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Planktons as Indicators of Heavy Metal Pollution along South West Coast of India

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Abstract: ***Planktons are excellent indicators of environmental stress. Due to differential tolerance and very restricted movements, they are among the most common organisms used to access anthropogenic impacts.The study was carried out on the plankton diversity along two environmentally disturbed sites along the coast of Kollam, Kerala. The sites selected for the study were Chavara-titanium (9º 07' N latitude& 76 º 31' longitude-site I) characterized by industrial pollution from the Kerala Minerals and Metals Ltd, titanium dioxide factory and Neendakara (8⁰ 56' latitude &76⁰ 32' longitude-site II) which is a large fish landing center of South India. Sampling was carried out for two seasons (pre-monsoon and monsoon) from March to June 2015. Hydrological variables such as pH, Temperature, DO, TDS, Nutrients, Chlorophyll-a and Heavy Metals (Hg, Pd, Cd &Cr) were analyzed. Pollution tolerant species such as Navicula, Trochophore larvae and Discorbis*** **sp** ***were found at site 1.Three factor ANOVA and t- test shows that there is significant seasonal and site wise difference in hydrological parameters and heavy metal concentrations. The outcome of the study will serve as a baseline data to carry out future environment impact assessment (EIA) studies for minimizing pollution and also a pointer that stringent biomonitoring may be necessary along the coast of Kerala.***

Keywords: Plankton, Diversity, Composition, Hydrological parameters, Heavy metals

1. Introduction

Planktonsare diverse group of organisms that live in the water column of large bodies of water and that cannot swim against a current [1]. Plankton consists of a diverse range of living organisms that inhabit the pelagic zone of oceans, seas or bodies of freshwater water. The term plankton is actually a Greek word, meaning *that which is made to wander or drift* [2]. Plankton typically flows with ocean currents. While some forms are capable of independent movement and can swim hundreds of meters vertically in a single day, their horizontal position is primarily determined by the surrounding currents. Plankton abundance and distribution are strongly dependent on factors such as ambient nutrient concentrations, the physical state of the water column, and the abundance of other plankton. Plankton term is further divided into two; the phytoplankton and zooplankton, meaning plant- (Gk. *phyto*) and animal- (Gk. *zoon*) drifters respectively. Phytoplankton is the primary producer community and consists mainly of algae such as diatoms, dinoflagellates,

and a variety of forms. Study of planktons has received considerable attention due to their significance as biological indicators of environmental change in aquatic ecosystems and also as source of fish food organisms. When water bodies are subjected to the influence of sewage and industrial pollution, a considerable stress on their faunal communities' result.

2. Literature Survey

Many organisms serve as indicators of marine pollution. The health of the coastal area mainly depends on plankton community [3], [4]. Any factor affecting the production of plankton directly affects the plankton feeders such as commercial fishes [5]. Ocean health is mainly affected by the pollution activities. Phytoplankton plays an important role in the pelagic food web.They transfer energy to the higher trophic level.The species, distribution, composition of phytoplankton have been well studied from some tropical marine waters in India [6], [7], [8], [9], [10]. The density of phytoplankton was maximum in pre-monsoon and was least in the monsoon season in all the sites, this may be due to heavy influx of rainwater in monsoon whereas the zooplankton have comparatively better environment in the pre-monsoonseason. Thus, high zooplankton density observed during Monsoon and low during Pre monsoon due to role played by the Monsoon flood [11],[12]. Variation in the plankton abundance during the season could be attributed to the interaction of different anthropogenic stressors as reported [13]. The planktons are thus the best indicators of different kinds of aquatic pollution. Human activity has profoundly affected natural waters globally. The phytoplankton species such as *Oscillatoria*, *Cladophora*and *Nitzchia*are the main indicators of organic pollution. An imbalance in its population structure could bring about far reaching effects on the dependent fishery resource. The imbalance could be brought by natural as well as manmade reasons.

3. Problem Definition

Marine environment is the ultimate recipient of pollutants generated by industries and other operational activities. Hence a thorough knowledge of the marine status is essential for minimizing adverse impacts. Studies on marineenvironment of Kollam coast, situated on the south-west coast ofIndia is meager. The quantum of pollution by direct or indirect discharge of sewage into the marine environment of Kerala coast especially Kollam is alarming. The studies on the pollution status of Kollam coast reported that the major causes of water quality degradation are pathogenic bacteria and petroleum hydrocarbon [14], [15]. The boat fitted with outboard engines which are used extensively for fishing are the source of high Petroleum Hydrocarbon content.Large quantities of limonite are available along the coastline of Kerala.Mining operations occurs at Chavara in Kollam for the dredging of these heavy minerals. The Kerala Minerals and Metals Limited a government of Kerala undertaking company discharges effluents that cause adverse impact on the coastline of Kollam. The studies conducted on the marine algae along the coast line of Kollam have reported high contents of manganese and strontium

In the present work, an effort will be made to assess the dynamics of the plankton diversity and assemblages of two environmentally disturbed sites along the Kollam coast of Kerala, south west coast of India. An attempt is also made to correlate temporal and spatial distribution of plankton communities with environmental parameters. Therefore, the study will give valuable information on the plankton diversity along the coast of Kollam and also on its present pollution status.

4. Methodology

Two sampling sites were selected representing differing anthropogenic stressors that are likely to affect water quality and plankton diversity. (Fig 1).

Figure 1: Map of Kerala showing study sites

Site 1 – Chavara- Titanium (9º 07' N latitude & 76 º 31' 55 E longitude): Characterized by waste disposal and heavy metal influx from KMML and Indian Rare Earth Ltd-a factory.

Site 2 – Neendakara (8º 56' N latitude & 76 º 32' E longitude): characterized by inorganic pollution of heavy metals and oil since it is a fishing harbor and port with large scale motor boat / trawler traffic.

Sampling was carried out twice during March 2015 and June 2015 representing the Pre-monsoon and Monsoon. The time of collection was between 6.00 am to 9.30 am in the morning. Plankton net of mesh size 20µ was used for the collection of zooplankton. The net was operated along the intertidal area of the study sites. The net was operated by hauling it from the open sea to the beach using a rope tied to the mouth portion. The collected samples were carefully transferred to a 5L capacity fish packing cover filled with sea water and transported to the laboratory. Aeration was provided using battery operated aerator. Surface water was also collected in plastic bottles and bottom water by Nessler's bottom water sampler for subsequent chemical analysis.

The collected samples were sieved using a 50µ sieve. The residues retained on the sieve were transferred to a petridish and the plankton movement was arrested by adding chilled water for the purpose of live identification. After this, samples were fixed in Rose Bengal solution (1g in 1000ml 4% formaldehyde) and placed in polythene vials for later sorting and identification using the standard keys [16], [17], [18].

P^H: Measured in the field itself using a digital pH pen, Temperature: Recorded with a thermometer, Dissolved Oxygen (DO): Estimated with Winkler's method (1883).Total Dissolved Solids (TDS), Salinity and Conductivity: Estimated by water - analyzer (Eutech).Nutrients (nitrate, nitrite, phosphate, & silicate): APHA (1985).Heavy Metals (Hg, Pb, Cd & Cr): Determined with the help of ICP- AES, Estimation of Biomass - Chlorophyll-a: Determined by the method of Dere *et al.* (1998), Wet - weight: Determined by the method of Rao *et.al.* (1995).

5. Results and Discussion

Studies on the diversity of plankton, relation with pollution effects in marine environments are limited compared to that of terrestrial environment. Change in species composition and diversity may produce changes in plankton growth rate and their response to irradiance or other limited factors. It is important to understand how these changes are reflected in ecosystem functioning [19].

Thirty species of planktons were identified from the study area. The variation in the Composition and numerical abundance of Plankton diversity along the study sites are given in Figs3 -6.

Plankton composition composed of *Asterionella* sp, *Amphipoda* sp, *Bacillaria*sp,*Bidulphia*sp, *Cheatocerus* sp, *Cladophyxis* sp, *Discorbis* sp, *Fragellaria* sp,*Foramniferance*sp, *Lauderia*sp, *Licmophora*sp. *Mysis Larvaea,Navicula sp, Nitzchia* sp, *Noctiluca* sp, *Odontella sp, Pleurosigma* sp, *Polycheate worm, Radiolarians* sp, *Pseudonitzchia sp, Rizhosolenia*sp, *Sarcodina* sp, *Skeletonema*sp, *Trochophore larvae, Thalassionema* sp,*Thalassioriosira*sp, *Thalassiothrix*sp, *Trichocerca* sp.

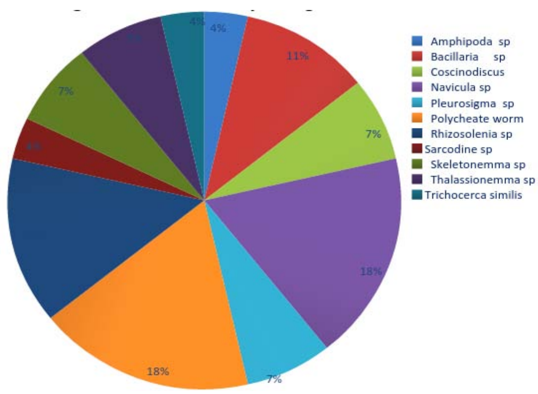

Figure 2: Plankton Diversity along site 1- Premonsoon

At Site 1, of the thirty species, *Polycheate worm and Pleurosigma*spwas the numerically abundant (18%) whereas the least abundant taxa were *Amphipoda* sp, *Trichocerca* spand*Sarcodina* sp *(3%)* during Pre-monsoon. At monsoon, *Biddulphiamobilensis, Rhizosolenia, Coscinodiscusgranii* were the numerically abundant (67%) whereas the least abundant sp was *Ditylum, Nitzchia* spand *Trochophore larva* (3%).

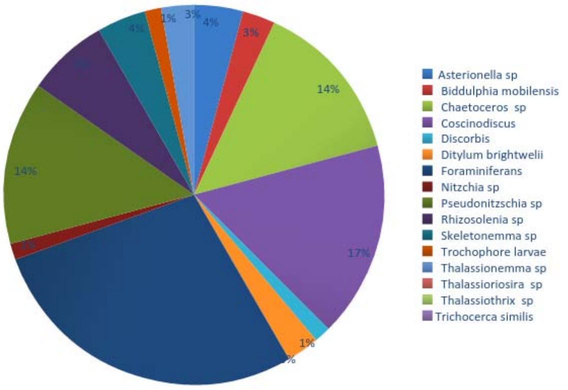

Figure 3: Plankton Diversity along site 1- Monsoon

At site 2, of the thirty species,*Cladophyxhemibrachiata*and *Pleurosigma was* the numerically abundant (40%) whereas the least abundant include *Fragellaria* sp (30%) and *Noctiluca* (30%) during Pre-monsoon. At monsoon,*Cheatocerus*sp, *Rhizosolenia*,(75%) was numerically abundant and*Bacillaria*sp *(3%)* forms the least.

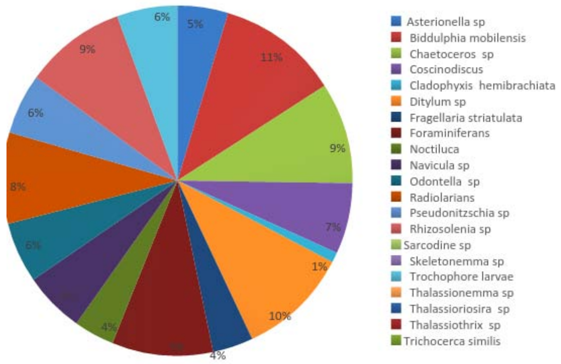

Figure 4: Plankton Diversity along site 2- Pre- Monsoon

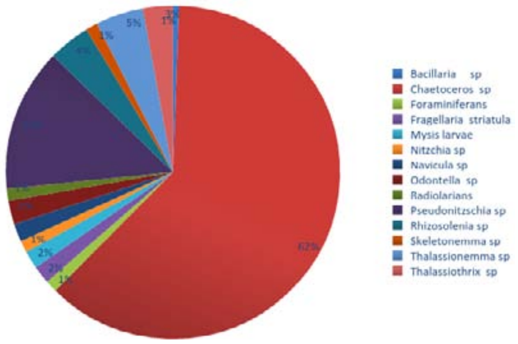

Figure 5: Plankton Diversity along site 1- Monsoon

Light is the most important factor that influences phytoplankton growth. In marine environment, the light incident on the surface is rapidly reduced exponentially with depth [20]. Phytoplankton obtains energy through the process of photosynthesis in the well-lit surface layer (euphotic zone) of marine environment. Phytoplankton accounts for half of all photosynthetic activity on Earth [21] and are responsible in balancing the oxygen content in Earth's atmosphere [22].

Temperature was found to be more important influencing the vertical distribution. Temperature was found to be high at site 1 during pre-monsoon (30ºC) and these shows the presence of temperature tolerant species such as *Navicula,Anabaena*etc. in site 1 abundantly.pH is the measure of the level of activity of hydrogen ions in a solution, resulting in its acidic or basic quality. P^Hwasfound to be highest along the site 2 during pre-monsoon (8.2), indicating extremity of acidic factory effluent discharged from KMMLfactory. The high pHmay also be lethal to some of faunal species.

The maximum amount of dissolved oxygen was found to be at site 1 during pre-monsoon (6.2) mg/l.Salinity is the saltiness or dissolved content of body of water. The influenza of salinity on phytoplankton varies widely because different species have different salinity preferences. Comparing the two sites, the salinity was reported high at site 2 during pre-monsoon (26.9ppt) and it may be due to absence of surface run off.

The Nitrate-nitrogen (µg/l) concentration was recorded high at site 2 during pre-monsoon and this may be due to biological oxidation of organic nitrogen originated from the industrial waste. The presence of plankton *Pseudonitzchia*in high concentration in this site reveals that plankton can tolerate high nitrate-nitrogen concentration.The Nitrite – nitrogen (µg/l) concentration was also highly recorded at site 2 during monsoon and the plankton *chaetoceros* survive in this high nitrite-nitrogen concentration.The Silicate concentration was also highly recorded at site 1 during pre-monsoon. Since silicate is essential for growth of diatoms and dinoflagellates which possess frustule, composed of silica, the abundant plankton present in this site include *Navicula sp; Thalassionema* sp etc. which have high tolerance against these silica concentrations.

The concentration of phosphate was recorded high at the site 2during monsoon and the plankton abundantly found that can tolerate phosphate concentration include *chaetoceros,pseudonitzhia*etc. this may be due to the discharge of sewage and industrial effluent from the site which is one of the major fishing harbour in Kerala.The chlorophyll 'a' was recorded at site 2 during monsoon and the abundant phytoplankton found from this site include *chaetoceros*, *Thalassionema* etc., and these may be due to enhanced nutrient supply to the study area, similar observation was also made along South west coast of India [23].

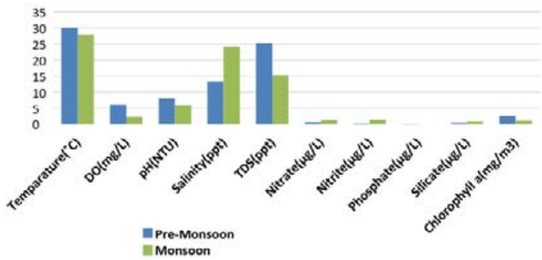

Figure 6: Hydrological parameters along site 1

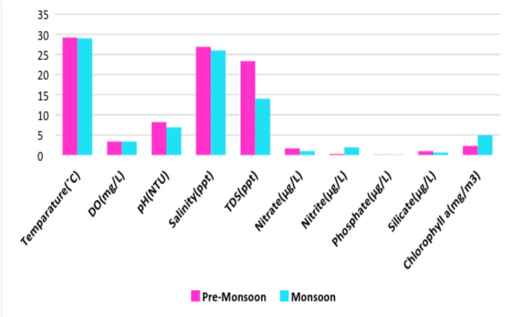

Figure 7: Seasonal variation of Hydrological parameters along site 2

Statistical technique like ANOVA (Analysis of Variances) and T-test were used to test whether there is a significant seasonal and site wise difference between Hydrological parameters and Heavy metal concentrations. The level of significance is calculated at 1% level (Table II & III). Results showed that there is a significant difference in the hydrological parameters ($p<0.001$), between seasons ($p<0.001$) and between sites ($p<0.001$). With regard to the heavy metal concentrations, site I shows significantly higher concentrations compared to site II. Among seasons there is a significant gradual decrease in the metal concentration in monsoon.

Table 1: 3 Factor ANOVA for comparison of Seasonal variation in the Hydrological parameters along the study sites

Source of Variation	*Sum of Squares(ss)*	*Degrees of freedom(df)*	*Mean square(MS)*	*P-value*
Hydrological parameters	61788.3	10	6178.826	0.016
Sites	1610.86	1	1610.855	0.009
Error	14622	10	1462.199	
Total	78021.1	21		

Table 2: t-Test- Two-Sample Assuming Equal Variances

Sites	*Site I*	*Site II*
Mean	422.6916	61.209
Variance	805732.9	14975.24
Observations	5	5
Pooled Variance	410354.1	
df	8	
t Stat	0.892232	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.39831	
t Critical two-tail	2.306004	

From the study, it is clear that nutrients have direct relationships with phytoplankton abundance. This is contrary to the opinion of Devassy and a Goes (1989) state that nutrient acts as a limiting factor for phytoplankton growth. In the study area, the plankton diversity was found high at site 2 during monsoon and these might be due to the high nutrient concentration in the area. The decline in plankton and nutrient density at site 1 may be due to the effect of release of IRE effluents.

Concentrations of different metals in surface and bottom water reveals that the level of metals exhibit seasonal fluctuations, the higher concentration were found during pre-monsoon along site 1 because this site receive a portion of the effluent from the factory containing toxic heavy metals which is pumped into the sea posing a great environmental problem [24]. The pollution indicator species of plankton such as F*oraminiferans* and *diatoms* such as *Navicula* are highly found in this region because of which they are highly tolerant to heavy metal concentrations.

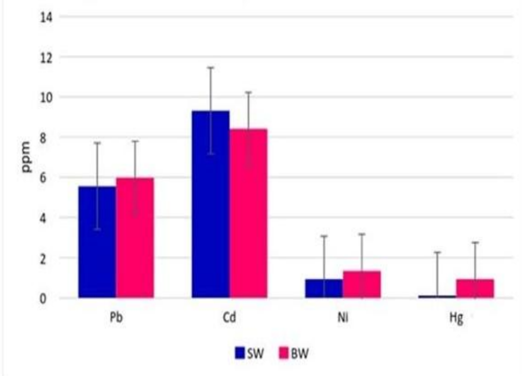

Figure 8: variation of Heavy metal concentration during premonsoon along site

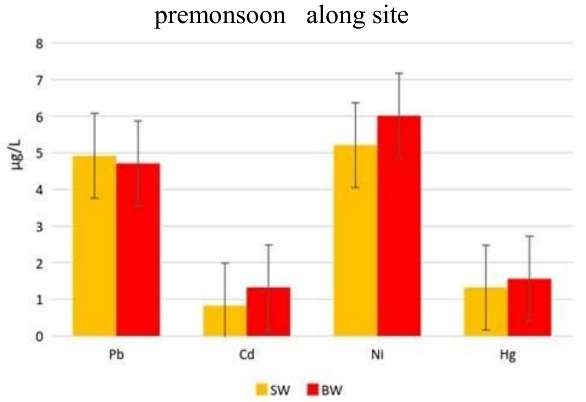

Figure 9: variation of Heavy metal concentration during premonsoon along site 2

The species such as *Anabaena,Polychaeteworm,Navicula*sp,*Thalssionemma* sp were found abundantly at site 1 and these shows that these species of planktons have high tolerance against heavy metal pollution.Among the zooplanktons crustaceans,cladocerans and copepod were found at high rate can be used as indicator of aquatic environmental pollution.The high zooplankton density such as adult copepod,Cladocerans were found to be high at site 2 and these may be due to relatively stable environmental conditions like optimalsalinity,temperature. The high salinity also shows significant positive correlation with zooplankton density at site 2.The presence of species such as *Foraminiferans* and *pseudonitzchia*in high amount is present in site 1 during monsoon which shows the presence of pollution and it is also responsible for the shell fish poisoning in the area.

Diatoms that indicates the anthropogenic pollution which include the *Pleurosigma* sp,*Navicula* sp indicate sewage pollution where found to be higher at site 1 during pre-monsoon and these may be due to the discharge of sewage from the IRE factory located in the site. The plankton *Rhizosolenia*sp,*Nitzhia*where found in high amount at site 1 during monsoon indicating that these have the capacity to tolerate organic pollution.

Among the zooplanktons adult copepod can be used as an indicator of aquatic environment pollution and the species can be found at site 2 during pre-monsoon. The high zooplankton density where found in site 2 and these might be due to relatively stable environmental conditions like optimal salinity, temperature, salinity etc., present in these areas.

6. Conclusion

Thus, the present study reveals that the plankton diversity may vary from season to season and among the planktons the highly tolerable species only survive in the polluted area. Presence of few toxic species is indicating the imbalance of the environment. The outcome of the present study will serve as baseline data to carry out future environmental impact assessment (EIA) studies for minimize pollution and stringent biomonitoring along the coast of Kerala.

7. Future Scope

Most marine organisms that live benthically as adults have a life cycle that involves a larval stage which is pelagic. The adaptiveness of the life cycle is debated [25], [27]. So, the conditions of the pelagic realm affect the benthic biota since they spend a part of their life cycle away from the sea floor. Benthic invertebrates are directly related to the sediment they inhabit [28], [29] and any sand-mining activity or associated human-related change in sediment features may negatively affect the resident community and consequently impact trophic relationships.

Hence physical and chemical environment has shaped and affected the benthic organisms. However, information about the marine benthic invertebrates of Kerala is limited, even though they are critical components of an aquatic system. It is important to establish a baseline data for tropical regions and improve our understanding of biodiversity in the marine environment. The present work recommends stringent bio-monitoring along the coast of Kerala.

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