6. Discussion:

The disposal of waste products are indiscriminately discharged into the nearby rivers, canals, reservoirs, lakes, tanks and even in the adjoining fields without any precaution or proper treatment (Jhingran,1971). The major industries located in mouth of Haldi river. Although these industries have recycled their waste products but lot of waste including heavy metals discharge in the mouth of Haldi river. Population density is much higher around the river which is increasing day by day. Unfortunately, this population growth leads to increased anthropogenic pressure on the river, resulting in severe degradation of the ecosystem. River became the ultimate sink of anything and everything coming through surface runoff and in the bargain it is losing its utility functions at a faster pace. Due to the mixing of effluents from industrial, municipal and agricultural sources the physico- chemical, biological characteristics of rivers gets altered. Water and sediment quality parameters have their direct influence on aquatic organism present therein. Biodiversity of rivers are modified as per the changes in habitat and also with the water and sediment quality parameters. So, continuous monitoring of water and sediment quality is necessary to formulate suitable management norms to prevent any unwanted changes of aquatic biodiversity. The effects of all these factors from the biodiversity perspectives are discussed below in the given study area.

6.1. PHYSICO-CHEMICAL PARAMETERS OF SOIL

Soil plays an important role in maintaining the ecological status of water body and has the ability to store the nutrient and release the nutrients into the water through varied mechanism under different circumstances.

6.1.1. Soil pH:

During the present study the soil pH in the mouth of Haldi river in Site-1 fluctuates in rainy season 6.6 to 7.5; summer season 7.5 to 8.3 and winter season 7.6 to 8.2; in Site-2 the pH value recorded was rainy season 7.6 to 7.8; summer season 7.8 to 8.3 and winter season 6.7 to 7.3; in Site-3 rainy season 6.9 to 7.4, summer season 7.4 to 7.9, winter season 7.8 to 8.3. During the present study period pH did not exhibit wider variation and found uniformly distributed throughout the study period at the sampling site. However, the pH ranged from 7.1 to 8.5 in pre monsoon and 7.4 to 8.6 during monsoon as observed by Samanta et al. in 2007 in Hooghly and Haldi estuaries District of Purba Medinipur, West Bengal. The result of pH values in different sites are represented in the Fig.1.

According to Samanta (2006a) pH of soil should be neutral to slightly alkaline sediment is most productivity. Banerjea (1967) recorded the pH values from different soil zones of eastern and central India in relation to production of fish. His work showed that pH ranging from 6.5 to 7.5 (near neutral) is productive but 7.5 to 8.5 (moderately alkaline) are productive on an average. According to Saha (1978), Patra and Roy (1988) and Patra (1993) the optimum pH range should be 7.0 to 8.5 and low pH has adverse effects on the growth and production of fish. The soil pH value of the experimental canal ranged within the productive limits. The values are in the present

study more or less similar to the values suggested by different workers Singh and Mahavar (1998); Singh et al. (2005); Singh et al. (2012) and Bhardwaj et al. (2010).

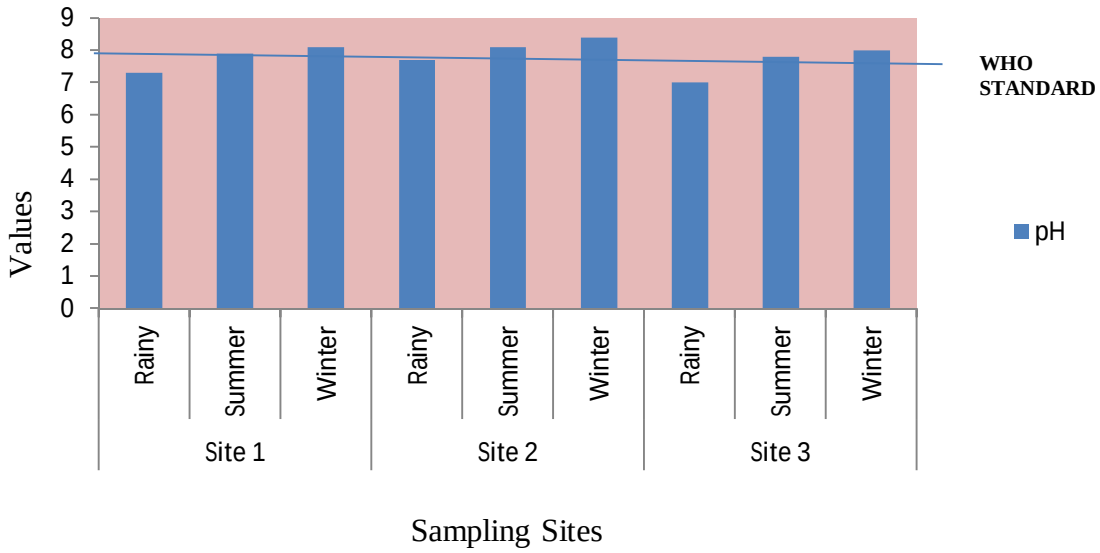

Fig. 1: Seasonal variations of soil pH in the mouth of Haldi River

6.1.2. Organic Carbon:

Organic carbon is mostly controlled by amount of organic matter coming through surface drainage with the little benefit from plankton. A direct source of energy to microbes present in soils that take part in mineralization. In the present study the soil organic carbon in Site-1 seasonal ranges are respectively as 0.09 to 0.27% in rainy; 0.41 to 0.48% in summer; 0.46 to 0.49% in winter. Site-2 the range of organic carbon are 0.42 to 0.52% in rainy; 0.50 to 0.66% in summer and 0.64 to 0.71% in winter ; at Site-3 the organic carbon value are in between 0.43 to 0.63% in rainy; 0.71 to 1.11% in summer and 0.62 to 0.97% in winter during study period. The organic values recorded by Samanta (2006a) that sediments with less than 0.5% organic carbon are considered as less productive. 0.5-1.5% and > 1.5% organic carbon are considered as medium and high productive categories. Banerjea (1967) studied the effect of organic carbon on

the pond productivity and recommended the range between 1.5% and 2.5% as optimal value. In this study the recorded results are similar as mentioned by different earlier workers Singh and Mahavar (1998), Samanta et al. (2007), Sarkar et al. (2003) .

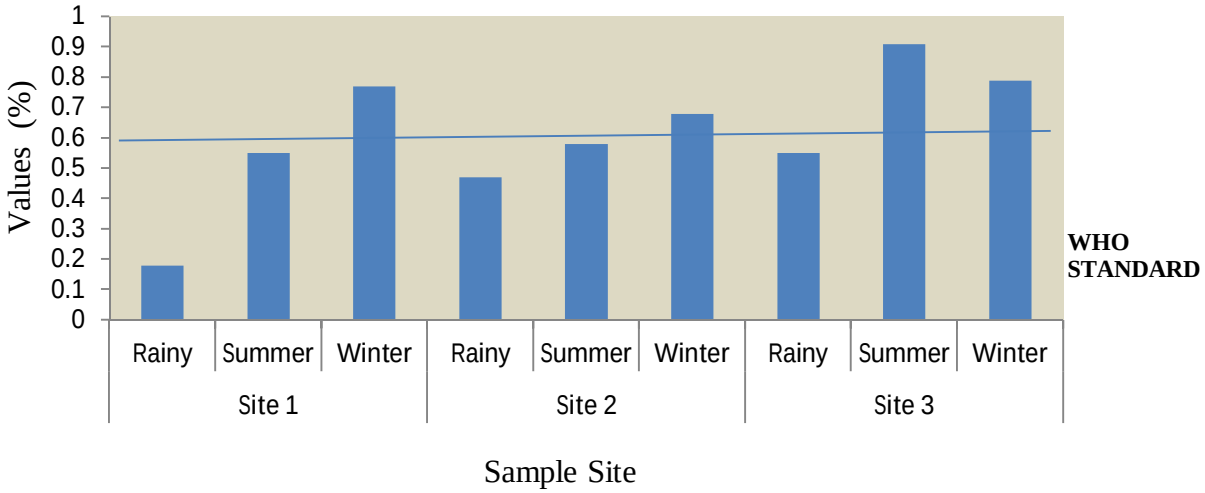

Fig. 2: Seasonal variations of soil organic carbon in the mouth of Haldi River

6.1.3. Available nitrogen:

Soil nitrogen is one of the most controlling factors in aquatic productivity. In the present study the soil available nitrogen in Site-1 seasonal ranges are respectively as 3.9 to 5.2 mg/g in rainy; 9.1 to 11.9 mg/g in summer; 9.3 to 11.5 mg/g in winter. Site-2 the range of available nitrogen are 9.95 to 11.69 mg/g in rainy; 14.70 to 16.84 mg/g in summer and 15.3 to 17.70 mg/g in winter ; at Site-3 the available nitrogen value are in between 21.70 to 23.03 mg/g in rainy; 53.57 to 55.59 mg/g in summer and 59.33 to 61.38 mg/g in winter during study period. For any productive soil, available nitrogen must be above 250 mg/kg (Samanta,2006a). The values are in the present study more or less similar to the values suggested by different workers Samanta (2013); Samanta *et al.* (2007); Singh *et al.* (2005) and Singh *et ai.* (1999) showed Hooghly- Bhagirathi river system.

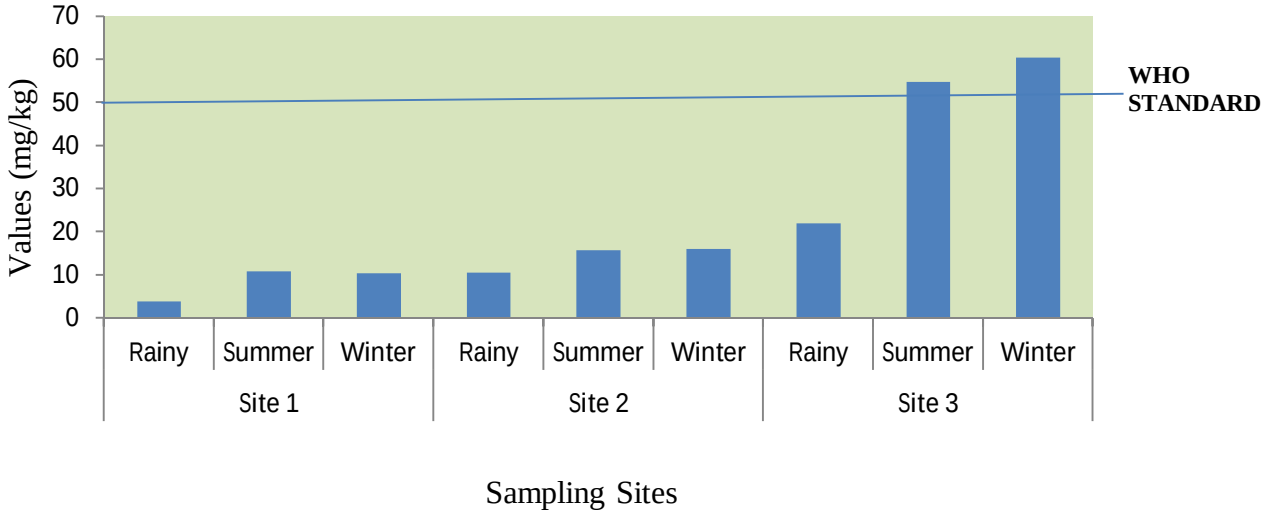

Fig. 3: Seasonal variations of soil available nitrogen in the mouth of Haldi River

6.1.4. Available phosphorous:

During the study period at the sampling sites the seasonal ranges of sediment available phosphorous levels are respectively as Site-1 in rainy 0.01 to 0.11 mg/g; in summer 0.5 to 1.6 mg/g; in winter 0.77 to 1.03 mg/g. At Site-2 rainy 0.19 to 1.13 mg/g; in summer 1.53 to 3.14 mg/g; in winter 1.01 to 2.07 mg/g. At Site-3 rainy 1.70 to 2.90 mg/g; in summer 4.16 to 6.63 mg/g; in winter 5.11 to 7.74 mg/g. This finding is also somewhat similar with the findings of Pathak *et al.* (2001) and Samanta *et al.* (2007). A soil must have above 3 mg/ l00g of available phosphorus for good productivity (Banerjea, 1970). Lower availability of phosphorous in the river bottom may be due to higher percentage of sand and lower organic carbon (Samanta and Chakrabarty 1997).

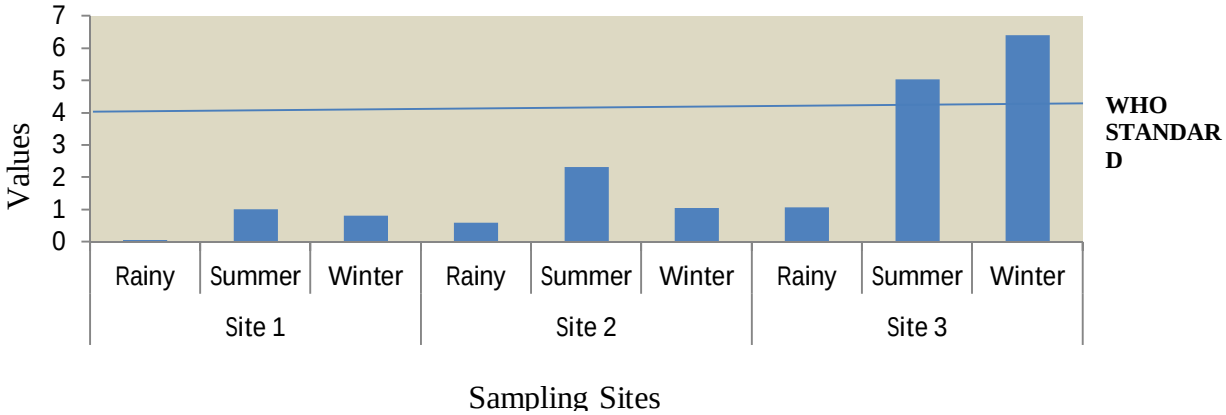

Fig. 4: Seasonal variations of soil available phosphorous in the mouth of Haldi River

6.1.5. Available Potassium:

In the present study, the sampling sites the sediment available potassium Site-1 ranged from 0.4 to 0.9 mg/g in rainy season; 0.7 to 1.6 mg/g in summer season; 0.2 to 0.9 mg/g in winter season. Site-2 ranged from 0.5 to 1.8 mg/g in rainy season; 0.73 to 2.11 mg/g in summer season; 0.2 to 1.6 mg/g in winter season. Site-3 ranged from 1.2 to 1.6 mg/g in rainy season; 3.11 to 3.63 mg/g in summer season; 3.5 to 4.5 mg/g in winter season. The values of potassium in sediment are found ranging from 0.013 to 0.89 mg/gm in Sharavathi river which considered as low because of least pollution and human activities (Kumar and Ramchandra, 2003).

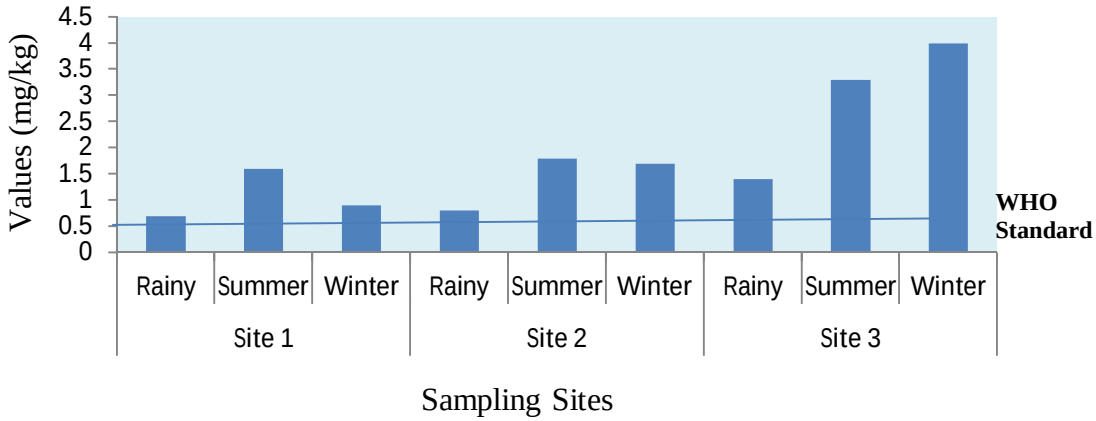

Fig. 5: Seasonal variations of soil available potassium in the mouth of Haldi River

6.2. PHYSICO-CHEMICAL PARAMETERS OF WATER

6.2.1. Temperature:

Temperature is one of the most important factors of an aquatic ecosystem especially fluctuate the parameter effect of different environment. In the present study the season-wise water temperature in Site-1 ranged from 28.3 °C to 30.6 °C in rainy; 34.1 to 34.8 °C in summer; 25.0 to 25.6 °C in winter, in Site-2 the ranges are 26.5 to 26.8 °C in rainy; 31.4 to 32.2 °C in summer; and 28.1 to 28.6 °C in winter, in Site-3 the ranges are 21.1 to 21.6 °C in rainy; 30.1 to 30.4 °C in summer and 20.7 to 21.3 °C in winter. However, Shinde *et al.* (2010) has found the water temperature values in between 17.0°C to 32.8°C, lowest temperature in winter months and highest temperature in summer months. Basu *et al*. (2010) observed the water temperature from 20.0 °C minimum and 34.7 °C maximum in Vadgaon tank, Kolhapur, Maharashtra. The present study corroborates with the findings of Mukherjee (2012), Singh et al. (1999) and Ranjan et al. (2001), where higher temperature values have been observed during summer. The season wise analysis also showed that the average maximum temperature was found in summer months, moderate in monsoon months and minimum in winter months.

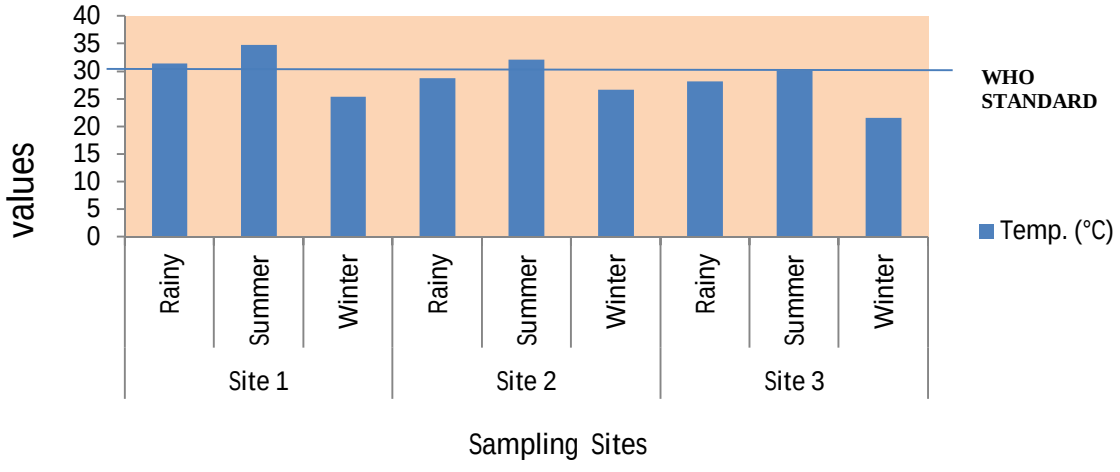

Fig 6: Seasonal variations of water temperature in the river mouth

6.2.2. Water pH:

During the present study seasonal-wise the water pH in Site-1 ranged from 6.3 to 6.7 in rainy; 8.0 to 8.5 in summer; and 7.6 to 7.9 in winter, in Site-2 the pH levels are 7.3 to 7.6 in rainy; 7.6 to 7.9 in summer; 7.4 to 7.7 in winter, in Site-3 the range of pH are 7.4 to 7.8 in rainy; 7.6 to 7.9 in summer; 7.5 to 8.1 in winter. The pH in natural water bodies is an important role to environmental factor. The variation in pH is connected with the species composition and life processes of animal and plant communities inhabiting in the water bodies (Jhingran, 1982). According to Kurbatova (2005) and Tanner *et al*. (2005) in a reservoir the pH range in between 6.0 to 8.5 indicative of medium productivity, pH range more than 8.5 is highly productive and less than 6.0 is less productive. Nair and Abdul Azis (1987) reported that in Ashtamudi estuary and in Kadinamkunal Kayal estuary the pH range was in between 7.0 to 8.50 and 6.8 to 8.1 respectively. Choudhary *et al.* (2014) reported a range of pH in between 7.0 and 8.3. According to Umavathi *et al.* (2007) the pH ranged in between 5.0 to 8.5 is best for planktonic growth. According to ICMR (1975) and WHO (1985) the safe pH limit is 7.0 to 8.5, while ISI (1991) the range of safe pH is 6.5 to 8.5. So, the pH recorded in the present study is within the limit.

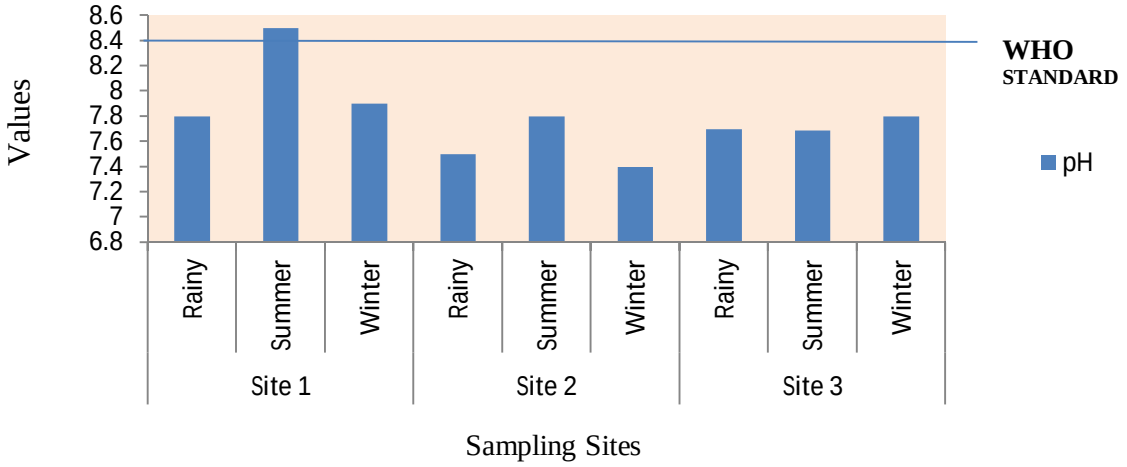

Fig 7: Seasonal variations of water pH in the river mouth

6.2.2. Dissolved Oxygen (DO):

Seasonal wise in this study the dissolved oxygen levels in Site-1 ranged from 2.3 to 2.6 mg/l in rainy; 2.7 to 2.9 mg/l in summer; and 2.6 to 2.8 mg/l in winter, in Site-2 the dissolved oxygen levels are 2.9 to 3.3 mg/l in rainy; 3.6 to 4.1 mg/l in summer; 3.0 to 3.6 mg/l in winter, in Site-3 the range of dissolved oxygen are 4.6 to 5.8 mg/l in rainy; 6.9 to 8.3 mg/l in summer; 4.5 to 6.1 mg/l in winter. Dissolved oxygen is the most important role in aquatic ecosystem to regulates the metabolic activity of the aquatic organisms. Thirupathaiah *et al.* (2012) reported a range of DO in between 5.18 to 9.72 mg/lit. Benerjee (1967) and Torzwall (1957) had reported that if the concentration of DO is about 5.0 mg/lit, throughout the year, the reservoir will be productive for fish culture. Low photosynthetic activity by low density of plankton in highly turbid water during rainy season might have caused lower dissolved oxygen (DO) in water. According to APHA (1985) and Chang (2005) suggested that the lowest level of dissolved oxygen required for maintaining healthy condition of fish is 5.0 mg/lit and critical level is 3.0 mg/lit. The findings of Karthikeyani et al. (2002), Das and Konar (2003), Mukhopadhyay et al. (2004), Daimari et al. (2005), Gasim et al. (2007), Panwar et al. (2001), show some differences with present findings which might be due to difference in organic load, temperature and photosynthetic activity.

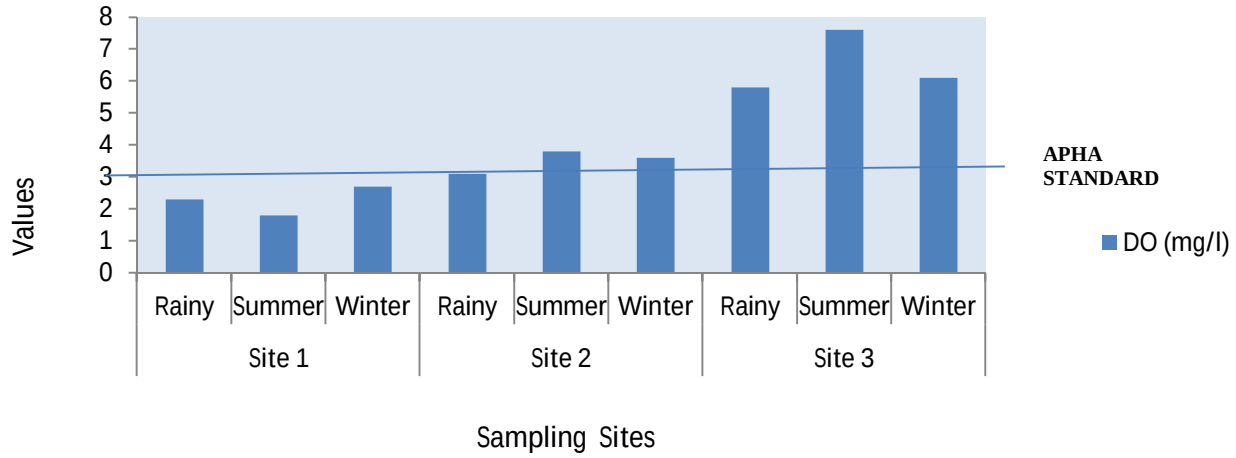

Fig 8: Seasonal variations of water dissolved oxygen in the river mouth.

6.2.3. Biological Oxygen Demand (BOD):

Biological oxygen demand (BOD) is most important of quality of water and it refers for the amount of used oxygen for biochemical decomposition of organic matter in water. BOD is used for determination of an indicator of pollution level. Seasonal wise in this study the BOD levels in Site-1 ranged from 9.8 to 10.1 mg/l in rainy; 10.1 to 10.3 mg/l in summer; and 9.6 to 9.8 mg/l in winter, in Site-2 the biological oxygen demand levels are 6.9 to 6.3 mg/l in rainy; 4.1 to 4.4 mg/l in summer; 3.3 to 3.6 mg/l in winter, in Site-3 the range of biological oxygen demand levels are 4.2 to 3.8 mg/l in rainy; 3.9 to 3.3 mg/l in summer; 3.5 to 3.1 mg/l in winter. The finding by Singh et al. (2005), indicated that the BOD were between 5 mg/1 to 8.79 mg/l during pre-monsoon was observed in Gomti river. Hynes (1960) stated that the water having BOD values of 3.0 mg/l or more is of moderately polluted in water and that with more than 5.0 mg/l is polluted. In this study the recorded results are similar as mentioned by different earlier workers Mishra and Saksena (1991), Singh (1999), Usharani et al. (2010).

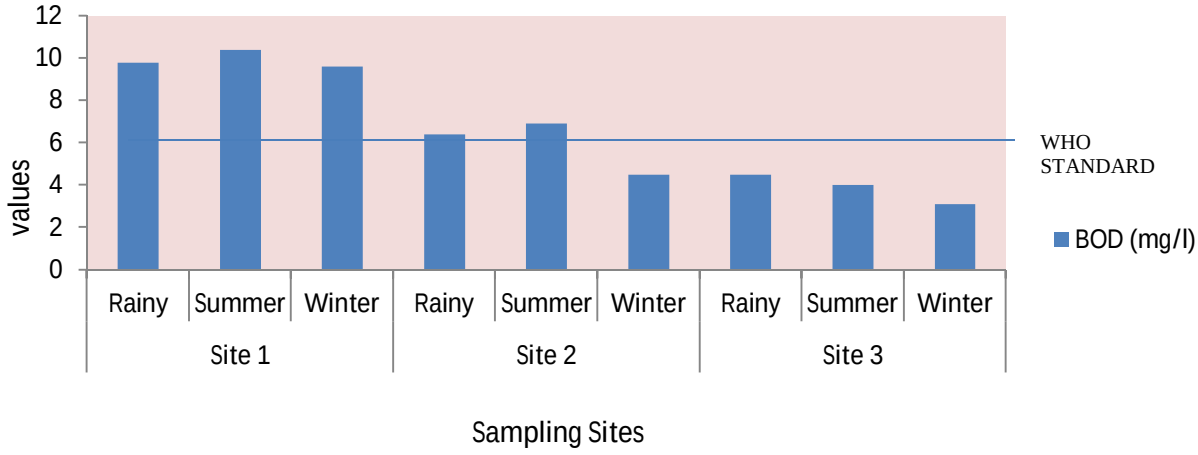

Fig. 9: Seasonal variations of water BOD in the mouth of Haldi river

6.2.4. Chemical Oxygen Demand (COD):

In the present study the COD content in water at Site-1 levels are 54.0 to 58.9 mg/l in rainy; 56.7 to 64.6 mg/l in summer; 44.3 to 53.5 mg/l in winter, at Site-2 levels are 25.5 to 29.4 mg/l in rainy; 39.2 to 33.1 mg/l in summer; 29.0 to 30.5 mg/l in winter, at Site-3 levels are 13.9 to 19.2 mg/l in rainy; 17.4 to 20.3 mg/l in summer; 10.6 to 18.3 mg/l in winter. Chemical oxygen demand useful as an indicator of organic pollution in surface waters Mamais et al.(1993), King et al. (2003). Chemical oxygen demand is a measure of the oxygen equivalent to the organic content of the water that is susceptible to oxidation by strong chemical oxidant (APHA, 2000). In the present investigation the COD values are comparable with the report of Joseph (1998) and Singh et al. (1999) where the COD values ranging from 2.8 to 25 mg/l and 4.2 to 10.6 mg/l the values of Singh et al. (2005). As per acceptable standards the limit of COD in surface water is 10 mg/l WHO (1993). Thus the water is favorable for fish growth and their sustenance. During hot period increase in Chemical oxygen demand can mainly be attribute to increase temperature, naturalizing the decomposition of organic matter Singh, (1999).

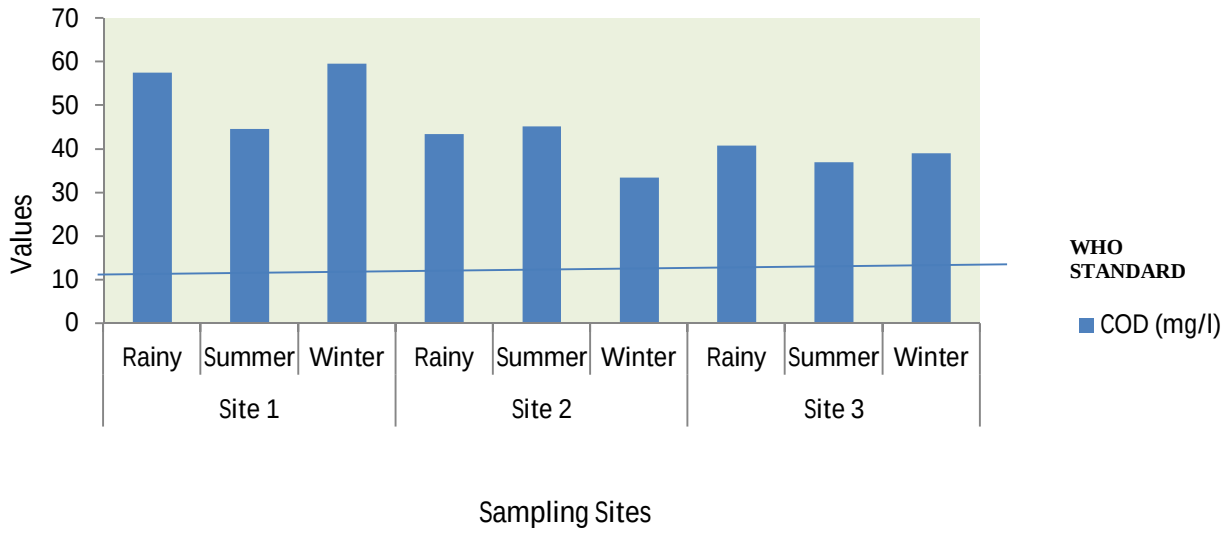

Fig 10: Seasonal variations of water COD in the mouth of Haldi river

6.2.5. Alkalinity :

In this study the alkalinity value of water in Site-1 ranges are 79.6 to 145.1 mg/l in rainy season; 120.0 to 150.3 mg/l in summer season; 127 to 174.2 mg/l in winter season, in Sie-2 the range are 98 to 138 mg/l in rainy season; 140.1 to 163.6 mg/l in summer season; 110.8 to 167.0 mg/l in winter, in Site-3 the levels are 131.5 to 139.7 mg/l in rainy season; 129 to 160 mg/l in summer season, 140 to 168 mg/l in winter season. Pawar and Kanavate (2010) found minimum alkalinity during monsoon months and maximum during pre and post monsoon months. Bade (2008) has found the total alkalinity values of 142.5 to 187.2 mg/lit in Sai reservoir, Latur district. Chuturbhuj (2004) observed total alkalinity of 102.6 to 215 mg/lit and reported that alkalinity is high during summer months and low during monsoon. The findings are comparable with the findings of Hassan et al. (1998), Singh et at. (1999), Singh and Mahavar (2003), Ranjan et al. (2001), Panwaret at. (2001) and Mukhopadhyay (2004). The results of present investigation reflecting high alkalinity during summer and sharp decline in rainy as like Pahwa and Melhrotra (1966) and Srivastava and Kulshresthe, (1990). The minimum level of alkalinity needed for the water to be most productive is > 50 ppm (Ohle,1993).

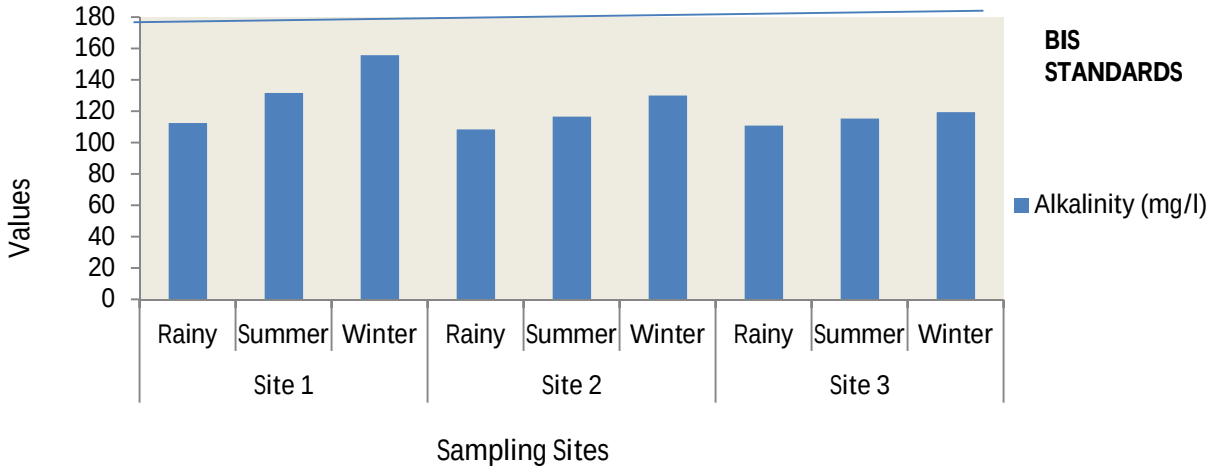

Fig 11: Seasonal variations of water alkalinity in the mouth of Haldi river

6.2.6. Salinity:

The most characteristics aspect of seawater is salinity. The salinity of water is of great importance on the distribution and abundance of floral and faunal community. The salinity range of confluence is mainly controlled by the influx of freshwater and by the process of evaporation and direct precipitation. In the present study seasonally the salinity of water in Site-1 levels are respectively in rainy 0.3 to 0.8 ppt; in summer 1.5 to 3.2 ppt; in winter 1.4 to 2.5 ppt, in Site-2 the ranges of salinity are respectively in rainy 0.9 to 1.8 ppt; in summer 2.1 to 3.8 ppt; in winter 1.1 to 3.8 ppt, in Site-3 the salinity values are in rainy 1.5 to 2.3 ppt; in summer 1.8 to 4.8 ppt; in winter 1.5 to 4.1 ppt. In all the three sites mouth of Haldi river, the lowest salinity range are observed during the period of rainy season, in summer season period the observed range are increased and in case of winter it was intermediate. Such kind of seasonal change in salinity has been reported earlier by Manna et al. (2013); Gopinathan (1972); Gopinathan et al. (1974 and 1982); Anirudhan *et al.* (1987); Preetha (1991) and Shajina (1992) in Cochin back waters.

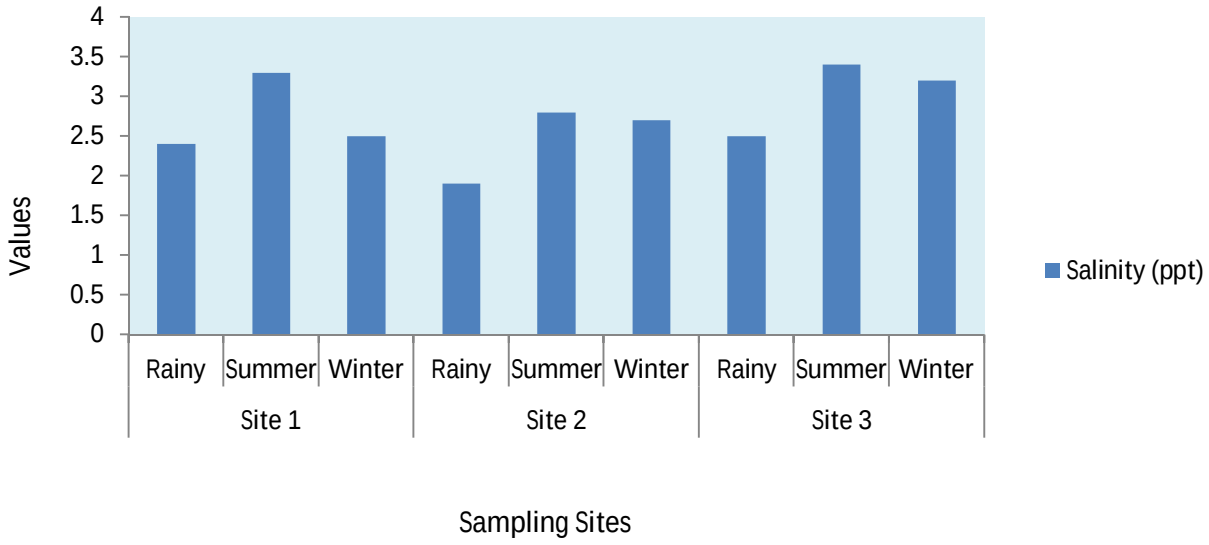

Fig 12: Seasonal variations of water salinity in the mouth of Haldi river

6.2.7. Nitrate (NO_3):

In the present study the nitrate content in water at Site-1 levels are 14.0 to 18.9 mg/l in rainy; 16.7 to 21.6 mg/l in summer; 15.3 to 18.5 mg/l in winter, at Site-2 levels are 5.5 to 9.4 mg/l in rainy; 6.2 to 8.1 mg/l in summer; 6.0 to 8.5 mg/l in winter, at Site-3 levels are 1.2 to 1.6 mg/l in rainy; 1.4 to 2.3 mg/l in summer; 1.3 to 1.9 mg/l in winter. The nitrate (NO_3) present the final product of biological; oxidation from organic pollution. Although there were variations in nitrate between the sampling locations, values were at safe level as per the limits prescribed by WHO(1993). Dissolved inorganic nitrogen in the range of 0.2 to 0.5 mg/l may be considered favourable for fish productivity (Samanta, 2006a).

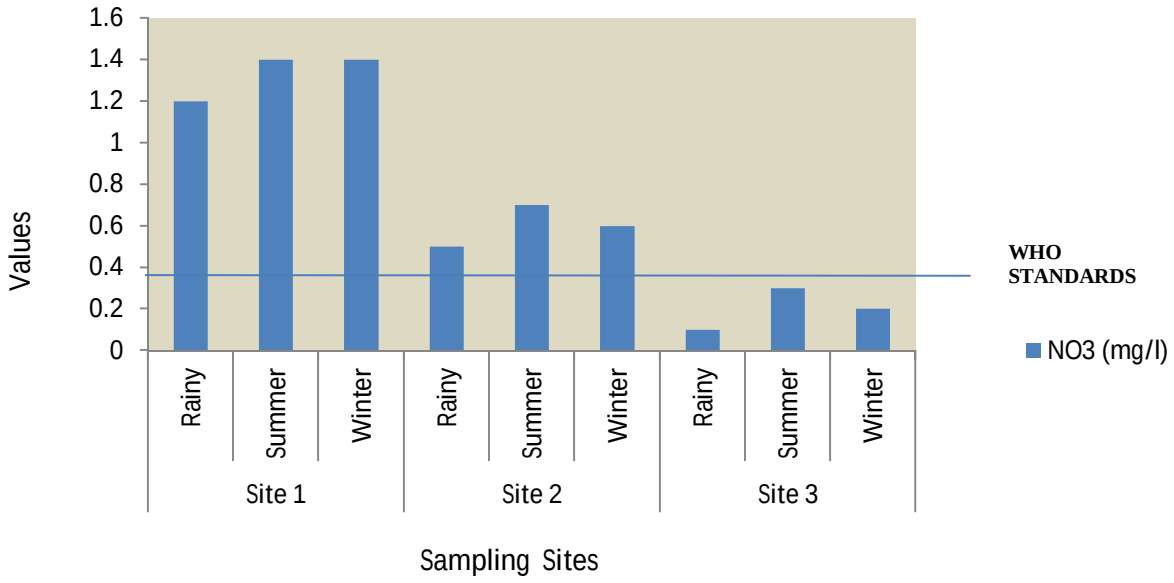

Fig 13: Seasonal variations of water nitrate in the mouth of Haldi river

6.2.8. Phosphate (PO_4):

Seasonal wise in this study the phosphate levels in Site-1 ranged from 2.8 to 3.6 mg/l in rainy; 2.1 to 3.6 mg/l in summer; and 2.6 to 3.1 mg/l in winter, in Site-2 the phosphate levels are 0.5 to 0.9 mg/l in rainy; 0.9 to 1.1 mg/l in summer; 0.3 to 0.6 mg/l in winter, in Site-3 the range of phosphate are 0.3 to 0.6 mg/l in rainy; 0.4 to 0.8 mg/l in summer; 0.3 to 0.5 mg/l in winter. The average phosphate concentration of Site 1 of the river was found to be above permissible limits 0.1 mg/l (WHO 1993). Singh *et al.*, (2005) found that the phosphate values at middle Ganga plain were between 0.021 to 0.052 mg/l in pre-monsoon and 0.068 to 0.086 mg/l in monsoon, which may be comparable with present study. The findings can be comparable with the findings of Singh *et al.*, (1999), Ranjan *et al.*, (2001), Panwar *et al.*, (2001), Kumar *et al.*, (2006) and Singh *et al.*, (2012).

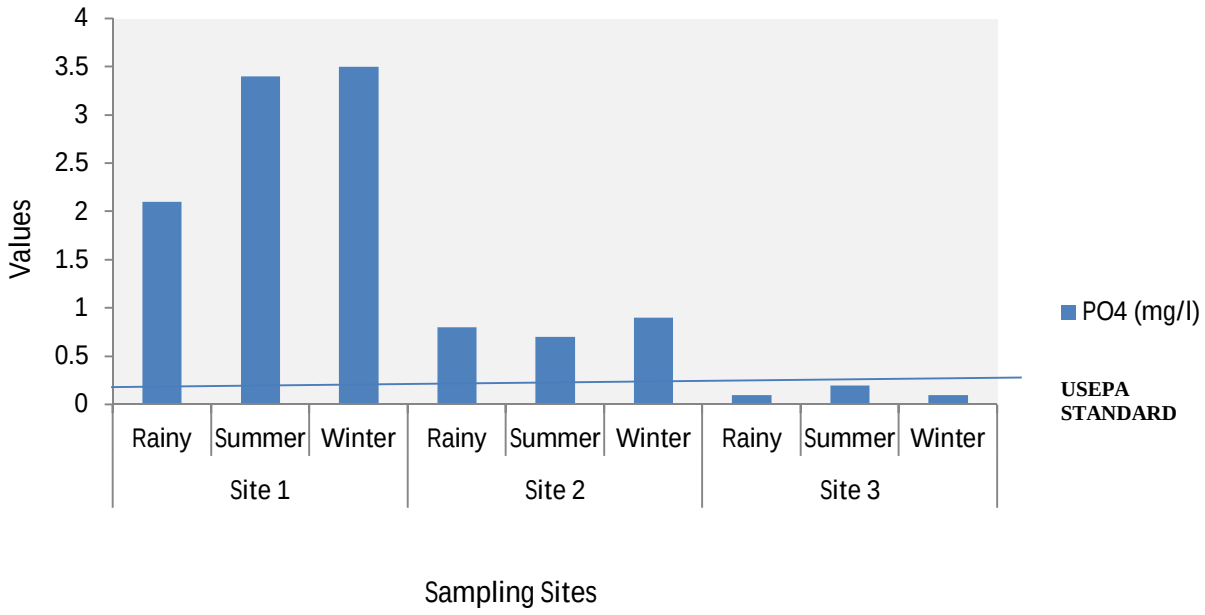

Fig 14: Seasonal variations of water phosphate in the mouth of Haldi river

Metal content in soil:

The study of metal contamination of soil in the mouth of Haldi river. The Cadmium (Cd) levels are Site 1 ranged from 2.01 to 2.09 mg/kg in rainy; 2.32 to 2.68 mg/kg in summer; and 3.30 to 3.33 mg/kg in winter, in Site-2 the Cd levels are 1.60 to 1.62 mg/kg in rainy; 2.78 to 2.81 mg/kg in summer; 1.74 to 1.77 mg/kg in winter, in Site-3 the range of Cd are 0.28 to 0.36 mg/kg in rainy; 1.07 to 1.11 mg/kg in summer; 0.84 to 0.86 mg/kg in winter. Comparison of the observed values with the respective available permissible limits of 1mg/kg US EPA (2011 b) indicated that site 1 and Site 2 are Cd crossed marginally the non-pollution limit. High concentration of Cd in soil is highly toxic to lower organisms as well as plants and animals(Friberg et al., 1986; Kazantzis et al., 1987).

Zn was detected seasonally in the range of Site 1 86.32 to 91.67 mg/kg during rainy, 91.06 to 97.94 mg/kg during summer and 91.22 to 100.14 mg/kg during winter; Site 2 rainy season 81.78 to 84.08 mg/kg, summer season 85.25 to 90.54 mg/kg, winter 88.26 to 95.22 mg/kg; Site 3 levels are 81.29 to 82.52 mg/kg in rainy, 70.96 to 76.29 mg/kg in summer, 87.11 to 93.70 mg/kg in winter. Comparison of the observed values with the respective available permissible limits of >90 mg/kg US EPA (2011 b) indicated that Site 1, 2, and 3 are moderately polluted. Zn was found untreated or partially treated sewage discharge (Mohiuddin et al., 2011), motor boat ferry services (Sorme et al., 2002) and discharge from prawn culture (Cuong and Obbard, 2006).

Copper (Cu) was detected in the range of Site 1 29.91 to 27.96 mg/kg during rainy season; 25.32 to 26.05 mg/kg during summer season and 23.05 to 23.36 mg/kg during winter season; in Site-2 the Cu levels were 26.62 to 26.81 mg/kg in rainy; 20.24 to 19.51 mg/kg in summer; 19.57 to 20.08 mg/kg in winter, in Site-3 the range of Cu 24.12 to 26.52 mg/kg in rainy; 28.46 to 29.43

mg/kg in summer; 18.12 to 19.08 mg/kg in winter. Available permissible limits of Cu indicated 25 to 50 mg/kg US EPA (2011 b) is moderately polluted. Site 1 rainy season Cu values is high indicated. According to (Venugopal et al., 1982) found that low values of copper during premonsoon indicated a low terrestrial supply of copper from agricultural fields. The concentration of dissolved trace metals gradually decreased towards the lower reaches of the estuary, may be, due to the salinity induced solubilization of the particulates associated matter (Duinker and Kramer, 1977). Most of heavy metals flocculate in highly saline waters substantiates the decrease in copper concentrations with increasing salinity levels (Rantala and Loring, 1985).

Manganese (Mn) was detected in the range in Site 1 during rainy season 384.33 to 410.57 mg/kg; summer season 275.26 to 295.32 mg/kg; winter season 215.11 to 240.27 mg/l; Site 2 levels are 254.30 to 226.29 mg/kg in rainy; 148.80 to 197 mg/kg in summer; 95.09 to 106.05 mgkg in winter; Site 3 levels are 228.29 to 204.25 mg/kg in rainy season, 117 to 109 mg/kg in summer season 93.22 to 98.13 mg/kg in winter. Mn is the most trace element since it is present with the highest percentage in the other tace metals (Kiratli and Ergin 1996; Dassenakis et al., 2003). Mn was found in all three sites, as observed by other researchers (Usero et al., 1998; Ngiam and Lim 2001).

Lead (Pb) was detected in the range in Site 1 during rainy season 37.33 to 34.57 mg/l; summer season 31.13 to 30.42 mg/l; winter season 37.11 to 39.27 mg/l; Site 2 levels are 29.61 to 31.29 mg/l in rainy; 33.48 to 35.17 mg/l in summer; 30.85 to 29.05 mg/l in winter; Site 3 levels are 27.48 to 28.25 mg/l in rainy season, 30.88 to 31.09 mg/l in summer season, 30.29 to 28.33 mg/l in winter. The major source of Pb are from intensive human activities, including agriculture in the drainage basin (Monbet 2006), auto exhaust emission together with atmosphere deposition

(Adriano 1986). Due to grows of industries the Hugli river increased the lead producing and plays a vital role as referred by (Sarkar et al.,2007) for aquatic organisms.

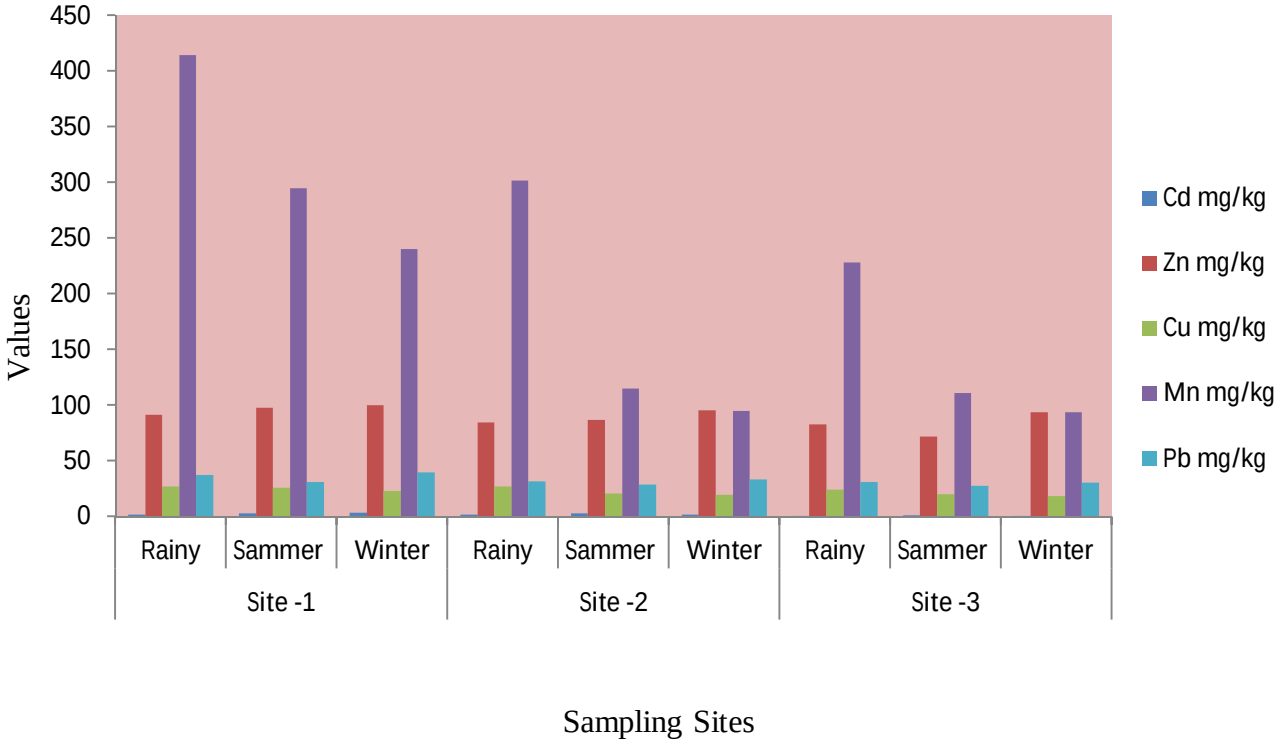

Fig. 15: Seasonal variations of metal contamination in soil

Metal content in water:

The study of metal contaminations in water mouth of Haldi river indicated the cadmium (Cd) level in Site-1 ranged from 1.04 to 1.09 mg/l in rainy; 1.33 to 1.36 mg/l in summer; and 0.95 to 0.96 mg/l in winter, in Site-2 the Cd levels are 0.35 to 0.37 mg/l in rainy; 0.55 to 0.59 mg/l in summer; 0.26 to 0.29 mg/l in winter, in Site-3 the range of Cd are 0.08 to 0.09 mg/l in rainy; 0.38 to 0.40 mg/l in summer; 0.23 to 0.25 mg/l in winter. The Cd level was highest in Site 1 the values of these seasons are well above the standard limit of BIS (0.10 mg/l) and Permissible limit for aquatic life (0.25 mg/l) US EPA,(2011 a). It could bioaccumulation in lower organisms (e.g.

phytoplankton, algae, molluscs and some fish) but not in higher organisms; biomagnifications in food-chains is not expected to be very significant (ATSDR, 2000). Higher levels of Cadmium in aerobic waters are usually associated with industrial pollution.

Seasonal wise in this study the Chromium (Cr) levels in Site-1 ranged from 0.09 to 0.11 mg/l in rainy; 0.14 to 0.16 mg/l in summer; and 0.07 to 0.11 mg/l in winter, in Site-2 the Cr levels are 0.05 to 0.09 mg/l in rainy; 0.05 to 0.10 mg/l in summer; 0.06 to 0.08 mg/l in winter, in Site-3 the range of Cr are not detected in rainy; 0.01 mg/l in summer; not detected to 0.02 mg/l in winter. High level seasonally over all effected in Site 1 but the effect was not visualized downstream probably due to dilution effect. The Cr level was highest in Site 1 the values of these seasons are closely crossed the standard limit of BIS (0.1 mg/l) and Permissible limit for aquatic life (0.1 mg/l) US EPA,(2011 a). Chromium is widely used in Industries, such as paint, electroplating, fertilizer, pigment manufacturing (Ganguli and Tripathi 2002).

Copper (Cu) was detected in the range of Site 1 16.93 to 17.89 mg/l during rainy season; 21.32 to 26.05 mg/l during summer season and 18.05 to 20.31 mg/l during winter season; in Site-2 the Cu levels were 9.85 to 10.61 mg/l in rainy; 11.24 to 13.25 mg/l in summer; 7.32 to 10.08 mg/l in winter, in Site-3 the range of Cu 8.12 to 8.52 mg/l in rainy; 9.46 to 11.43 mg/l in summer; 8.12 to 9.08 mg/l in winter. Sampling data Comparison with the EPA permissible limit for aquatic life (9 mg/l, 2011a) indicated that the level of Cu was within the limit in the Site 3 and above within the standard limits of BIS (l.5mg/l) and WHO (2.0mg/l) Site 1 to Site 3. At lower alkalinity copper is generally more toxic to aquatic life (Train, 1979).

In the present study the nickel (Ni) content in water at Site-1 levels are 1.40 to 1.69 mg/l in rainy; 1.87 to 2.16 mg/l in summer; 1.53 to 1.85 mg/l in winter, at Site-2 levels are not detected in rainy; 0.48 to 0.53 mg/l in summer; not found data in winter, at Site-3 levels are all three

seasons data is below detective level. Nickel is an essential metal for several animal species, micro-organisms and plants, and toxicity symptoms can occur when too little or too much nickel is taken up (Cempel and Nikel 2005).

Lead (Pb) was detected in the range in Site 1 during rainy season 7.23 to 10.57 mg/l; summer season 8.13 to 15.32 mg/l; winter season 5.11 to 10.27 mg/l; Site 2 levels are 4.30 to 6.29 mg/l in rainy; 3.48 to 7.17 mg/l in summer; 3.09 to 6.05 mg/l in winter; Site 3 levels are 2.17 to 3.25 mg/l in rainy season, 2.17 to 4.09 mg/l in summer season, 2.32 to 3.33 mg/l in winter. The Pb level was crossed in Site 1, Site 2 and Site 3 at Permissible limit for aquatic life (2.5 mg/l) US EPA,(2011 a). Lead is a most toxic heavy metal and commonly distribute all over the environment (Greenwood and Earnshaw 1984).

Zn was detected seasonally in the range of Site 1 36.07 to 38.16 mg/l during rainy, 43.33 to 47.27 mg/l during summer and 38.22 to 41.64 mg/l during winter; Site 2 rainy season 22.78 to 24.08 mg/l, summer season 33.25 to 36.54 mg/l, winter 28.26 to 30.22 mg/l; Site 3 levels are 23.29 to 26.52 mg/l in rainy, 34.96 to 36.29 mg/l in summer, 20.11 to 33.70 mg/l in winter. The Zn level was below at Permissible limit for aquatic life (120 mg/l) US EPA,(2011 a) in all sites . In the study area all the water quality samples having zinc concentration is well within the acceptable and permissible limits of Bureau of Indian Standard (BIS) 10500 (2012) and there is no toxicity of Zn in the river water. The Hooghly estuary by Kar *et al.* (2008); Sarkar *et al.* (2007) and Singh *et at.* (2012) also found no contamination in river Ganga.

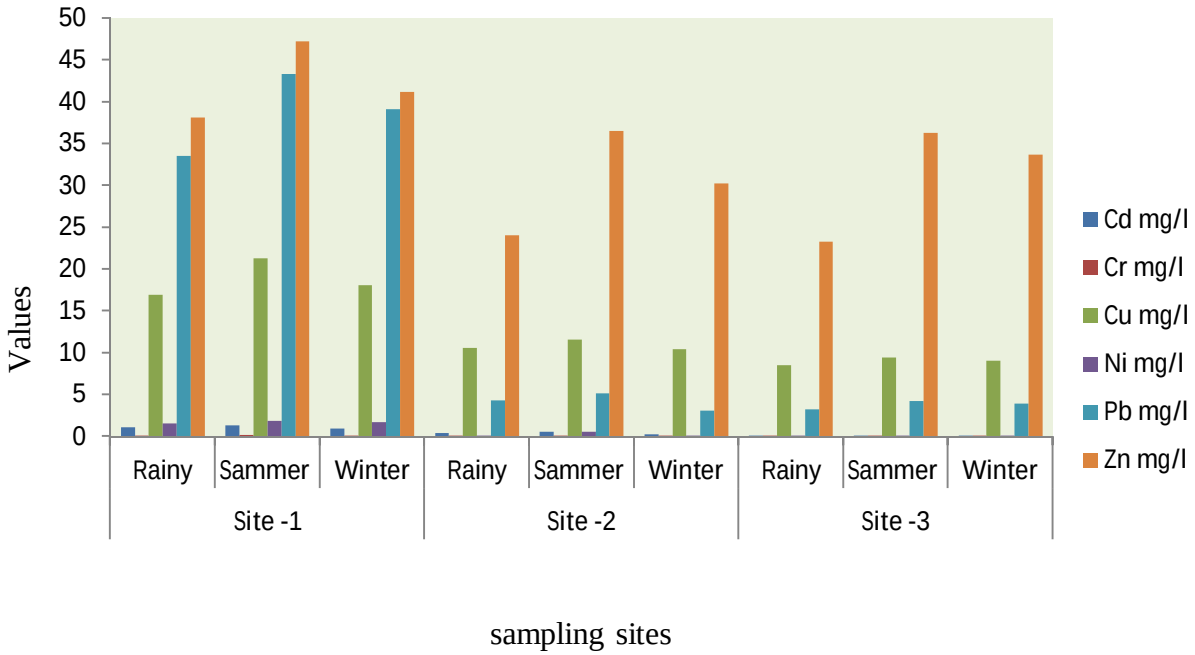

Fig. 16: Seasonal variations of metal contamination of water in the mouth of Haldi river

Bioaccumulation of fish:

In food the amount of heavy metals is defined by norms which are based both on WHO recommendations . Therefore, rules for heavy metals in food materials vary in each country. For example, according to Lithuanian Standards of Hygiene (2001), the maximum tolerable limit of lead (Pb) in fish meat is 0.4 mg/kg, where as in the European Union (2000) it is 0.2 mg/kg. The mouth of Haldi river fish *Arius sp.* contained totally six heavy metals like Zn,Cu,Cd,Cr,Pb and Ni in the body tissues. The concentration of metals in fish caught lower part of selection sample. The heavy metal concentration were observed in the following sequences : Zn>Pb>Cu>Cd>Cr>Ni.

The Zn and Pb were observed at 21.05 mg/kg and 4.01 mg/kg respectively in the gill tissues where as muscle of fish Zn 9.81 mg/kg and Pb 2.72 mg/kg. Other heavy metals was high levels of Gills and fish muscle. The high levels of heavy metals in the gills could also be attributed to

the fact that the water always enters through mouth of the fish filtered through the gills and it could be related to the finding of Olowu et al., (2009). Water are taken by fish through gills and gastrointestinal tract, where they can be accumulated in inner organs, leading to pathological changes (Blasco et al.,1999).

The observation shows that the heavy metal accumulation in the gills and fish muscle can be attribute to differences in the physiological role of each organ. Increase the heavy metals in water for accumulation in the aquatic organisms .

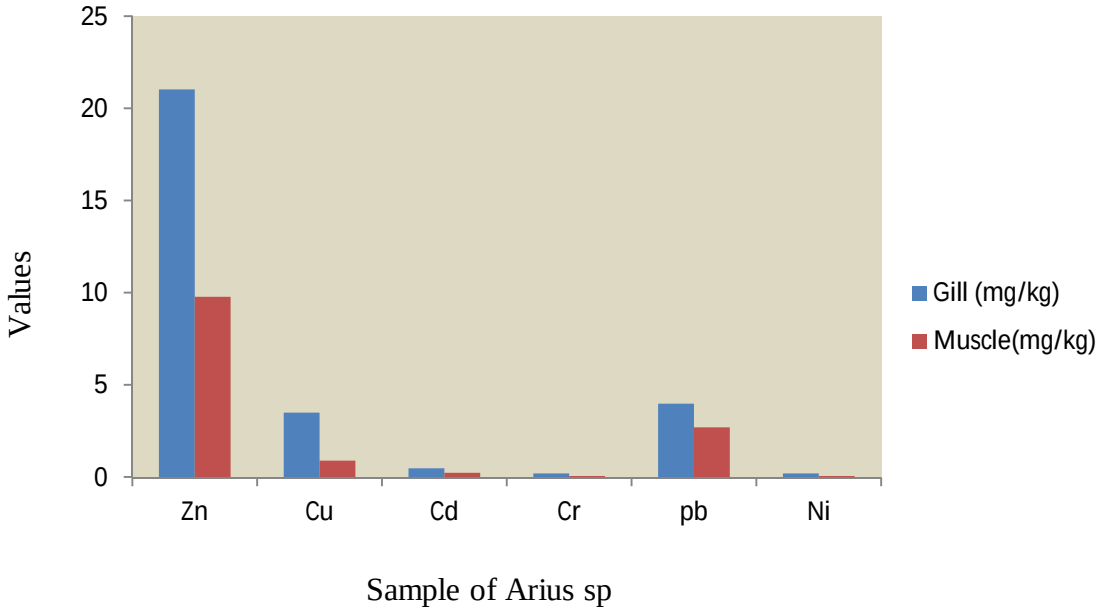

Fig. 17: Bioaccumulation of fish in the mouth of Haldi river

Plankton diversity:

Present study observed that totally 24 plankton species were identified from the three study sites of Haldi river mouth. The seven species were found in phytoplankton community and seventeen species from zooplankton community. Phytoplankton belonged to *Spirogyra sp, Chlamydomonus*

sp, Volvox sp, Anabaena sp, Nostoc sp, Stigeoclonium sp, Uronema sp while three species *Spirogyra sp, Volvox sp, Chlamydomonus sp, Uronema sp* are present in all sites. Belonged to zooplanktons *Daphnia* sp, *Cyclops* sp, *Mysis* sp, *Keratella* sp (rotifers and arthropods)are present in dominantly. High quantity of plankton was recorded in Site 3 (21 species) and low quantity of plankton was recorded in Site 1 (9 species). *Keratella* sp, *Cyclops* sp , Nauplius stage are found in all station.

The result indicated that the plankton population was rich in Site 3 and low in Site 1. Previous studies have proved that the rich plankton productivity, species composition, diversity, seasonal variation on estuarine region. Here, sampling station of Site 3 is a estuarine zone. The study locations could also be sequenced based on plankton species richness as Site 3> Site 2> Site 1. Mustapha (2009) has reported 14 genera of Zooplankton among rotifera are the dominant group over others. Rocha et al., (1999) reported that the dominance of *Branchionus* is an indication eutrophic condition of reservoir and their abundance was due to the presence of high organic load in the reservoir. Pailwan *et al*. (2008) has observed 35 species of Zooplankton belonging to 5 major groups namely- copepoda, cladocera, ostracoda and protozoa during the study period in three tanks near Kohlhapur district of Maharashtra and also suggested that among the Zooplankton rotifera was the dominant group. Gaikwad (2010) has reported total 11 species of rotifera in lower Seen a river and found that rotifers varied in between 2 to 48 number/lit at three different sites of the river. According to Adholia and Vyas (1992) the abundance of copepods during summer may be due to lesser dilution and turbulence in water. Pandey *et al*. (1992) while studying the seasonal fluctuation in plankton composition in river Mahananda, Kathir, Bihar found that the copepods showed highest peak during summer and lowest during the periods of winter. Gaikwad (2010) has reported total 6 species of copepods in lower Seen a river and the

number of copepods varied in between 9 to 26 nos./lit at three different sites. Pandey *et al*. (1992) while studying on the seasonal fluctuation in plankton abundance of river Mahananda, Katihar, Bihar found that the cladocerans showed highest peak during summer and lowest during winter. He reported that the highest cladocerans in summer is due to the pattern of life present or absence of predators. Gaikwad (2010) has reported total 5 species of cladocera in lower Seena river and the numbers of cladocerans varied in between 14 to 40 nos./lit at three different sites of the river. Bais and Agrawal (1995) while studying on Zooplankton of Sager lake and Military Engineering lake, Madhya Pradesh found maximum cladocera during summer months and minimum during monsoon period.

In the present study coefficient of correlation among physic-chemical factors are shown in table 11. In the present study the coefficient of correlation between water and temperatures and occurrence of zooplankton showed positive (0.38) correlation in Site 3 where as it showed negative correlation between air temperature and occurrence of zooplankton. Ali et al., (1980) found that the positive correlation with temperature with the zooplankton (except protozoans). During the study zooplankton showed the inverse relationship with pH (-0.05). According to Patra and Azadi (1987) similar result in Halda river of Bangladesh. The dissolved oxygen showed negative correlation with zooplankton (-0.29). The correlation of coefficient between free CO_2 with zooplankton and TDS with zooplankton showed negative relation (0.45 and 0.21). Total hardness showed negative correlation (-0.37). Singh and Singh (1993) drew similar result.

Fish Varieties:

The varieties of fish species also investigated throughout the mouth of Haldi river (Site 1, Site 2 and Site 3). The present information of the phyto and zooplankton distribution and abundance

would form a useful tools for fish population. According to Jhingram, (1974) the study of zooplanktonic composition, abundance and seasonal variations is helpful in planning and successful fishery management. It was observed that fish species like- *Channa punctatus, Channa striata, Apogon nitidus, Oreochromis niloticus, Gobiomorus dormitor, Lates calcarifer, Pomadasys argenteus, Glossogobius giuris, Sillago sihama, Gobiosoma hildebrandi* (Perciformes); *Catla catla, Hypophthalmicthys molitrix* (Cypriniformes); *Arius* sp, *Mystus gulio* (Siluriformes); *Coilla* sp, *Setipina phasa*, *Sardinella* sp, *Setipina taty* (Clupeiformes); *Mastacembelus* sp (Mastacemebliformes); *Mugil cephalus* (Mugiliformes); *Anguilla* sp. (Anguilioformes). *Xenetodon cancila* (Belonidae).