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Assessment Water Quality and Seasonal Variations Based on Aquatic Biodiversity of Sundarbans Mangrove Forest, Bangladesh

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Abstract

This study examines the seasonal variation and asses surface water quality of Sundarbans Mangrove Forest in Bangladesh. The statistical analysis ANOVA was used to explore the seasonal variations among three seasons. Water quality and seasonal variation were assessing by measured twelve physico-chemical parameters like Temperature, EC (Electrical Conductivity), pH, Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Salinity, Total Alkalinity, Total Acidity, Free dissolved CO_2, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen demand (COD). The values most of the water quality parameters indicate that the sundarbans aquatic habitat is at suitable range for aquatic species but have a little concern about Salinity values. During study time low level of BOD and COD value indicates that the organic waste pollution was insignificant in the Sundarbans water. The statistical analysis ANOVA shows a significant seasonal variation among three seasons at 0.01 levels of significance.

***Keywords:** Seasonal Variation; Water Quality; Aquatic Biodiversity; Sundarbans Mangrove Forest*

Introduction

Sundarbans is the current spelling of “Sunderbunds” by Walter Hamilton of the East India Gazetteer, meaning the “Forests of the Soondry” (now spelled “Sundri” meaning beautiful). The scientific name is Heritierafomes, a dominant species of the Bangladesh part of the Sundarbans Mangrove Forests (BSMF) [1]. It is the largest contiguous tract of mangroves covering about 10,000 km^2, but an area of 9277 km^2 has also been reported [2-5].

Its ecological importance is associated with its rich biodiversity and the ecosystem’s valuable services. As a consequence of both natural and anthropogenic activities, the valuable ecosystem of Sundarbans has been subjected to considerable degradation. In addition human activities such as resource collection, fishing, shrimp farming, agriculture, and tourism, also interferes the dynamic coastal ecosystem.

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Saltwater and freshwater meet in the rivers of Sundarbans. Thus, it is a region of transition between the freshwater of the rivers originating from the Ganges and the saline water of the Bay of Bengal. Rupsha, Passur, Shibsa, Bhola, Baleswar, Arpangashia, Kholpetua, Malancha and other rivers open into the Bay of Bengal through the Sundarbans Reserve Forest and carry large amounts of nutrients that vary with tides and seasons, affecting the productivity in the area. These regions also play an important role in processing nutrients exchanged between land and sea [6].

As a life supporting natural resource, importance of water is not as crucial as for its quantity rather than for quality and distribution. The diversity of fish, crustaceans, and other aquatic organisms in aquatic system depends on a suitable environment in which they can reproduce and grow. Because these organisms live in water, the major environmental concern within the system is water quality. Quality of water as habitat is one of the most important parameters for the biodiversity of that aquatic system. The quality of water also various in river from season to season. So assessing water quality, seasonal variation is an important factor.

The Sundarbans as unique ecosystem shows greater interest in a number of ways. The Sundarbans water support 53 species of pelagic fish belonging to 27 families, 124 species of demerasal fish belonging to 49 families, 7 species of crabs belonging to 3 families, 2 species of gastropods, 6 species of pelecypods, 8 species of locust lobster and 3 species of turtles are reported from the Sundarbans [7]. But the productivity of Sundarbans water has gone down with water becoming polluted by the toxic effluents discharged from the huge number of shrimp farms in nearby areas, with dumping of domestic and industrial wastes from the Mongla Port. These wastes are dispersed in the entire Sundarbans water and cause damage to the water quality varied species, especially the Penaeid shrimp. In this study twelve water quality parameters were determined from 20sampling stations selected throughout the entire Sundarbans with the basis of the four main river systems of the forest. There is an attempt to know the key components, which could enhance the probability of extinction, and habitat loss, which epitomize our sense to biodiversity crises.

Study area and Methodology

Water samples were collected from 20 stations of the four river systems of Sundarbans FIG. 1 in which every river system covered 5 stations; Summer season (March, 2016 to April, 2016), Rainy season (July, 2016 to August, 2016), winter season (December, 2017 to February, 2017) and in the year of 4th March, 2016 to 12th February, 2017 with fortnightly variations. The samples were collected from each site both in high tide and low tide from near about 10 cm depth from the surface of the four river systems of Sundarbans. The purpose of sampling was to handle the water sample very carefully in such a way that no significant changes occur in composition before the tests are made. The sampling bottles were properly labeled and stored at room temperature. The sampling stations and analytical methods were used for determine the water quality parameters are shown in TABLE 1 and TABLE 2.

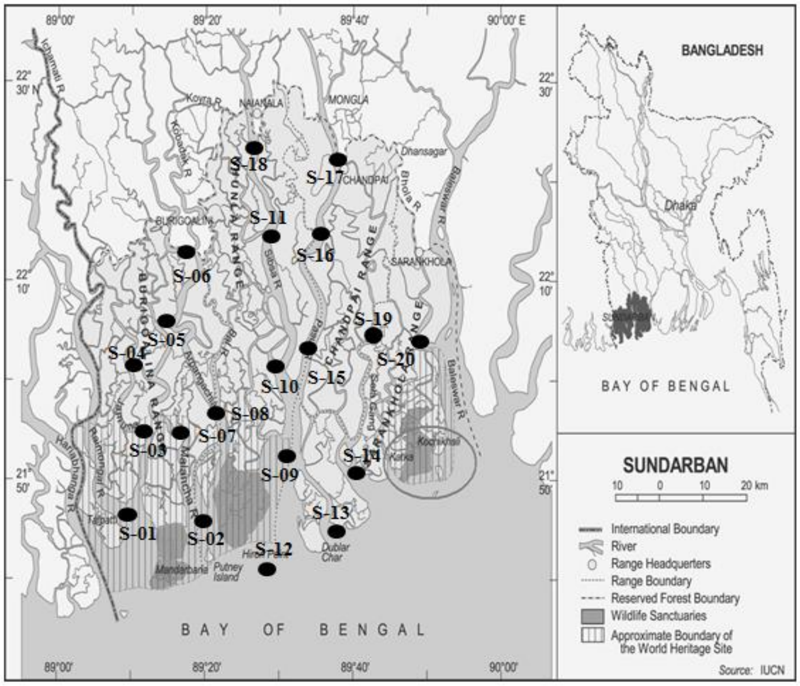

Figure 1: Map of the study area indicating the sampling station (source: Banglapedia)

Table 1: Location & sample ID of the sampling points.

SL. No.	Location	Sample ID	SL. No.	Location	Sample ID
1	Kalir Char	S-01	**11**	Sibsa	S-11
2	Putney Island	S-02	**12**	Hiron point	S-12
3	Holdibunia	S-03	**13**	Dublar Char	S-13
4	DIngimari	S-04	**14**	KachiKhal	S-14
5	Baluijhaki	S-05	**15**	Harintana	S-15
6	Burigoalini	S-06	**16**	Velmari	S-16
7	Malancha	S-07	**17**	Chandpal	S-17
8	Arpanghatia	S-08	**18**	Kalabogi	S-18
9	Arpangasia	S-09	**19**	Sarankhola	S-19
10	Aresh Khali	S-10	**20**	Supti Baleshwar	S-20

Table-2: Analytical methods to be followed for different water quality parameters.

Sl. No.	Parameter	Analytical Method	Reference
1	Temperature	Thermometer	Instrumental method
2	pH	Electrometric	Instrumental method
3	EC	Electrometric	Instrumental method
4	Transparency	Secchi disk	Instrumental method

5	TDS	Electrometric	Instrumental method
6	Salinity	Refractometric	Instrumental method
7	Total Alkalinity	Titrimetric	APHA, 1992
8	Total Acidity	Titrimetric	APHA, 1992
9	Free Dissolved CO_2	Titrimetric	APHA, 1992
10	DO	Winkler's method	APHA, 1992
11	BOD	Winkler's method	APHA, 1992
12	COD	Reflux Titration method	APHA, 1992

Results and Discussion

Temperature

Water temperature is an important factor to consider when assessing water quality. It plays an important role in determining the distribution of species of organisms, which can live in a particular water body. Water temperature affects the natural productivity of aquatic ecosystems and directly or indirectly affects all other water quality variables. Fish and crustaceans are poikilothermic or "cold-blooded." This means that their body temperature is roughly the same as the temperature of the water surrounding them, and because water temperature changes daily and seasonally, the body temperature of fish and crustaceans also changes frequently. The rate of all biochemical processes is temperature dependent. During the study period, temperature was varied from 21^{o}C to 29^{o}C with on average of 25.37±4.02^{0}C at the Sundarbans river system shown in FIG. 2. Water temperature is generally low, ranging from 5^{0}C-36^{0}C which is standard for fisheries and aquaculture [8].The range of water temperature was found within the standard range and higher in summer season due to low water level and high air temperature. Present observation is similar to the seasonal fluctuation in temperature studied by Sharma et al. [9].Water temperature has a significant correlation with most of our studied parameters.

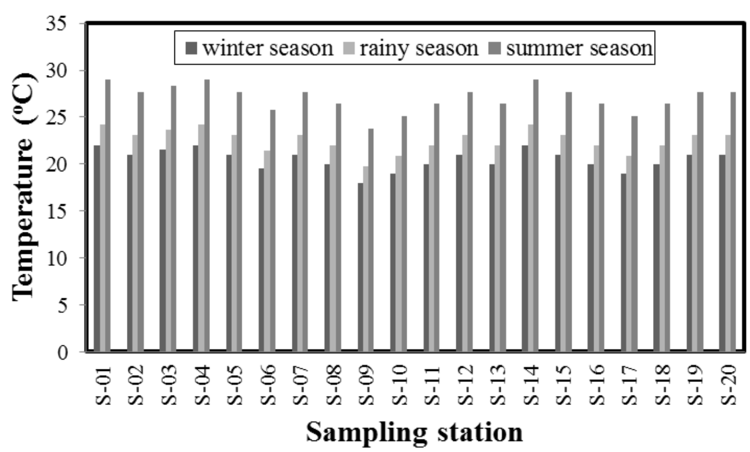

Figure 2: **Seasonal variations of temperature of the Sundarbans mangrove forest river system in Bangladesh.**

pH

Aquatic organisms are affected by pH because most of their metabolic activities are dependent on it. pH of an aquatic system is an important indicator to assess water quality and the extent of pollution in the watershed areas [10]. It greatly affects the equilibria of hydroxide, carbonate, phosphate and silicate between bottom mud and overlying water and thereby the precipitation of soluble nutrients and dissolution of solid materials, sorption and desorption of ions and the concentrations of aluminum, manganese, iron etc which have nutritional significance in aquatic habitat. During the study period, pH value was varied from 7.0 to 9.2 with mean 7.89 ± 1.04 at the Sundarbans river system shown in FIG. 3. The mean pH was found at the Sundarbans river system which indicates the river water is slightly alkaline in nature. The alkaline nature of river water values may be due to sewage discharged by Sundarbans animals, surrounding villages and agricultural fields. In the rainy season, the highest average of pH is observed because in this season, sewage and agricultural discharges increase. Water with pH ranging from 6.0 to 9.0 is generally regard as suitable for organism's growth and aquatic animals [11].The result showed that, pH values were within the permissible limit. The acid and alkaline death points are approximately pH 4 and pH 11, respectively. Marine fish evolved in the highly buffered seawater environment, which is not subject to a wide variation in pH. Consequently, most marine animals typically cannot tolerate as wide a range of environmental pH as freshwater animals, and the optimum pH is usually between pH 7.5 and 8.5. Fish and crustaceans living in brackish water are often exposed to a wide range of pH values as the relative amounts of fresh water and sea water change with variations in river discharge and tidal flow.

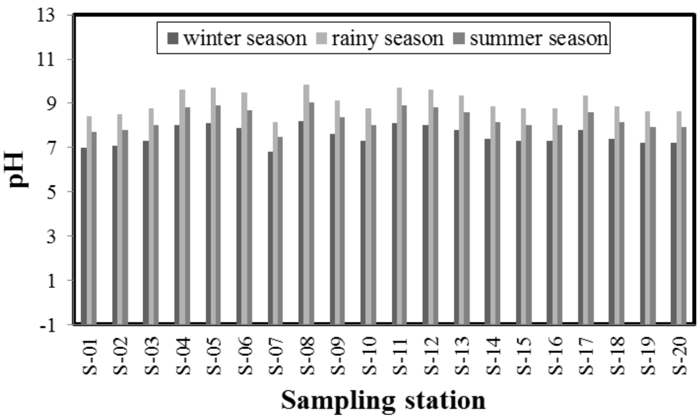

Figure 3: **Seasonal variations of pH of the Sundarbans Mangrove Forest river system in Bangladesh.**

Electrical conductivity and transparency

Conductivity is a measure of the ability of water to conduct electricity. Electrical conductivity is closely related to the amount of total dissolved solids and is also used as index of salt content of water. It is dependent on the ionic concentration and water temperature. The EC value of study area was varied from 4.0 mS/cm to 32.4 mS/cm with mean 15.83 ± 12.40 mS/cm. The electrical conductivity values at different season are shown in FIG. 04. According to Federal Environmental Protection Agency (FEPA) the sustainable EC value for aquatic organism is 10.77 mS/cm to 12.30 mS/cm [12].The most western river was characterized by high EC values of around 20-33mS/cm. The Passur-Sibsa River System, in the central part of the forest was found to have EC values of low level of 12mS/cm to 3mS/cm. The southwest part of Sundarbans gets reduced supply of freshwater since the rivers in the region are almost becoming dry. Another parameter Transparency is determined by the depth that sunlight penetrates in water [13]. The mean Transparency for mangrove river system was found 9.66± 2.52 mS/cm with maximum transparency value 14.56 cm in summer season. The Transparency values at different season are shown in (FIG. 05). The Transparency of the fresh water is 35 to 45 cm which is suitable for aquatic environment [14]. The higher transparency value was observed, during summer due to absence of rain, runoff and flood water as well as gradual settling of suspended particles [15]. The observed EC value is slightly higher and Transparency value is lower than the standard value but Transparency and EC has less effect on aquatic life.

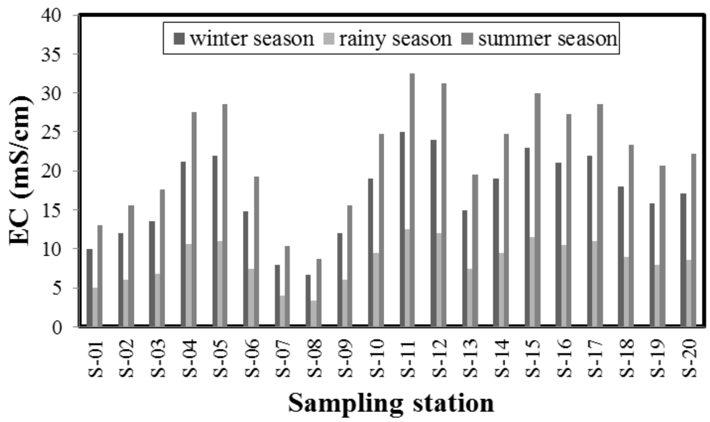

Figure 4: **Seasonal variations of EC of the Sundarbans Mangrove Forest river system in Bangladesh.**

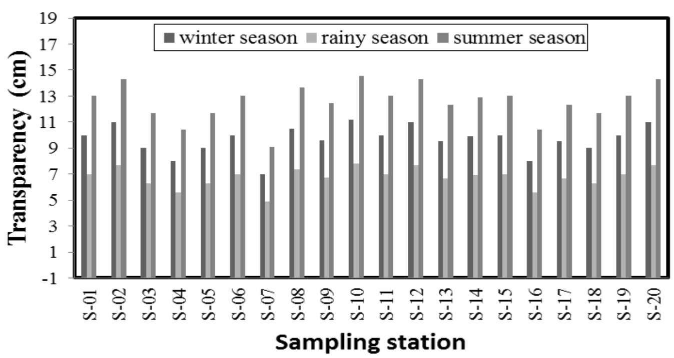

Figure 5: **Seasonal variations of Transparency of the Sundarbans Mangrove Forest river system in Bangladesh.**

Total Dissolved Solid (TDS)

Total Dissolved Solid (TDS) is a measurement of inorganic salts, organic matter and other dissolved materials in water [16]. The values of TDS in the study area were ranging from 5.04 to 12.65 ppt and mean TDS value was found 8.02 ± 2.89 ppt. The TDS values at different season in Sundarbans mangrove forest river system are shown in (FIG. 06). Water with total dissolved solids concentration within 0.1 ppt to 20 ppt is considered as suitable for aquatic life (ENVIRO SCI INQUIRY, 2000-2011).The TDS levels recorded in the entire sample points were within the standard guideline for the protection of fisheries and aquatic life. If the TDS levels are high due to dissolved salts, many forms of aquatic life are affected. The salts act to dehydrate the skin of aquatic animal which can be fatal [17]. In our study area TDS value was high in summer season because the parameter TDS shows positive correlation with water temperature not exceeding the standard level [18]. So the TDS value of river Bhadra is not harmful for aquatic life.

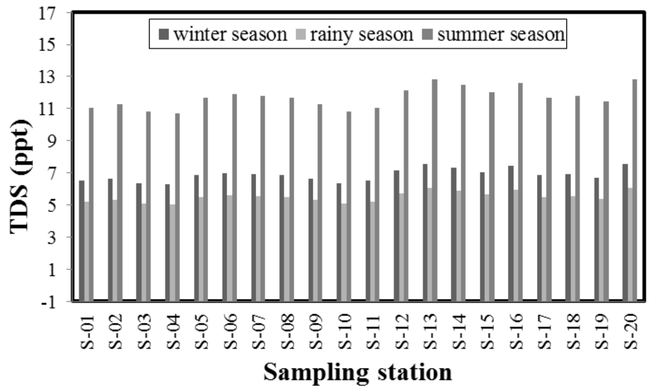

Figure 6: **Seasonal variations of TDS of the Sundarbans Mangrove Forest river system in Bangladesh.**

Salinity

Water Salinity indicates the presence of ionic substances that may come from the reaction of metals and acids present in the water. Since salinity influences survival, distribution, growth, reproduction and zonation of mangroves, different species prefer different level of salinity. There is an optimum salinity for maximum growth of different mangrove species such as *Rhizophora* which is an obligate halophyte whereas *Heriterafomes* has strong preference for salinity and its growth rate significantly decreases with increasing level of salinity. This consideration is also valid for aquatic species like fishes. It is observed that in Mangrove forest river system, the mean valve of Salinity was 12.09± 5.74 ppt with range 0.0 to 27.3 ppt. The Salinity values for Sundarbans mangrove forest in different season are shown in (FIG. 07). For good aquatic growth and survival, Salinity range should be 0.0 to 25 ppt [19].The minimum Salinity value was obtained in the study area during rainy season. River water salinity decreases in rainy season due to excessive rainfall and soft water enter into the river from surrounding village and Mangrove forest [20].

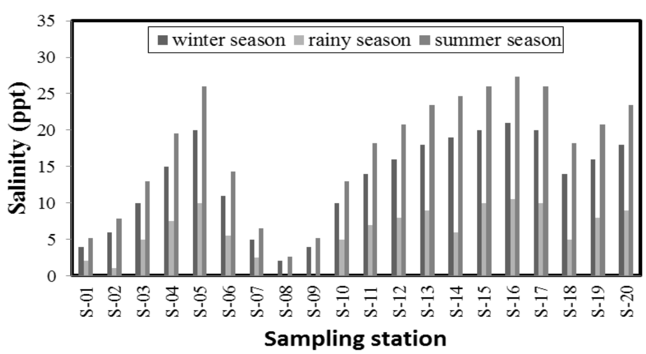

Figure 7: Seasonal variations of Salinity of the Sundarbans Mangrove Forest river system in Bangladesh.

Total alkalinity and total acidity

Water alkalinity is a measure of its capacity to neutralize acids. Alkalinity affects the behavior of some compounds in the water, for example, copper sulphate; used to control algal growth, snail, and many protozoan ectoparasites. It varies in its toxicity both target and the non target organisms. Alkalinity also contributes to the equilibrium nature of carbonate and bicarbonate with free carbon dioxide, which is necessary for photosynthesis. Water with high alkalinity is undesirables. The obtained total alkalinity range from 91.0-151.2 mg/L is shown in (FIG. 08). The standard value of alkalinity for river water is (100-200) mg/L for fisheries activities [8]. On the other hand Acidity is a measure of the capacity of water to neutralize bases. The average Total acidity content varied from 9.0 mg/L to 15.12 mg/L is shown in (FIG. 09). The mean Total acidity content of the river was 11.79 ± 3.03 mg/L. The standard value of acidity for river water is less than 19 mg/L [21]. The maximum Total alkalinity and Total acidity value were obtained during summer season and minimum value during winter and rainy season respectively. During summer season the water temperature was high and the parameter of Total acidity and Total alkalinity show positive correlation with water temperature. For this reason, Total alkalinity and Total acidity value were maximum in summer season [22,23]. The values were obtained for alkalinity and acidity within standard range and these make the sundarbans river system suitable for aquatic life.

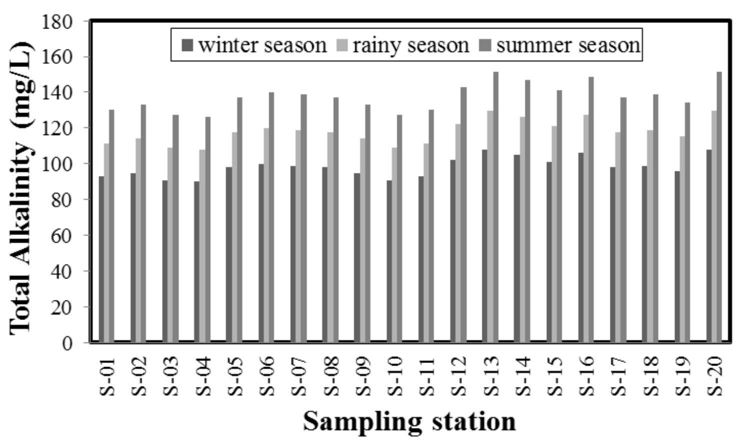

Figure 8: **Seasonal variations of Total Alkalinity of the Sundarbans Mangrove Forest river system in Bangladesh.**

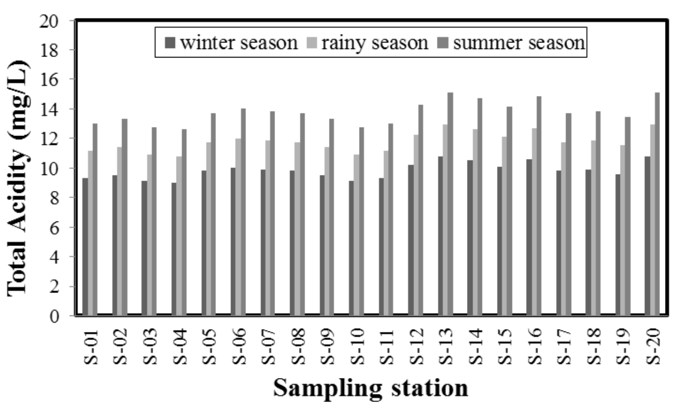

Figure 9: **Seasonal variations of Total Acidity of the Sundarbans Mangrove Forest river system in Bangladesh.**

Free dissolved CO_2

The delicate balance between photosynthesis and respiration in receiving water may beperturbed by addition of either an excess of organic compounds or an excess of inorganic algal nutrients (e.g., phosphorus, nitrogen). This process is dominated by free dissolved CO_2. The seasonal variation of free dissolved CO_2 shown in (FIG. 10). The maximum Free dissolved CO_2 value was observed during summer season [24]. The optimum level of free carbon dioxide level for the survival of organisms is less than 5 mg/L [11]. When the water is polluted with large amount of organic matter, a lot of dissolved oxygen will be rapidly consumed and Free dissolved CO_2 in the biological aerobic decay will affect the water quality and aquatic life [25]. The Free dissolved CO_2 values in different season for Sundarbans mangrove river systems are shown in (FIG. 10).

In the present study although free dissolved CO_2 was somewhat high viz., 5.0ppm but in most cases the value was below5.0ppm which is deemed suitable for aquatic habitat.

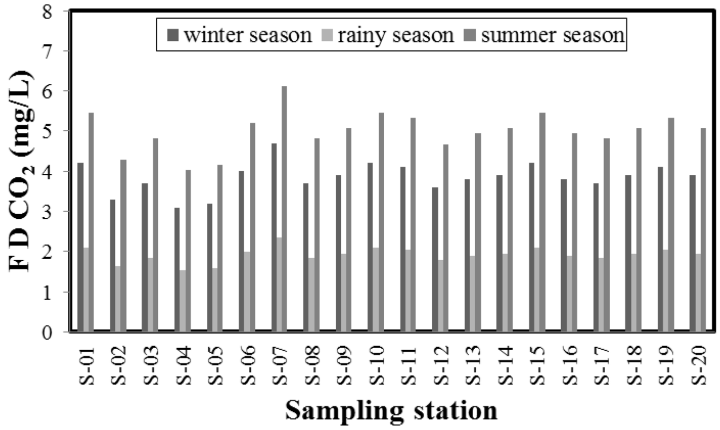

Figure 10: **Seasonal variations of Free Dissolved CO_2 of the Sundarbans Mangrove Forest river system in Bangladesh.**

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is present in water in the form of a dissolved gas. Dissolved oxygen (DO) is the most widely analyzed chemical parameter in aquatic system for water quality assessment. It is also one of the index parameters for organic pollution [26]. DO levels of 6 mg/l are considered optimal for proper growth of fish and other aquatic life. As dissolved oxygen levels in water drop below 5.0 mg/L, aquatic life is put under stress. Most fishes cannot survive for prolonged periods at DO levels below 3 mg/L [27]. Oxygen-demanding organic matter particularly requires the oxygen from water for the process of decomposition. More organic waste in water results in to decrease in average DO concentrations. However, in water bodies where a large proportion of the organic matter is brought in from outside the water bodies, the oxygen production and consumption are not balanced and DO may decrease [28]. (FIG. 11) reveals that DO was high during rainy season following by winter and summer. In Sundarbans river system DO was ranged between (5.12-8.89) mg/L. Increased DO level during monsoon is in accordance with the research findings [29-31]. Increased value of DO during rainy season was attributed to the addition of freshwater in rainy days. An ideal DO value of 5.0 mg/L is the standard for drinking water [32]. DO was found to be in permissible limits at all the study sites among various seasons, therefore water is of good quality for aquatic life.

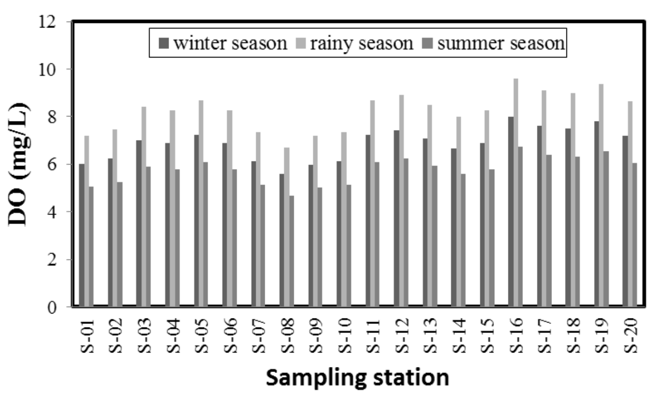

Figure 11: **Seasonal variations in concentration of Dissolved Oxygen (DO) of Sundarbans Mangrove Forest river system in Bangladesh.**

Biological Oxygen Demand (BOD)

BOD is the amount of the oxygen required by microorganisms for the decomposition of the organic matter present in water. Therefore, it reflects the amount of organic pollutants in water. A high BOD value indicates the presence of a large number of microorganisms, which shows a high level of pollution [33]. (FIG. 12) reveals that BOD was high during summers following by winter & rainy season. High BOD in summer and low in winter is in accordance with the findings [34,35].

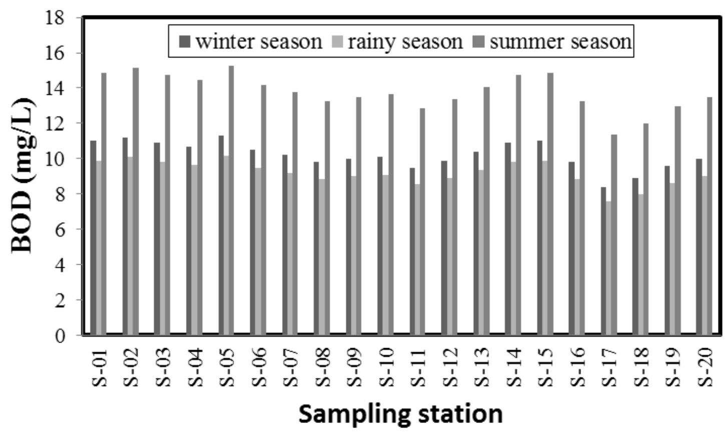

Figure 12: **Seasonal variations in concentration of Biological Oxygen Demand (BOD) of Sundarbans Mangrove Forest river system in Bangladesh.**

Chemical Oxygen Demand (COD)

COD is the measure of pollution in aquatic system. Chemical oxygen demand (COD) is a measure of the total amount of oxygen which is required to oxidize all the organic matter in a sample to CO_2 and H_2O. High COD may cause oxygen depletion on account of decomposition of microbes to a level detrimental to aquatic life (COD, http://www.businessdictionary.com). It is the amount of oxygen present in the water that is required or used in various chemical reactions (mainly oxidation) occurring in the water. (FIG. 13) shows that COD was maximumin summer followed by winter & monsoon. In sundarbans river system the COD values was varied from (8.69-17.54) mg/L. The level of COD in all of our selected study sites of Sundarbans river system, below the permissible limit. The optimum range may be considered to be between 80 and 100 mg/L. The COD value was found at low level in Sundarbans indicating that the organic waste pollution was insignificant in the Sundarbans waters.

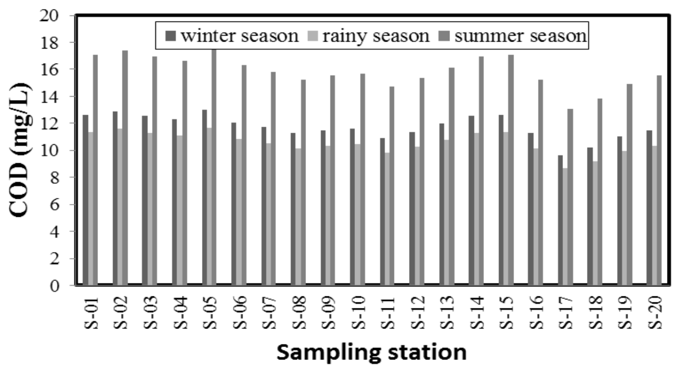

Figure 13: **Seasonal variations in concentration of Chemical Oxygen Demand (COD) of Sundarbans Mangrove Forest river system in Bangladesh.**

From the data and above discussion it is clear that the most of the physical and chemical parameter ranges of Mangrove forest river system fall within standard range and are able to maintain the productivity of water and normal physiology of aquatic life. From ANOVA analysis it concluded that all parameters are shows a significant seasonal change at 0.01 levels of significance.

1. Conclusion

The ecosystem of sundarbans is under management for long time but desired information about floral or faunal diversity cannot be generated due to lack of well-planned and long-term study. From the study, it can be conclude that most of our studied parameters within suitable ranges for aquatic organism but have a little concern about Salinity values. During study time low level of BOD and COD value indicates that the organic waste pollution was insignificant in the Sundarbans water. From the recent studies, it has also mentioned that the Sundarbans is encountered with many problems like over exploitation, geomorphological changes, salinity increases etc affecting it overall production. The carrying capacity of the Sundarbans is unknown. Even it is not clear whether its aquatic resources are at over exploitation or at under exploitation. A huge number of people in the coastal areas are engaged in catching seeds of *Penaeusmonodon* using small nets. In the process a huge quantity of larvae of other organisms including fin fish and Zooplankton get killed. This causes decline in biodiversity of aquatic animals. Another important point is pollution in mangrove areas due to deposition of solid or liquid industrial effluents. Moreover, in recent years there has been increasing occurrence of oil spills in the costal seas. It is necessary to design a management program to combat pollution due to Mongla Port adjacent to Sundarbans. The statistical analysis ANOVA shows a significant seasonal variation among three seasons at 0.01 levels of significance.

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