + MIBK) for metal analysis. The trace metals in the sea water samples were determined by the atomic absorption spectrophotometry (GBC SensAA - AAS, Australia) in flame mode [11].

2.3 Bacteriological analysis

All the selective media were prepared with the addition of old age seawater and autoclaved properly. The bacterial populations in different water samples were estimated by pure culture technique on selective medium plates with 100 µL of suitable dilutions. All the media plates were incubated at 37°C ± 1°C for 24–48 h, except M-FC agar plates. The M-FC agar plates were incubated at 44.5°C ± 1°C for 24–48 h. After incubation, the final counts of colonies were noted and all trials were performed in triplicate. Based on the media manufacturer's guide and our earlier experiences, typical colonies were recognized and initial enumeration of bacterial groups was completed. The specific biochemical tests were performed for identification (Rapid Microbial Limit Test kits used) of bacterial strains and are referred to as like organisms (LO) [6] [12]. Typical colony characteristics of each bacterial group and specific media used for enumerating them are listed in Table 1.

2.4 Statistical analysis

Pearson correlation coefficient was employed for the better understanding of relationship between the concentrations of multiple variables (physiochemical vs bacteriological vs trace metal parameters) by using statistical package of ORIGIN8.0 [10].

3. Result and discussion

In this study, the range of pH, EC and TDS in sample were 7.76-8.34, 21823 – 32734 µS/cm and 34640 – 51960 mg/L, respectively. The mean level of salinity in S1, S2, S3, S4 and S5 sites were 30, 28, 22, 20 and 23 respectively. The DO and BOD levels in S1, S2, S3, S4 and S5 sites at premonsoon were 6.1 and 7.8, 3.1 and 5.7, 5.3 and 7.8, 5.2 and 6.3, and 4.1 and 6.4, respectively (Figure 1 and 2). The physiochemical and bacterial parameters were higher in Goa coast [13], Mumbai water [14], India when compared to our study regions. But, the present results were higher than the Visakhapatnam coast [15] and was indicated that the Indian coast is highly fluctuated every day owing to the severe contamination through different ways. The growing problem of degradation of our coastal ecosystem has necessitated the monitoring of water quality of various regions all over the country to evaluate their state of purity for different utilization [16]. Kistemann *et al* [17] in 2003 observed that during rainfall, the microbial loads of running water may suddenly increase and reach reservoir.

Total viable counts (TVC) were in the order of magnitude above 10^3/mL for all the five locations and it also contains many number of *Enterobacteriaceae* family strains. The counts of TVC, TC, TS, FC and FS were in the range of 5.5 - 10.4 [x 10^4], 2.0 – 8.6 [x 10^3], 2.1 – 12.4 [x 10^2], 2.2 – 8.2 [x 10^2] and 0.2 – 1.0 [x 10^2] respectively (Figure 3 and 4). Conformation with microbiological standards is of special interest because of the capacity of water to spread diseases within a large population [7]. Fecal material from human, domestic animals (dogs, cattle, and horses), as well as birds/waterfowl (geese, gulls, and ducks), all lead to increases in bacterial/ pollution indicators loading in aquatic regions. Monitoring of physicochemical characteristics is not only decided the quality of water but the microbiological studies are also an important analysis for assessment of water quality [7].

Most of the parameters in the sea waters showed marked variation at each sampling locations due to the accumulation of mass discharges of different waste materials into the coastal zone. The mean value of pollution index in S1, S2, S3, S4 and S5 was 8.2, 11.0, 7.8, 7.9 and 15.5 respectively. The FC and FS levels in S1, S2, S3, S4 and S5 sites at premonsoon were 820 CFU/mL and 100 CFU/mL, 220 CFU/mL and 20 CFU/mL, 710 CFU/mL and 90 CFU/mL, 630 CFU/mL and 80 CFU/mL, and 310 CFU/mL and 20 CFU/mL, respectively. The TC and TS levels were higher in all the locations and was 5 – 10 fold higher than the FC and FS levels. The mean TC levels in S1, S2, S3, S4 and S5 were 8.4

[x10^3], 2.0 [x10^3], 8.6 [x10^3], 8.3 [x10^3] and 3.4 [x10^3] CFU/mL, respectively. The TS level was 4 – 10 fold lower than the TC levels.

In this study, the physiochemical, microbial and trace metal parameter levels were high in the sea water and it can be classified either polluted or unpolluted based on Bureau of Indian Standards [18] and World Health Organization [19] guidelines. Sewage contamination in aquatic environments is commonly detected and quantified by enumerating the coliforms bacterial groups [20]. The aquatic environment is able to recover from the inorganic/organic/trace metal pollution stress only after the diffusion and probably through their self-purification system [9].

Metals are very important for humans, plants and environment. Some of these elements are indispensable for humans and plants while some are toxic. In addition, concentrations of beneficial elements above a certain level may also create toxic effect. The mean Cd level in S1, S2, S3, S4 and S5 were 0.28, 0.22, 0.18, 0.32 and 0.21 mg/L while mean Pb levels were 0.18, 0.24, 0.18, 0.32 and 0.21 mg/L respectively (Figure 5). High levels of heavy metals (e.g., cadmium, cobalt, mercury, copper lead, vanadium, and zinc) in aquatic ecosystems are regarded as serious pollutants, because they can be toxic and incorporated into the food chain. The determination of trace metal contents in coastal environment is one of the important indicators for the assessment of environmental pollution [21].

Correlation matrix

Pearson coefficient correlations between the parameters provided interesting information on their relationship and sources. The coefficient correlations between the variables are listed in Table 2. The bacterial and physiochemical parameters showed less / moderate negatively between them. Interestingly, the pH is not positively correlated with other parameters such as EC, TDS, Salinity, DO and BOD whereas Cd and Pb is high positive correlated. The positive correlation indicated that the variables are strongly associated with each other due to the same origin. The lead was negatively correlated with all physiochemical parameters except pH. Interestingly, the pH was positively correlated with Cd and Pb only remaining parameters showed that negative correlation. At the same time, the bacterial parameters showed high positive correlation with each other. Similar pattern was observed in Tamil Nadu coastal waters [10].

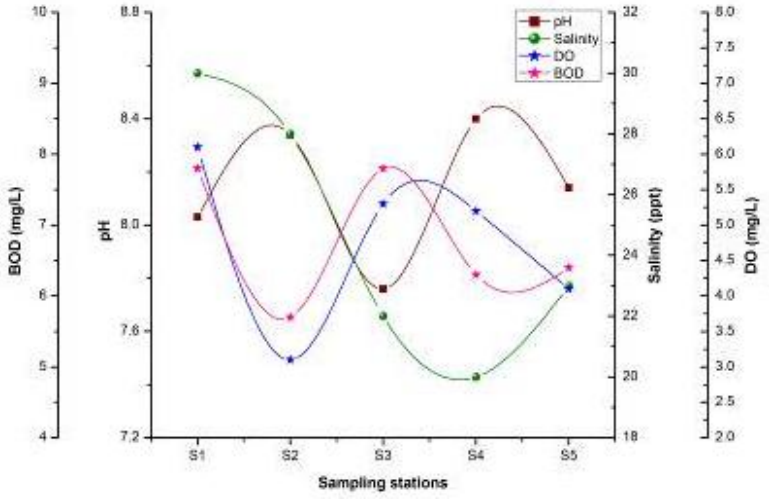

Figure 1: Concentrations of pH, Salinity, DO and BOD levels in seawater sample of Tamil Nadu coast

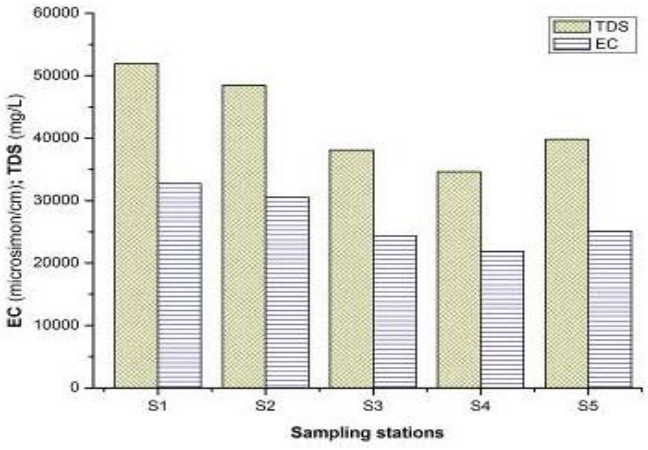

Figure 2: Concentrations of EC and TDS levels in seawater sample of Tamil Nadu coast

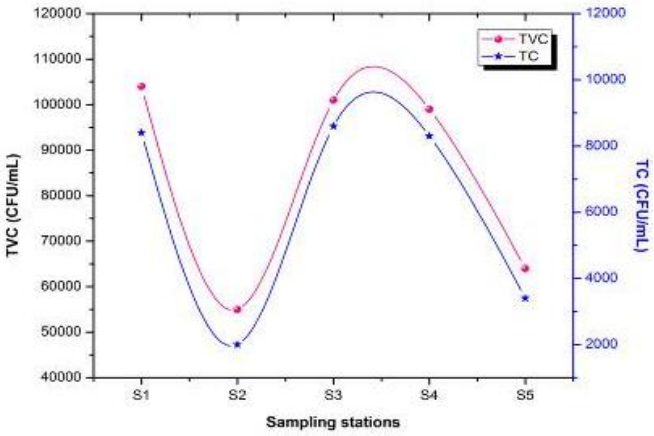

Figure 3: Counts of TVC and TC levels in seawater sample of Tamil Nadu coast

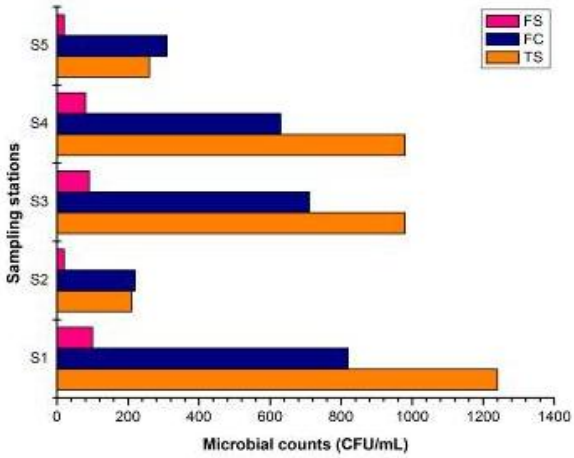

Figure 4: Counts of TS, FC and FS levels in seawater sample of Tamil Nadu coast

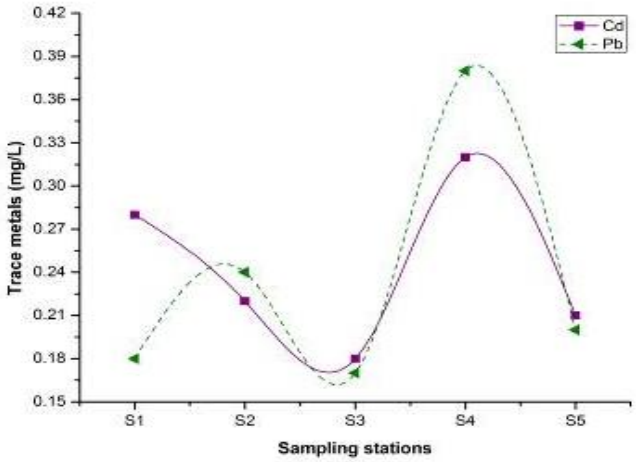

Figure 5: Concentrations of Cd and Pb levels in seawater sample of Tamil Nadu coast

Table 1: Details of specific culture media used for quantitative bacterial analysis

S.No	Bacterial Indicators	Culture medium	Positive Colonies	References
1.	Total Viable Count **(TVC)**[a]	Nutrient Agar	All colonies counted	Nagvenkar and Ramaiah [13]
2.	Total Coliforms **(TC)**[a]	MacConkey Agar	All colonies counted	Clark *et al* [15]
3.	Total *Streptococci* **(TS)**[a]	M *Enterococcus* Agar	All colonies counted	Vignesh *et al* [6]
4.	Fecal Coliforms **(FC)**[b]	M FC Agar	Blue colonies counted	Vignesh *et al* [7]
5.	Fecal *Streptococci* **(FS)**[a]	KF *Streptococcus* Agar	Red colonies counted	Vignesh *et al* [10]

[a] Media plates were incubated at 37°C ± 1°C for 24–48 h; [b] Media plates were incubated 44.5°C ± 1°C for 24–48 h

Table 2: Coefficient correlation between microbial, physiochemical and trace metal parameters in Tamil Nadu coastal waters

Parameters	TVC	TC	TS	FC	FS	pH	TDS	EC	Salinity	DO	BOD	Cd	Pb
TVC	1												
TC	1.00	1											
TS	0.98	0.97	1										
FC	0.98	0.97	0.99	1									
FS	0.99	0.97	0.99	0.99	1								
pH	**-0.44**	**-0.44**	**-0.40**	**-0.51**	**-0.46**	1							
TDS	**-0.18**	**-0.26**	**-0.01**	**-0.01**	**-0.04**	**-0.03**	1						
EC	**-0.17**	**-0.24**	0.00	0.00	**-0.02**	**-0.06**	1.00	1					
Salinity	**-0.18**	**-0.26**	**-0.01**	**-0.01**	**-0.04**	**-0.03**	1.00	1.00	1				
DO	0.96	0.94	0.96	0.98	0.94	**-0.47**	-0.04	**-0.03**	**-0.04**	1			
BOD	0.79	0.77	0.78	0.86	0.81	**-0.86**	0.12	0.15	0.12	0.84	1		
Cd	0.41	0.39	0.47	0.36	0.38	0.60	**-0.02**	**-0.04**	**-0.02**	0.41	-0.12	1	
Pb	0.07	0.10	0.04	**-0.08**	0.00	0.79	**-0.50**	**-0.52**	**-0.50**	**-0.08**	**-0.56**	0.73	1

Negative correlation value shown in bold form

TVC – Total viable count; TC – Total coliforms; TS – Total *Streptococci*; FC – Fecal coliforms; FS – Fecal *Streptococci*; TDS – Total dissolved solids; EC – Electrical conductivity; DO – Dissolved oxygen; BOD – Biological dissolved oxygen; Cd – Cadmium; Pb - Lead

4. Conclusion

The present study identified the relationship between the different variables (trace metal, microbial and physiochemical) by Pearson coefficient correlation method and was also studied their elevated level in the study area. The pollution index indicates that the study sites were highly contaminated by human activities (fecal matters). The correlation indicated that microbial accumulation is not depending on the physiochemical and trace metal concentrations while those variables are closely associated with each other, except physiochemical parameters. The efforts need to be made to raise awareness among the public about the risks that occur in their environment and are due to their activities.

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