Studies on Pollution and Contamination in Fishing Harbor Environment, Tamil Nadu, Southeast Coast of India

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***Abstract*: - This study aimed to determining the pollution and contamination of fishing harbor environment. Temperature (3.12, 1.874, 1.04, 1.25 ^{o}C), Salinity (2.05, 2.50, 2.49, 2.52 ppt.), pH (0.08, 0.10, 0.04, 0.06), Dissolved oxygen (0.56, 0.52, 0.53, 0.37 ml/l), Total Nitrogen (0.05, 0.11, 0.19, 0.07 µg/g), Total phosphorous (0.03, 0.03, 0.09, 0.06 µg/g), Total organic carbon (1.16, 0.26, 0.87, 0.63 mg/g); Soil texture *viz.* Sand (0.83, 0.99, 1.57, 2.28 %), Silt (0.60, 1.26, 1.58, 1.44 %), Clay (0.43, 0.47, 0.23, 1.36 %); Heavy metals are Cadmium (5.86, 3.58, 5.67, 0.05 µg/g), Copper (10.39, 54.74, 56.81, 15.98 µg/g), Lead (8.63, 9.05, 7.58, 5.88 µg/g), Nickel (28.86, 34.20, 23.56, 5.48 µg/g), Zinc (44.18, 48.19, 57.16, 52.56 µg/g), Chromium (28.06, 55.25, 38.23, 12.55 µg/g), Mercury (20.61, 22.99, 12.50, 7.37 µg/g) at st.1,2,3,4 respectively. Benthic faunal density ranged between 602 and 2988 nos. /m^2 with Shannon–Wiener index (*H'*) ranged 2.03 - 3.5, evenness (*J'*) 0.79 - 0.98, richness (*d'*) 1.24 - 6.49. According to these estimations point calimar (Station. 4) contains less pollution contamination than other stations; indicated by rich density and diversity of benthic fauna occurrence in this station.**

***Key words*: Benthic fauna; Soil; Heavy metals; Contamination; Pollution**.

I. INTRODUCTION

In recent years the marine environments are contaminating from various waste discharge. Kinds of anthropogenic and industrial waste create pollution in particularly water environment due to their daily activity. The marine environment is sensitive ecosystem for protect flora and fauna [1]. When a benthic community is undergoing stress due to unfavorable environmental conditions there are presumed to be notable changes in community parameters such as diversity, abundances, dominance and biomass[2]. Assessments of the benthic fauna communities depend on the variety of ecological factors with the biotic effect, facing kinds of phenomena, with that important parameters are climate, geology and geographical distributions[3].

Present days the global species dispersal affects the biodiversity in aquatic environment[4,5]. The composition of benthic macro invertebrate communities is influenced by a variety of environmental factors, main effects from chemical and biological factors, several benthic taxa especially indigenous gammarids and *Asellus aquaticus* tended to decline with increased densities of the invasive amphipod *Dikerogammarus villosus*[6].

Anthropogenic disturbance of marine habitats is constantly increasing in scope and severity; macro benthic invertebrates are useful for bio-indicators providing a more accurate understanding of changing aquatic conditions than other chemical analysis[7]. Plenty of research effort has recently focused on the development of methods for detecting such changes and understanding their consequences[8-12]. Some benthic fauna indicate pollution in particular environment based on the kinds of waste matters[13].

Biological monitoring is on important for species identification in the specific environment condition[14], and used for industrial implementation[15], with the coarser taxonomic has sensitive for environmental destruction[16]. Investigation of pollution impact is difficult to determine in the ecosystem[17]. These kinds of problems occur from the waste discharge to the environments[18]. The calculation of species richness and other taxonomical evidence to described various water pollution[15] some of the species can tolerate the metal pollution[20]. The surrounding distribution of any water ecosystem will affect the macro invertebrates which provide the health to the environment[21, 22]. In this way the present study focused on four different areas besides the fishing and industrial activity along the Tamil Nadu coast. This often makes the interpretation of the disturbing effects of contaminants a complex and confounding process.

II. MATERIALS AND METHODS

Four different study areas were selected around the Tamil Nadu, Southeast coast of India from Chennai to Tuticorin with the location described below **(Fig 1).**

1) Chennai (Station 1) = Lat.13°7'22.8''N; Long. 80°17'57.01''E
2) Cuddalore (Station 2) = Lat.13°14'06.1''N; Long. 080°19'43.4''E
3) Tuticorin (Station 3) = Lat.08° 47'25" N; Long.78 ° 09' 36" E
4) Point calimere (Station 4) = Lat.10°16'21.53" N; Long.79°49'37.83" E

Water and soil samples were collected from Chennai, Caddalore, Tuticorin and Point Calimar harbor area; season wise sampling was made from January – December 2014 (one year). Water and soil quality was estimated through various analyses by the help of standard equipment with methodology. Physical, Chemical and biological parameters[23], Soil texture[24], organic carbon and heavy metals[25], Biological parameter of benthic fauna collected triplicate samples was carried out using a long armed peterson grab which covered inner area of 0.0251m^2 [26], benthic fauna identification [27-31]. Data analysis used by SPSS (Ver. 20.0), Margalef's species the richness (*d'*), Shannon – Wiener diversity (*H'*), Pielou's evenness (*J'*), PRIMER (Plymouth Routines In Multivariate Ecological Research Ver. 6.0). Station. 1 Chennai: Pre-monsoon (CHPM); Post-monsoon (CHSM); Summer (CHPR); Monsoon (CHMO). Station. 2 Cuddalore: Pre-monsoon (CUPM); Post-monsoon (CUSM); Summer (CUPR); Monsoon (CUMO). Station. 3 Tuticorin: Pre-monsoon (TUPM); Post-monsoon (TUSM), Summer (TUPR); Monsoon (TUMO). Station. 4 Point Calimer: Pre-monsoon (POPM); Post-monsoon (POSM); Summer (POPR); Monsoon (POMO).

III. RESULTS

Station wise physico-chemical characteristics:

Estimated parameters were varied based on the concentration of pollution discharge in the study area. The average range of temperature (°C) 30.63, 29.31, 29.21, 29.87, Salinity (ppt) 31.33, 31.00, 31.01, 30.71; pH 8.12, 8.09, 8.15, 8.06; Dissolved oxygen (ml/l) 3.52, 3.62, 4.39, 5.23. Soil characters *viz*. Sand (%) 96.81, 95.43, 95.59, 94.26; Silt (%) 2.45, 3.77, 3.83, 4.03, Clay (%) 0.74, 0.80, 0.58, 1.71; Chemical properties of Total Nitrogen (µg/g) 0.39, 0.36, 0.50, 0.44; Total phosphorus (µg/g) 0.10, 0.19, 0.21, 0.17; Total organic carbon (mg/g) 3.07, 1.13, 3.58, 5.00; Heavy metal concentration of Cadmium (µg/g) 7.80, 3.28, 6.17, 0.23; Copper (µg/g) 178.00, 204.49, 178.55, 131.23; Lead (µg/g) 14.12, 14.71, 11.51, 6.44; Nickel (µg/g) 40.63, 51.89, 39.42, 14.31; Zinc (µg/g) 67.51, 55.32, 78.63, 64.93; Chromium (µg/g) 143.54, 158.04, 200.85, 100.18; Mercury (µg/g) 30.75, 35.50, 23.50, 14.75 at St.1,2, 3 and 4 respectively.

Station wise benthic composition:

There are four major groups of macro benthic fauna were identified in four station soil samples, with this groups covered 61 species *viz*. polychaetes (34), bivalves (12), gastropods (9) and crustaceans (6) among the group's polychates are dominant phyla than other groups. Maximum macro benthic density were recorded 901, 923, 1276 and 2985 nos. /m^2 followed by the station 1, 2, 3 and 4 respectively.

Season wise physico-chemical characteristics:

Maximum value of temperature 35.13 °C (CHSM), Salinity 34 ppt (CHSM, CUSM, TUSM, POSM), pH 8.2 (CHPR, CHMO, TUSM, TUPR), DO 5.68 mg/l (POPM); Soil texture of Sand 97.65% (CHSM), Silt 6.10% (TUPM), Clay 3.74% (POMO), Organic nutrients are Total nitrogen 0.76 µg/g (TUPM), Total phosphorus 0.32 µg/g (TUMO), Total organic carbon 5.75 (POPM); Heavy metals are Cadmium 15.13 µg/g (CHMO), Copper 265.30 µg/g (CUMO), Lead 26.65 µg/g (CUMO), Nickel 96.62 µg/g (CUMO), Zinc 138.48 µg/g (TUPR), Chromium 256.20 µg/g (TUMO), Mercury 65.00 µg/g (CUMO) was recorded at station 1,2,3, and 4 respectively.

Minimum value of temperature 27.67 °C (CUSM), Salinity 29 ppt (CHMO, CUPM, CUMO, TUPM, TUMO, POPM, POMO), pH 8.0 (CHPM, CUPM, POPM), DO 3.02 mg/l (CUSM): Soil texture of Sand 91.65% (POMO), Silt 1.61% (CHSM), Clay 0.36% (CUPM), Total nitrogen 0.23 µg/g (CUPM), Total phosphorus 0.05 µg/g (CHPR), Total organic carbon 0.89 mg/g (CUPM); Heavy metals are Cadmium 0.17 µg/g (POPR), Copper 112.42 µg/g (POSM), Lead 2.14 µg/g (POPM), Nickel 8.46 µg/g (POSM), Zinc 14.64 µg/g (POSM), Chromium 84.32 µg/g (POPR), Mercury 6.00 µg/g (POPM) was noticed in station 1,2,3, and 4 respectively with the detailed results were showed in fig. 2 - 5.

Statistical analysis:

Water quality parameters did not show any variation between the stations except temperature and dissolved oxygen. Temperature have highly positive correlated with richness in station 3 and station 4 ($r=0.961$; $p<0.05$) and ($r=0.954$; $p<0.05$) respectively. Dissolved oxygen significantly positive correlated ($r=0.960$; $p<0.05$) with richness of the species in station 3. Sediment organic nutrients are positive correlated between total nitrogen with macro faunal diversity ($r=0.994$; $p<0.01$) at station 1. The evenness have positive correlation with total organic carbon ($r=0.994$; $p<0.01$) at station 2. Diversity of fauna positively correlated with total organic carbon ($r=0.974$; $p<0.05$); the diversity and evenness have the week negative correlation with total phosphorous ($r=0.973$; $p<0.05$) and ($r=0.990$; $p<0.01$) at station 3 .The sediment composition, sand positively correlated with richness ($r=0.989$; $p<0.05$) and diversity negatively correlated with silt ($r=0.988$; $p<0.05$) at station 4. The heavy metals such as cadmium, copper, nickel chromium and lead showed a week negative correlation with the species diversity, richness and evenness showed in table 1-4.

From the results of MDS ordination and hierarchical clustering, on species abundance data representing the four stations with seasons (Fig. 6 & 7). Cluster analysis showed that the grouping of macro faunal abundance, stations (Station 1, 2 and 3) were combining, separate indication showed in station 4. The 2D stress value (0.11) indicated that the results are credible and also it confirmed by the MDS plots.

Multiple k-dominance plots facilitate the discrimination of benthos according to species-relative contribution to standard stock. The k-dominance plot curve was drawn based on high- and low flow macro faunal community data. In the present investigation the data collected during various seasons and from all four stations was fed into to the dominance plot (Fig. 8). Highest dominance was observed at station 4 (POPM), where the macro faunal assemblage indicates high diversity. The curve for stations 1, 2 and 3 showed the minimum diversity. The higher diversity was recorded in post monsoon season and lower diversity in the monsoon season in less disturbed area. The dominance curve did not show an 'S' shape due to the presence of opportunistic species in stations 1, 2 and 3.

Species diversity indices:

The Shannon–Wiener index (H') ranged from 2.33 to 3.50 with the maximum diversity value was found at station 4 during summer and the minimum was found at station 1 during post monsoon. The evenness (J') varied from 0.79 to 0.98 and with the maximum was found at station 3 during post monsoon and summer seasons and the minimum was found at station 4 during monsoon. The richness (d') value varied from 2.11 to 6.49 with the minimum was found at station 1 during post monsoon and maximum was found at station 4 during pre monsoon.

The dendarogram results showed unequivocally that the stations of four areas were grouped separately. Among the study area, station 4 reflected linked at the higher level of similarity (80%) compared to other areas. To confirm this pattern of grouping, MDS (multi dimensional scaling) was performed and ordination map revealed the same grouping as observed in cluster analysis.

IV. DISCUSSION

Anthropogenic disturbances are affecting the benthic community in marine environment, which may result to change the growth of organism with increase mortality. Based on these phenomena, for estimate the faunal abundance and identified the species specification to use determined the environment condition[32]. Present study shows that the macro faunal assemblages of four station of Tamil Nadu coast exhibit marked variations. Macro benthic assemblages are characterized by temporal and spatial changes in the populations. Macro faunal distribution pattern seems to be fully governed by the physico-chemical and biological characteristics of the environment. Benthic animals on the bottom have to endure a wide range of environmental changes[33], based on this description also indicate this present study of benthic community varied due to the environmental changes.

Pollution discharge was affecting the benthic community in tuticorine harbor environment[34], Tamil Nadu, India. Polycheates density was increased in organic pollution in soil that due to the total organic carbon [35-37], with these similar results was observed in these harbor soil. Polychaete and bivalve groups was abundant in Indian harbor sediment[38]. Hence the similar finding are observed in present study, its indicate domination of benthic species of *Capitella capitata*, *Meretrix meretrix*, *Certhidia cingulata* some crustaceans of Amphipods.

The major group of bivalve and gastropods are richly placed in benthic environment, that's due to the enriched nutrient availability in the bottom soil; specific species of *Meretrix meretrix*, *Cerithidia cingulata* was occurring[39-40]. Amphipods are widely distributed in organic waste spread environment of estuarine and mangrove soil[41], which gives feed to the benthic fauna was reported in Vellar estuary and Pondicherry mangroves.

Our present finding determined the physical, chemical and biological properties in four harbor environment, which is magnified the status of water and soil conditions. Among the four stations, the maximum faunal density and diversity was recorded in station 4 and minimum range of faunal dispersal in station 1. Hence, the meaning of healthy environment supposed to indicate the pollution free area. Rich density and diversity of the benthic community are always occurring in the pollution free environment[42]; these reasons are similarly relevant in station 4.

V. CONCLUSION

Contaminated harbor water and soils are generating environmental issue to the benthic community, which create pollution in the ecosystem. Present study was evaluated the environmental quality of fishing harbor in Tamil Nadu. Comparison between the four stations, station 4 indicate pollution free fishing harbor. The reason was derived by parameters changes which are pointed out the benthic fauna density and diversity was more found in station 4 and the same duration, station 1 contain less density of benthic fauna, because station 4 has less organic and inorganic contamination was found than station 1. Whereas station 2 and 3 found moderate water and soil contamination.

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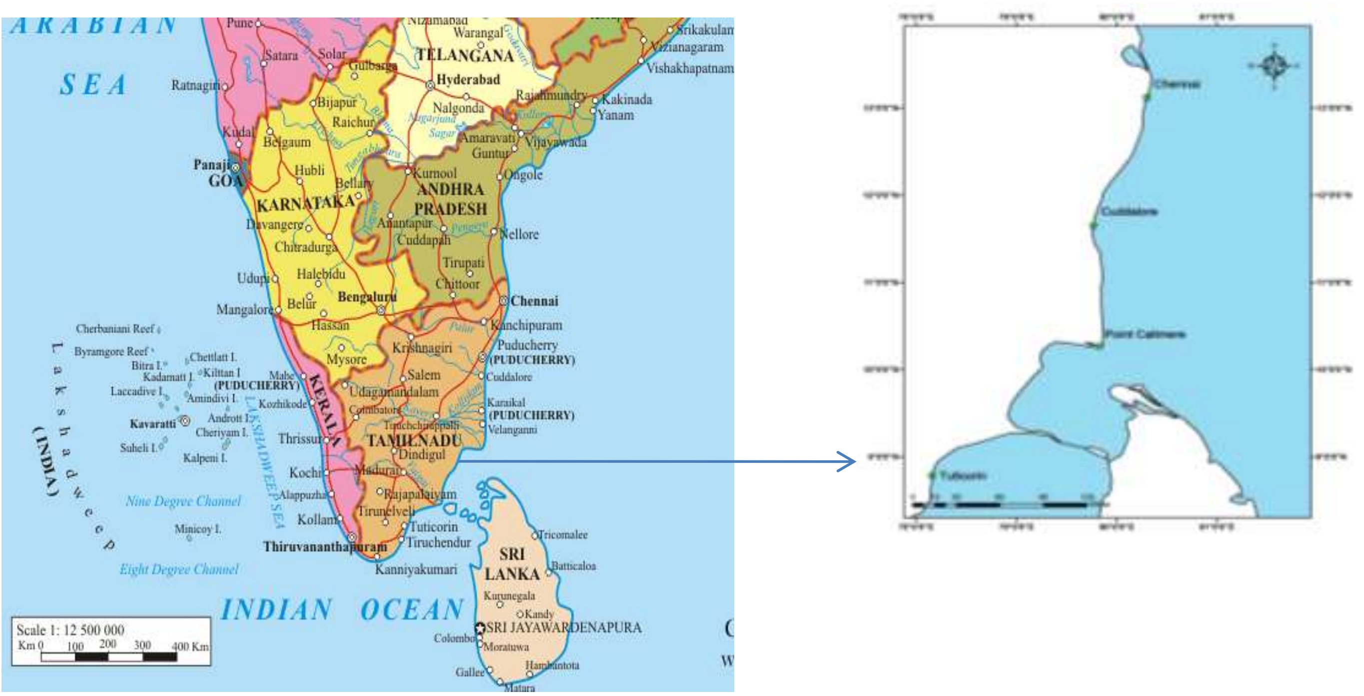

Fig. 1. Map showing study locations in Tamil Nadu coast

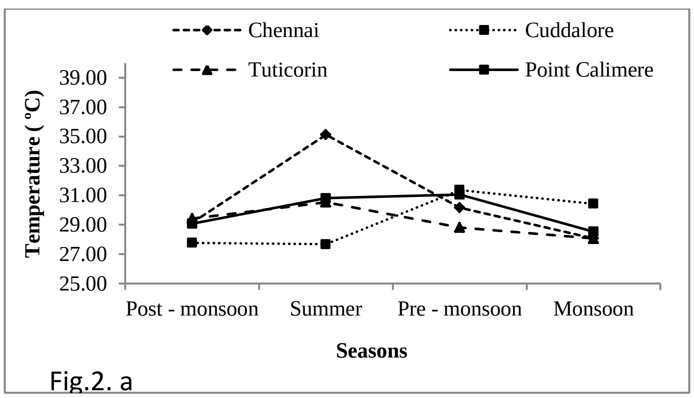

Fig.2.a = Seasonal variation of Temperature in water

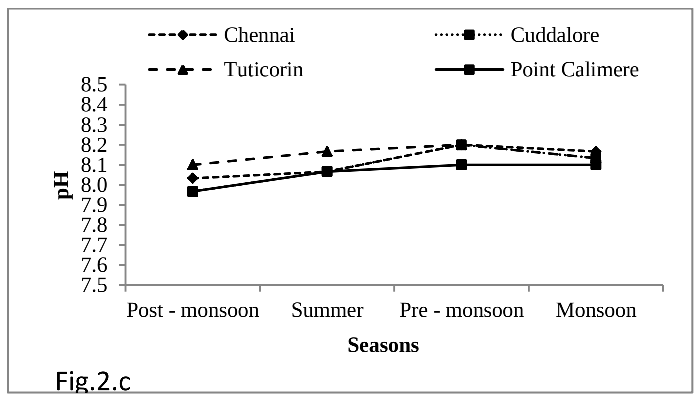

Fig.2.c=Seasonal variation of pH in water

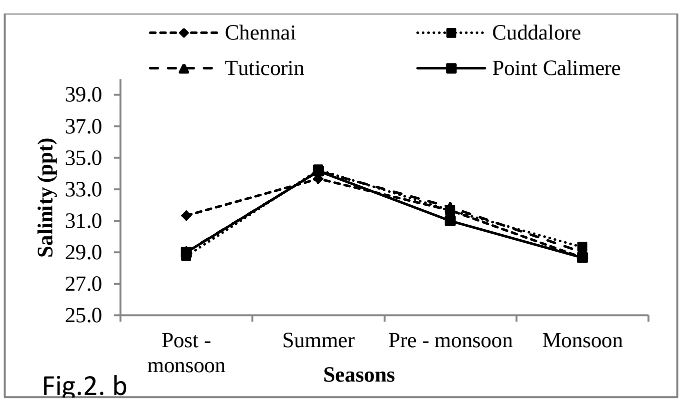

Fig.2.b =Seasonal variation of Salinity in water

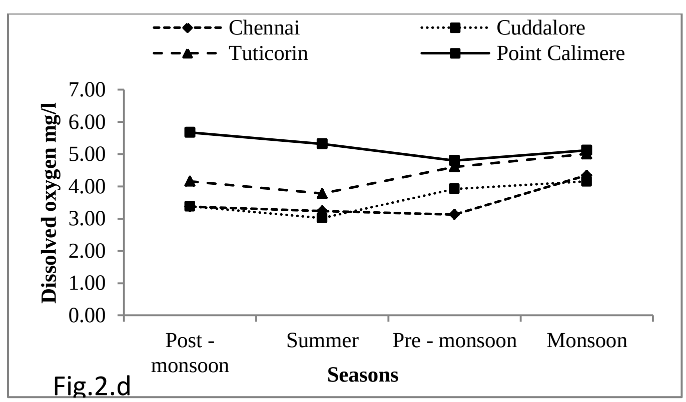

Fig.2.d =Seasonal variation of D.O in water

Fig.2. Seasonal variation of physico-chemical parameters in St.1,2,3,4

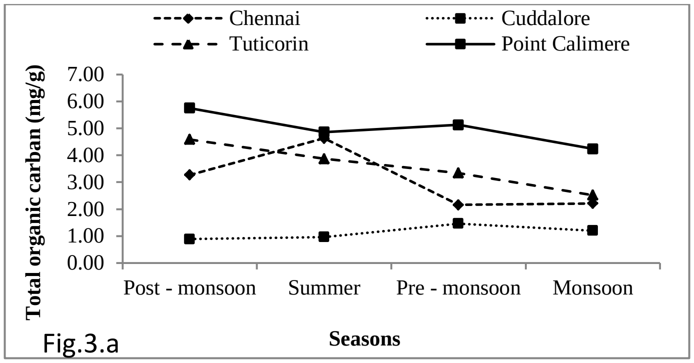

Fig.3.a = Seasonal variation of TOC in sediment

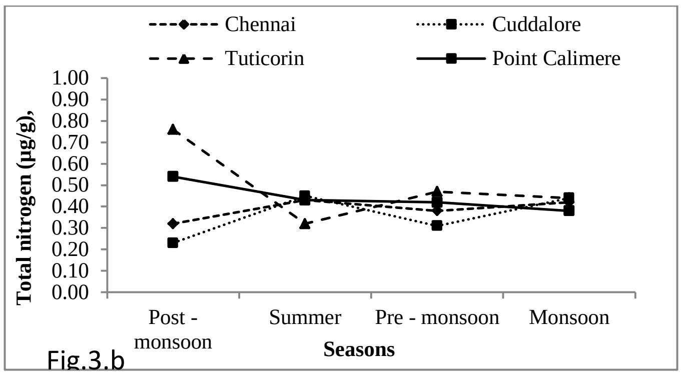

Fig.3.b = Seasonal variation of TN in sediment

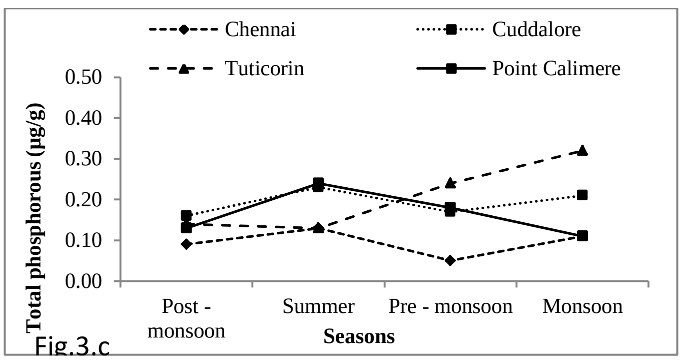

Fig.3.c = Seasonal variation of TP in sediment

Fig. 3 (a-c) Seasonal variation of chemical parameters

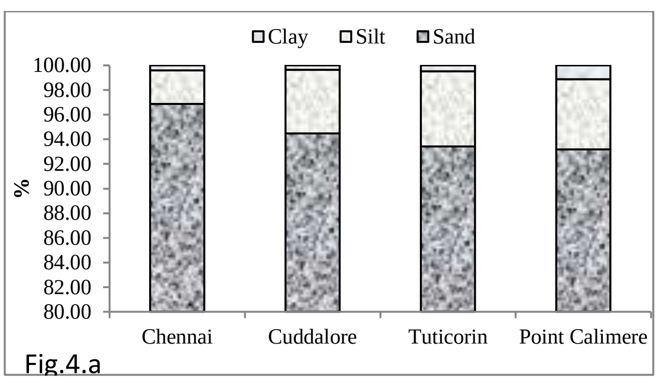

Fig.4. (a). Soil texutre in post monsoon

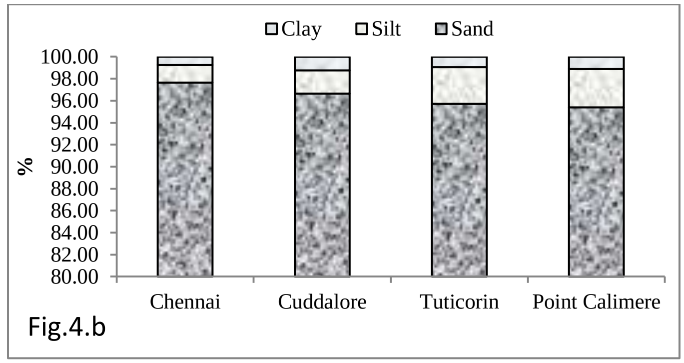

Fig.4. (b) Soil texutre in summer

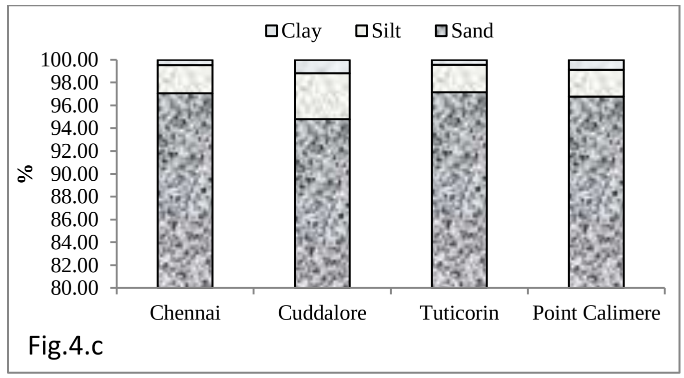

Fig.4. (c). Soil texutre in pre – monsoon

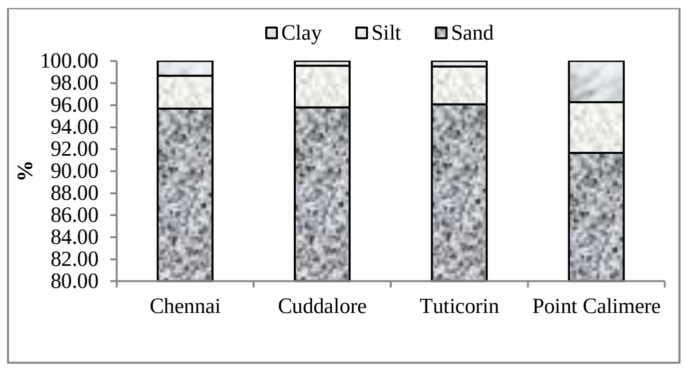

Fig.4. (d). Soil texutre in monsoon

Fig. 4 (a-d): Seasonal variation of soil texture

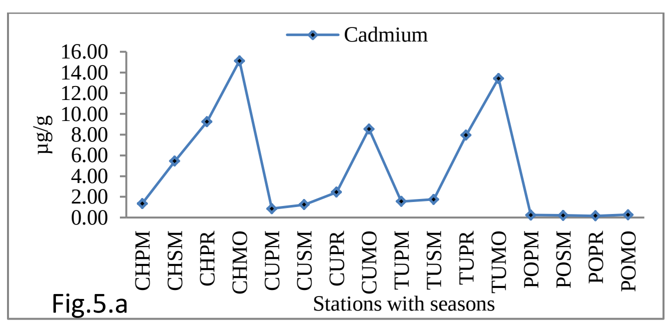

Fig.5. a = Cadmium (Cd)

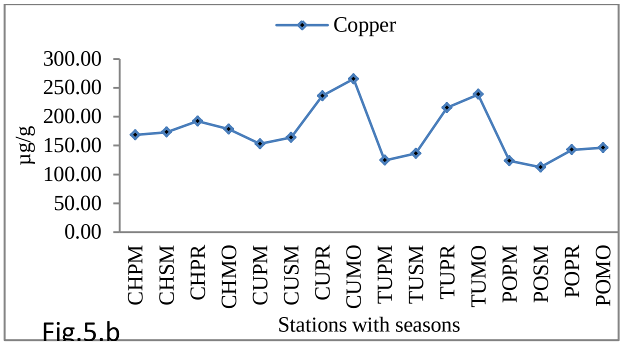

Fig.5.b =Copper (Cu)

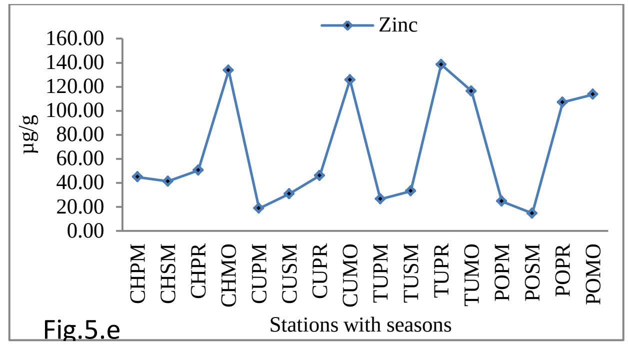

Fig.5.e =Zinc (Zn)

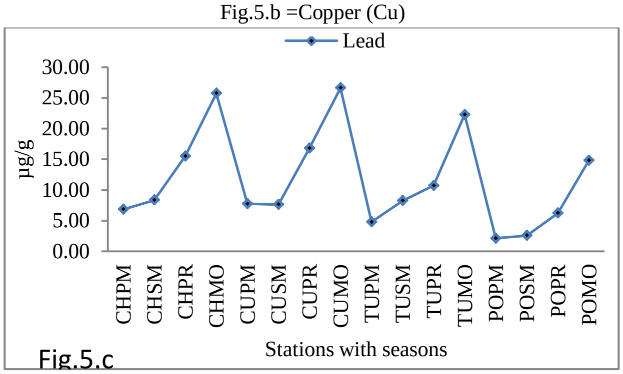

Fig.5.c =Lead (Pb)

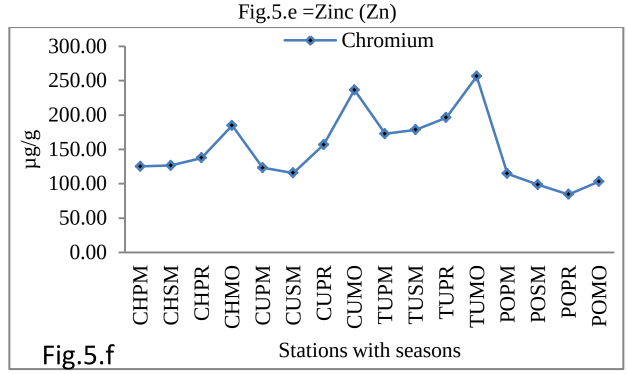

Fig.5.f =Chromium (Cr)

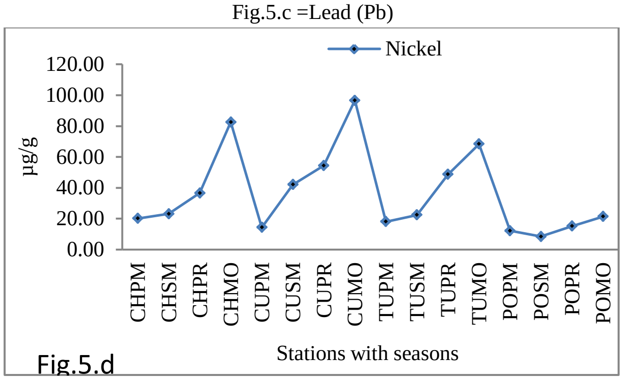

Fig.5.d =Nickel (Ni)

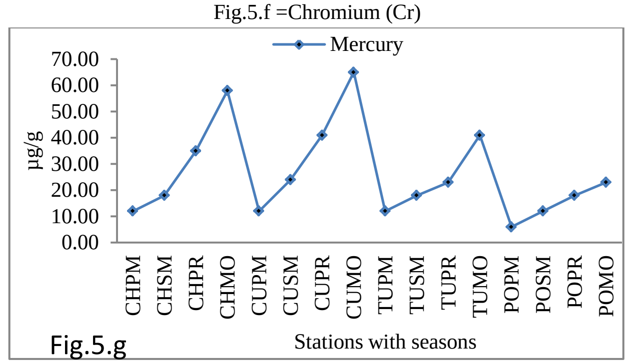

Fig.5.g =Mercury (Hg)

Fig. 5 (a-g). Seasonal variation of heavy metal in station 1,2,3 and 4

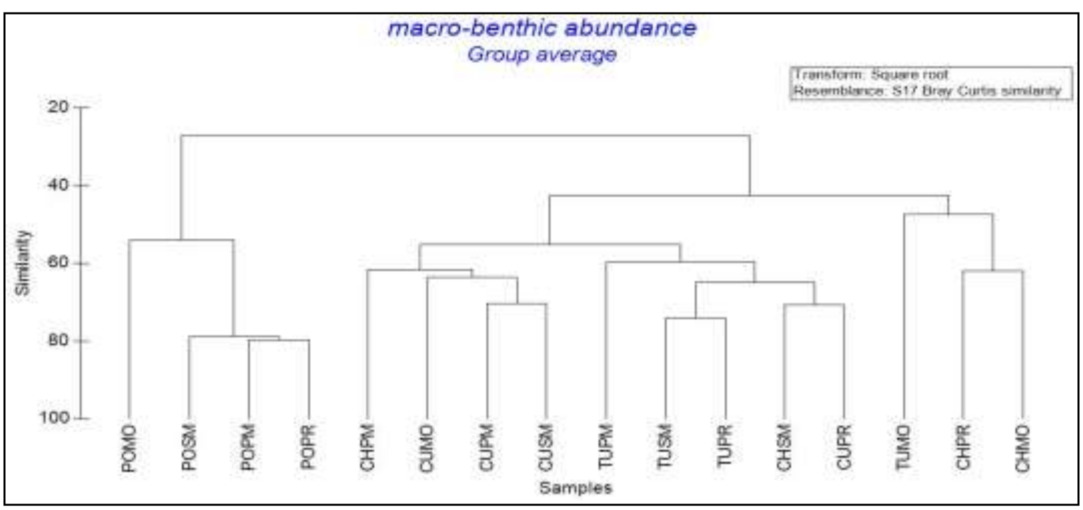

Fig.6. Dendrogram showing the macro faunal abundance in between stations and seasons

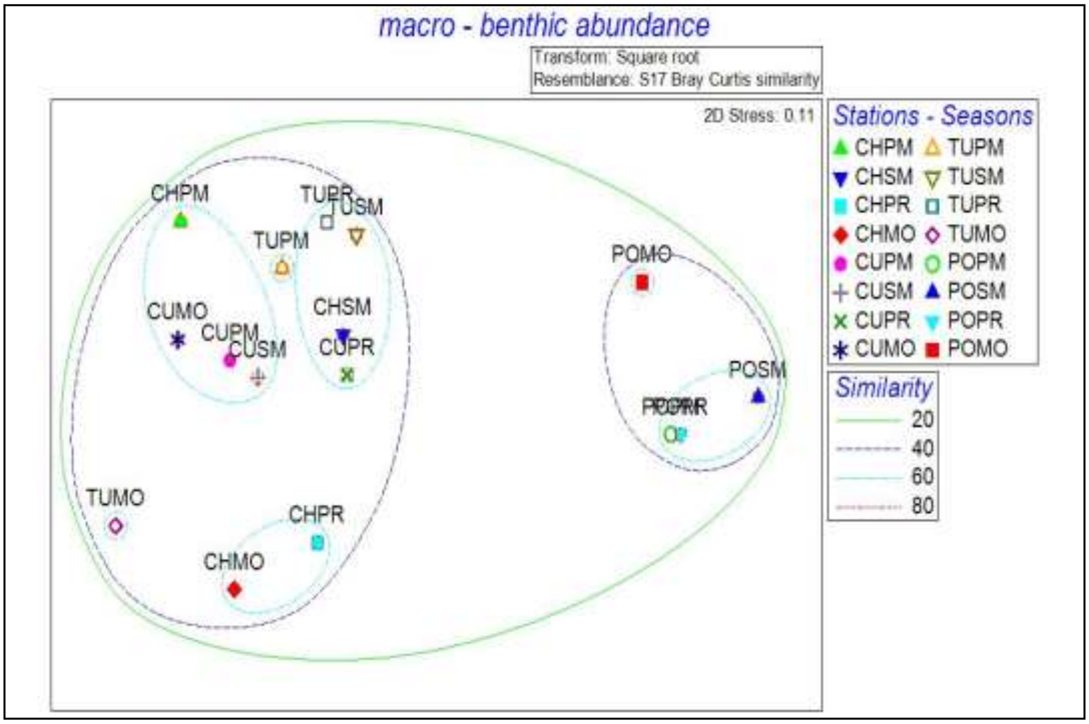

Fig.7. MDS plots for macro faunal abundace in between stations and seasons

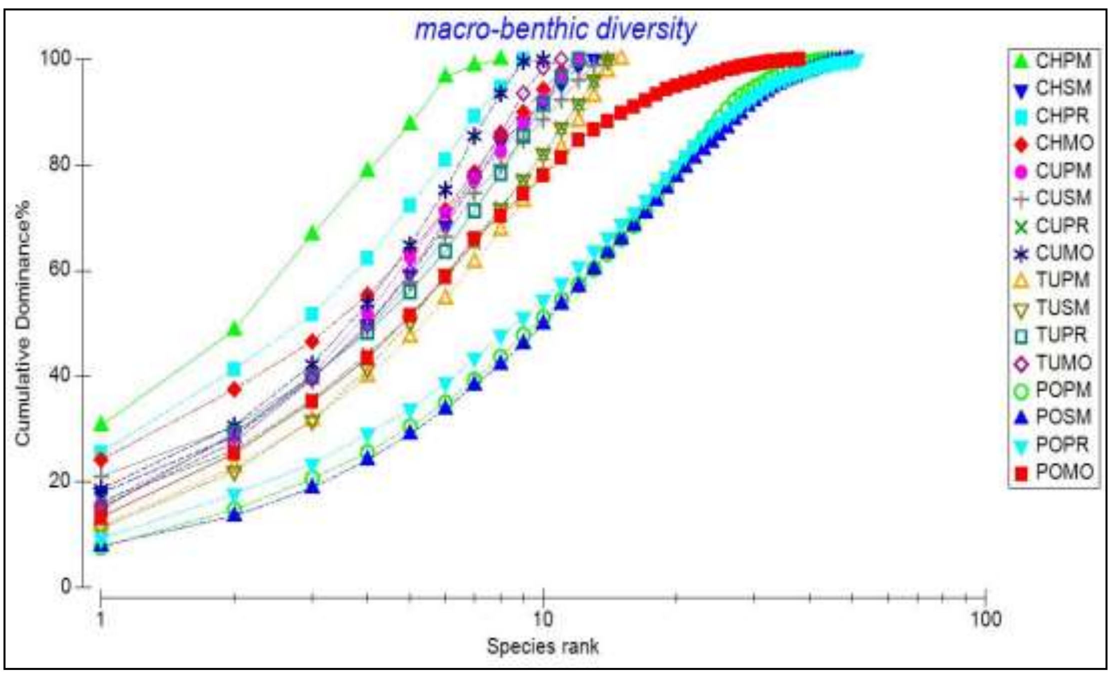

Fig.8. *k*- Dominance curve for all the stations and seasons

Table 1 Correlations between the physico-chemical, biological parameters and heavy metals at station.1

Parameters	Temp.	Salinity	pH	DO	Sand	Silt	Clay	TN	TP	TOC	Cd	Cu	Pb	Ni	Zn	Cr	Hg	Diversity	Richness	Evenness
Temp.	1.00																			
Salinity	0.89	1.00																		
pH	-0.34	-0.45	1.00																	
DO	-0.57	-0.87	0.28	1.00																
Sand	0.83	0.992**	-0.42	-0.92	1.00															
Silt	-1.00	-0.92	0.33	0.63	-0.87	1.00														
Clay	-0.23	-0.64	0.35	0.91	-0.73	0.29	1.00													
TN	0.45	0.03	0.41	0.33	-0.06	-0.41	0.68	1.00												
TP	0.46	0.13	-0.50	0.37	0.01	-0.40	0.54	0.52	1.00											
TOC	0.86	0.79	-0.76	-0.42	0.72	-0.84	-0.22	0.18	0.69	1.00										
Cd	-0.37	-0.68	0.83	0.72	-0.71	0.40	0.81	0.64	-0.01	-0.62	1.00									
Cu	-.15	-.11	.91	-.15	-.05	.11	-.05	.23	-.72	-.63	.53	1.00								
Pb	-0.56	-0.83	0.78	0.81	-0.84	0.59	0.81	0.47	-0.06	-0.72	0.974*	0.45	1.00							
Ni	-0.57	-0.86	0.64	0.91	-0.90	0.61	0.89	0.47	0.10	-0.63	0.94	0.26	0.979*	1.00						
Zn	-0.59	-0.89	0.49	0.972*	-0.93	0.64	0.92	0.41	0.21	-0.56	0.86	0.09	0.93	0.983*	1.00					
Cr	-0.58	-0.88	0.60	0.93	-0.91	0.62	0.90	0.45	0.13	-0.62	0.92	0.21	0.967*	0.999**	0.992**	1.00				
Hg	-0.52	-0.79	0.81	0.79	-0.81	0.55	0.80	0.51	-0.06	-0.71	0.985*	0.49	0.998**	0.970*	0.91	0.956*	1.00			
Diversity	0.53	0.11	0.31	0.30	0.01	-0.48	0.66	0.994**	0.59	0.29	0.56	0.14	0.39	0.40	0.35	0.39	0.43	1.00		
Richness	0.49	0.05	0.11	0.42	-0.07	-0.43	0.74	0.94	0.78	0.39	0.49	-0.12	0.35	0.41	0.41	0.41	0.37	0.963*	1.00	
Evenness	0.40	0.16	0.72	-0.04	0.13	-0.40	0.29	0.81	-0.05	-0.09	0.60	0.72	0.42	0.29	0.14	0.25	0.47	0.77	0.57	1.00

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 2 Correlations between the physico-chemical and biological parameters and heavy metals at station 2

Parameters	Temp.	Salinity	pH	DO	Sand	Silt	Clay	TN	TP	TOC	Cd	Cu	Pb	Ni	Zn	Cr	Hg	Diversity	Richness	Evenness
Temp.	1.00																			
Salinity	-0.17	1.00																		
pH	0.90	0.27	1.00																	
DO	0.89	-0.54	0.65	1.00																
Sand	-0.26	0.69	0.12	-0.33	1.00															
Silt	0.16	-0.88	-0.28	0.38	-0.94	1.00														
Clay	0.13	0.93	0.50	-0.33	0.42	-0.70	1.00													
TN	0.06	0.52	0.38	0.03	0.93	-0.85	0.32	1.00												
TP	-0.21	0.61	0.14	-0.24	0.993**	-0.91	0.34	0.961*	1.00											
TOC	0.56	-0.58	0.22	0.55	-0.94	0.83	-0.24	-0.79	-0.93	1.00										
Cd	0.56	-0.39	0.45	0.79	0.21	-0.01	-0.41	0.52	0.32	-0.05	1.00									
Cu	0.90	-0.23	0.82	0.93	0.01	0.02	-0.07	0.36	0.09	0.27	0.85	1.00								
Pb	0.79	-0.38	0.66	0.93	0.03	0.08	-0.28	0.39	0.14	0.19	0.951*	0.968*	1.00							
Ni	0.67	-0.08	0.69	0.75	0.38	-0.27	-0.07	0.68	0.47	-0.13	0.94	0.91	0.94	1.00						
Zn	0.57	-0.33	0.49	0.78	0.25	-0.06	-0.35	0.56	0.36	-0.08	0.998**	0.87	0.954*	0.957*	1.00					
Cr	0.67	-0.46	0.52	0.88	0.06	0.11	-0.42	0.40	0.17	0.12	0.985*	0.91	0.984*	0.92	0.981*	1.00				
Hg	0.77	-0.17	0.74	0.84	0.22	-0.14	-0.11	0.56	0.32	0.03	0.94	0.966*	0.976*	0.987*	0.952*	0.95	1.00			
Diversity	0.04	0.56	0.19	-0.38	-0.22	-0.11	0.76	-0.37	-0.32	0.28	-0.79	-0.36	-0.58	-0.56	-0.76	-0.71	-0.52	1.00		
Richness	-0.21	0.73	0.04	-0.62	0.03	-0.33	0.82	-0.20	-0.08	-0.02	-0.85	-0.54	-0.73	-0.62	-0.82	-0.83	-0.63	0.951*	1.00	
Evenness	0.59	-0.49	0.29	0.53	-0.91	0.77	-0.14	-0.76	-0.91	0.994**	-0.09	0.28	0.17	-0.13	-0.11	0.08	0.03	0.36	0.06	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3 Correlations between the physico-chemical, biological parameters and heavy metals at station 3

Parameters	Temp.	Salinity	pH	DO	Sand	Silt	Clay	TN	TP	TOC	Cd	Cu	Pb	Ni	Zn	Cr	Hg	Diversity	Richness	Evenness
Temp.	1.00																			
Salinity	0.73	1.00																		
pH	0.14	0.74	1.00																	
DO	-.988*	-0.63	-0.03	1.00																
Sand	-0.29	0.43	0.87	0.42	1.00															
Silt	0.17	-0.54	-0.89	-0.31	-.989*	1.00														
Clay	0.81	0.77	0.20	-0.73	-0.01	-0.14	1.00													
TN	-0.17	-0.71	-0.69	0.02	-0.75	0.84	-0.61	1.00												
TP	-0.92	-0.46	0.10	0.968*	0.57	-0.48	-0.55	-0.22	1.00											
TOC	0.70	0.13	-0.31	-0.80	-0.74	0.70	0.20	0.58	-0.92	1.00										
Cadmium	-0.89	-0.42	0.12	0.95	0.59	-0.51	-0.49	-0.28	0.998**	-0.95	1.00									
Copper	-0.85	-0.27	0.34	0.92	0.74	-0.66	-0.50	-0.35	0.971*	-0.94	0.969*	1.00								
Lead	-0.75	-0.34	0.02	0.83	0.50	-0.47	-0.23	-0.42	0.92	-.955*	0.95	0.87	1.00							
Nickel	-0.87	-0.35	0.20	0.93	0.65	-0.58	-0.46	-0.34	0.992**	-.962*	0.997**	0.984*	0.94	1.00						
Zinc	-0.77	-0.15	0.52	0.83	0.81	-0.72	-0.57	-0.30	0.86	-0.80	0.85	0.95	0.66	0.87	1.00					
Chromium	-0.81	-0.46	-0.08	0.87	0.43	-0.38	-0.33	-0.30	0.94	-0.92	0.956*	0.86	0.992**	0.94	0.66	1.00				
Mercury	-0.76	-0.32	0.05	0.83	0.54	-0.50	-0.24	-0.43	0.94	-.966*	0.956*	0.89	0.999**	0.950*	0.69	0.989*	1.00			
Diversity	0.82	0.24	-0.31	-0.90	-0.73	0.67	0.40	0.42	-.973*	.974*	-.981*	-.991**	-0.92	-.993**	-0.90	-0.91	-0.93	1.00		
Richness	0.961*	0.80	0.20	-0.91	-0.15	0.01	0.94	-0.40	-0.78	0.49	-0.74	-0.72	-0.54	-0.71	-0.70	-0.63	-0.55	0.65	1.00	
Evenness	0.92	0.53	0.02	-.960*	-0.47	0.39	0.52	0.19	-.990**	0.91	-.991**	-0.93	-.950*	-.976*	-0.78	-.973*	-0.95	0.94	0.77	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4 Correlations between the physico-chemical, biological parameters and heavy metals at station 4

Parameters	Temp.	Salinity	pH	DO	Sand	Silt	Clay	TN	TP	TOC	Cd	Cu	Pb	Ni	Zn	Cr	Hg	Diversity	Richness	Evenness
Temp.	1.00																			
Salinity	0.81	1.00																		
pH	0.32	0.25	1.00																	
DO	-0.46	-0.13	-0.90	1.00																
Sand	.981*	0.69	0.25	-0.47	1.00															
Silt	-0.85	-0.58	-0.75	0.85	-0.83	1.00														
Clay	-0.75	-0.54	0.37	-0.12	-0.80	0.33	1.00													
TN	-0.13	-0.17	-.971*	0.78	-0.03	0.58	-0.56	1.00												
TP	0.87	.991**	0.21	-0.15	0.77	-0.62	-0.63	-0.10	1.00											
TOC	0.19	-0.04	-0.81	0.51	0.31	0.25	-0.78	0.93	0.06	1.00										
Cd	-0.94	-0.58	-0.17	0.45	-.989*	0.78	0.83	-0.06	-0.68	-0.41	1.00									
Cu	-0.30	-0.66	0.52	-0.66	-0.22	-0.19	0.56	-0.52	-0.65	-0.43	0.16	1.00								
Pb	-0.53	-0.52	0.62	-0.48	-0.55	0.00	0.92	-0.74	-0.59	-0.82	0.57	0.81	1.00							
Ni	-0.59	-0.74	0.45	-0.44	-0.55	0.09	0.83	-0.53	-0.78	-0.59	0.52	0.93	0.94	1.00						
Zn	-0.15	-0.48	0.70	-0.79	-0.10	-0.37	0.55	-0.68	-0.48	-0.55	0.07	.976*	0.83	0.88	1.00					
Cr	-0.76	-0.43	-0.79	0.93	-0.76	.985*	0.24	0.62	-0.47	0.28	0.73	-0.36	-0.12	-0.07	-0.52	1.00				
Hg	-0.10	-0.19	0.90	-0.80	-0.14	-0.43	0.69	-0.93	-0.24	-0.87	0.18	0.79	0.90	0.80	0.89	-0.54	1.00			
Diversity	0.73	0.61	-0.40	0.21	0.77	-0.28	-.988*	0.57	0.70	0.76	-0.78	-0.68	-.959*	-0.90	-0.66	-0.16	-0.74	1.00		
Richness	.954*	0.65	0.11	-0.35	.989*	-0.74	-0.88	0.12	0.74	0.45	-.993**	-0.28	-0.65	-0.62	-0.19	-0.67	-0.27	0.84	1.00	
Evenness	0.56	0.50	-0.60	0.42	0.60	-0.05	-0.95	0.73	0.58	0.84	-0.62	-0.76	-.997**	-0.92	-0.78	0.07	-0.88	.973*	0.70	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).