

PROJECT REPORT  
ON  
**“Environmental assessment of coastal water at Bakkhali (Bay  
of Bengal), West Bengal”**

Submitted in partial fulfillment of the requirement for the Degree of  
**Master of Chemical Engineering**

of  
**Jadavpur University**

By  
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## *Certificate*

The project entitled “*Environmental assessment of coastal water at Bakkhali (Bay of Bengal), West Bengal*” is satisfactorily carried out by *Shiv Singh* as a partial prerequisite for the award for the degree of Master of **Chemical Engineering** from Jadavpur University, Kolkata. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein, but approve the project only for the purpose for which it is submitted.

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## SELF ATTESTATION

*This is to certify that I have personally worked on the project titled "Environmental assessment of coastal water at Bakkhali (Bay of Bengal), West Bengal". The data mention in the project has been generated during the work and genuine. Data / information obtained from other agencies have been duly acknowledged. None of the findings / information pertaining to the work has been concealed. The results in this project report have not been submitted to any other university or institution for the award of any degree or diploma.*

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## Abstract

Spatial variations of some physicochemical properties of the coastal waters of a segment of Bakkhali (Bay of Bengal) were measured between month of November 2009 to February 2010 before 12:00 AM. The study was carried out at 3 coastal site of Bakkhali Beach (south extreme point, middle point and far north point, about 1.2 km along the shore) which is influenced by anthropogenic input from land-based sources. During this season, the water level in the upstream part of the estuarine channels is controlled by the amount of runoff in the channel. The study site receive domestic and other waste. The waters are used for fishing activities, transport of goods and people, and recreation. The banks of the estuarine channels have traditionally been preferred locations for human settlement. Considering the various uses of this coastal segment, between Bakkhali to Haldia is very crucial for constant monitoring of water quality.

pH, temperature, turbidity, salinity, TDS and conductivity vary in range of 8.24 – 8.65, 27.5<sup>0</sup>C-31.5<sup>0</sup>C, 480 NTU - 808 NTU, 21.6 PSU-30.0 PSU, 676 mg/l -934 mg/l and 1.72 mS/cm -1.97 mS/cm respectively . Dissolved oxygen, biochemical oxygen demand(BOD) concentrations at different sites vary within a narrow range 6.05mg/l–8.1mg/l and 1.05 mg/l – 3.0 mg/l respectively .Chemical oxygen demand concentrations varied in wide range of 170mg/l – 812mg/ l. The bacterial colony at sampling site was varied from 76-150 CFU.

## Introduction

Bakkhali is one among the popular beaches of India. It is situated in the state of West Bengal and is located 80km away from Diamond Harbour. Bakkhali is located on one of the many deltaic islands spread across southern Bengal. Coastal length of only about 1.2 Km. Bakkhali (latitude  $21^{\circ} 35'$  N, longitude  $88^{\circ} 15'$  E) is situated in the lower reaches of south 24-parganas along the coastal tract of west as shown in fig 1. Most of the islands are part of the Sunderbans, barring a few at the fringes. Some of these are joined together with bridges over narrow creeks. This small island juts out into the vast expanse of the Bay of Bengal. There is a 7 km long beach stretching from Bakkhali to Frasergunj with gently rolling waves. These are twin towns now forming one continuous locality. Except on an occasional holiday the beach is not crowded. A small stretch near Bakkhali has been lighted up. It is a hard beach suitable for cycling or even driving. Bakkhali's soft sands lie towards the east and is a tourist destination. Fraserganj is a busy fishing village and port lying to the west. The beach here is hard, muddy and uneven. Both have significant dunes covered with tall casuarina trees. This beach has beautiful sea waves and soft sands. This beach offers beautiful view of sun rising and sun setting.

Coastal waters of Bakkhali are one of the nation's greatest assets, yet they are being bombarded with pollution from tourism. The heavy concentration of activity in coastal areas, combined with pollutants flowing from streams far inland and others carried through the air great distances from their source, are the primary causes of nutrient enrichment, hypoxia, harmful algal blooms, toxic contamination, sedimentation, and other problems that plague coastal waters. (www.rangan-datta.info/Fraserganj,2010)



Changes in chemical, physical, biological, and radiological quality of water, can be harmful to its existing, intended potential uses (viz. boating, waterskiing, swimming, fish harvesting and as a healthy home for aquatic organisms and ecosystems).

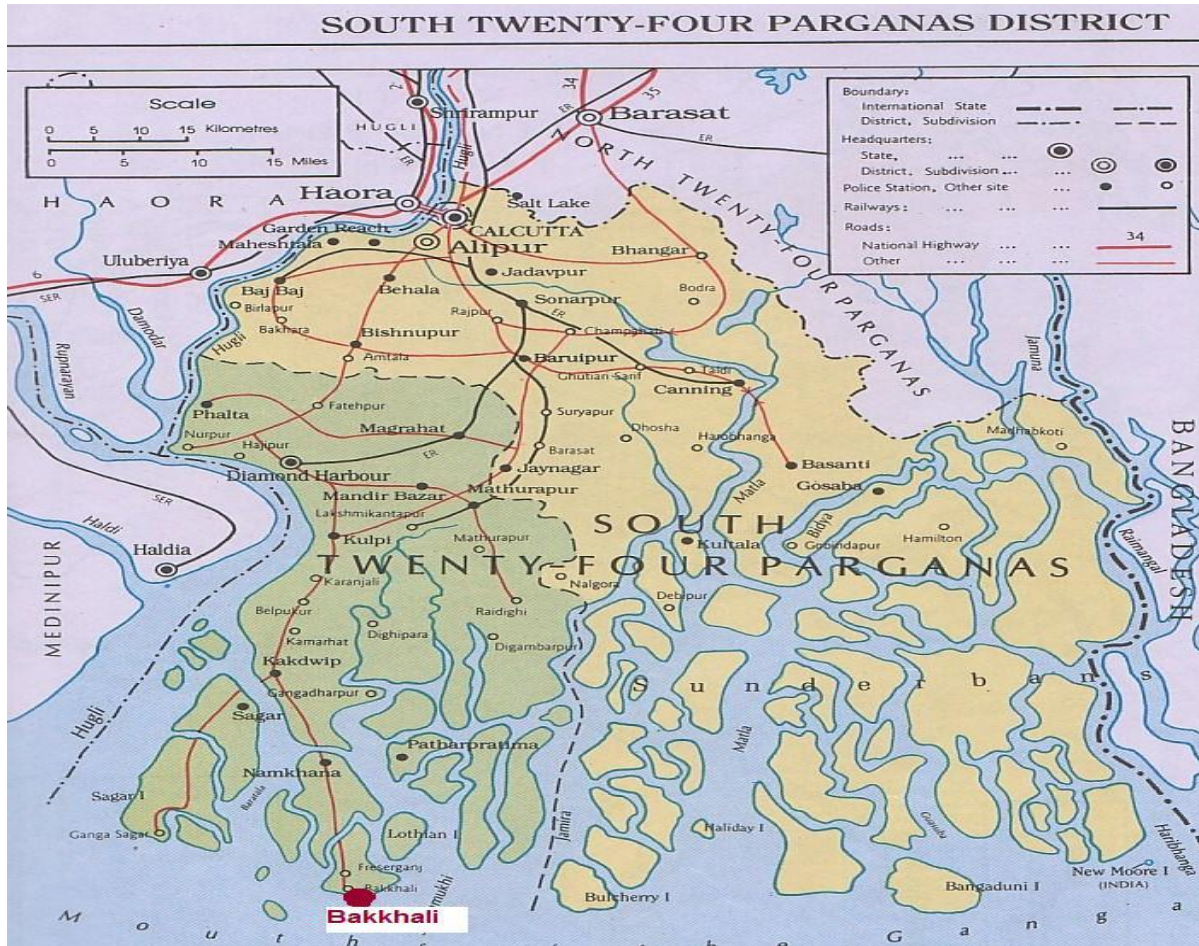


Figure:1 Location of Bakkhali Beach

The term “water pollution” generally refers to human-induced (anthropogenic) changes of water quality, which result in deterioration of its quality. Thus, discharge of toxic chemicals from an industry waste pipe or the release of livestock waste into a nearby water body is considered pollution. On the other hand nutrients generated from natural processes, are not considered as pollutants. Coastal waters are subject to cumulative impacts from a variety of pollutants—from near and far, and from point, nonpoint, and airborne sources. For this reason, any remedial measures for restoration of environmental quality must be based on an

ecosystem and watershed management approach involving inputs from a broad range of agencies, programs, and active individuals. Such solutions require a substantial financial investment and take time. Over the last few decades, great strides have been made in controlling water pollution from point sources, although further improvements could be realized through increased funding, strengthened enforcement, and promotion of innovative approaches such as market-based incentives. However, substantial enhancement of coastal water quality will require significant reductions in nonpoint source pollution—a technical and political challenge. Establishing measurable pollution reduction Bakkhalils for coastal areas is needed, as is coordination of the many related agencies and programs to effectively target the various laws, programs, funds, training, technical assistance, incentives, disincentives, and other management tools to address nonpoint source pollution of coastal waters.( National Research Council, 1993)

Many of the largest cities of the world have evolved along the water bodies or the ocean's rim. The exponential growth of metropolises and the concentration of people in small urban areas have tremendously increased the burden of governance of waste and wastewater. For many communities, the discharge of untreated and semi-treated polluted water into the high seas and to the oceans is issue of serious concern. Many rivers in the developed and developing countries are polluted due to anthropogenic activities. The discharge of wastewater into the oceans, affects the economy and tourism potential, dwindles the aesthetics of the beaches and estuaries, and creates magnitude of hygiene problems. The assimilation of wastewater treatment mechanisms is essential to have a sustainable environment. Enabling the bacterial and chemical oxidation of organic matter derived from any source can reduce the deterioration of water quality. In doing this, the major elements from the waste, namely carbon, nitrogen and phosphorus can be oxidized thus reducing the biological and chemical oxygen demand of the aquatic systems. This facilitates the survival

of fauna and flora in the natural environment. The levels of suspended and dissolved organic, inorganic matter and gases reflect the chemical characteristics of wastewater. Commonly used laboratory methods for measurements of gross amounts of organic matter include DO (dissolved oxygen), BOD(Biochemical Oxygen Demand), COD(Chemical Oxygen Demand), pH, salinity and turbidity. The BOD test is very valuable in the analysis of sewage, industrial effluents and grossly polluted waters. It is considered as the major characteristic used in stream pollution control. Chemical Oxygen Demand is an important and quickly measured parameter for stream, sewage and industrial waste samples to determine their pollution levels and is a measure of the oxygen equivalent to that portion of organic matter, present in the wastewater sample that is susceptible to oxidation. Salinity is identity of a saline water body and accounts for the total amount of salts. Salinity may be affected by human interference in case any industrial waste water be released at sites of low dispersal. Temperature, pH, Turbidity, Conductivity, Total Suspended Solids (TSS), Nitrate and Nitrite, Total Nitrogen and Total Phosphate are other most important physicochemical properties of seawater.(Goolsby et al,1999)

Rivers are the main inland water sources for domestic, industrial and irrigation purposes and often carry large municipal sewage, industrial wastewater discharges and seasonal run-off from agricultural land to the coastal region. It is for this reason that river water is mostly enriched in nutrients as compared to other environments (Panda et al,2006). The spatial heterogeneity within the river, however, is due to existing local environmental conditions such as light, temperature, water discharge and flow velocity that change with time, and differences in the local channel form. (Chakrapani, 2005) Coastal environments are economically important and are significantly involved in transporting terrestrial organic matter and associated nutrient elements to the sea where these further contribute to biogeochemical cycling. The balance in the concentrations of biogenic elements in coastal water reflects the healthy state of this water, while their excess supply as observed in the

continental shelf and upwelling areas has been found to trigger high primary productivity. The complex dynamism in physicochemical characteristics of coastal waters is related to riverine flow, upwelling, atmospheric deposition, vertical mixing and other anthropogenic sources. (Berger et al,1989 and Longhurst et al, 1995)

The main objectives of this project are to assess the coastal water quality in a segment of Bay of Bengal at Bakkhali, which is frequented by tourists. Comparing this to that of other pristine waters would enable one to measure impact of tourism activities on these coastal waters. The physicochemical properties measured here are, DO, BOD, COD, TDS, Temperature, Turbidity, Microbial properties and Salinity.

## Review of literature

Some Mexican scientists studied on the concentration and isotopic fractionation of oxygen dissolved in freshwater and seawater in equilibrium with the atmosphere of oxygen solubility values for high salinity conditions have used synthetic solutions. The object of this study was therefore to propose an equation, valid for high salinity conditions, based on the analysis of oxygen saturation in evaporated seawater.(Alcocer et al, 1998) In this study, the solubility of oxygen in evaporated seawater has been determined over a temperature range of 8–35<sup>0</sup>C and with salinity values of up to 133%. Based on experimental data, an equation is proposed that introduces a S<sup>2</sup> (salinity) term, at 1 atm pressure, giving increased importance to salinity. The equation provides a valid means of predicting the amount of dissolved oxygen in this range of temperatures and salinities. In addition, for high salinity conditions, with this equation there is no need to extrapolate other established equations, which are less accurate at salinities higher than 40%. The use of the proposed equation offers a more precise way of calculating oxygen solubility in seawater at high salinity values (up to 133%), and small deviations from experimental values, of the order of 2  $\mu\text{mol kg}^{-1}$ , are obtained.( Benson et al, 2002)

Seasonal and inter annual variations in physicochemical properties were investigated in the neritic area of Sagami Bay, Kanagawa, Japan, from December 2000 to December 2005. Physicochemical properties (i.e. temperature, salinity, density, dissolved oxygen and dissolved inorganic nutrient concentration) revealed clear seasonal variations, which were similar to each other during all 5 years. Temperature, salinity and dissolved inorganic nutrients showed rapid, drastic variations within a few days and/ or weeks. These variations are related to sea levels, principally due to the shifting effects of the Kuroshio Current axis: they were strongly affected by the Kuroshio Water and other waters, when sea level difference was greater than ca. 35 cm and lower than ca. 15 cm, respectively. Temperature

difference (*DFT*) increased with sea level difference, and the difference of salinity and dissolved inorganic nutrients increased and decreased with *DFT*, respectively. All these correlations are significant. Total dissolved inorganic nitrogen (N), phosphate (P) and silicate (Si) revealed seasonal variations in the ranges of 0.57–16.08, 0.0070–0.91 and 0.22–46.38  $\mu\text{M}$ , respectively. From the regression equations between these elements, the following relation was obtained; Si:N:P = 14.8:13.4:1. Dissolved inorganic nutrients were characterized by Si and/or P deficiency, especially in the upper layer (0–20 m depth) during summer. Single and/or combined elements are discussed on the basis of potential and stoichiometric nutrient limitations, which could restrict phytoplankton (diatom) growth as a limiting factor. Water column temperature, salinity and density varied from 12.34 to 28.16°C, from 29.27 to 34.75 and from 19.94 to 25.92, respectively. Temperature, salinity and density ( $\delta t$ ) showed similar seasonal variations during all 5 years. From November to April, temperature, salinity and density ( $\delta t$ ) were homogeneous throughout the water column. Thermo-, halo- and pycnoclines started to form in May and developed at 20–30 m depth during summer (June–September), while at the surface temperatures rose to 26–28°C and salinities declined to 29–32 due to the increase in rainfall and freshwater discharge from the rivers. In October, surface waters were cooled and dense, and vertical mixing between surface and deeper waters weakened seasonal stratification. Thereafter, seasonal stratification disappeared in November. Dissolved oxygen varied from 3.39 to 8.69 ml L<sup>-1</sup>, while oxygen saturation ranged from 58.5 to 161.2% . Surface water was saturated or supersaturated throughout the study period, especially at 0–10 m depth in spring– summer. During the summer stratified period, relatively low rates of oxygen saturation (<70%) were observed in the lower layer. (Koichi and Hiromi, 2008)

Many industrial waste waters, containing a variety of chemicals, reach the sea either by direct discharge or via estuaries and rivers in which the residence times are low compared with the

period necessary for complete biodegradation of many of the chemicals present. Because of growing awareness of the need to protect the marine environment against increasing loads of chemicals and the need to estimate the probable concentration of chemicals in the sea, test methods for biodegradability in sea water have been developed.(Kreuk and Hanstveit, 1981)Marine pollution can start as far away as middle-America. Any toxic materials that are put into rivers and bodies of water can flow eventually to the oceans. Run-off from drains and areas adjacent to the ocean is also a severe problem, bringing all kinds of materials into the sea.Toxic pollutants in the ocean have considerable impacts on plants and animals. Heavy metal poisoning from elements such as lead and mercury, caused by industry, builds up in the tissues of top predators such as whales and sharks, causing birth defects and nervous system damage. Dioxins from pulp and paper mills, and poly-aromatic hydrocarbons (PAH's) from oil pollution and burning wood and coal cause genetic problems in marine animals. Polychlorinated biphenyls (PCB's) from electrical equipment can cause birth problems in most marine organisms. Sewage can cause massive nutrient loading in the oceans, which leads to algal blooms, effectively decreasing the amount of dissolved oxygen in the water and many organisms die from lack of oxygen. Sewage also introduces parasites and bacteria, which can cause beach and shellfish harvesting closures. ( Duce,2008)

Garbage has always been discarded into the ocean, but since the 1940s, plastic use has increased dramatically, resulting in a huge quantity of nearly indestructible, lightweight material floating in the oceans and eventually deposited on beaches worldwide. Marine garbage includes fishing nets, plastics, party balloons, beach toys, general household garbage. Animals eat this garbage and it strangles them or blocks their digestive system causing starvation. Entanglement can also constrict growth and circulation, causing eventual slow death, or trap marine animals within large debris, leading to drowning, starvation or attack by predators. Even if just attached, it slows the animals' ability to move through the water, and

animals starve due to their inability to catch prey. Pollution can be reduced a number of ways. Many communities have beach-clean-up days. Recycling reduces the amount of trash that is available to go into the ocean. Care should be taken to make sure that oil from cars, suds from washing, and other pollutants do not go down your storm drain. Any landscaping should be protected until it is stable so that silt does not get washed into rivers and streams. Party balloons should be popped and never released into the air. Always pick up your trash when you leave the beach. (Tegner et al, 1995)

When considering the BOD level as a measure of organic pollution, the state of the aquatic system may be classified as follows: BOD (<5 mg/L)= Unpolluted; BOD (5–10mg/L)= slightly polluted; BOD (>10–20 mg/ L)=polluted and BOD (>20 mg/L)= highly polluted. Based on this classification the water quality of the effluent from the treatment works is exceptionally good, with the BOD level zero and COD level 25.6 mg/L. It can be seen that the Water Treatment Works, Durban (North) are quite effective in lowering the BOD, COD, DS, and SS levels of wastewater. ( Boon et al, 1992)

National Institute of Oceanography scientists have analysed water quality scenarios around an offshore outfall off Kochi were simulated using MIKE21 water quality model, assuming a high Biochemical Oxygen Demand (BOD=50 mg l<sup>-1</sup>) effluent discharge. They analysed simple BOD–DO model formulation of WQ model has been used considering only the dissolved BOD. The following equation was used.

$$\frac{dDO}{dt} = K_2(C_s - DO) - K_d BOD \theta^{d_3} (T - 20) - R_2 \theta^{2(T - 20)} + P - B$$

The model calculates the oxygen balance without taking into account the nutrients or the suspended part of BOD; the DO depletion is directly related to the dissolved BOD in the water column. The discharge is introduced into the model through an outfall located at a distance of 6.8 km from the shore at a depth of 10 m. Three scenarios were simulated with



different discharge rates such as 2, 5 and 10 m<sup>3</sup> s<sup>-1</sup>, with BOD load of 8640, 21,600 and 43,200 kg day<sup>-1</sup> respectively. Model simulations were carried out to estimate the assimilation capacity of the waters off Kochi for the three discharge rates. The results show that for 10 m<sup>3</sup> s<sup>-1</sup> effluent discharge, the initial BOD of 50 mg l<sup>-1</sup> reduced to 3.33 mg l<sup>-1</sup> at the outfall after 48 h. High BOD values were confined to an elliptical area of 8 km<sup>2</sup> around the outfall. Based on this, the assimilative capacity of the waters off Kochi in terms of BOD can be estimated as 38,000 kg day<sup>-1</sup>. It is suggested that offshore waters could be used as a feasible alternative to the Kochi backwaters for the disposal of treated effluent (Babu et al, 2006)

Spatial and temporal variations of Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) in the Gulf of Kachchh (GoK), India are assessed based on data collected since 1976. DO concentrations in the interior GoK vary within a narrow range (6.05–6.86mg l<sup>-1</sup>), whereas near-shore waters show wider variations (3.5–7.8mg l<sup>-1</sup>). The DO concentration levels in the Gulf waters are close to saturation, varying from 75.4% to 108.6%, which is much higher than the 60% saturation level set for the SW-1 waters. BOD–DO simulation shows that when effluents containing a BOD concentration of 50.0mg l<sup>-1</sup> are introduced at three selected locations, DO reduces from 5.1mg l<sup>-1</sup> to 3.1, 5.0 and 3.8mg l<sup>-1</sup>, respectively, indicating a strong sensitivity to effluent load. Based on the DO analysis, BOD assimilation capacity of coastal waters around the Marine National Park (MNP) and Marine Sanctuary (MS) in the Gulf is determined. DO available for utilization for various categories of water use is illustrated, keeping in mind the ecology of MNP and MS areas. The significance of DO as a target indicator to zone the Gulf for different water use, is highlighted in this study.(Desa et al, 2005)

A typical tropical monsoonal pattern was observed by National Institute of Oceanography scientists in water temperature, salinity, and dissolved oxygen over an annual cycle. Generally the estuaries are well mixed, except in the monsoon season (especially in Zuari estuary) when stratification is caused by salinity gradient. With the exception of salinity in

the monsoon season (in Zuari estuary), stratification did not bring about any significant differences ( $p > 0.05$ ) in the physicochemical characteristics between surface and bottom waters. Dissolved oxygen concentration remained high ( $> 4 \text{ mg l}^{-1}$ ) throughout the water column, suggesting that the system is well oxygenated. Significant differences in salinity, dissolved oxygen and dissolved inorganic nitrogen (DIN) were observed between monsoon and non-monsoon seasons (ANOVA,  $p < 0.02$ ). The average concentrations (surface and bottom waters) of organic carbon, nutrients and C:N ratio during non-monsoon and monsoon seasons are summarized in Table 1.

During the study period the overall primary productivity (PP) was high in the Zuari ( $22.8 \mu\text{g C l}^{-1} \text{ h}^{-1}$ ) than Mandovi estuary ( $14.3 \mu\text{g C l}^{-1} \text{ h}^{-1}$ ). In both the estuaries the PP maxima was observed in the non-monsoon season. Heavy precipitation in the monsoon season, characterized by low salinity and high turbidity led to a significant decrease in PP in Mandovi (ANOVA,  $p < 0.001$ ) and Zuari estuary (ANOVA,  $p < 0.05$ ) when compared to non-monsoon seasons. The average PP in the Mandovi and Zuari estuaries during the monsoon season were  $4.4 (\pm 2.5) \mu\text{g C l}^{-1} \text{ d}^{-1}$  and  $18.2 (\pm 15.4) \mu\text{g C l}^{-1} \text{ d}^{-1}$  respectively (Table 1). (Pradeep Ram et al, 2005)

Parameters	Mandovi			Zuari			Coastal waters
	Average (n = 24)	Non mon <sup>a</sup> (n = 16)	Mon <sup>a</sup> (n = 8)	Average (n = 24)	Non-mon (n = 16)	Mon (n = 8)	Non-mon (n = 16)
Temp. (°C)	28.5 (±1.2)	29.9 (±1.6)	27.1 (±0.9)	28.6 (±1.5)	29.4 (±1.6)	27.4 (±1.4)	28.2 (±2.0)
pH	7.7 (±0.2)	7.9 (±0.1)	7.6 (±0.2)	7.9 (±0.1)	8.0 (±0.1)	7.9 (±0.2)	8.1 (±0.1)
Salinity (psu)	12.7 (±4.2)	23.2 (±6.1)	2.1 (±2.3)	25.6 (±6.6)	29.9 (±6.1)	21.2 (±7.0)	31.1 (±4.5)
DO (mg l <sup>-1</sup> )	5.8 (±1.1)	5.4 (±0.5)	6.2 (±1.7)	5.0 (±1.2)	4.5 (±0.7)	5.6 (±1.6)	5.1 (±0.9)

Table -1

Devi estuary is one of the major tributaries of the Mahanadi riverine system in Orissa. Modernization and industrialization in its neighbourhood in the north in the recent past have greatly influenced many tributaries of the Mahanadi and the adjacent coastal environments. To trace the influence of this modernization activity further down south off Devi estuary and to understand the quality of the Devi estuarine water reaching the coastal region, investigations on physicochemical parameters (temperature, pH, salinity, dissolved oxygen), including dissolved nutrients ( $\text{PO}_4\text{-P}$ ,  $\text{NO}_3\text{-N}$ ,  $\text{NO}_2\text{-N}$ ,  $\text{SiO}_4\text{-Si}$ ) were carried out in the water off the mouth of the Devi estuary, during different months of the summer and winter seasons in 2006–07. The multivariate statistics and principal component analysis applied to the datasets, indicated three factors each during the summer and winter seasons influencing the water to the extent of 77 and 80% respectively. Principal axis factoring and alpha factoring have been used to observe the mode of association of parameters and their interrelationships, for evaluating water quality during the summer and winter seasons. The results indicated the addition of phosphates and silicates to the coastal water by the Devi estuary from natural sources during both the seasons. The anthropogenic nitrogenous species, as a fall out from modernization activities in the north, are more clearly observed off the mouth of the Devi estuary during the winter season. The study indicated that the Devi estuary adds sufficiently well-oxygenated, nutrient-rich water to the coastal region.(Pradhan et al, 2007)

This paper presents the results of preliminary assessment of water quality along Red Sea coast adjoining Jeddah, Saudi Arabia. Jeddah is a major city with a population of over 2.6 million and an area  $1,200 \text{ km}^2$ . To study the impacts, samples of the Red Sea were collected from 24 important locations near Jeddah and analyzed in the laboratory for various water quality parameters. These parameters included: biological oxygen demand (BOD), chemical oxygen demand (COD), phosphorus, dissolved oxygen, ammonia nitrogen, nitrates, sulfates, total alkalinity, chlorides, and pH. The results of the study show considerable variations in

water quality depending upon the location along the Red Sea coast. The BOD values in the sea water are negligible except in the Balad downtown lake near treatment plant where the values are quite high ranging from 51 to 812 mg/l. Here, the total phosphorus is also high with value of 3.81 mg/l. Dissolved oxygen values along the coast vary from 2.5 to 6.4 mg/l. The variations in nitrate concentration in the Red Sea water along the coast are observed to range from 6.90 to 26.61 mg/l. This study provides a preliminary assessment of the coastal pollution and will act as a data base for future investigations and monitoring of the Red Sea

For a description of the Bay of Bengal as a shared ecosystem, see (Aziz Ahmad et al, 1998). The LME is affected by monsoons, storm surges, and cyclones but has no seasonal upwelling. However, in nearshore areas, the mixing of nutrient rich bottom waters and warm surface waters creates conditions similar to upwelling (Dwivedi and Choubey, 1998). The number and intensity of cyclones in the northern part of the Bay of Bengal are likely to increase due to global warming. For more on the southwest monsoon, see Desai and Bhargava, 1998. Major rivers such as the Brahmaputra and Ganges discharge large quantities of fresh water into the Bay of Bengal (see Dwivedi and Choubey, 1998). For a map of freshwater drainage of the Northern Bay of Bengal, see Dwivedi, 1993, p. 45. This input of freshwater and silt impacts the salinity of the coastal and estuarine waters as well as coastal circulation patterns. It influences and governs LME dynamics during the southwest monsoon. For more information on hydrography and productivity, see Dwivedi, 1993. Wetlands, marshes, and mangroves play an important role in the overall productivity. The Bay of Bengal LME is considered a Class II, moderately productive (150-300 grams of carbon per square meter per year) ecosystem based on SeaWiFS global primary productivity estimates. Changing environmental conditions are influencing currents, productivity and coastal pollution. Lakes connected to the Bay of Bengal LME are changing. Some coastal areas serving as nursery grounds for commercially valuable species of prawns

are polluted. For a map of distribution of zooplankton biomass in the Bay of Bengal LME, see Desai and Bhargava, 1998, p. 303. For more information on biological production and fishery potentials in India's EEZ, see Desai and Bhargava, 1998. For benthic biomass production in the shelf region of the Bay of Bengal, see Parulekar et al, 1982. A graph is reproduced on page 303 of Desai and Bhargava, 1998. Six areas of critical biological diversity are: the Sundarbans, one of the world's most extensive mangrove systems, Palk Bay, the Gulf of Mannar, the Marine (Wandur) National Park in the Andaman and Nicobar Islands, the Maldives Atolls, Mu Ko Similan National Park and Mu Ko Surin National Park in Thailand.

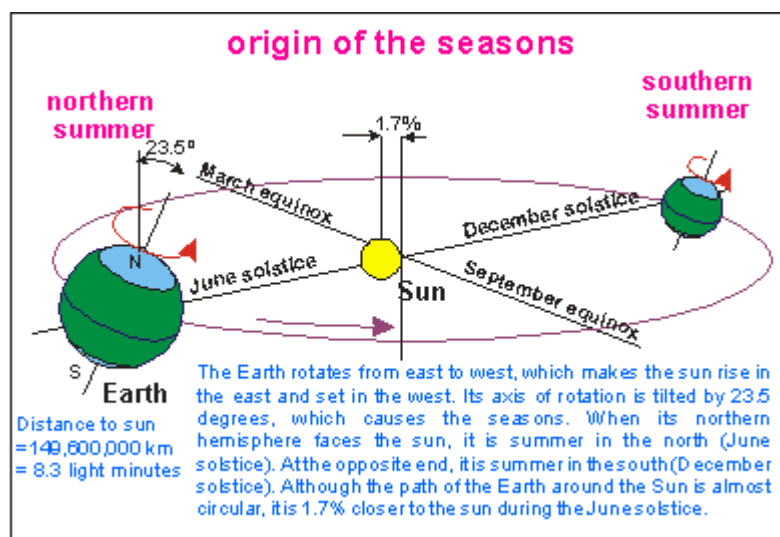
The ecosystem stresses experienced are connected to the size of the coastal populations bordering the LME (Aziz Ahmad et al, 1998). Issues of ecosystem health that are common throughout the region are: environmental stresses on the Bay of Bengal's water quality; the degradation of many of the coral, mangrove, wetland and seagrass bed habitats that support fisheries; and the use of fishing gear that may affect the long-term sustainability of the fisheries resource. For more information on anthropogenic changes, see Dwivedi, 1993. The major rivers bring in large concentrations of pollutants from agricultural pesticides and industrial waste that damage fish spawning and nursery areas, cause fish kills and lead to possible changes in trophic structure. High levels of pesticides can be found along the coast, especially near cities and ports (see Dwivedi, 1993). A major part of Bangladesh consists of a delta plain positioned below the confluence of the Ganga, Brahmaputra and Meghna Rivers. Environmental refugees regularly flee the flooded plain, and many deaths occur with the floods. For a map of the effect of sea-level rise on low-lying Bangladesh, (Dwivedi, 1993). Sediment loading in the Ganga-Brahmaputra watershed caused by accelerated soil erosion in the Himalayas is considered to be one of the main factors contributing to downstream flooding. In some regions of the Bay of Bengal, a change in composition of plankton species has been observed. There is heavy oil

tanker traffic between Japan and the Middle East, with the main shipping route passing South of Sri Lanka before entering the Straits of Malacca via a passage below the Nicobar Islands. For this reason, oil spills are a major concern. In 1993, India approved a national oil spill contingency plan. There is inadequate information on pollution and sedimentation loads entering the Bay of Bengal, on coastal habitats and endangered species. This information is necessary in order to understand the functioning of the ecosystem and its reaction to stress over time.

The theories and classification schemes commonly used for understanding estuarine dynamics often refer to a steady state of the estuary in which the salinity field is time-independent. In this state salinity ingress into the estuary due to different processes (diffusion, gravity current formation, impact of tidal asymmetries, etc.) is balanced by salinity egress induced by runoff. Here we point out that the salinity field of the estuaries that are located on the coasts of the Indian subcontinent and come under the influence of the Indian Summer Monsoon (ISM) is never in a steady state. We refer to such estuaries as “monsoonal estuaries”, an example of which is the Mandovi estuary located on the west coast of India. We describe the annual cycle of the salinity field in this estuary and conclude that the essential unsteadiness of the salinity field arises from two features of the runoff into it. First, most of the runoff occurs as a series of episodes of highs and lulls spread over about 4 months of the wet summer monsoon. Second, the total runoff is large, well over an order of magnitude larger than the estuarine volume. We define two parameters to represent these two features, and show that they can be used to distinguish the monsoonal estuaries from others. (Vijith et al, 2009)

## Effects of different parameters on water quality (EPA,2002)

Temperature - Temperature influences the volume of dissolved oxygen any water can hold and the rate at which chemical reactions occur, as well as metabolism and tolerances for flora and fauna. The temperature of the surface of the Earth, the atmosphere, depends on a delicate balance between solar radiation from the sun and the Earth radiating it out back into space. Only a very small amount percolates up through the crust from the Earth's hot core. As the Earth rotates around its axis, day and night occur. Its once a year rotation around the sun would have been unnoticeable if the Earth's axis of rotation had not been tilted. Its tilt of 23.5 degrees, creates the seasons, which means, that every place on Earth experiences at least once a year, a period of intense sunlight, bright enough for life to blossom. Although the path of the Earth around the sun is almost perfectly circular, it stands closest to the sun in the June solstice, the northern summer. Being 1.7% closer, lands 3.4% more sunlight on the outer atmosphere, which is a noticeable amount in the radiation balance. But it is not only this that makes the northern summers warmer.



pH-Hydrogen ion content influences chemical reactions due to dissolved substances, in particular the dissolution of carbon dioxide and the equilibrium of the carbonate buffer system. It is a critical tolerance parameter for living organisms and can change by orders of magnitude in response to heterotrophic and phototrophic metabolism.

Salinity- Aquatic life is sensitive to the volume of dissolved salts. Salinity may vary slightly with fresh water input, precipitation and evaporation at the marine sites. Dissolved salt content determines conductivity, which is very high in ocean water compared to freshwater streams.

Salinity is identity of seawater. It helps to study the movement of different water masses.

Conductivity- Dissolved material in water has the ability to conduct electric currents. The rate of conductance is dependent on the concentration of dissolved ions. As a stream moves down slope the conductivity of the water increases as dissolved salts increase in concentration.

Turbidity - The cloudiness of water due to small individual particles can be measured as turbidity. Finely dispersed minerals, microscopic bacteria, algae, colloidal matter and organic debris affect turbidity. It directly affects the rate of photosynthesis. The particles themselves or the decrease in light penetration can affect aquatic life. Benthic algae can perish and corals die from excess turbidity.

Dissolved Oxygen- Nearly all aquatic life depends on the dissolved oxygen in the water for survival. The amount of dissolved oxygen is dependent on the physical parameters of water such as temperature, salinity, turbulence and the oxygen pressure in the atmosphere. Additionally production and consumption by the microscopic and larger stream biota can greatly affect oxygen concentration. Typically, the higher the dissolved oxygen within a body of water, the healthier the stream.

Biochemical Oxygen Demand - The biochemical oxygen demand (BOD) is a measure of how much oxygen would be consumed by the stream bacteria if no additional oxygen enters the water. It is an important parameter to determine organic loading and stability of the water to changing conditions. If the BOD of the water sample is greater to or approaches the dissolved oxygen concentration a change in the system could result in anaerobic (no oxygen) water which would kill all the fish and create a noxious condition.



Velocity- Velocity of the stream is correlated with the transfer rate of nutrients and the ability of the stream to transport suspended sediment.

Depth and Width-Depth and width are related to stream flow and in combination with velocity can give stream volume.

Suspended Solids -Suspended solids are the small particles, both organic and inorganic, that can be transported down the stream. Suspended solids can impact biology by silting river mouth bottoms and physically changing benthic environments. The transport of organic material can lead to high biological oxygen demands in sediments, anaerobic sediments and be regenerated into more nutrients.

### Total dissolved solids

Total Dissolved Solids (often abbreviated TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular (colloidal sol) suspended form. Generally the operational definition is that the solids must be small enough to survive filtration through a sieve the size of two micrometer. Total dissolved solids are normally discussed only for freshwater systems, as salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects) it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants.

### Water classification

Water can be classified by the amount of TDS per litre

- fresh water < 1500 mg/L TDS
- brackish water 1500 to 5000 mg/L TDS

- saline water > 5000 mg/L TDS

Nutrients (Combined Nitrogen and Phosphate)-Nutrients are essential for plant growth which ultimately animals depend on. It is important for aquatic systems to have adequate nutrients for growth purposes, but nutrients in abundance can lead to overgrowth of algae and at high enough concentrations eutrophic conditions.

## Conductivity

Conductivity of sea water depends strongly on temperature, somewhat less strongly on salinity, and very weakly on pressure. If the temperature is measured, then conductivity can be used to determine the salinity. Salinity as computed through conductivity appears to be more closely related to the actual dissolved constituents than is chlorinity, and more independent of salt composition. Therefore temperature must be measured at the same time as conductivity, to remove the temperature effect and obtain salinity. Accuracy of salinity determined from conductivity: 0.001 to 0.004. Precision: 0.001. The accuracy depends on the accuracy of the seawater standard used to calibrate the conductivity based measurement. (Michaud, 1991) The conductivity  $\sigma$  is defined as the ratio of the current density  $J$  to the electric field strength  $E$ :

$$\mathbf{J} = \sigma \mathbf{E}.$$

<b>Solution</b>	<b>Conductivity</b>
Absolute pure water	0.055 $\mu\text{S/cm}$
Power plant boiler water	1.0 $\mu\text{S/cm}$
Good city water	50 $\mu\text{S/cm}$
Ocean water	53 $\text{mS/cm}$

## Materials and methods

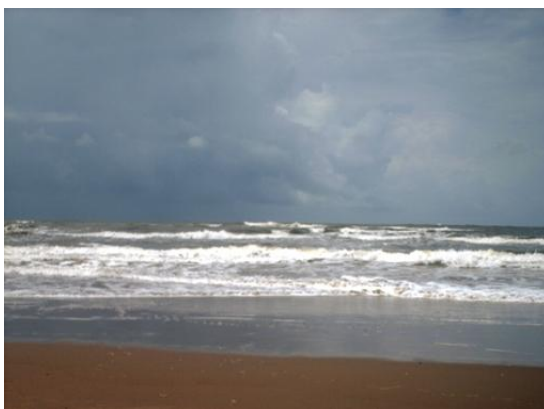
### Study Site

The study was carried out at 3 coastal site of Bakkhali Beach (south extreme point, middle point and far north point, about 1.2 km along the shore) which is influenced by anthropogenic input from land-based sources. The study stations latitude is  $21^{\circ} 35'$  N and longitude is  $88^{\circ} 15'$  E (Fig). Surface water samples were collected on different month at all the sites during high tide and low tide (before 12:00 PM) in month of November 2009 to February 2010 and transported immediately to the laboratory for experimental studies. During southwest and northeast monsoon seasons (June–September and November–January/February), the coastal currents are quite high ( $50\text{--}60\text{ cm s}^{-1}$ ) during high tide time (Nov) and low ( $18\text{--}28\text{ cm s}^{-1}$ ) during low tide time (December, January and February). Samples were collected after heavy rain and post monsoon season. Water temperature and pH were measured in situ by digital pH meter and also cross check in laboratory.



Fig: Sketch of Bakkhali Beach sampling Site

Water samples were fixed immediately after collection for analysis of dissolved oxygen by Winkler's method (Grasshoff et al, 1983). Let site name A= south extreme point (beside wind energy plant, solitary beach human activity is very little & towards the Haldia), B= middle part (highly affected by tourist & boating much affected by local fisherman & other people, some waste water canal directly open in sea), C= far north point (Cleanest part of Bakkhali Beach away from Haldia). All the analysis repeated by four replications.





Site photograph during sampling

## pH-

pH was measured at 30<sup>0</sup>C in the laboratory. Samples were collected in small dark bottles and to each sample a few drops of Chloroform were added as preservative. pH was measured by following electrometric method using a pH meter (make : Elico Limited, LI 120 / LI 610 ) after necessary calibration with standard buffers ( buffer 4, 9.2, 7 pH) .

General Permissible limit: - 5.5 - 9.5 pH

## Apparatus -

### pH Meter -

**Principle:** Lab India pH Meters operate on the principle of determination of [H<sup>+</sup>] ion concentration in logarithmic variation in linear relation to voltage generated at the glass membrane according to NERNST EQUATION.



Potential which is a function of the free hydrogen ion activity is measured by Glass pH Electrode in conjunction with Reference Electrode. The developed voltage in relation with pH, is calibrated according to isopotential of pH sensitive electrode.

Specifications:	Emf in mV :
Range : 0 to 14	Range : 0 to ± 1999
Resolution : 0.01	Resolution : ± 1
Accuracy : ± 0.01	Accuracy : ± 0.1 % of fs or ± 2
Repeatability: ± 0.01	Repeatability: ± 1
Stability : ± 0.05 in 8 hrs	Power requirement: 230 V ± 10 % , 50 Hz, 15 VA

## Temperature:

Temperature had been measured at the sampling spot with a thermometer.

## Turbidity:

Turbidity measurements are of extreme importance in quality monitoring in water, wastewater, beverage production, electroplating and petrochemical applications. Light passing through liquid which contains undissolved solids, such as algae, mud, microbes and other insoluble particles, is both absorbed and scattered. Turbidity increases with the amount of undissolved solids present in the sample. However, the shape, size and composition of the particles also influence the degree of turbidity. Turbidity has been determined by simply measuring light passing through the sample. Measuring the scattered light at an angle of 90° has proved to be a more accurate method particularly at lower measuring ranges.

## Apparatus –

Turb 430 IR Portable Turbidity Meter

Principle: Nephelometric measurement according to DIN EN ISO 7027

Light Source: Infrared LED



## Specification:

Measuring Range: 0.01 to 1100 FNU/NTU	Accuracy: $\pm 0.01$ or $\pm 2\%$ of the measured value
Resolution:	Reproducibility: 0.5% of the measured value
0.01 from 0.01 to 9.99 NTU/FNU	Response Time: 4 seconds
0.1 from 10.0 to 99.9 NTU/FNU	

## Total Dissolve Solid

Optics Technology manufactures Digital Total Dissolve Solid TDS Meter. Optics Technology is an ISO 9001:2000 certified company. The Digital Total Dissolve Solid [TDS] Meter is used for measuring TDS of aqueous solutions accurately. It measures Conductivity in five ranges. It provides resolution 0.1 ppm respectively in the lowest range. It shows cell constant in its digital display and it is adjustable from the front panel. This Digital Total Dissolve Solid [TDS] Meter is available in various ranges like 0 to 200 ppm, 0 to 2.000 ppt, 0 to 20.00 ppt, 0 to 200.00 ppt and 0 to 1000 ppt. It is used to monitor soluble salts in soils and salt contents in water. It is also used in swimming pools, refineries, agricultural and soil analysis labs, fertilizer plants, petroleum, textiles plants etc.

### Digital Total Dissolve Solid Tds Meter

Salient features of the Digital Total Dissolve Solid TDS Meter are as follows:

Display: 3½Digit LED

Measurements: TDS

Specification:

Ranges: 0 to 200 ppm, 0 to 2000 ppm, 0 to 20 ppt [20000 ppm], 0 to 200 ppt [200000 ppm], 0 to 1000 ppt [1000000 ppm], Accuracy: $\hat{A}\pm 1\%$ FS $\hat{A}\pm 1$ Digit
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### Salinity–

Aquatic animals and plants are adapted for a certain range of salinity. Outside this range, they are either negatively affected or they may die. Some animals can tolerate higher salinity than normal, but they have no tolerance for low salinity, while others can handle low salinity, but not high salinity.

### Definition –



“The practical salinity, symbol S, of a sample of sea water, is defined in terms of the ratio K of the electrical conductivity of a sea water sample of 15°C and the pressure of one standard atmosphere, to that of a potassium chloride (KCl) solution, in which the mass fraction of KCl is 0.0324356, at the same temperature and pressure. The K value exactly equal to one corresponds, by definition, to a practical salinity equal to 35.”

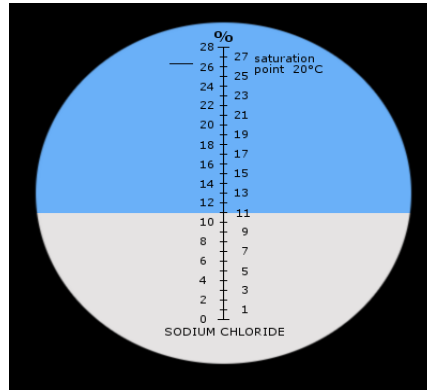
### Salinity Measurement with an optical Refractometer

The easiest way and probably the most cost effective way (compared to electronic salinity measurement devices) is an optical refractometer. This device is based on the physical principle that light is refracted differently depending on the salinity in the medium applied on the prism.

Model - MASTER- $\alpha$ Scale range - Brix 0.0 to 33.0% Measurement Accuracy- Brix $\pm 0.2\%$ (10 to 30°C)	Cat.No. - 2311 Minimum Scale - Brix 0.2% Repeatability - $\pm 0.1\%$
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When the medium to be tested is applied on the prism with a pipette (refractometer was calibrated before by applying distilled water on the prism and adjusting the grey/bluish "line" to zero) you see an image like this:



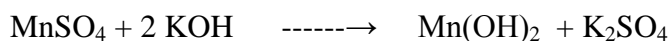
By reading the value on the scale where the greyish/bluish line appears, I determined the salinity. In this case we have a salinity of about 11% or 110 grammes of salt per litre of water.

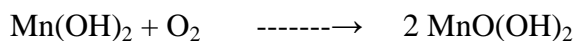
#### Dissolved Oxygen Titration- Azide Modification–

Dissolved oxygen (DO) levels in natural and wastewaters depend on the physical, chemical, and biochemical activities in the water body. The analysis for DO is a key test in water pollution and waste treatment process control. Use the azide modification for most wastewater, effluent, and stream samples, especially if samples contain more than 50 mg NO<sub>2</sub>–N/L and not more than 1 mg ferrous iron/L. Other reducing or oxidizing materials should be absent. If 1 mL KF solution is added before the sample is acidified and there is no delay in titration, the method is applicable in the presence of 100 to 200 mg ferric iron/L. (APHA,1998 and Grasshoff et al,1983)

Basic reactions in Dissolved Oxygen determinations are -

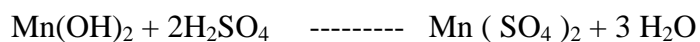
The basic procedure involves the oxidation of manganous hydroxide by Dissolved Oxygen:-



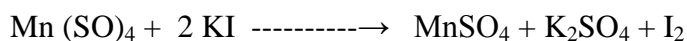


The Mn(OH)<sub>2</sub> is white flocculant precipitate which changes to light brown when oxidized.

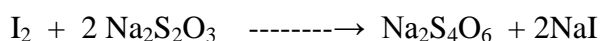
When manganic hydroxide is acidified, manganic sulphate is formed.



In presence of Iodide, the manganic salt acts as an oxidizing agent, releasing free Iodine.



The Iodine which is stoichiometrically equivalent to the Dissolved Oxygen of the sample, is titrated with sodium thiosulphate.



(Balachandran, 2004)

## Reagents

a. Manganoussulfate solution: Dissolve 480 g MnSO<sub>4</sub>.4H<sub>2</sub>O, 400 g MnSO<sub>4</sub>.2H<sub>2</sub>O, or 364 g MnSO<sub>4</sub>.H<sub>2</sub>O in distilled water, filter, and dilute to 1 L. The MnSO<sub>4</sub> solution should not give a colour with starch when added to an acidified potassium iodide (KI) solution.

b. Alkali-iodide-azide reagent:

1) For saturated or less-than-saturated samples—Dissolve 500 g NaOH (or 700 g KOH) and 135 g NaI (or 150 g KI) in distilled water and dilute to 1 L. Add 10 g NaN<sub>3</sub> dissolved in 40 mL distilled water. Potassium and sodium salts may be used interchangeably. This reagent should not give a colour with starch solution when diluted and acidified.

2) For supersaturated samples—Dissolve 10 g NaN<sub>3</sub> in 500 mL distilled water. Add 480 g sodium hydroxide (NaOH) and 750 g sodium iodide (NaI), and stir until dissolved. There will be a white turbidity due to sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>), but this will do no harm.

c. Sulfuric acid, H<sub>2</sub>SO<sub>4</sub>, conc: One millilitre is equivalent to about 3 mL alkali-iodide-azide

reagent.

d. Starch: Use either an aqueous solution or soluble starch powder mixtures. To prepare an aqueous solution, dissolve 2 g laboratory-grade soluble starch and 0.2 g salicylic acid, as a preservative, in 100 mL hot distilled water.

e. Standard sodium thiosulfate titrant: Dissolve 6.205 g  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  in distilled water. Add 1.5 mL 6N NaOH or 0.4 g solid NaOH and dilute to 1000 mL. Standardize with bi-iodate solution.

f. Standard potassium bi-iodate solution, 0.0021M: Dissolve 812.4 mg  $\text{KH}(\text{IO}_3)_2$  in distilled water and dilute to 1000 mL.

**Standardization**—Dissolve approximately 2 g KI, free from iodate, in an erlenmeyer flask with 100 to 150 mL distilled water. Add 1 mL 6N  $\text{H}_2\text{SO}_4$  or a few drops of conc  $\text{H}_2\text{SO}_4$  and 20.00 mL standard bi-iodate solution. Dilute to 200 mL and titrate liberated iodine with thiosulfate titrant, adding starch toward end of titration, when a pale straw colour is reached. When the solutions are of equal strength, 20.00 mL 0.025M  $\text{Na}_2\text{S}_2\text{O}_3$  should be required. If not, adjust the  $\text{Na}_2\text{S}_2\text{O}_3$  solution to 0.025M.

**Procedures:**

**At Sampling Location:**

1. Proper sampling directions was taken for the collection of a water sample and to the filled DO bottle add 1 ml of the  $\text{MnSO}_4$  solution and 1 ml of the Alkali-iodide-azide reagent.
2. Stopper carefully making sure to exclude air bubbles and invert the bottle several times to ensure proper mixing. A brownish precipitate will form at this point. Label the sample, identify both the sampling location, students initials, and the DO meter reading.

### At Laboratory:

3. 1 ml of conc  $\text{H}_2\text{SO}_4$  was added to the bottle contents, re-stopper and invert the bottle holding tight the stopper several times to ensure complete mixing. Wait until complete dissolution of the precipitate occurs, at which time the solution will turn dark golden colour.
4. Take a 202 ml aliquot (202 is used to make up for the displacement of sample by the reagents) of the water sample and place in a 500 ml Erlenmeyer flask. Titrate with 0.025 M sodium thiosulfate solution until the solution becomes a light straw colour.
5. Add a few drops of the starch indicator to the solution, which will turn the solution a dark blue colour. Continue the titration until the first disappearance of the blue colour, record this volume as the final burette reading. Disregard any reappearance of the blue colour.



Step 2

Step 3

Step 4

Step 5

Endpoint

### Biochemical Oxygen Demand ( $\text{BOD}_5$ )

The BOD concentration of most wastewater samples exceeds the concentration of dissolved oxygen (DO) available in that sample (even if the sample is saturated with oxygen). Therefore, it is necessary to dilute the sample with specially prepared dilution water in order to bring the oxygen demand and supply into an appropriate balance. It is vital that the dilution water used has no contaminants that would cause an increase or a decrease in the BOD.

Because it is not feasible to allow every sample to come into complete oxygen equilibrium with the dilution water, the standard incubation time for samples is 5 days. If a different duration for incubation is chosen, it must be clearly noted and reported as such. Once a duration has been established, it is critical that this duration be adhered to so that test results are comparable. Because a significant oxygen demand is present within the first fifteen minutes after dilution of the sample, it is vital that the initial oxygen content of the dilution be measured as soon as possible after the liquid components of the dilution have been mixed. It is also very important for the oxygen demand to take place in a closed system (for measurement purposes); thus it is important to stopper the individual dilution bottles immediately after the initial oxygen content has been determined. The presence of chlorine in the sample being analyzed can artificially suppress the oxygen demand. Because of this, it is usually recommended that wastewater treatment plants collect effluent samples prior to the chlorination point. If the sample is collected after the chlorination process, the sample must be seeded during the analysis.

## Apparatus

a. Incubation bottles: Use glass bottles having 60 mL or greater capacity (300-mL bottles having a ground-glass stopper and a flared mouth are preferred). Clean bottles with a detergent, rinse thoroughly, and drain before use. As a precaution against drawing air into the dilution bottle during incubation, use a water seal. Obtain satisfactory water seals by inverting bottles in a water bath or by adding water to the flared mouth of special BOD bottles. Place a paper or plastic cup or foil cap over flared mouth of bottle to reduce evaporation of the water seal during incubation.

b. BOD Incubator (SSC-105)-This is special type of incubator designed to meet the requirements for incubation of Biochemical Oxygen demand (BOD) on water and sewage. Also recommended for preservation of vaccines at low temperature and supply of enzymatic digestion Processes and other tests demanding constant and uniform low temperature. The unit is highly suitable for work at Temperature below as well as above the ambient. “SSC BOD incubator is being also used as Environmental Study and Growth Chambers by incorporating Lighting & cooling and heating systems. Inside walls are of anodized Aluminium. Out Side of mild steel. Finished in attractive white enamel.Mounted on castor wheels. Glass wool insulation prevents heat losses. Full view inner Glass Door allows inspection of samples without disturbing temperature of chamber.



#### Specification:

- Temperature range 5-50<sup>0</sup>C uniform cooling with cooling embedded in the walls. Temperature uniformity up to  $\pm 0.5$ oC. Operating at 20oC  $\pm$  1oC.
- Forced air circulation ensure uniformity of the temperature.
- Digital Temperature Cum Controller graduated in 1oC.
- Three perforated removable Aluminium or stainless steel shelves.

#### Reagents

Reagents were prepared in advance but discard if there is any sign of precipitation or biological growth in the stock bottles. Commercial equivalents of these reagents are acceptable and different stock concentrations may be used if doses are adjusted proportionally.

- a. Phosphate buffer solution: Dissolve 8.5 g  $\text{KH}_2\text{PO}_4$ , 21.75 g  $\text{K}_2\text{HPO}_4$ , 33.4 g  $\text{Na}_2\text{HPO}_4 \cdot 7\text{H}_2\text{O}$ , and 1.7 g  $\text{NH}_4\text{Cl}$  in about 500 mL distilled water and dilute to 1 L. The pH should be 7.2 without further adjustment. Alternatively, dissolve 42.5 g  $\text{KH}_2\text{PO}_4$  or 54.3 g  $\text{K}_2\text{HPO}_4$  in about 700 mL distilled water. Adjust pH to 7.2 with 30% NaOH and dilute to 1 L.
- b. Magnesium sulfate solution: Dissolve 22.5 g  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  in distilled water and dilute to 1 L.
- c. Calcium chloride solution: Dissolve 27.5 g  $\text{CaCl}_2$  in distilled water and dilute to 1 L.
- d. Ferric chloride solution: Dissolve 0.25 g  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  in distilled water and dilute to 1 L.
- e. Acid and alkali solutions, 1N, for neutralization of caustic or acid waste samples.
- 1) Acid – Slowly while stirring, add 28 mL conc sulfuric acid to distilled water. Dilute to 1 L.
  - 2) Alkali – Dissolve 40 g sodium hydroxide in distilled water. Dilute to 1 L.
- f. Sodium sulfite solution: Dissolve 1.575 g  $\text{Na}_2\text{SO}_3$  in 1000 mL distilled water. This solution is not stable; prepare daily.
- g. Nitrification inhibitor, 2-chloro-6-(trichloromethyl) pyridine.
- h. Glucose-glutamic acid solution: Dry reagent-grade glucose and reagent-grade glutamic acid at  $103^\circ\text{C}$  for 1 h. Add 150 mg glucose and 150 mg glutamic acid to distilled water and dilute to 1 L. Prepare fresh immediately before use.
- i. Ammonium chloride solution: Dissolve 1.15 g  $\text{NH}_4\text{Cl}$  in about 500 mL distilled water, adjust pH to 7.2 with NaOH solution, and dilute to 1 L. Solution contains 0.3 mg N/mL.
- j. Dilution water: Use demineralised, distilled, water for making sample dilutions

## Procedure

- Two 300 ml BOD bottles were partially filled with dilution water. With a large tipped pipette, the precalculated amount of sample was dispensed into each of the two 300



ml of BOD bottles. Then each bottle was filled with dilution water and the stopper was inserted and all air bubbles was excluded.

- An additional two 300 ml BOD bottles with only dilution water were filled and the stoppers was inserted as in step 1.
- At 20 ° C, one bottle containing diluted samples and one containing only dilution water was incubated.
- A DO determination on the remaining BOD bottles from step 1 and step 2 were run and the initial DO content were recorded.
- After 5 days, DO determination tests were done with the incubated bottles. The DO content of the incubated bottles was recorded. There should not be an increase or decrease of more than 0.2 mg/l of DO between Initial dilution water and final dilution water. Large changes may be caused by improper testing techniques or contaminated dilution water. The following equation was used :

When dilution water is not seeded:

$$\text{BOD}_5, \text{ mg/L} = \frac{D_1 - D_2}{P}$$

When dilution water is seeded:

$$\text{BOD}_5, \text{ mg/L} = \frac{(D_1 - D_2) - (B_1 - B_2)f}{P}$$

where:

$D_1$  = DO of diluted sample immediately after preparation, mg/L,

$D_2$  = DO of diluted sample after 5 d incubation at 20°C, mg/L,

$P$  = decimal volumetric fraction of sample used,

$B_1$  = DO of seed control before incubation, mg/L .

$B_2$  = DO of seed control after incubation mg/L, and

$f$  = ratio of seed in diluted sample to seed in seed control = (% seed in diluted sample)/(% seed in seed control).

If seed material is added directly to sample or to seed control bottles:

$f$  = (volume of seed in diluted sample)/(volume of seed in seed control)

## Chemical Oxygen Demand Dichromate Reflux Technique Standard Method -

Chemical oxygen demand (COD) is used as a measure of oxygen requirement of a sample that is susceptible to oxidation by strong chemical oxidant. The dichromate reflux method is preferred over procedures using other oxidants (eg potassium permanganate) because of its superior oxidizing ability, applicability to a wide variety of samples and ease of manipulation. Oxidation of most organic compounds is 95-100% of the theoretical value (APHA,1998)

### Apparatus-

Model 2015D COD Digestion Apparatus (Spectralabcompany) is a Solid block heated unit with provision for 15 samples at a time in 40mm dia Reaction Vessels.



### Specifications-

Glassware: 15 Reaction Vessels & Air Condensers.

Temperature:  $150^{\circ}\text{C} \pm 1\%$

Capacity: 15 Samples at a time.

Range: 0 to 500 ppm without dilution. Further samples can be analysed using appropriate dilution.

Timer: 2 Hours Timer with Buzzer

## Reagents-

- a. Standard potassium dichromate solution, 0.04167M: Dissolve 12.259 g  $K_2Cr_2O_7$ , primary standard grade, previously dried at  $150^\circ C$  for 2 h, in distilled water and dilute to 1000 mL. This reagent undergoes a six-electron reduction reaction; the equivalent concentration is  $6 \times 0.04167M$  or 0.2500N.
- b. Sulfuric acid reagent: Add  $Ag_2SO_4$ , reagent or technical grade, crystals or powder, to conc  $H_2SO_4$  at the rate of 5.5 g  $Ag_2SO_4$ /kg  $H_2SO_4$ . Let stand 1 to 2 d to dissolve.
- c. Ferroin indicator solution: Dissolve 1.485 g 1,10-phenanthroline monohydrate and 695 mg  $FeSO_4 \cdot 7H_2O$  in distilled water and dilute to 100 mL. This indicator solution is also available readymade.
- d. Standard ferrous ammonium sulfate (FAS) titrant, approximately 0.25M: Dissolve 98 g  $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$  in distilled water. Add 20 mL conc  $H_2SO_4$ , cool, and dilute to 1000 mL. Standardize this solution daily against standard  $K_2Cr_2O_7$  solution as follows. Dilute 25.00 mL standard  $K_2Cr_2O_7$  to about 100 mL. Add 30 mL conc  $H_2SO_4$  and cool. Titrate with FAS titrant using 0.10 to 0.15 mL (2 to 3 drops) ferroin indicator.

### Molarity of FAS solution

$$\text{Molarity} = \frac{\text{ml } 0.04167M \text{ } K_2Cr_2O_7}{\text{Volume FAS used in titration, mL}} \times 0.2500$$

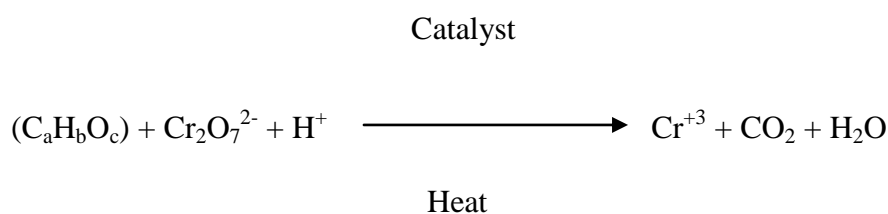
- e. Mercuric sulfate,  $HgSO_4$ , crystals or powder.
- f. Sulfamic acid: Required only if the interference of nitrites is to be eliminated
- g. Potassium hydrogen phthalate (KHP) standard,  $HOOC C_6H_4 COOK$ : Lightly crushed and then dried KHP to constant weight at  $110^\circ C$ . Dissolve 425 mg in distilled water and dilute to 1000 mL. KHP has a theoretical  $COD^1$  of 1.176 mg  $O_2$ /mg and this solution has a theoretical

COD of 500  $\mu\text{g O}_2/\text{mL}$ . This solution is stable when refrigerated, but not indefinitely. Weekly preparation usually is satisfactory.

### Procedure-

Organic substances in the sample are oxidized by Potassium dichromate in 50% Sulphuric acid solution at reflux temperature. Silver sulphate was used as a catalyst and mercuric sulphate was added to check Chloride ion interference. The excess Potassium dichromate was titrated with standard ferrous ammonium sulphate solution using Orthophenanthroline ferrous complex (Ferrouin) Indicator.

The principal reaction is :



To keep the loss of organic low, the flask cooled during addition of Sulphuric acid. Simultaneously, a blank test following the same procedure should be done with distilled water in place of sample.

Treatment of samples with COD of  $>50 \text{ mg O}_2/\text{L}$ : Blend sample if necessary and pipet 50.00 mL into a 500-mL refluxing flask. For samples with a COD of  $>900 \text{ mg O}_2/\text{L}$ , use a smaller portion diluted to 50.00 mL. Add 1 g  $\text{HgSO}_4$ , several glass beads, and very slowly add 5.0 mL sulfuric acid reagent, with mixing to dissolve  $\text{HgSO}_4$ . Cool while mixing to avoid possible loss of volatile materials. Add 25.00 mL 0.04167M  $\text{K}_2\text{Cr}_2\text{O}_7$  solution and mix. Attach flask to condenser and turn on cooling water. Add remaining sulfuric acid reagent (70 mL) through open end of condenser. Continue swirling and mixing while adding sulfuric acid reagent.

Mixed reflux mixture thoroughly before applying heat to prevent local heating of flask bottom and a possible blowout of flask contents.

Cover open end of condenser with a small beaker to prevent foreign material from entering refluxing mixture and reflux for 2 h. Cool and wash down condenser with distilled water. Disconnect reflux condenser and dilute mixture to about twice its volume with distilled water. Cool to room temperature and titrate excess  $K_2Cr_2O_7$  with FAS, using 0.10 to 0.15 mL (2 to 3 drops) ferroin indicator. Although the quantity of ferroin indicator is not critical, use the same volume for all titrations. Take as the end point of the titration the first sharp colour change from blue-green to reddish brown that persists for 1 min or longer. Duplicate determinations should agree within 5% of their average. Samples with suspended solids or components that are slow to oxidize may require additional determinations. Blue-green colour may reappear. In the same manner, reflux and titrate a blank containing the reagents and a volume of distilled water equal to that of sample

#### Reagent Quantities and Normalities for various Sample Sizes:

Sample size , ml	0.25N Standard Dichromate ml	Conc. $H_2SO_4$ with $Ag_2SO_4$	$HgSO_4$ ml	Normality of $Fe(NH_4)_2(SO_4)_2$	Final Volume Before Titration, ml
10	5	15	0.2	0.05	70
20	10	30	0.4	0.10	140
30	15	45	0.6	0.15	210
40	20	60	0.8	0.20	280
50	25	75	1.0	0.25	350

$$(a - b) N \times 8000$$

$$COD \text{ mg/l} = \frac{\text{-----}}{\text{ml sample}}$$

ml sample

where,

a = ml  $Fe(NH_4)_2(SO_4)_2$  used for blank

b = ml of  $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2$  used for sample

N = normality of  $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2$

## Elimination of Interference

One gram of mercuric sulphate ( $\text{HgSO}_4$ ) will complex 100mg of chloride in a 50ml sample (2,000 mg/l). For samples higher in chloride more  $\text{HgSO}_4$  should be used in the ratio of 10:1  $\text{HgSO}_4$ . Interference from nitrites can be prevented by the addition of 10:1 ratio of sulfamic acid :nitrite. The addition of the silver sulphate ( $\text{AgSO}_4$ ) concentrated sulphuric acid ( $\text{H}_2\text{SO}_4$ ) refluxing acid will aid in the oxidation of some organic nitrogen compounds, but aromatic hydrocarbons and pyridine are not oxidized to any appreciable amount.

## Conductivity

Conductivity is the measure of a material's ability to conduct an electric current. In ocean sciences, the electrical conductivity of seawater is used as an indication of salinity. The saltier the water, the higher the conductivity will be. Seawater salinity can be calculated from measured values of conductivity and temperature. Electrical conductivity (EC) estimates the amount of total dissolved salts (TDS), or the total amount of dissolved ions in the water. There are a number of sources of pollutants, which may be signalled by increased EC:

Wastewater from sewage treatment plants (point source pollutants; see: links) Although a minor fraction of the total dissolved solids, nutrients (ammonium-nitrogen, nitrate-nitrogen and phosphate from fertilizers) and pesticides (insecticides and herbicides mostly) typically have significant negative impacts on streams and lakes receiving agricultural drainage water. If soils are also washed into receiving waters, the organic matter in the soil is decomposed by

natural aquatic bacteria, which can severely deplete dissolved oxygen concentrations

Hanna benchtop conductivity meter

Model EC215

Specification



<b>description</b>	Probe: HI 76300 platinum 4-ring
<b>measuring range</b>	0-1999 $\mu\text{S/cm}$ conductivity, accuracy: 1% full scale 0.0-199.9 $\text{mS/cm}$ conductivity, accuracy: 1% full scale
<b>size</b>	240 mm $\times$ 182 mm $\times$ 74 mm
<b>battery power</b>	(12 V DC power adapter included)

## Bacterial analysis of samples

The apparatus used for the test are being mentioned in the following Table. All the apparatus were thoroughly washed and sterilized in autoclave at  $121^{\circ}\text{C}$  at 15 lb for 20 minutes. Agar was dissolved in water and bring up to the required volume by the addition of water and autoclaved at  $121^{\circ}\text{C}$  at 15 lb for 20 minutes..(Tortora *et al.*,1998)

## Preparation of Nutrient Agar Media

7g of nutrient agar was weighed and dissolved in 100ml of distilled water. The solution was made up to 250 ml by addition of distilled water. The solution was poured into a 500ml conical flask and its mouth was plugged with cotton and it was sterilized in autoclave for 20 minutes at  $121^{\circ}\text{C}$  and 15 lbs/inch<sup>2</sup> pressure. The composition used for the test of Nutrient Agar media is mentioned in below Table 4.(Tortora *et al.*,1998)

## Preparation of sample solution (serial dilution)

Nine sterilized test tubes were taken and numbered. 9 ml distilled water was poured in each tube. They were closed with cotton plugs and were sterilized in autoclave. One gram of the sample was mixed with a test tube containing 9 ml of distilled water to make  $10^{-1}$  dilution. 1 ml of this was added in next test tube to make  $10^{-2}$  dilution. The procedure is repeated till  $10^{-4}$  dilution is obtained..(Tortora *et al.*, 1998)

Apparatus used in microbial tests

Equipments	Number
Sterilized Petri dish	24
Sterilized pipettes	24
Spirit lamp	2
Beaker 500ml	6
Conical flask 200ml	8
Glass rod	1
Sterilized test tubes	7

Table:3

Preparation of Agar Media

Composition	Amount
Peptone	5g
Beef Extract	3g
NaCl	5g
Distilled Water	1000ml
Agar	15g

Table:4

Preparation of plates

Sterilized Petri dishes were taken to the laminar airflow cabinet and 15-20g of warm medium was poured into each plate. This was done near a flame to prevent contamination of the plate by microbes. 0.1ml of sample was poured on the prepared petridish. Sample and agar media



were mixed and kept for solidification. Then the plates were placed into the incubator for 48 hours and then the formed colonies were counted on the plates.

Total plate count is calculated as follows:

$$\text{TPC} = \frac{\text{Number of colonies}}{\text{Amount of solution taken} \times \text{dilution}}$$

Since amount of solution taken was 0.1 ml, the dilution should be increased by a power of 10. (Tortora et al., 1998)

### Bacteria Counting

5 test tubes were taken and added 9 ml distilled water in each. Then added 1 ml sea water sample in one of the test tubes, this was the neutral solution. Then 1 ml was taken from this test tube and transferred it into another test tube and named it as -2. This number shows the dilution factor, this was repeated up to the dilution factor of -5. After that agar media was transferred in each petri dish in such a manner that it covered total surface area of Petri dish. Then 1 ml of neutral solution was taken in front of spirit lamp and pour it into the Petri dish, and named it as neutral. This step was repeated for each of the test tubes and named the Petri dishes same as it was named on test tubes. Then all petri dishes were transferred into incubator at 35°C to 40°C. After 2 to 3 days the bacterial colonies were counted. The bacterial colonies were counted with naked eyes on digital colony counter. (Tortora et al., 1998)

### Counting of bacterial colony from sea water sample

Each Petri dish was divided into four equal parts and then the colonies were counted in a single part and then multiplied by 4, this gives the total number of colonies in a single Petri

dish Colonies on Petri dishes were enumerated with the help of colony counter.



Fig.Bacterial growth in petri dishes

## Result and Discussion

### pH

pH value for surface coastal water of all the site varies between 8.24 to 8.65 during month of October 2009 to February 2010 as shown in Figure-2 and has been tabulated in Table 5. These value are average values of sites (n=4). The max pH value at the Site A was 8.65 in the month of February and min value at Site B (8.24) in month of November. pH value of all the sample increases from month of November to February because all the sampling sites contain maximum rain water in month of November. Site A has maximum pH value (8.65) in month of February since Site A is towards the Haldia industrial area and in February there is no rain and vaporization rate is high as compared to November to January. This may probably be due to some alkaline discharge from the Haldia industrial area or due to rainwater runoff from embankments rich in soluble alkaline matters. Site B has minimum value of pH value (8.24) in month of November due to heavy rain water and this place having water canal in which waste water and rain water come in more quantity. Statistical analysis of pH at different sites are shown in Table 6.

pH of Site (avg n=4)												
Site	A				B				C			
month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
pH	8.26	8.36	8.5	8.65	8.24	8.49	8.4	8.64	8.36	8.45	8.5	8.52

Table 5: Results of the samples pH:

Table 6: Statistical analysis of sample pH :

Mean	8.464545
Standard Error	0.036689
Median	8.49

Mode	8.36
Standard Deviation	0.121685
Sample Variance	0.014807
Kurtosis	-0.0342
Skewness	-0.12367
Range	0.41
Minimum	8.24
Maximum	8.65
Sum	93.11
Count	11
Confidence Level(95.0%)	0.081749

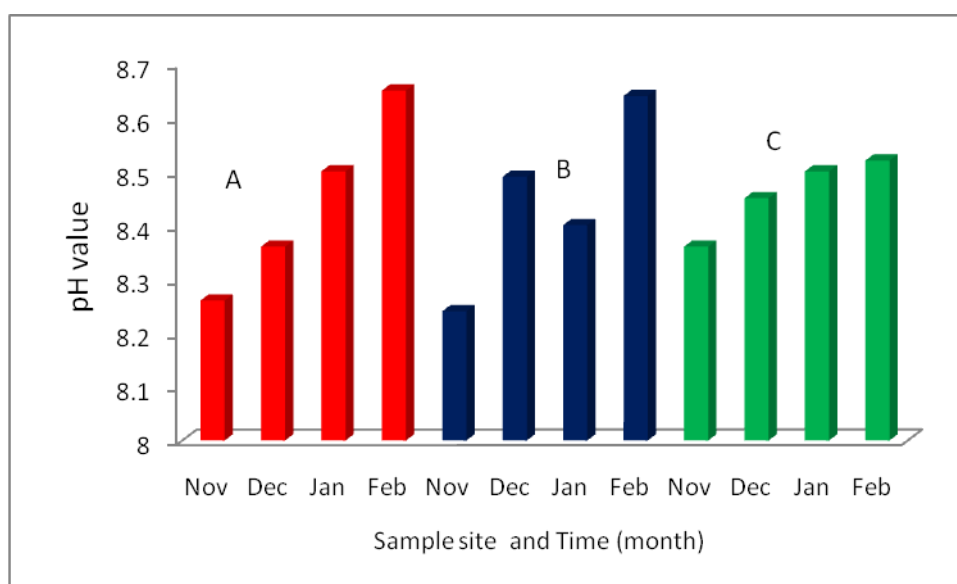


Figure 2- pH variation w.r.t. site and time (month)

## Temperature-

Temperature range of surface coastal water of site A, B, C from October 2009 to February 2010 is tabulated in Table: 7. The temperature of surface water of these sites varies from 27.5<sup>0</sup>C to 31.5<sup>0</sup>C during sampling time. These value are average values of sites (n=4). The max temperature was found at site A and site B (31.5<sup>0</sup>C) during month of November and min temperature was at site A and site B (27.5<sup>0</sup>C) during December. The temperature variation along with site and time during study period shown in Figure- 3. Statistical analysis of temperature variation are shown in Table: 8.

Table 7: Results of the samples temperature:

Temperature of Site (avg n=4)												
Site	A				B				C			
Month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
Temp(°C)	31.5	27.5	28.9	30	31.5	27.5	28	29.8	31	28.5	28	30

Table 8: Statistical analysis of sample temperature:

Mean	29.15455
Standard Error	0.419819
Median	28.9
Mode	27.5
Standard Deviation	1.392382
Sample Variance	1.938727
Kurtosis	-1.152961
Skewness	0.372707
Range	4
Minimum	27.5
Maximum	31.5
Sum	320.7
Count	11
Confidence Level(95.0%)	0.935415

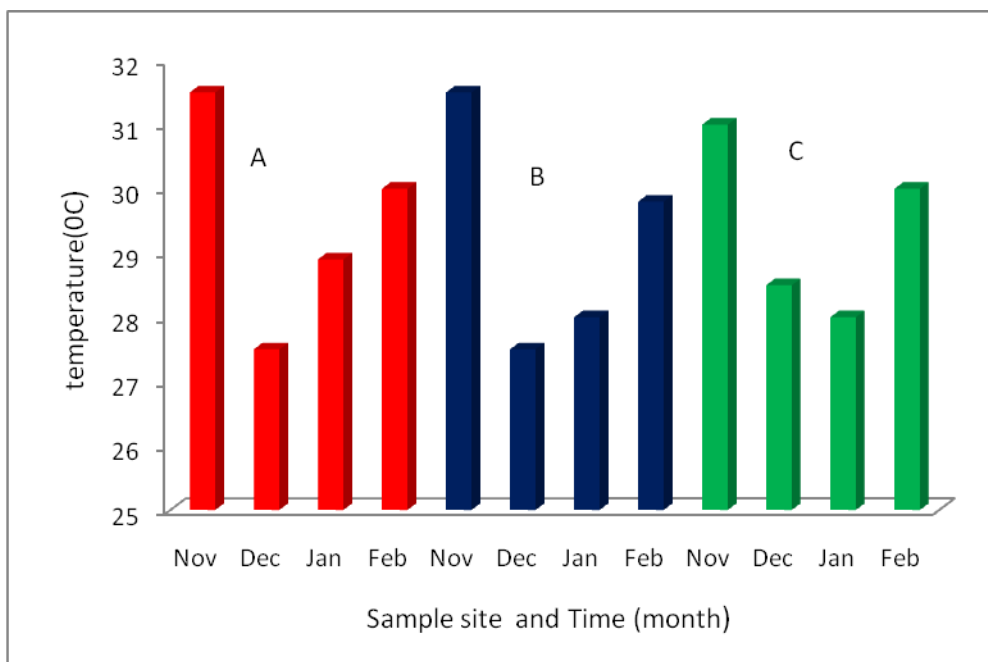


Figure 3- Temperature variation w.r.t. site and time (month)

## Dissolved Oxygen:

DO is a very important water quality parameter required to assess the waste assimilative capacity of the coastal waters. DO is affected largely by waste influx, especially the organic particulate matter, which causes depletion of DO in the process of organic degradation. (Balachandran,2004)Dissolved oxygen level (7.2 to 8.9 mg /l) was generally high at all the sites indicating that these systems were well oxygenated. This value is high because of all the sampling done at the time of 10:00AM to 11:00AM. At that time photosynthetic rate of sea algae are maximum. These value are average values of sites (n=4). The maximum value of dissolved oxygen is at site C (8.9 mg/l) during month of February and minimum value is at Site B (7.2 mg/l) in month of November during sampling time. Dissolved oxygen variability with respect to site and time (month) is tabulated in Table: 9 and shown in Figure: 4. There is slight difference in dissolved oxygen value of coastal water. The DO value was high at site C in February due to it was a clean site away from tourist and local people activity. The DO value was lower at site B in month of November due to flood water from river and tourist activity (fishing boating, swimming etc). This site is also affected by waste water coming from the locality situated near the beach. There are many shops, restaurants and hotel at Bakkhali beach. statistical analysis is carried out of these samples and the results are tabulated in Table: 10.

Table 9: Results of the samples Dissolved Oxygen:

Dissolved Oxygen of Site (avg n=4)												
Site	A				B				C			
Month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
DO(mg/l)	6.8	7.5	8.1	8.5	7.2	7.7	7.9	8.7	7.6	7.8	8.5	8.9

Table 10: Statistical analyses of samples- dissolved oxygen:

Mean	8.036364
Standard Error	0.164744
Median	7.9
Mode	8.5
Standard Deviation	0.546393
Sample Variance	0.298545
Kurtosis	-1.14851
Skewness	0.194647
Range	1.7
Minimum	7.2
Maximum	8.9
Sum	88.4
Count	11
Confidence Level(95.0%)	0.367072

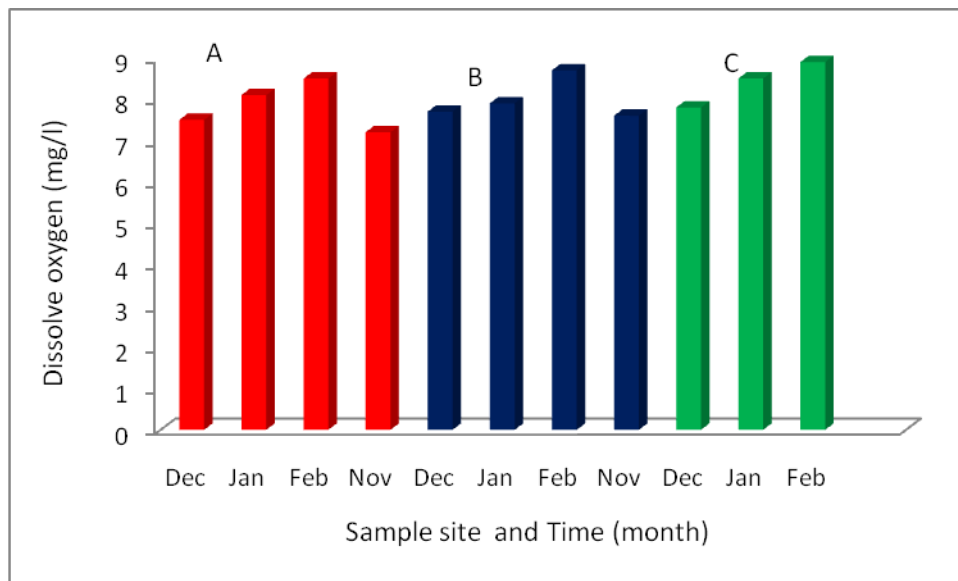


Figure 4 -Dissolved oxygen variation w.r.t. site and time (month)

## Biological oxygen demand:

Normally Biochemical oxygen demand of seawater varies in between 0.4 mg/l – 4.5 mg/l. BOD is employed as a gross measure of the oxygen demanding potential of the effluent. Assimilative capacity varies in accordance with variations in hydrodynamic conditions and other ecological processes.( Babu, 2006)Based on the measured data, the average values of BOD varied between 3.3 mg/l – 5.8 mg/l tabulated in Table: 11 and shown in Figure:5 with respect to time and site. In most of cases BOD value decreases from month of November to February. BOD test performed in absence of photosynthesis hence all bottles were kept in dark. BOD<sub>5-20</sub> values are higher (5.8 mg/l) at site C in December and lower (3.3 mg/l) at site C in month of November. The maximum level of BOD for sea water type 2 (SW2) designated for bathing and commercial fisheries is 3.0 mg/ l(CPCB,1993). BOD value at site C in December is high due to digging of earth at near sampling point.BOD value at site C in month of November is lower since this point is the cleanest point at beach. Site C was not affected by tourist activity. Statistical analysis of BOD samples are tabulated in Table: 12.

Table 11: Results of the samples Biochemical Oxygen Demand:

Biological oxygen demand of site (avg n=4)												
Site	A				B				C			
Month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
BOD(mg/l)	5.3	4.2	4.1	3.9	5.0	5.3	4.8	4.4	3.3	5.8	3.9	4.1

Table 12: Statistical analysis of sample Biochemical Oxygen Demand:

Mean	4.436364
Standard Error	0.217537
Median	4.2
Mode	4.1
Standard Deviation	0.721488



Sample Variance	0.520545
Kurtosis	-0.11103
Skewness	0.501689
Range	2.5
Minimum	3.3
Maximum	5.8
Sum	48.8
Count	11
Confidence Level(95.0%)	0.484702

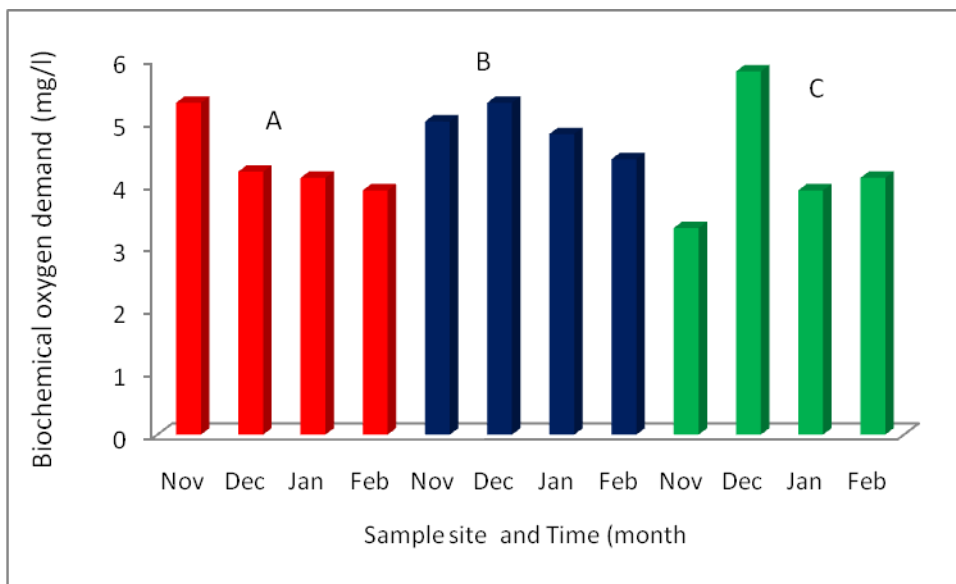


Figure:5 Biochemical oxygen Demand variation w.r.t. site and time (month)

### Chemical oxygen demand:

Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes. Contrary to BOD, with COD

practically all compounds are fully oxidized. The COD average value of different sites w.r.t. site and time (month) is tabulated in Table 13 and shown in Figure: 6. It varies between 400 mg/l – 676 mg/l. the value is higher as expected value as compare to BOD. This signifies that sampling site is highly effected by organic matter which come from Haldia industrial region (petrochemical, leather, fertilizer industries etc.). COD value is totally depending on total dissolve solid value. Sampling site contain higher TDS value. The maximum value found at Site C(676mg/l) during December 2009. This is because of digging operation at site C. at the sampling time current was quite high. The min value found at site C (400 mg/l). This sampling was done soon after heavy rainy season. Due to constant dilution of the saline water by rain water, the COD at this place was low. The statistical analysis is tabulated in Table: 14.

Table 13: Results of the samples Chemical Oxygen Demand:

Chemical oxygen demand of site (avg n=4)												
Site	A				B				C			
Month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
COD(mg/l)	560	540	420	520	496	556	468	560	400	676	464	490

Table 14: Statistical analysis of sample chemical oxygen demand:

Mean	508.1818
Standard Error	22.9251
Median	496
Standard Deviation	76.03396
Sample Variance	5781.164
Kurtosis	1.377004
Skewness	0.80576
Range	276
Minimum	400
Maximum	676

Sum	5590
Count	11
Confidence Level(95.0%)	51.08031

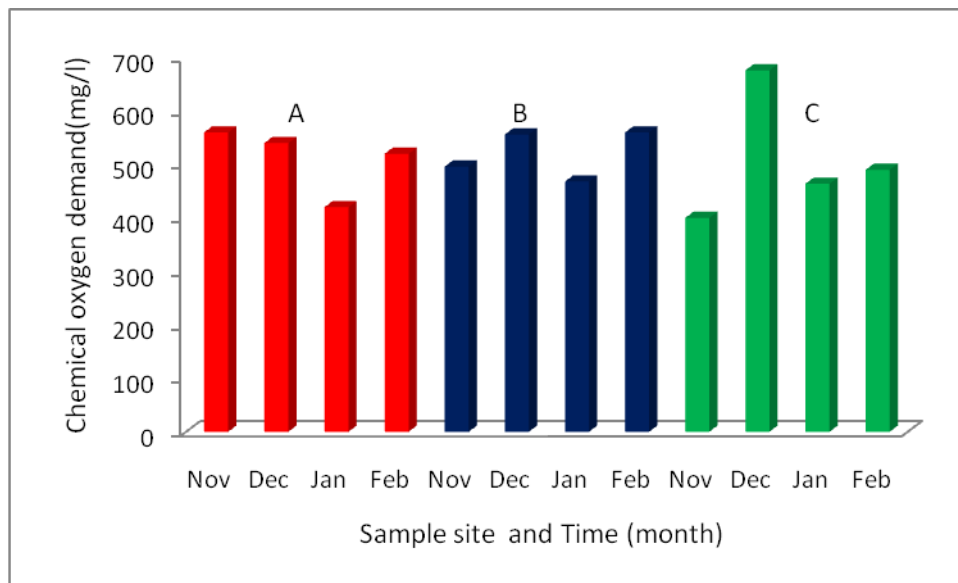


Figure:6 Chemical oxygen demand variation w.r.t. site and time (month)

### Salinity:

The average value of salinity of surface water of sampling site during the study time ranges from 21.6- 30.0 PSU tabulated in Table: 15The salinity corresponding to each location and time is shown in Figure: 7. Salinity of Site C (30.0 PSU) during month of February is higher than other because of high tide time and no dilution of river water and local waste water and Site A has lower value (21.6 PSU) in month of November because of more river or fresh water. In month of November the coastal site A contain more rain water and flood water so it contain lesser salinity. The average salinity of sea water is 35 PSU. Indian estuaries have often been described as “monsoonal”. The salinity of estuary totally depends upon nature of

tide and salinity coastal water depends on amount of rain water during the Monsoon time. At the end of the monsoon, the coastal water at Bakkhali beach is completely changed due to replacement of the premonsoon water by freshwater flowing through the estuaries. This replacement is complete because the estuaries are flushed many times over. Salinity of all sampling site increases from month of November to February The statistical data of salinity variation is tabulated in Table: 16.

Table 15: Results of the samples salinity:

Salinity of site (avg n=4)												
Site	A				B				C			
Month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
Salinity(PSU)	21.5	22.5	28.5	29.6	21.6	22.9	28.0	29.5	22.2	23.0	28.6	30.0

Table 16: Statistical analysis of sample salinity:

Mean	26.03636
Standard Error	1.056863
Median	28
Standard Deviation	3.505217
Sample Variance	12.28655
Kurtosis	-2.23685
Skewness	-0.16572
Range	8.4
Minimum	21.6
Maximum	30
Sum	286.4
Count	11
Confidence Level(95.0%)	2.354837

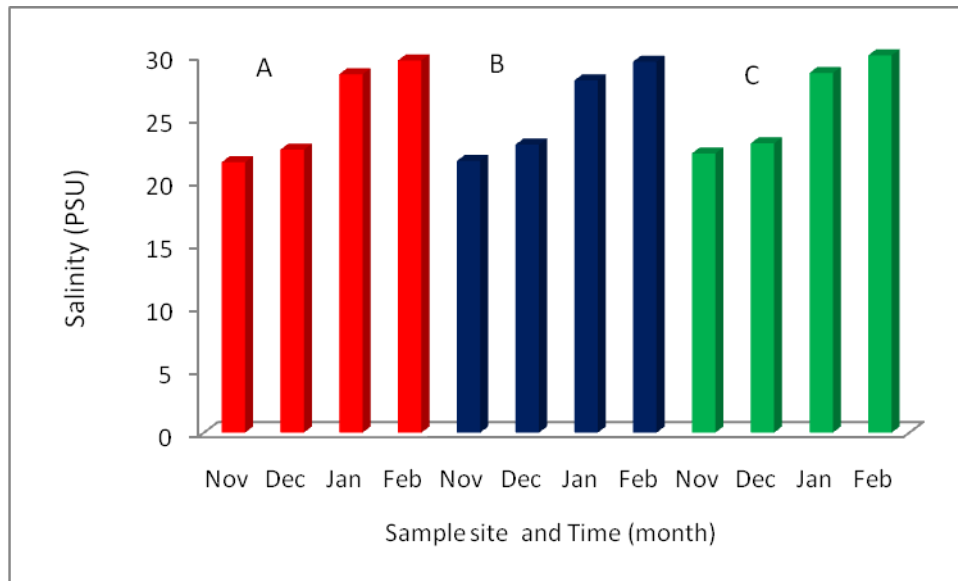


Figure 7-Salinity variation w.r.t. site and time (month)

### Total Dissolve Solid:

Total Dissolved Solids (TDS) consist mainly of carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron, manganese, and a few others. They do not include gases, colloids, or sediment. The TDS can be estimated by measuring the specific conductance of the water. Average value of TDS of surface water of sampling site during the study time is ranges from 800-994 mg/l tabulated in Table: 17. The TDS corresponding to each location and time (month) is shown in Figure: 8. The maximum value of TDS is 994 mg/l at site A in month of November. It is due to flood water collected at this point. This water also contain huge quantity of organic and inorganic mater which came out from Haldia industrial area. The sampling done at high tide time and the wave currents are high at this time. The minimum value of TDS is 800 mg/l at site A in month of January. Low tide season and lesser sea wave current is responsible for this value. There is no dilution

of rain flood water in month of January. The statistical data of TDS variation is tabulated in

Table: 18.

Table 17: Results of the samples total dissolve solid:

Total Dissolve Solid of site (avg n=4)												
Site	A				B				C			
Month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
TDS(mg/l)	994	934	800	940	910	897	880	987	887	876	820	980

Table 18: Statistical analysis of sample total dissolve solid:

Mean	849.9091
Standard Error	29.64317
Median	820
Standard Deviation	98.31526
Sample Variance	9665.891
Kurtosis	-1.71667
Skewness	0.294199
Range	258
Minimum	800
Maximum	934
Sum	8711
Count	11
Confidence Level(95.0%)	66.04909

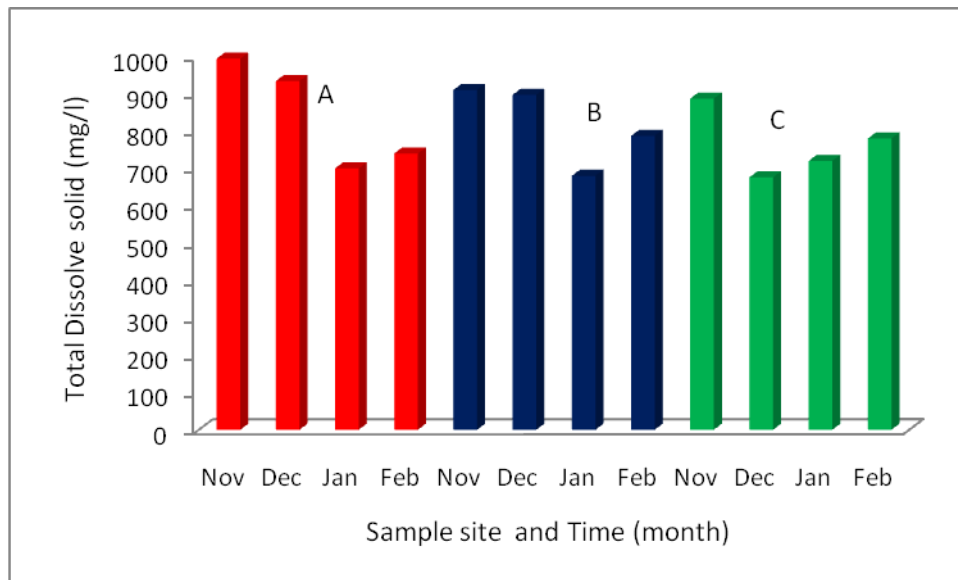


Figure 8-Total dissolve solid variation w.r.t. site and time (month)

### Turbidity:

During study period turbidity of surface water of different site varied between 480 NTU - 808 NTU and is tabulated in Table: 19 and shown in Figure:9. The maximum value was found at site B (808 NTU) in November and minimum value at site C (480 NTU) during February. Maximum value is just after the rainy season and minimum value is when sea water is clear and low tide time. In month of February sea wave is very slow. When rain falls on land it is either absorbed by vegetative areas and loose soil, or it flows over the hard surfaces into local waterways such as lakes, rivers and the ocean. As rainwater runs off hard surfaces such as concrete, asphalt and evenly packed soil, it gathers speed and is able to carry a large suspension of particles such as soil. The swiftly moving water also can erode land and dissolve pollutants such as fertilizers and motor oil. As the water moves faster and increases in volume, more erosion occurs and more pollutants and soil particles are carried into local bodies of water. Depending on the size of the particles in the soil, the water can remain turbid

(cloudy) for several days. More severe impact targets plant and animal life if the turbidity remains longer without dispersal. Water clarity is an important parameter in most bodies of water. Algae, phytoplankton and bottom dwelling plants, submerged aquatic vegetation, need sunlight to manufacture food through photosynthesis. If the turbidity of the water is so high that it will not allow sunlight to penetrate to the necessary depth, plant life will begin to die. Since plants are the basis of the food chain, other animals are soon affected. The statistical data of turbidity shown in Table: 20. Turbidity is continuously decreasing during sampling time from November to February.

Table 19: Results of the samples turbidity:

Turbidity of site (NTU)(avg n=4)												
Site	A				B				C			
Month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
Turbidity	801	601	549	550	808	757	550	600	628	602	580	480

Table 20: Statistical analysis of sample turbidity:

Mean	609.5455
Standard Error	28.61988
Median	600
Mode	550
Standard Deviation	94.9214
Sample Variance	9010.073
Kurtosis	1.129039
Skewness	1.169332
Range	328
Minimum	480
Maximum	808
Sum	6705
Count	11
Confidence Level(95.0%)	63.76907



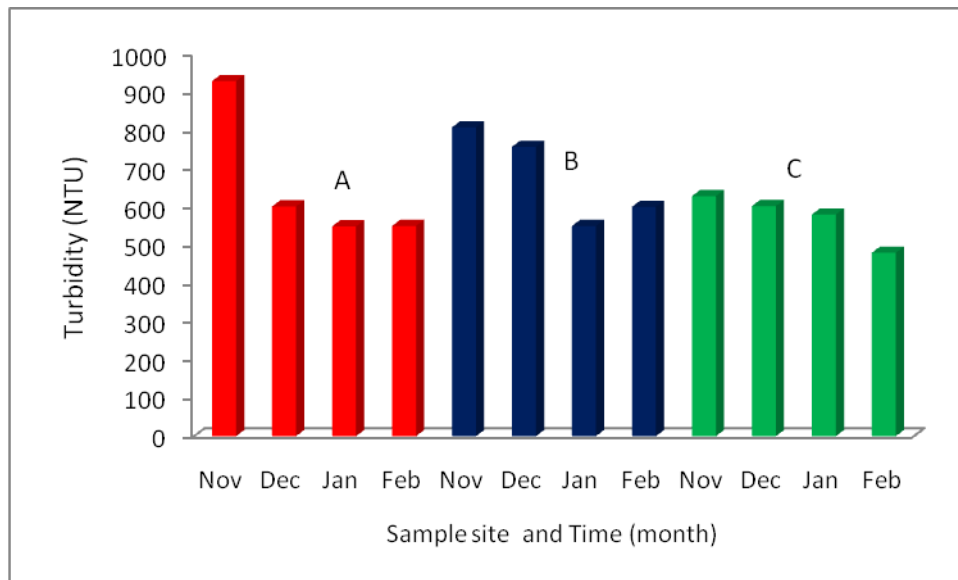


Figure 9-Turbidity variation w.r.t. site and time (month)

## Conductivity

Conductivity or specific conductance is a measure of a material's ability to conduct an electric current. When an electrical potential difference is placed across a conductor, its movable charges flow, giving rise to an electric current. Average value of conductivity of surface water of sampling site during the study time ranges from 1.72-1.97 mS/cm tabulated in Table: 21. The conductivity corresponding to each location and time (month) is shown in Figure: 10. The minimum value of conductivity is at site A (1.72 mS/cm) in month of November. The value of conductivity is totally depends on salinity and TDS value. Salinity value is minimum in month of November. So conductivity is also less. Maximum value of conductivity are found at site C (1.97 mS/cm) during February 2010. It is due to higher salinity and TDS value. Salinity high means higher NaCl, MgCl<sub>2</sub> and other inorganic compounds. Although a minor fraction of the total dissolved solids, nutrients (ammonium-nitrogen, nitrate-nitrogen and phosphate from fertilizers) and pesticides (insecticides and herbicides mostly) typically have significant negative impacts on streams and lakes receiving agricultural drainage water. If soils are also washed into receiving waters, the organic matter in the soil is decomposed by

natural aquatic bacteria, which can severely deplete dissolved oxygen concentrations. All the above processes increase the conductivity. The statistical data of conductivity shown in Table: 22. Conductivity is continuously increasing during sampling time from November to February.

Table 21: Results of the samples conductivity:

Conductivity of site (mS/Cm)												
Site	A				B				C			
Month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
Conductivity	1.72	1.78	1.88	1.91	1.75	1.79	1.81	1.95	1.77	1.81	1.87	1.97

Table 22: Statistical analysis of sample conductivity:

Mean	1.812727
Standard Error	0.020498
Median	1.81
Mode	1.81
Standard Deviation	0.067984
Sample Variance	0.004622
Kurtosis	2.027522
Skewness	1.17264
Range	0.25
Minimum	1.72
Maximum	1.97
Sum	19.94
Count	11
Confidence Level(95.0%)	0.045672

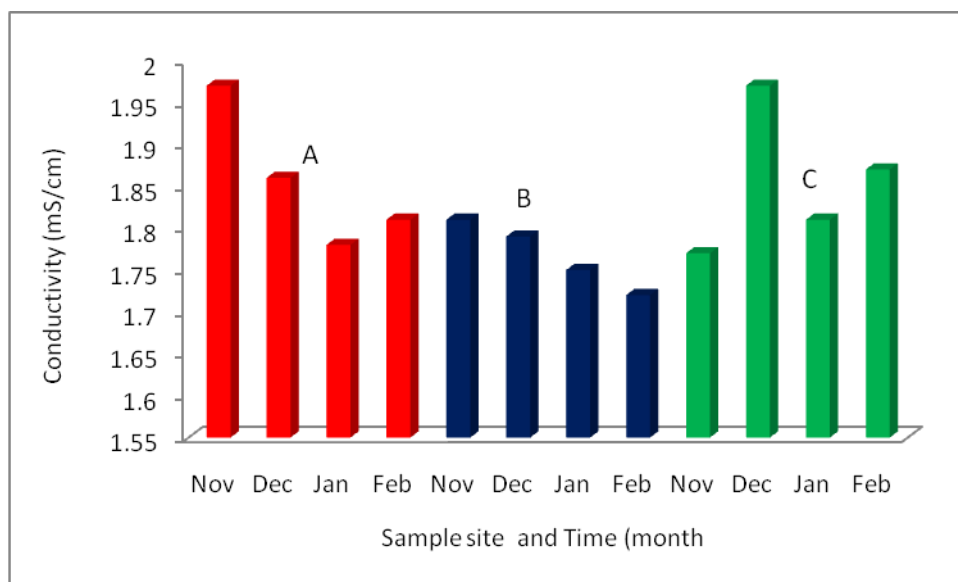


Figure 10-Conductivity variation w.r.t. site and time (month)

### Bacterial colony:

Sea water in shallow regions where the water was mixed from top to bottom, due to tidal or wave motions, had a consistently higher bacterial content, ranging from 20 to 200 cells per cubic centimetre. Some microbes living and transported in ocean water, however, threaten human health. In the open ocean, far from the influences of coastal human habitation, sea water still contains huge numbers of microbes. Coastal areas can contain even greater concentrations. Vast numbers of bacteria occurs both at the surface and in deep ocean waters.(Reuszer,2003).Average value of bacterial colony during sampling time varies between 76-150 are shown in Table 23 and shown in Figure 11. The maximum value of bacterial colony is found at site A (150) during November due to more polluted water at that point. This pollution due to flood water and other local waste water. Though this point is slightly effected by Haldia industrial area. Minimum value is found at site C (76) during February 2010. This point is very clean part of beach and away from local human activity. The bacterial colony is continuously decreasing during studying time from November 2009 to February 2010.The statistical data of bacterial colony are shown in Table: 24.

Table 23: Results of the samples Bacterial colony:

No of bacterial colony (avg no=4)												
Site	A				B				C			
month	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
No of colony	150	114	96	80	100	120	106	92	96	86	80	76

Table 24: Statistical analysis of sample Bacterial colony:

Mean	95.09091
Standard Error	4.301067
Median	96
Mode	96
Standard Deviation	14.26502
Sample Variance	203.4909
Kurtosis	-0.75292
Skewness	0.379871
Range	44
Minimum	76
Maximum	150
Sum	1046
Count	11
Confidence Level(95.0%)	9.583373

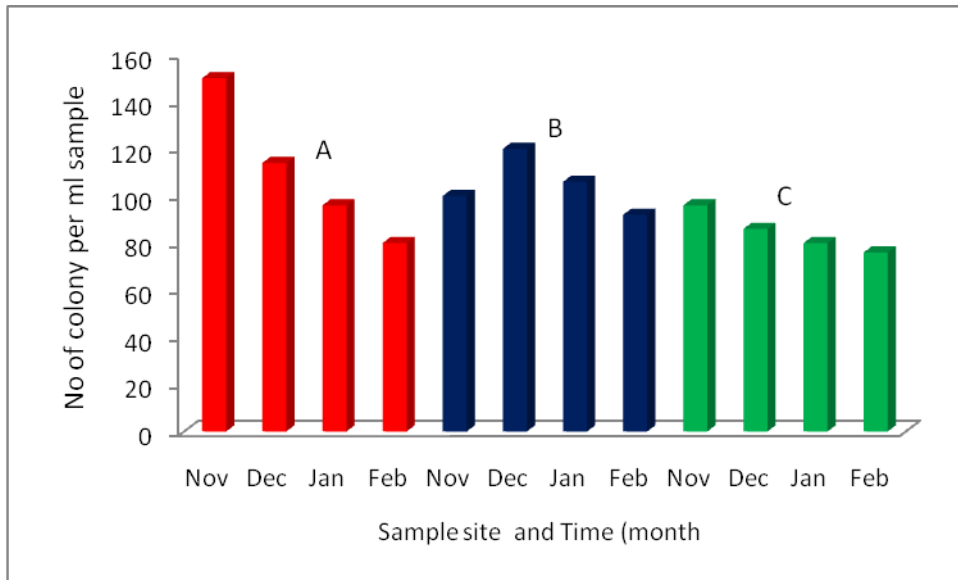


Figure 11-Bacterial colony variation w.r.t. site and time (month)

## Conclusion

November 2009 – February 2010 in terms of hydrodynamic conditions, was chosen to study the water quality around different sites of Coastal water of Bakkhali beach (3 sites). Overall it can be concluded that Bakkhali beach at site C is clean. Only coastal site B and A have been affected to some extent and exhibit elevated levels of pollution measuring parameters. An important aspect to be considered while discharging organic waste into the coastal sea is possible eutrophication of the coastal waters due to this, as the sewage contains significantly high amount of nutrients. Recently there have been several events of red tide and fish mortality at different locations along the east coast of India. These can be minimized through proper pre-treatment of effluents and other waste waters before releasing them in the sea. Constant monitoring of coastal waters is very essential as the frequency of new developments is fast increasing. Also a necessary balance is to be attained between the level of industrialization/urbanization and the exploitation of coastal zone environment so that the coastal ecosystem can be preserved intact

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