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DIURNAL VARIATION OF NUTRIENTS, WATER QUALITY AND PLANKTON COMPOSITION IN THE HAJAMRO CREEK (INDUS DELTA) DURING NORTH EAST MONSOON PERIOD

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Diurnal (24 hours) observations of dissolved nutrients, Chlorophyll-a, water quality (salinity, dissolved oxygen, temperature, pH and suspended solid matter) were recorded at one site in the Hajamro Creek of Indus Delta during the North East Monsoon period. The zoo- and phyto-plankton were recorded during low and high tides. Primary productivity was measured only during the day time. Dissolved nutrient concentration ranges were NH_4 (1.81 µM -12.30 µM), NO_3 (0.03 µM -1.48 µM), NO_2 (0.04 µM -0.122 µM), PO_4 (0.45 µM -1.69 µM), SiO_3 (4.84 µM -24.49 µM) and averages were 6.41, 0.28, 0.055, 0.722, 12.12 µM respectively. The suspended load ranged from 36.0 mg/l to 87.8 mg/l, pH from 8.24 to 8.38, temperature from 18.73 °C to 22.37 °C and salinity from 35.995 ppt - 37.062 ppt. Higher Chlorophyll-a concentration was recorded during the high tide in daytime and its range was 0.45 µg/l - 1.69 µg/l while its average concentration was 1.94 µg/l. The moderate value of primary productivity was recorded to be (0.475 g C/m^3/day). Eleven groups of zooplankton were identified. Copepods were the main species which were abundant during high tide. Bivalve, fish eggs, crab and polychaete larvae were observed during low tide. The present study shows that high amounts of suspended solids, dissolved nutrients (phosphate, silicate, nitrate and ammonia) and relatively more salinity in sea water were recorded during low tide. Presence of adequate dissolved nutrients and high turbidity is probably restricting productivity in the Hajamro Creek.

Keywords: Indus delta, Hajamro creek, Dissolved nutrient, Primary productivity, Diurnal variation

1. Introduction

Nutrients play an important role in the productivity of the coastal area and support fishery resources. Nutrients are used in plants in a complicated cycle. They are essential for the growth of marine producers like phytoplankton and sea grass. Indus Delta consists of 20 major and hundreds of small creeks. Supply of fresh water, dissolved organic matters and dissolved nutrients increase the productivity of the Indus Delta.

The Indus Delta, where the mighty River Indus meets the Arabian Sea is the seventh largest delta in the world. The Indus River Delta creates a complex system of swamps, streams and mangrove forests. Mangrove forests in the Indus Delta are spread over 263,000 hectares. The water, dissolved nutrients and silt deposited by the River Indus when discharged into the sea, sustain the mangroves. Mangroves are an important source for maintaining the carbon budget, sustaining microbial food chain and recycling of dissolved nutrients in the estuarine complex [1].

Hajamro Creek is next to Khobar Creek, which is directly connected to the Indus River and is an outlet to the Arabian Sea (Figure 1). The climate of Indus Delta is arid and sub-tropical. Relative humidity of Indus Delta is 76 %, the mean annual temperature is 84.2 °F, and the mean surface water temperature is 71.24 °F. During the summer, seawater inundates both the active and inactive parts of the Delta, leaving behind evaporated salt deposits [2].

Published literature shows that no study has been conducted on diurnal variation of dissolved nutrients; water quality and primary productivity of the Hajamro Creek except fish catch population dynamics in relation of Chlorophyll-a concentration [3]. Few studies were conducted on dissolved nutrients and phytoplankton dynamics in two mangrove tidal creeks in the Isaro creek [4] and productivity of Gharo creek in relation to its fisheries potential [5] of the Indus Delta as well as dissolved nutrient flux in polluted Lyari estuary [6]. The present paper is the first study to investigate diurnal changes in dissolved nutrients levels and Physico-chemical characteristics of Hajamro Creek water during the winter season and also to examine plankton distribution during high and low tides.

2. Materials and Methods

Twenty four hours diurnal observations of water quality, and water samples for dissolved nutrients, Chlorophyll-a were collected on an hourly basis from the surface during 13-14 February 2013, in the Hajamro Creek (close to the open sea). Due to strong seawater current only ten bottom seawater samples could be collected. The depth of sampling site was about 7

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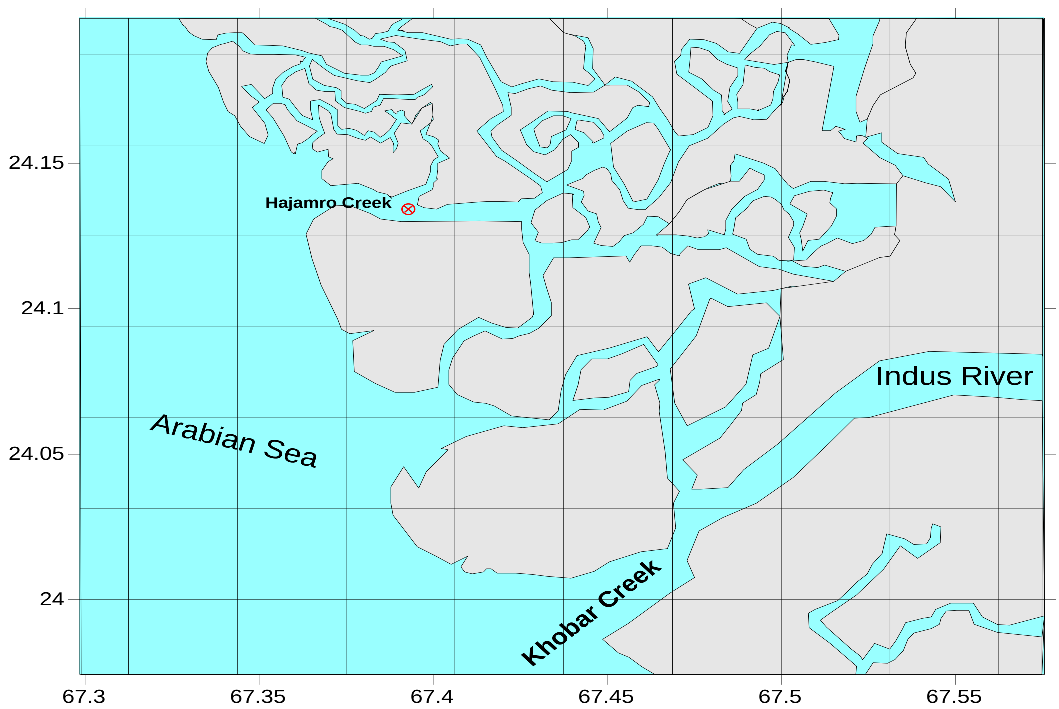

Figure 1. Location map shows sampling station.

meters during high tide. Soon after collection, the seawater samples were filtered through glass fiber filter paper (GF/F Whatman) and kept in an icebox and finally in a deep freezer till the analyses of dissolved nutrients.

Water quality parameters of temperature, pH, dissolved oxygen, salinity and Chlorophyll-a of Hajamro Creek were recorded using a water quality meter (Hydrolab Model MS-5). Luminescence Dissolved Oxygen (LDO) optical dissolved oxygen sensor of the water quality meter was calibrated with saturated air in synthetic seawater as mentioned in the manual. Dissolved oxygen was also measured chemically by Winkler method described [7].

Salinity sensor of water quality meter was calibrated through standard saline seawater. Chlorophyll-a sensor was calibrated using Rhodamine-B. Samples were analyzed for Chlorophyll-a using a spectrophotometer [7]. Suspended load samples were also collected and analyzed according to Food and Agriculture Organization [8].

Four Phytoplankton samples, two each at low and high tides from surface water were collected by filtering of 50 liters of surface sea water through a net of mesh size 60 micron. Two zooplankton samples, one each at low tide and high tide were also collected using ring net of 300 micron mesh size.

Dissolved nutrients (Nitrate, Nitrite, Phosphate and Silicate) samples were analyzed according to the Parsons method [7]. Primary productivity was measured twice (0830-1100 hrs. and 1130-1400 hrs) during day time using the “light and dark bottle method” as described by Strickland and Parsons [9].

3. Results

The tides of the study area (Hajamro Creek) are semi-diurnal and their maximum amplitude is 3.1 M during the spring tide. Sampling was carried out during spring when the difference between low and high tides was 2.46 M. The lowest tide level was at 1730 hours on 13th February, 2013 and the next day it was at 0730 hours. High water level was at 0030 hours on 14th February and the same day it was at1400 hours. The salinity, dissolved oxygen, sea water temperature, pH, suspended solid, Chlorophyll-a and dissolved nutrients were measured. These have been plotted in Figures 2 to 12 while the correlation matrix obtained from this data is given in Table 1.

3.1. Salinity

Salinity was found to inversely correlate with the tidal cycles. The maximum salinity of 37.06 ppt (parts per thousand) occurred during low tide, whereas, the minimum of 35.74 ppt was recorded at high tide (Figure 2). No distinct difference was observed between surface and bottom water salinity during either high or low tide.

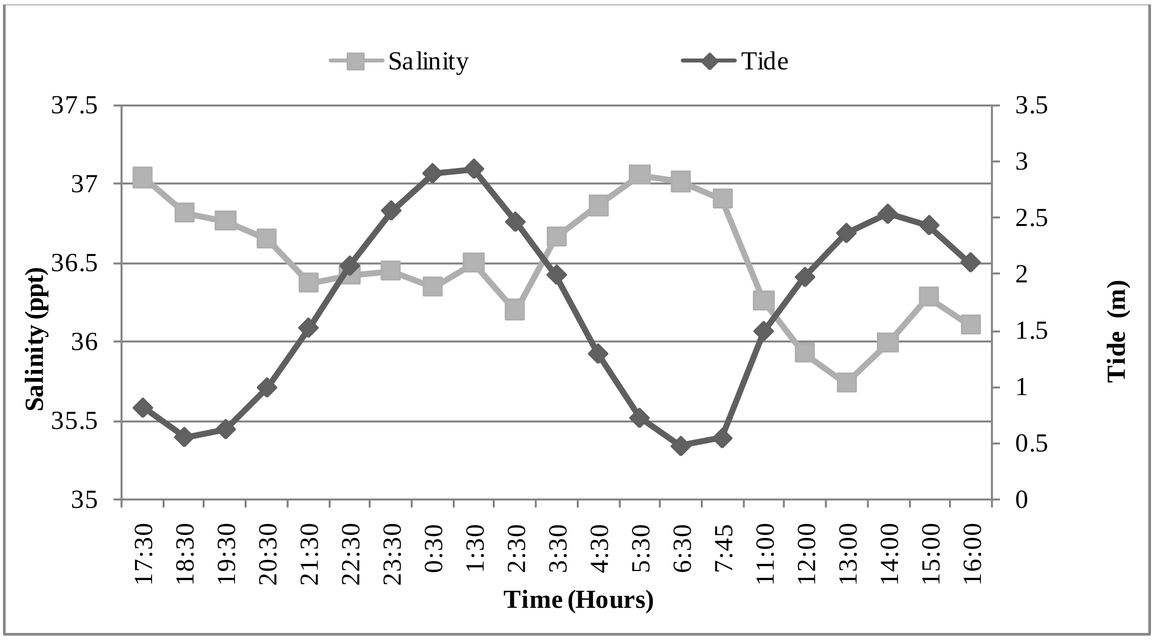

Figure 2. Diurnal variation (13-14 February 2013) of tide and salinity in Hajamro Creek.

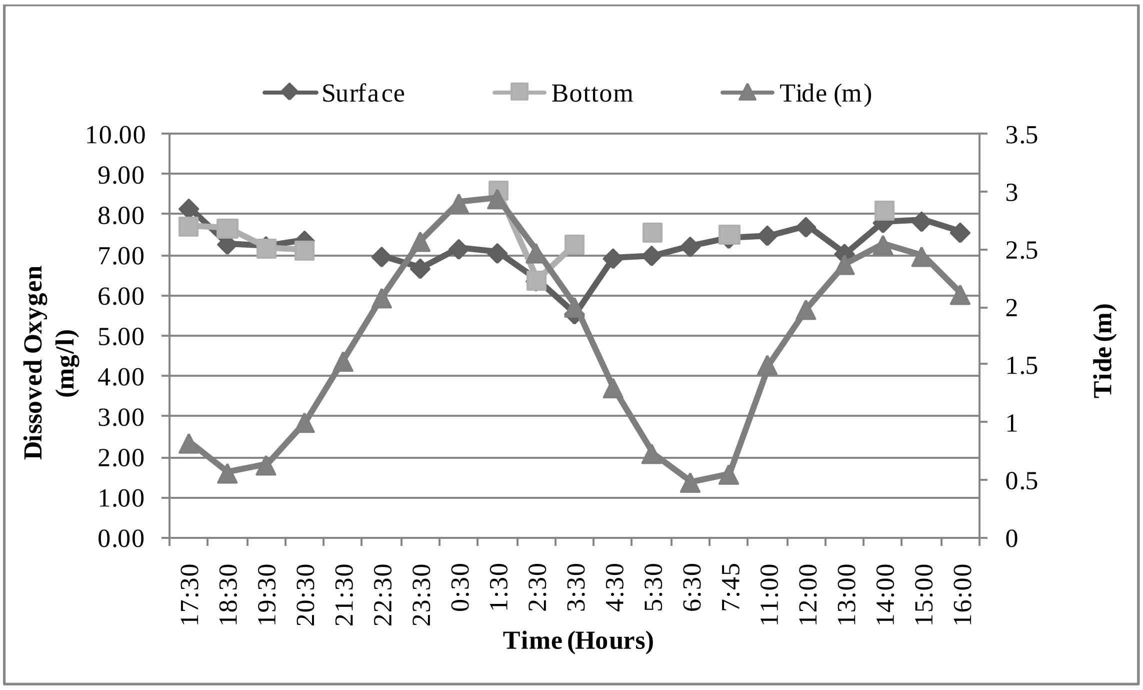

Figure 3. Diurnal variation (13-14 February 2013) of tide and dissolved oxygen in Hajamro Creek.

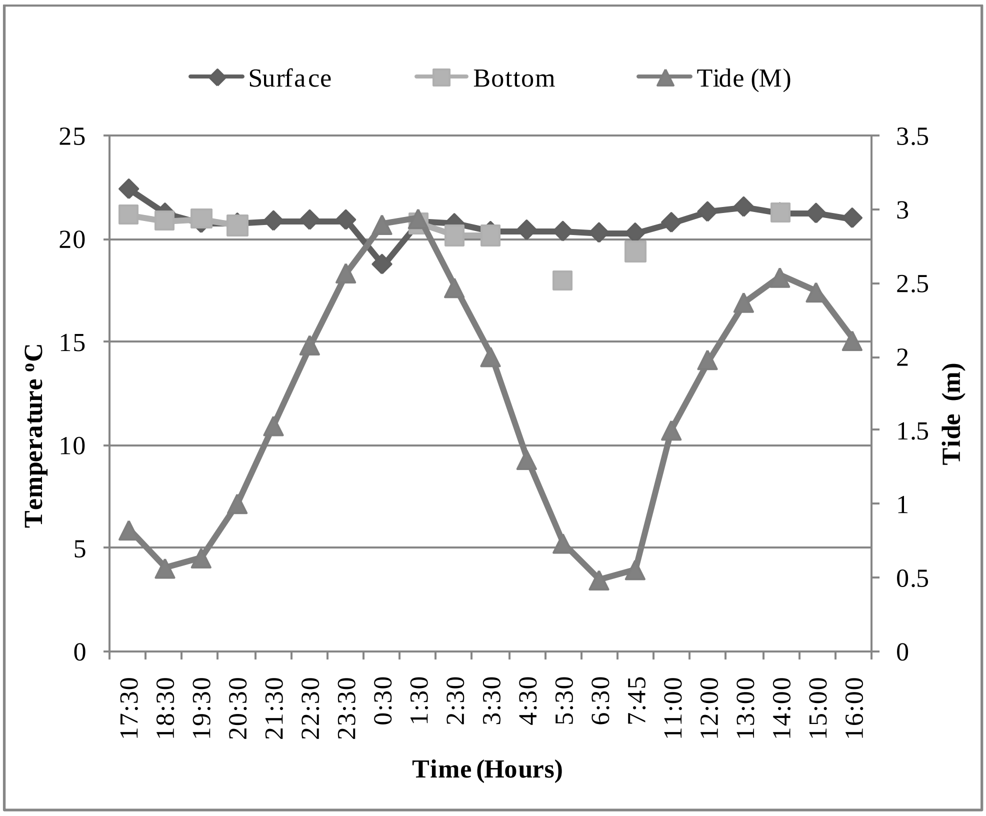

Figure 4. Diurnal variation (13-14 February 2013) of tide and temperature in Hajamro Creek.

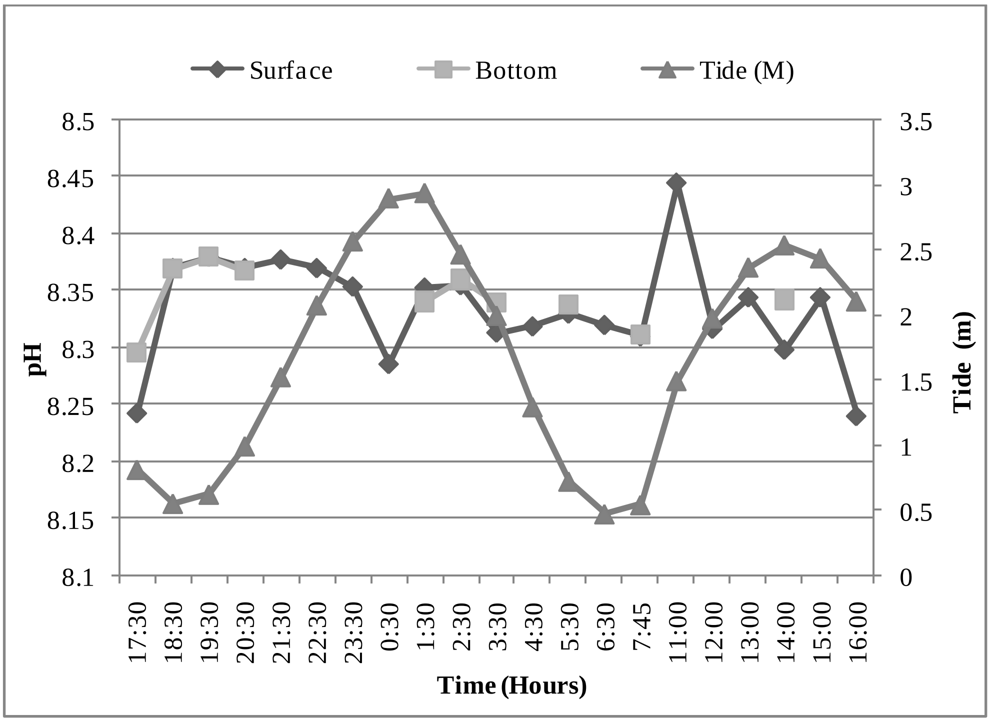

Figure 5. Diurnal variation (13-14 February 2013) of tide and pH in Hajamro Creek.

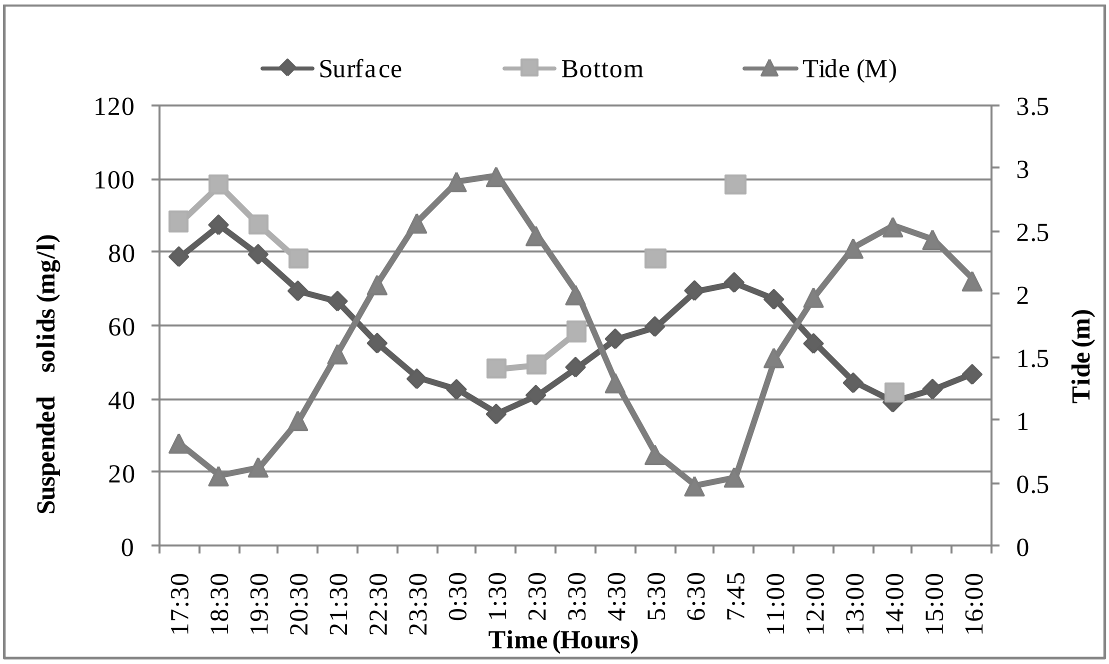

Figure 6. Diurnal variation (13-14 February 2013) of tide and suspended solids in Hajamro Creek.

Figure 7. Diurnal variation (13-14 February 2013) of tide and Chlorophyll-a in Hajamro Creek

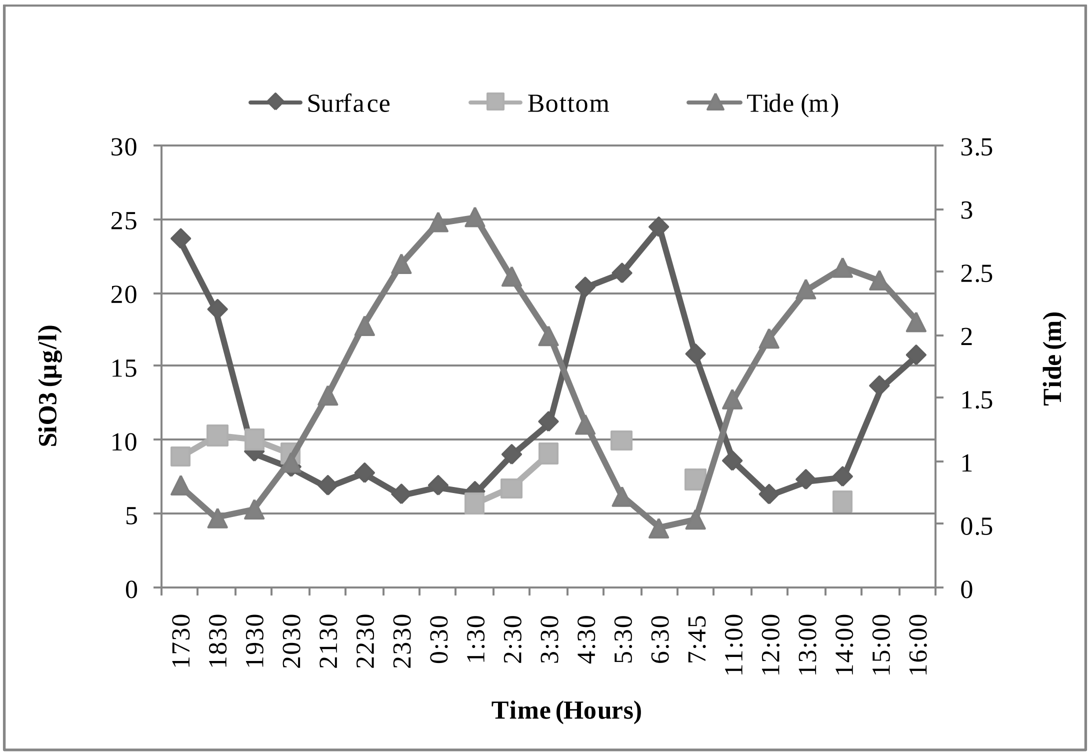

Figure 8. Diurnal variation (13-14 February 2013) of tide and silicate (SiO_3) in Hajamro Creek.

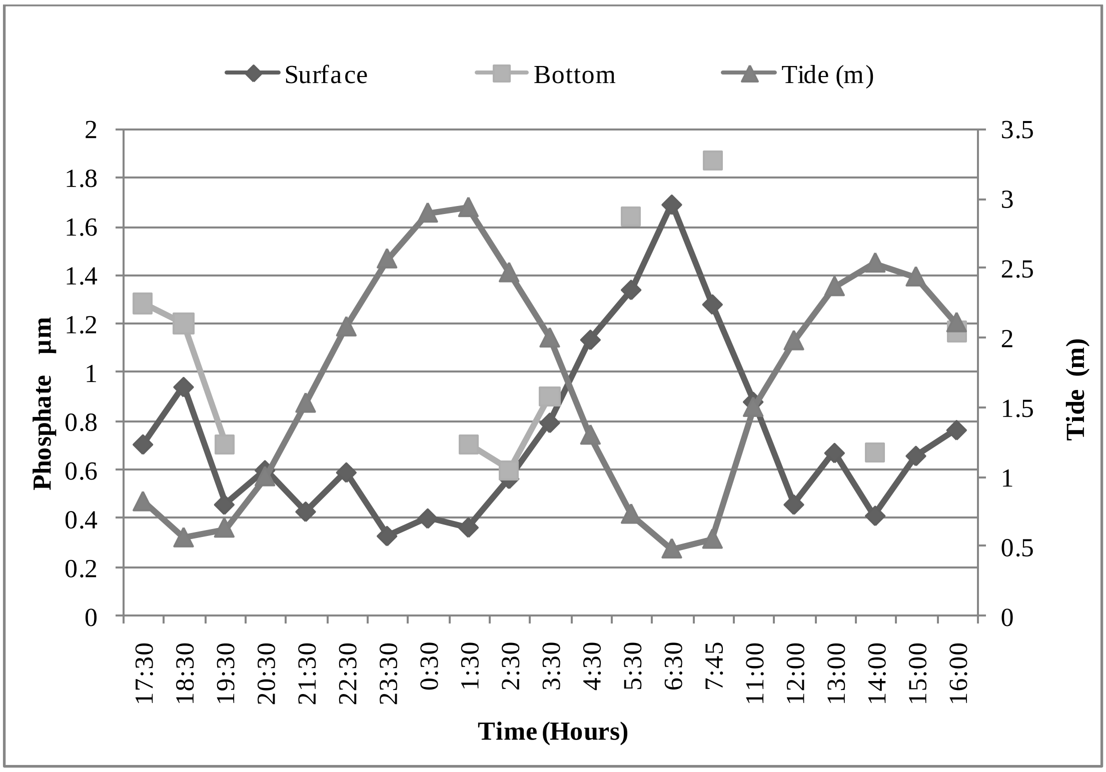

Figure 9. Diurnal variation (13-14 February 2013) of tide and dissolved phosphate in Hajamro Creek.

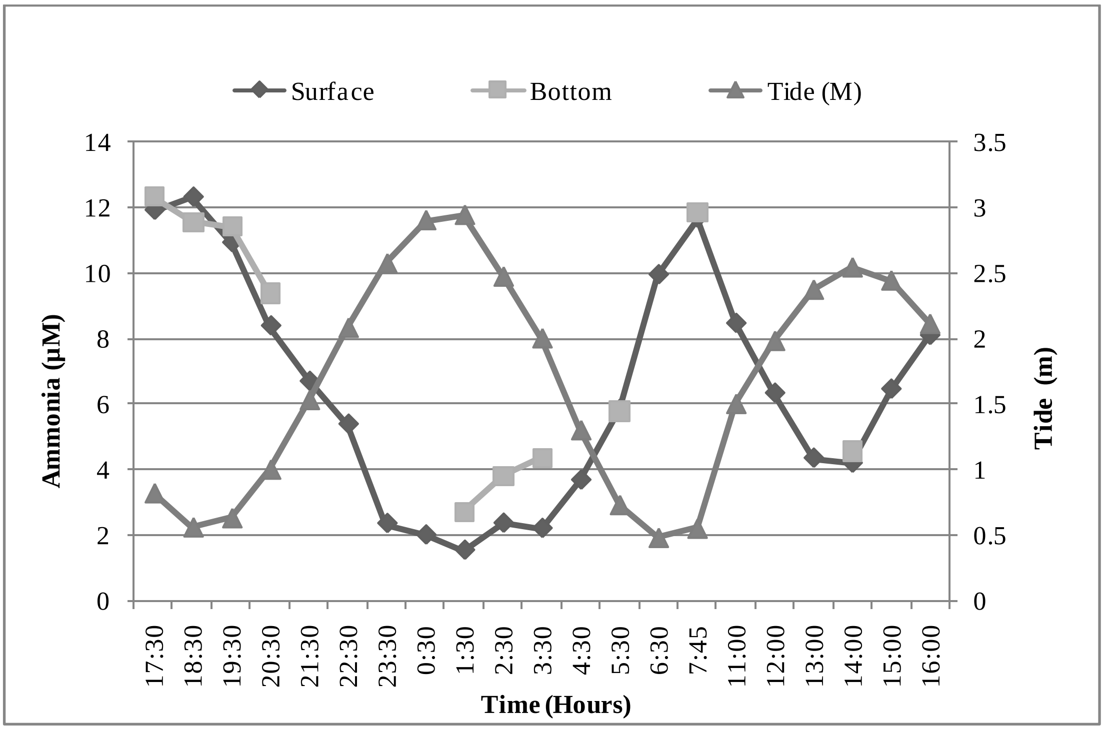

Figure 10. Diurnal variation (13-14 February 2013) of tide and ammonia in Hajamro Creek.

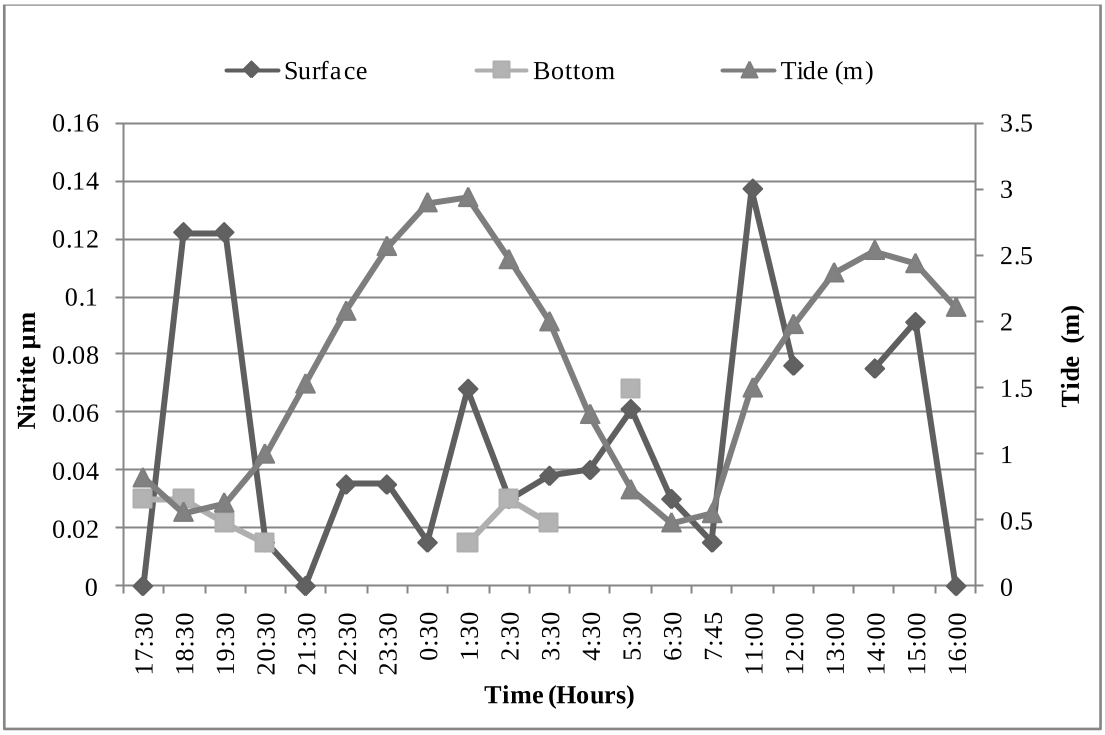

Figure 11. Diurnal variation (13-14 February 2013) of tide and nitrite in Hajamro Creek.

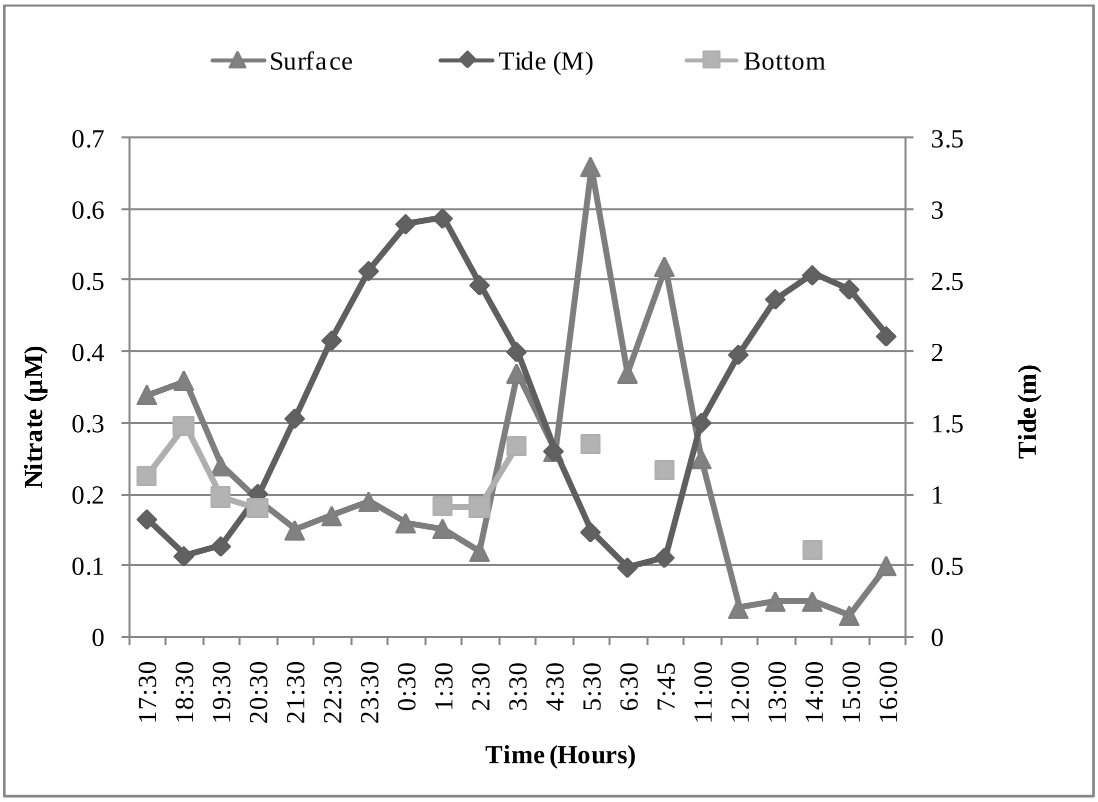

Figure 12. Diurnal variation (13-14 February 2013) of tide and nitrate in Hajamro Creek.

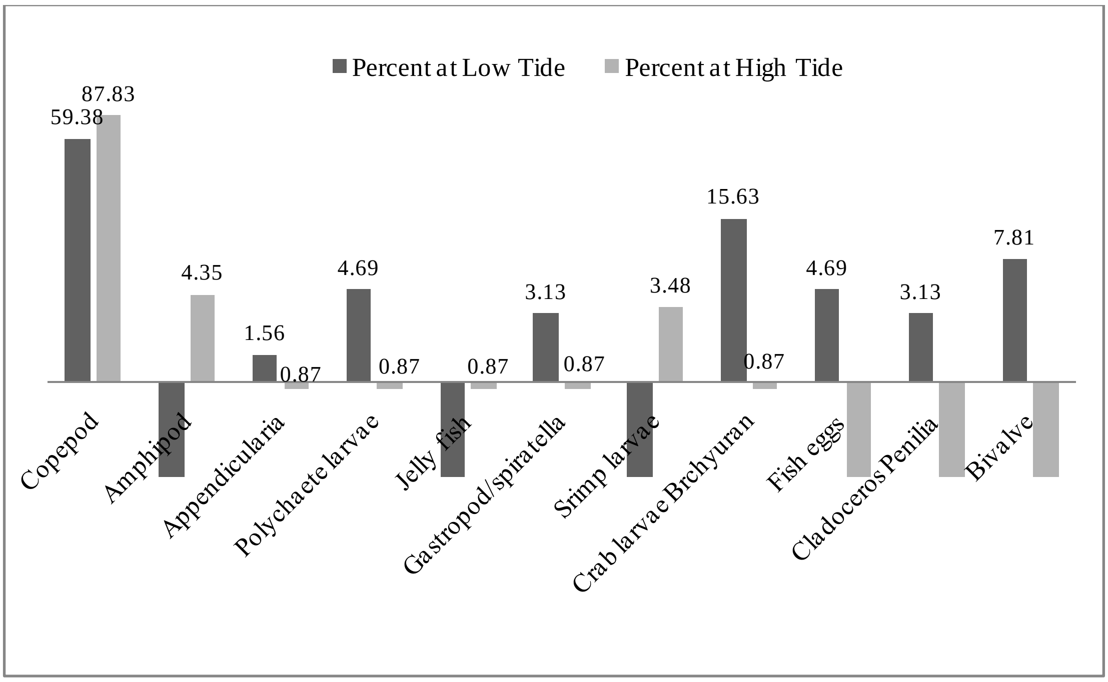

Figure 13. Zooplankton percentage composition during high and low tide in Hajamro Creek.

Table 1. Correlation matrix between seawater quality and dissolved nutrient.

	Tide	Temp.	D.O	S. S	pH	Salinity	Chl-a	NO_2	NO_3	NH_4	PO_4	SiO_3
Tide	1.000											
Temp.	-0.093	1.000										
D O	-0.193	0.418	1.000									
S. S	-0.915	0.183	0.265	1.000								
pH	-0.078	-0.030	-0.222	0.197	1.000							
Salinity	-0.706	-0.144	-0.019	0.588	-0.072	1.000						
Chl-a	0.285	0.456	0.432	-0.122	0.040	-0.489	1.000					
NO_2	-0.131	0.148	0.140	0.174	0.586	-0.070	0.135	1.000				
NO_3	-.0712	-0.245	-0.188	0.540	-0.044	0.786	0.527	-0.037	1.000			
NH_4	-0.827	0.334	0.560	0.878	0.000	0.448	0.114	0.163	0.380	1.000		
PO_4	-0.677	-0.187	-0.010	0.413	-0.106	0.593	-0.397	-0.034	0.720	0.428	1.000	
SiO_3	-0.671	0.102	0.204	0.481	-0.412	0.731	-0.313	-0.128	0.647	0.524	0.812	1.000

Temp. # Temperature, D.O # Dissolved Oxygen, S.S # Suspended Solid, Chl-a .# Chlorophyll-a

3.2. Dissolved Oxygen

Dissolved oxygen ranged between 6.36 mg/l and 8.15 mg/l (Figure 3). No relationship was observed between tide and dissolved oxygen. Dissolved oxygen concentration was comparatively higher in bottom water during the day time than during night time.

3.3. Seawater Temperature

The surface seawater temperature varied from 18.725 °C to 22.375 °C (Figure 4) and no correlation was noted with the tides (Table 1), although highest temperature was observed during the daytime and lowest during the night.

3.4. pH

pH of the Hajamro Creek sea water samples during the present study were measured in the range 8.24 -8.45 (Fig. 5). No correlation was observed with the tide, while positive correlation observed with nitrite (Table 1).

3.5. Suspended Solids

Suspended solids were found to inversely correlate with the tidal cycles (Fig. 6 and Table 1), while positive correlation observed with nutrient. The maximum value of 98.31 mg/l occurred during low tide from bottom water, whereas the lowest value was 42.80 mg/l at lowest tide. Surface suspended solid concentration ranges were slightly lower than in bottom waters.

3.6. Chlorophyll-a

Chlorophyll-a levels ranged between 0.80 µg/l and 2.70 µg/l in the surface waters and 0.80 µg/l and 2.16 µg/l in the bottom water (Fig. 7). From Table 1 it can be seen that the diurnal fluctuations of Chlorophyll-a content weakly correlated with the tidal cycle. Higher Chlorophyll-a values were obtained during high tides and were lower during low tides. Surface Chlorophyll-a concentration was almost similar to that of bottom water. Concentration of Chlorophyll-a was relatively lower at night time than during the day.

3.7. Dissolved Nutrients

Dissolved nutrients silicate, phosphate, ammonium, nitrite and nitrate were measured and their variations during the study period are given in Figures 8 to 12 respectively. Silicate levels ranged between 6.36 µM and 24.95 µM in the surface water during the sampling period (Fig. 8). Table 1 shows that diurnal fluctuations in the silicate levels negatively correlated with tidal highs. Silicate was higher in surface waters during low tides and lower during high tide.

Phosphate and ammonium showed similar patterns (Figure 9 and 10). Nitrite concentration remained below 0.20 µM. Moreover the concentrations of nitrite were relatively higher in the bottom waters (Figure 11) but in general, nitrate concentration was not high i.e. 0.45 µM - 1.69 µM and its concentration inversely correlated with tidal fluctuations (Figure 12 and Table 1). Higher nutrients (phosphate, silicate, nitrate and ammonia) values occurred during low tides and low values occurred during high tide. Ammonium ranged between 1.81 µM - 12.30 µM while phosphate between 1.00 µM and 23.60 µM. It was observed that dissolved nutrient concentrations were comparatively lower in surface waters than in bottom waters. Results of dissolved nutrients (phosphate, silicate, nitrate and ammonia) showed positive correlation with salinity, while negative correlation with the tide.

3.8. Primary Productivity

Primary productivity of the study area was recorded in triplicate on 14th February, 2013 and its average concentrations were recorded as 0.475 g C/m^3/day and were measured in the range (0.380 - 0.570 g C/m^3/day).

3.9. Zooplankton

A total of 11 groups of Zooplankton were identified during this study. A large number of Zooplankton collected during high tide and their composition is shown in Fig. 13. Copepod dominated during high tide (88.00 %), while a lower percentage (59.00 %) of copepod was collected during low tide among the Zooplanktons. The percentage of crab larvae (branchyuran) was higher (16.00 %) during low tide while it was lower (0.87 %) during high tide. Bivalves were 8.00 % at low tide and were absent during high tide. Fish eggs and polychaete larvae were equally present (5.00 %) at low tide. Fish eggs were absent during high tide, while a few polychaete larvae (1.00 %) were present during high tide. Amphipods were absent during low tide and ~4.00 % were found during high tide. Appendicularia, gastropod & cladoceras number varied between 1.56 % and 3.13 % at low tide. Very low percentages (1.00 %) of crab larvae, gastropod, jelly fish, polychaete larvae & appendicullaria were observed during high tide.

3.10. Phytoplankton

Thirteen types of phytoplankton were identified, including 6 each of diatom and dinoflagelate and one filamentous algae. *Planktoneilla* and *Coscinodiscus* were commonly found among diatoms, while *Dinophysis miles*, *Protoperidium* and *Ceratium* were found among the dinoflagelates. *Ceratium* was represented by three species, i.e., *C. azoricum*, *C. macroceros* and *C. horridum*. A few specimens of *Rhizoselenia*, *Amphidium*, *Chaetoceros*, *Ditylum*, *Melosira* and *Rhizoclonium* were also observed.

4. Discussion

Hajamro Creek is adjacent to Khobar Creek. It is connected to the Indus River through small creeks at some places, while Khobar Creek is directly connected to the Indus River. Very low salinity fluctuation (surface and bottom) was observed during high and low tides. The present study (during the North East monsoon period) indicates that fresh water only slightly influenced the creek salinity. From Table 1 it can be seen that sea water intrudes in the creeks area during high tide therefore salinity strongly anti-correlates (r^2 = -0.706) with the tide. Hence Hajamro Creek becomes a well-mixed estuary, especially during the winter season.

Hydrographic parameters such as dissolved oxygen, pH, temperature, etc. indicate no significant variation and weak correlation with tides (r^2= -0.193, -0.078, -0.093 respectively) was observed, while suspended solids strongly negatively correlated (r^2= -0.915) with tides during the diurnal changes in Hajamro Creek. Salinity strongly correlated with Nitrate and silicate (r^2= 0.786, 0.731 respectively).

Chlorophyll-a concentration shows no substantial variation and weak correlation was observed with the tide (r^2= 0.285). Most probably light was limited due to strong current and high suspended solids concentrations in seawater. Similar low Chlorophyll-a concentration was also noted by Rabbani during the North East monsoon period in the Hajamro Creek [3].

During the tidal cycle dissolved nutrients except chlorophyll-a (ammonium, nitrate, silicate and phosphate), showed extreme variations and strong negative correlation with tides (Table 1). Phosphate showed strong correlation with silicate and Nitrate (r2= 0.812, 0.720, respectively). During the low tide, high concentrations of dissolved nutrients probably originate by bacterial decomposition of mangrove leaf litter which produces dissolved organic matter (DOM) and dissolved nutrients both flushing out during the tidal fluctuations and spread in coastal areas. Similar situation in related estuaries has been described by Kathiresan [10], Altaf [2] and D'Elia et al. [11]. High concentrations of dissolved nutrients measured in the present study area during low tide is probably due to submarine groundwater discharge, as described by D'Elia et al., Simmons, Rutkowski et al., Corbett et al. and Jahnke et al. [12-16] in different global coastal waters.

Average primary productivity of the study area concentration was 0.475 g C/m^3/day, which is higher than the average concentration (0.238 g C/m^3/day) of

Gharo-Phitti Creek area [6]. It may be linked to the recent flooding (2012) of the Indus River, which most likely enhanced submarine groundwater discharge (SGD) as described by Bowen et al. [17].

5. Conclusions

The present study shows that at Hajamro Creek during low tide, high suspended solids, high concentrations of dissolved nutrients and relatively high salinity influenced by spring tides are measured. Creek water is flushed out in the coastal area which may enhance the productivity of coastal waters. Higher the number of Zooplankton in a creek during high tide indicates a flow of these organisms from coastal area, while the limiting number of phytoplankton species present was probably due to strong current and high suspended solids.

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