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Water Quality Assessment of Aquaculture Ponds Located in Bhitarkanika Mangrove Ecosystem, Orissa, India

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Abstract

Mangrove ecosystem being suitable for brackish water shrimp culture, large number of aquaculture ponds have been developed in the periphery of Bhitarkanika National Park area of Orissa, India. These ponds are regularly fed by brackish water from nearby Brahmani-Baitarani river system and the same water is ultimately discharged into the mangrove ecosystem. In the present study, some physico-chemical parameters such as pH, temperature, conductivity, dissolved oxygen, calcium, magnesium, total hardness, chlorine, phosphate, nitrate, and total dissolved solid contents of seven aquaculture ponds have been analysed for assessment of pollution status with respect to river water taken as control. Studies were undertaken for a period of six months from November 2005 to April 2006 during which the physico-chemical parameters were compared with the water quality standard of Bureau of Indian Standard (BIS) and Central and the State Pollution Control Board (PCB). pH values of the aquaculture ponds range between 5.63-8.5 as against the value of standard water quality i.e.6.5-8.5. Nitrate, total hardness, calcium, magnesium, phosphate, and chlorine contents show variation within different sites. Dissolved oxygen values vary from 3.0 to 8.3 mg/L during six months of investigation. Some of the sites show higher dissolved oxygen values than the permissible limits (4.0-5.0 mg/L) prescribed by PCB and BIS indicating that these waters do not pose any threat to aquatic life. The study indicates that the aquaculture pond water at present do not possess any pollution problem for the mangrove ecosystem.

Key words: dissolved oxygen, nitrate, physico-chemical, saline water, pollution.

Introduction

Mangroves are typically tropical coastal vegetation found in the inter tidal regions of river deltas and backwater areas. Extensive mangrove forests occur in the major river deltas such as Budhabalanga, Subernarekha, Brahmani-Baitarani (Bhitarkanika), Mahanadi and Devi river mouths of Orissa coast extending over 480 km along the Bay of Bengal. Mangroves of Bhitarkanika is the second largest viable mangrove ecosystem in India after Sunderbans. Adequate protection has been given to its rich floral and faunal diversity by declaring it as a Wildlife Sanctuary in the year 1975. Out of the total Sanctuary area of 672 sq km., the core area comprising of 145 sq kms was notified as a National Park in 1998 (Thatoi, 2004).

Shrimp farming is very profitable business compared to agriculture and animal husbandry (Kumar, 1997). Majority of shrimp farms in India are 100 per cent export oriented. Out of a total 1.456 million hectare of brackish water area available in India, 0.902 million hectares are being utilized principally for shrimp farms. It earns foreign exchange and generated employment for large coastal contiguous population (Mishra, 1998). Mangrove ecosystem being suitable for brackish water shrimp culture a large number of aquaculture ponds have been developed in Bhitarkanika area (Thatoi and Rath, 2006). These aquaculture ponds receive the river water either directly from Brahamani-Baitarani river system or its tributaries which fed saline water to the mangrove ecosystem. The water from aquaculture ponds ultimately finds their way into water channel (river or creeks) in the mangrove ecosystem.

To boost increase in production of shrimp farms, huge amount of artificial feed, pesticides, chemical additives and antibiotics are continuously added. These compounds with excrements from the shrimp make the water of the ponds polluted which is generally discharged into the mangrove environment. This discharged water of aquaculture ponds may have certain adverse impact on mangrove ecosystem. To our knowledge so far no studies have been carried out on aquaculture pond water discharged into Bhitarkanika mangrove ecosystem, or any environmental impact assessment related to shrimp farming activity. Hence, the present investigation was undertaken to assess the pollution load if any, through estimation of physico-chemical parameters of aquaculture pond water discharged into Bhitarkanika mangrove ecosystem of Orissa for a period of six months from November 2005 to April 2006.

Materials and Methods

Study Area

Bhitarkanika located at the confluence of Brahmani and Baitarani river deltas in the district of Kendrapara in Orissa and is the second largest viable mangrove ecosystem in India (after Sunderbans). Bhitarkanika Wildlife Sanctuary extended from 20°30' N to 20°50' N latitude and 86°30' E and 87°06' E longitude. Out of the total geographical area, the mangrove forests constitute approximately 130 km^2. The rest area covers water bodies, agriculture land, villages and other revenue lands. Bhitarkanika presents a variety of habitats and climatic conditions. The Sanctuary is bounded by river Dhamara in the north, the river Hansua to the west and Bay of Bengal on the eastern and southern sides respectively (Figure 1). Water quality of Brahmani river that is utilized for aquaculture pond is classified by the Central Board for prevention and control of water pollution as class "C" whose physico-chemical parameters considered as standards for assessment of pollution load in aquaculture ponds.

Water Analyses

The present study was carried out for a period of six months starting from November 2005 to April 2006. Monthly water samples were collected from eight different sampling sites which include one river water as site 1 and seven aquaculture ponds that utilizes the same river water as site 2 to 8 which are distributed in the periphery of the National Park. The sites were selected on the basis of location, natural or man-made and source of pollution to mangrove ecosystem. The water samples were collected between 8.00 a.m. to 9.00 a.m. using wide mouth sterile transparent plastic jar of five-liter capacity and usually from 10-15 cm depth from the water surface. For the analysis of dissolved oxygen, water samples were collected by BOD bottles of 300 ml capacity. The Manganese sulphate and the alkali iodide–azide reagent were added immediately at the collection site to fix the samples for studying dissolved oxygen. The measurement was carried out in the laboratory. The water temperature and pH were measured at the place of sampling sites using standard mercury thermometer and microprocessor based pocket pH meter (Waterproof pH scan WP 1). Immediately after arrival in to the laboratory the conductivity of the samples were measured with the help of a digital conductivity meter (Systronics model no. 341). For the study of nitrate-nitrogen, phosphate-phosphorus, chloride, calcium hardness, magnesium hardness and total hardness the samples were analysed in the laboratory following standard methods of American Public Health Association (APHA, 1992). The results of analysis were expressed as mg/L except temperature and conductivity measured as °C and milisiemens (ms) respectively.

Statistical Analyses

Statistical analyses were performed with MSTAT-C statistical software (1988) Month wise variations in eight different sites of each parameter were compared by using ANOVA. A significance level of P≤ 0.05 was used.

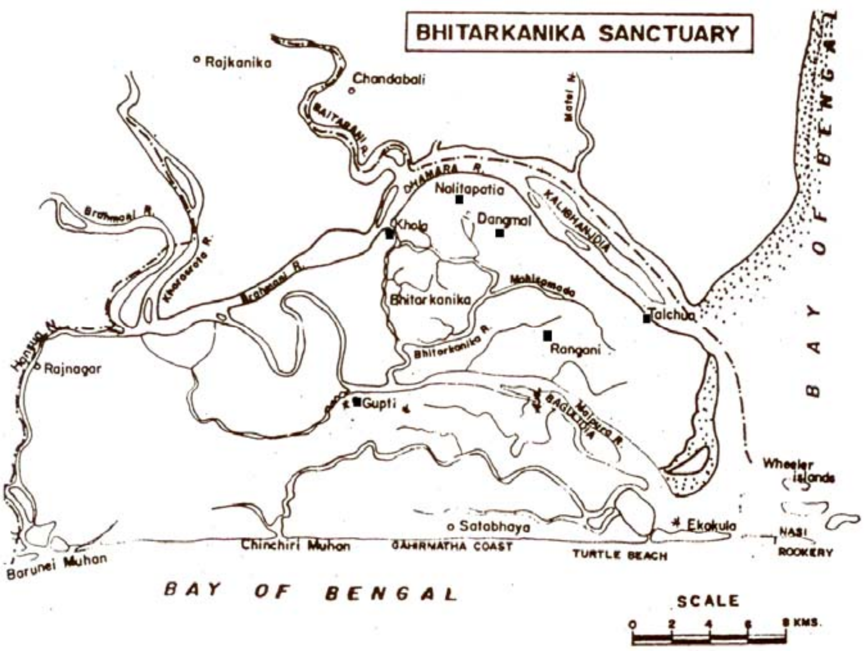

Figure 1. Location map of Bhitarkanika mangrove ecosystem showing sampling sites.
(# = square symbol of sampling sites)

Results

Results of analyses of various physico-chemical parameters of river water as control (site-1) and seven aquaculture pond water (site 2 to 8) are given in Figure 1 to 11. The average of six months data of river as well as aquaculture pond waters are presented in Table 1.

Water temperature of aquaculture ponds ranged from a low of 21.2ºC in December to a high of 35.8ºC in April through out the period of study in contrast to the values of river water which ranges from 21.6ºC (January) to 35.5ºC (April). A minor variation of temperature was recorded in all the sites irrespective of the river and aquaculture pond water (Figure 2). The average temperature among the seven sites varies 27.28ºC to 28.65ºC as against 28.65ºC of river water (Table 1).

pH value of aquaculture ponds were ranged between 5.63 (January) to 8.5 (November) during the study period. On the other hand pH of river water varies from 6.76 (November) to 7.9 (March) (Table 1). There was a marginal variation of pH observed in all the sites during the period of investigation. In comparison to months, pH did not change much among sites (Figure 3).

Conductivity values of aquaculture ponds at seven different sites varied greatly during these six months of investigation period along with the river water. The conductivity was found maximum in the month of March i.e. 0.45(ms) and minimum in the month of December i.e.0.025 (ms) with alternate increase and decrease trend during the study period except for site-6 where it was almost static from February to April (Figure 4). The monthly average value of conductivity ranges from 0.237 (ms) to 0.169 (ms).

The maximum value of dissolved oxygen concentration was observed in site-8 in the month of December i.e. 11.36±0.09 mg/L where as the minimum value of dissolved oxygen was found in the site-2 in January i.e. 3.70±0.03 mg/L. The six month average value of dissolved oxygen of river water was 6.02 mg/L (Table 1). The dissolved oxygen value gradually decreases from November to April in all the sites along with the control (Figure 5).

Calcium content increases in all the investigation sites along with the river water for first four months i.e. November to February and then there was a sudden decrease during last two months (Figure 6). There is a significant variation of calcium content during the six months period of investigation in all the sites except site-5 which showed a declining trend. The average value of calcium was 233 to 281.23 mg/L (Table 1).

Magnesium content varies greatly among different sites. Maximum values of magnesium were observed during the months of December and January for site-1, site-2, site-4 and site-6 where as the rest of the sites showed maximum value in the month of April (Figure 7). The six month average value of magnesium was 464.45 mg/L as highest among the aquaculture ponds against the river water value of 380.45 mg/L

Monthly estimate of total hardness showed significant increase in the month of December and January for maximum sites followed by a declining trend with the minimum values in the month of February (Figure 8). The average value of total hardness ranges from 1136.16 to 2,954.4 mg/L in aquaculture ponds whereas the average value of total hardness in river water was 1,769.42 mg/L (Table 1). Total hardness remains static in last two month (March & April) in six sites except site-1 (control) and site-7 where variation was not so significant (Figure 8).

Within the investigation period the chlorine contents for all the sites were found to be least in the month of December and maximum in the month of February. However the chlorine content remains static in last two months, in aquaculture pond water as well as in river water (Figure 9). The mean value of

Table 1. Six month mean values of water quality parameters at eight sampling sites, in Bhitarkanika

Parameter	River water	Aquaculture Pond Water						
	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
Temperature (ºC)	28.65	27.28	28.13	28.65	28.53	28.55	28.91	28.61
pH	7.38	6.96	7.31	6.53	7.16	7.04	7.12	7.04
Conductivity (ms)	0.188*	0.214	0.237	0.236	0.194	0.169	0.192	0.197
Dissol. Oxygen (mg/L)	6.02	5.16	6.67	4.1	5.46	4.74	6.06	8.30
Calcium (mg/L)	254.74	281.23	270.97	313.6	233	262.35	276.58	272.25
Magnesium (mg/L)	308.47	464.45	396.33	453.38	341.4	351.05	352.27	377.86
Total Hardness (mg/L)	1,769.42*	2,308.62	2,067.67	2,384.55	1,583.74	2,031.08	1,781.95	1,854.94
Chlorine (mg/L)	9,535.35	10,937.61	10,088.32	9,891.43	10,112.76	9,118.70	10,025.17	10,882.31
Phosphate (mg/L)	0.46	0.401	0.698	0.016	0.355	0.415	0.360	0.59
Nitrate (mg/L)	3.48 **	3.36	3.16	3.34	3.54	3.68	3.58	3.41
Total Dissolved Solid (mg/L)	8.38*	11.23	8.38	12.07	9.07	9.18	8.64	7.45

*There is a statistically significance difference between the sites of ($P\leq 0.05$).

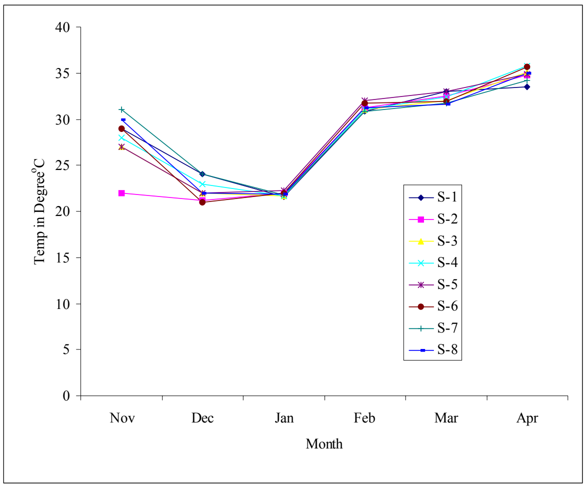

Figure 2. Monthly temperature values at eight sampling sites, in Bhitarkanika.

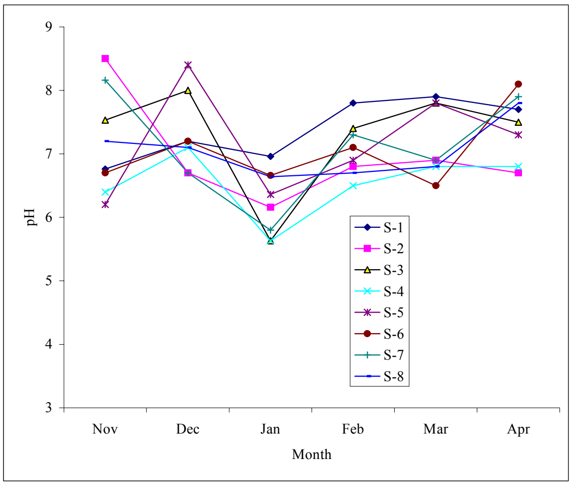

Figure 3. Monthly pH values at eight sampling sites, in Bhitarkanika.

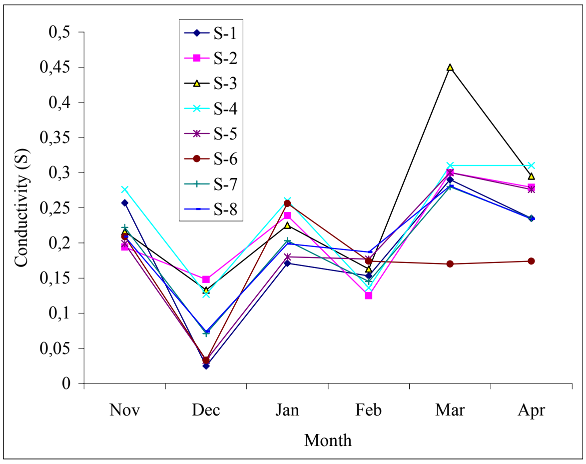

Figure 4. Monthly conductivity values at eight sampling sites, in Bhitarkanika.

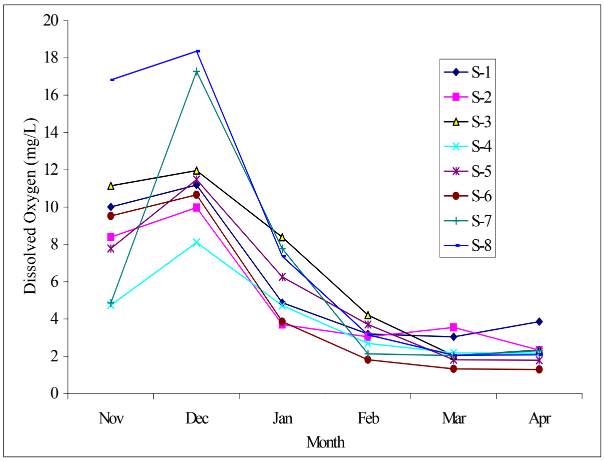

Figure 5. Monthly dissolved oxygen contents at eight sampling sites, in Bhitarkanika.

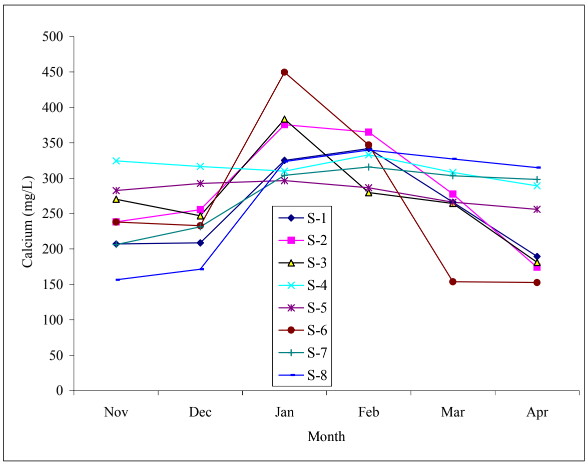

Figure 6. Monthly calcium contents at eight sampling sites, in Bhitarkanika.

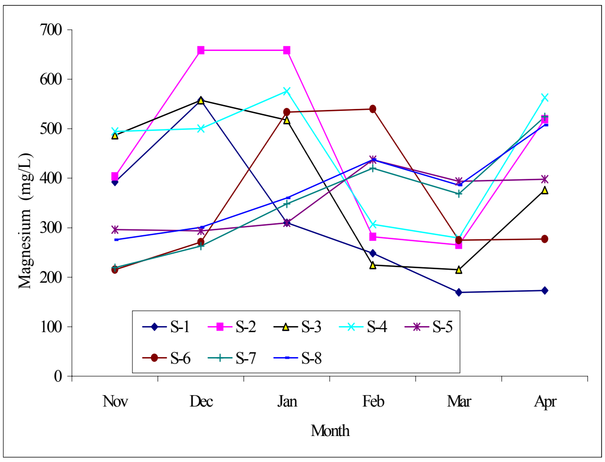

Figure 7. Monthly magnesium contents at eight sampling sites, in Bhitarkanika.

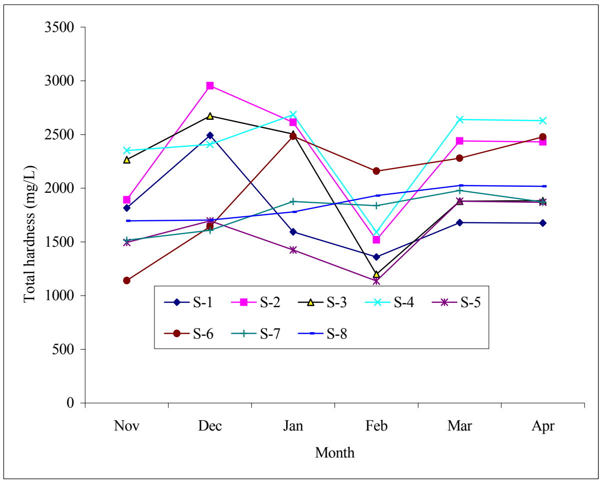

Figure 8. Monthly total hardness contents at eight sampling sites, in Bhitarkanika.

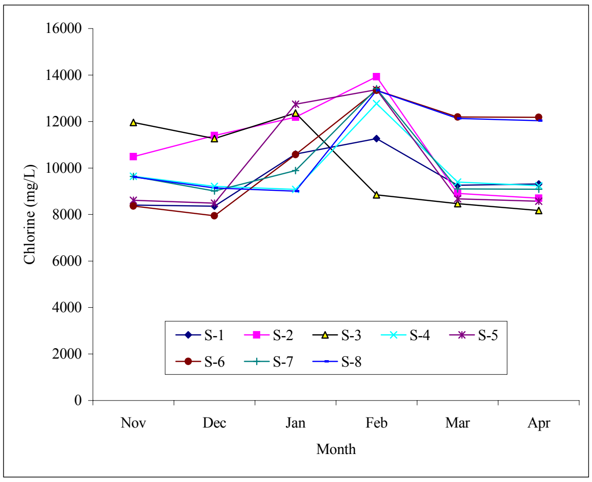

Figure 9. Monthly chlorine content at eight sampling sites, in Bhitarkanika.

chlorine in river water was 9,535.35 mg/L against the maximum and minimum values of 10,937.61 mg/L and 9,118.70 mg/L respectively observed for aquaculture pond water (Table 1).

Among the aquaculture ponds phosphate content was found to be highest i.e. 1.193 mg/L in site 6 in the month of December where as the lowest value i.e. 0.02 mg/L was observed in the month of November in the same site. On the contrary the maximum and minimum value of phosphate content of river water was 1.08 mg/L and 0.14 mg/L respectively. The mean value of phosphate in river water was calculated to be 0.46 mg/L (Table 1). The Phosphate content becomes more or less static from January onwards in all the investigation sites through out the period of study (Figure 10).

Nitrate content of all the aquaculture sites along with river water showed gradual declining trend for first three months from November to January. There was however an increase in nitrate content during the month of February followed by a gradual decrease in all the sites for rest of the months of investigation. The average value of nitrate in river water was 3.3.48 mg/L (Table 1). The nitrate content showed a prominent variation in two consecutive months i.e. January and February but in rest two months prior to January and after February depicts a gradual declining value. It was further noticed that there was a wide range of variation of nitrate content in first month (November) as compared to last month (April) at all the sites. (Figure 11)

The value of Total dissolved solid showed alternately high and low value from November to March followed by apparently static for some sites and gradual increased value for others. The mean value of total dissolved solid in river water was 8.38 mg/L (Table 1). The total dissolved solid among the sites showed a narrow range of variation among all the months except the month of March where comparatively wide range of variation was observed (Figure 12).

Discussion

The water of river Brahmani has been classified by the Central Board for prevention and control of water pollution as class “C” water from its origin to the point of emergence of distributaries in the coastal plains which means that, in this stretch the water should be suitable as the source of drinking water supply with conventional treatment followed by disinfection (not directly potable). From the emergence of the distributaries to the saline tidal limit, the water is classified as class “B” water that is suitable for outdoor bathing. Further down up to the Bay of Bengal, the water is classified as SW II class (commercial fishing and recreation–non contact). The water utilized for aquaculture in Bhitarkanika mangrove ecosystem is belonging to the SW II class. The result of physico-chemical parameters of aquaculture ponds were compared with the prescribed water quality standard given by Bureau of Indian Standard (BIS) and Pollution Control Board (PCB).

In India the temperature is quite high during the dry pre-monsoon season but with the advent of the southwest monsoon (June-September) water temperature reaches its lowest value (26°C) in August (Dwivedi *et al*., 1974). In the present study the observed values of temperature indicates that the water quality would not be affected by this parameter.

The pH of the aquaculture pond water samples varied from 5.63 to 8.5 over six months period of investigation. It can thus be concluded that the higher acidic value in some sites is due to the chemical additives applied to aquaculture pond with an objective of better production. In the present investigation it has been found that the pH of aquaculture pond water as well as river water (control) showed permissible limit of pH that has been prescribed by BIS and PCB. The high conductivity in the month of November may be due to high organic residue in the water body. As high temperature favours degradation of organic pollutants

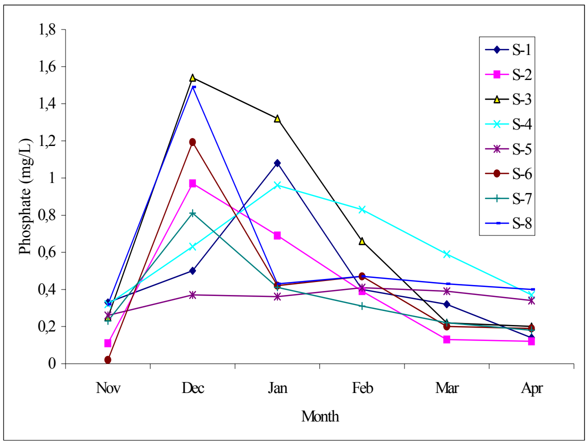

Figure 10. Monthly phosphate contents at eight sampling sites, in Bhitarkanika.

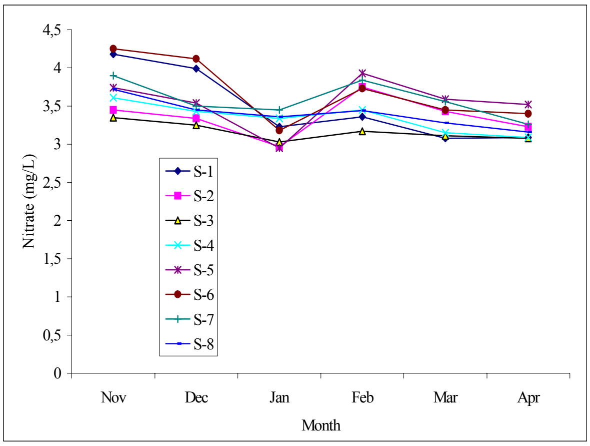

Figure 11. Monthly nitrate contents at eight sampling sites, in Bhitarkanika.

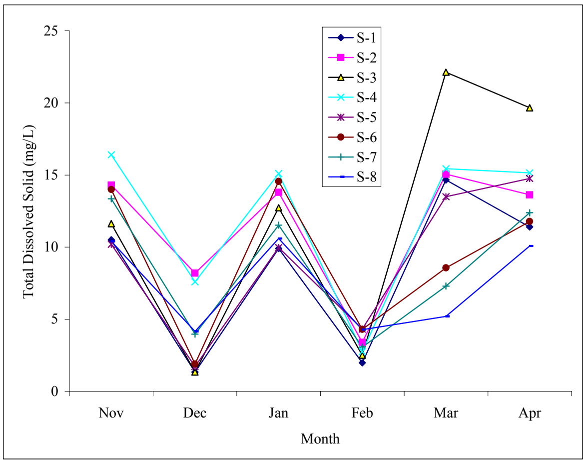

Figure 12. Monthly total dissolved solid contents at eight sampling sites, in Bhitarkanika.

thus it also increases the conductivity value in water bodies (Sarwar and Wazir, 1988).

Dissolved oxygen (DO) is one of the most important abiotic parameters influencing the life in the coastal environment. Normally high dissolved oxygen is encountered in unpolluted areas, while at polluted areas levels of DO is very low. Further depletion of DO to the level of anaerobia is the most critical manifestation of pollution (Lester, 1975). Dissolved oxygen concentrations were above 5 mg/L, which was adequate enough to support aquatic life. In the present investigation it has been found that the dissolved oxygen value is more in some sites. The high value of DO as compared to standard (4 mg/L) might be due to addition of chemicals like Oxyflow and mechanical aerators which is used to enhance shrimp production. The presence of chloride, where it does not occur naturally, indicates possible water pollution. Chloride does not affect plant and algal growth to a significant level. High chloride content could be attributed to the brackishness of the water as because it has a tendency to be salty being an estuary. The higher value of chlorine observed in the present investigation may be due to contamination of inflow of wastes from terrestrial runoff or of anthropogenic in origin.

The monthly mean value of magnesium and calcium content in river water and aquaculture pond water differ from one another. In the present study it has been found that the aquaculture ponds has more value of calcium and magnesium than that of river water (control). The high value of calcium and magnesium in aquaculture ponds may be due to addition of lime nnnnnnnand pesticides in a objective for better production. Total hardness is mainly due the presence of ions like calcium (Ca^{++}) and magnesium (Mg^{++}). Since the present study aquaculture pond water has more value of calcium and magnesium thus it indicates high value of total hardness. In the other hand the high value of total hardness in aquaculture ponds than river water may be due to exogenous and endogenous product formation in the aquaculture ponds.

The concentration of different forms of nitrogen gives a useful indication of pollution in the water and thus hence has the ability to support plant growth. Nitrogen does not occur naturally in soil minerals, but is a major component of all organic matter (both plant and animal). Some bacteria convert nitrate back to nitrogen gas under anaerobic conditions when soluble organic matter is present. The observed nitrate concentration in aquaculture pond water as well as in the river water much below than the prescribed BIS upper limit of 10 mg/L for domestic water. In the present study the phosphate content in aquaculture ponds varied greatly in some sites which may be attributed due to high organic load in ponds.

In the present study, it has been found that in most of the sites, aquaculture ponds have higher value of total dissolved solid than the river water. Total dissolved solid was more in aquaculture ponds may be due to sedimentation of unused agrochemicals, food additives, and excreta.

Majority of the prawn farms are in the small scale sector with water spread of overall area of less than two hectare. The traditional and extensive methods of farming do not adversely affect the environment. However, semi intensive and intensive methods of farming as well the clustering of farms in a particular locality can lead to degradation of coastal zone. The problems are due to unplanned and unregulated development of aquaculture ponds.

The prawn farm activity around the sanctuary though has no such significant impact on the flora and fauna at present however there is a fluctuation in the physico chemical parameters which if continues, would result in imbalance in the ecosystem in long run. Thus care must be taken not to destroy ecosystem and disturb the ecological balance by developing huge number of aquaculture ponds in Bhitarkanika national park.

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