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Research Article

A study on seasonal variation of physico-chemical properties in some freshwater lotic ecosystems in Gadchiroli District Maharashtra

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ABSTRACT

In the present investigation an attempt was made for assessment of Seasonal Variation in Physico-chemical properties in three different lotic ecosystems in Gadchiroli district of Maharashtra during the year 2006 and 2007. The study reveals that most of the properties of all the sites show moderate variation in their concentration for all seasons. All the three sites have more or less similar ecological status. The site-I and site-II have greater nutrient concentration. The region of the site-I and site-II are somewhat disturbed by the anthropogenic activities while site-III with less or undisturbed by the same. Having a glimpse of values of physico-chemical properties such as BOD, COD, Nitrate, Phosphate, Alkalinity, DO, Free CO2 etc. disclosed that all the three ecosystems under investigation are mildly polluted.

KEYWORDS

Lotic Ecosystems, Physico-Chemical Properties, Seasonal Variation

INTRODUCTION

Water is an elixir of life; it is the unique component of nature that has played an important role in the evolution of life from molecules. Since time immemorial the great human civilizations developed, evolved and flourished around water resources. For any nation, its aquatic ecosystems, the lakes, rivers and coastlines are national wealth and constant efforts are made to exploit them for the benefit of its population. Nowadays due to excessive exploitation and misuse, the lentic and lotic ecosystems are polluted. It is widely recognized that water is going to be one of the major issues, confronting humanity at the turn of the century and beyond. Fresh water is a natural resource of fundamental importance. In many respects the properties of water are unique. They seem to be especially designed for the living organisms. No other liquid can replace it. In an aquatic ecosystem the physico-chemical environment exerts profound influence on its biotic components. It controls diversity, biomass and spatial distribu- tion of biotic communities in time and space.

The physical and chemical parameters exert their influence both, individually and collectively and their interaction creates a biotic environment, which ultimately conditions the origin, development and finally succession of the biotic communities (Salaskar and Yeragi, 1997). It is generally agreed that a single factor never acts independently as a limiting factor but only with the interactions with others. Human activities that alter a watershed and interfere with the natural processes of wetlands have immediate as well as long lasting effects on the animals that live in the wetlands. We may monitor invertebrates because they represent an enormous diversity of body shapes, survival strategies, and adaptations. Many invertebrates require clear, cool water, adequate oxygen, stable flows, and a steady source of food in order to complete their life cycles. These animals, in turn, provide food for fishes and birds like herons and kingfishers. The quality of water affects species composition, abundance, productivity and physiological condition of aquatic communities. Lot of work is done on lotic ecosystems in India by several workers Kumar (1995), Bansal (1989), Dakshini and Soni (1979), Dutta and Singh (1978), Sinha *et al*., (1989) and others. In the present work the attempt was made to analyze the physico-chemical properties (Temperature, pH, DO, Free CO2, TDS, Transparency, Total Alkalinity, Total Hardness, Ca, Mg, Sulphate, Phosphate, Nitrate, BOD, COD) from three different lotic ecosystems in Gadchiroli district of Maharashtra to understand the status of water quality.

MATERIALS AND METHODS

Study Area:

S-I: The site on Wainganga River is situated near Wadsa city located at 20°36'00.08"N and 79°57'00.52"E representing the lotic systems disturbed by various anthropogenic activities, the site receiving the sewage, dirt form washed clothes, vehicles cleaning, idol immersion and animal washing activities, fishing activities and other activities in huge manner.

S-II: The site on Gadhavi River is situated near Armori city located at 20°26'28.31"N and 79°59'22.46"E victimized with the human disturbances and received waste from cattle washing, vehicle washing, idol immersion, cremation, nirmalya immersion and also used for fishing activities and watermelon farming.

S-III: The site on Khobragadhi River is situated near Deolgaon town located at 20°23'55.53"N and 79°59'23.33"E remaining almost natural and far away from the much human disturbances. But due to the water applied for irrigation to the nearby agriculture fields, it is also contaminated with the agriculture activities.

Water Sampling: The water samples were collected fortnightly in clean glass bottles of various sizes from the water surface of study sites. For the DO estimation, the sample was collected in the bottle of around 125-ml volume, as well as about 5 litre volumes of water was also collected in a container separately for other analysis. The sampling of surface water was done by simply dipping the container slowly in water without disturbing the surface and avoiding development of any air bubble in the near vicinity of collection spot as well as in the container. Some of water characteristics viz. Temperature, pH were determined at the sampling station with the help of portable water analysis kit and others were mostly tested within 24 hours of collection. The determination of physico-chemical properties were done by Standard methods for the examination of water and wastewater analysis (APHA, 1975). Preservation of water samples whenever necessary was done at 4°C. During the study period, the river water samples collected in the first year, i.e. January to December 2006 and the second year i.e. January to December 2007.

RESULTS AND DISCUSSION

The main objective of the seasonal variation in physico-chemical analysis of water is to determine its nutrient status. Since the water contains dissolved and suspended constituents in varying proportions, it has different chemical and physical properties along with biological variation. The quality of water may be affected in various ways by pollution. The results on water quality in terms of physico-chemical properties are summarized in the table 1, 2 and 3.

Temperature: The temperature at all the sampling sites range between 23.2°C to 31.9°C and seasonally ranges between 23.95°C To 29.47°C in winter and summer respectively with yearly average of about 27.63°C. Similar observations are reported by Koshy and Nayar, (1999) in river Pamba, reported temperature fluctuations between 25°C to 30°C and also reported that temperature fluctuations are dependent on seasons, geographic location as well the temperature of effluent poured into the river. In the present investigation the minimum temperature was recorded in winter and maximum during the summer at all collection sites, The low water temperature during winter may be due to high water level and low solar radiation and higher temperature in summer might be due to low water level, greater solar radiation and clear atmosphere. Similar results are reported by Kumar and Sing, (2002) in river Muyurakhi, Sawane *et al*., (2007) in river Irai. Bobday, (2002) in river Wainganga.

pH: In the present investigation pH value of all ecosystems under study is slightly alkaline throughout study period which range from 7.05 to 8.4. Similar pH ranges are reported by Abdul Rafiq and Khan, (2002) (7.0 t0 8.5) in river Godavari. Bobday, (2002) (7.0 to 8.5) in river Wainganga at Paoni. Seasonally in all the three ecosystem minimum pH was recorded during monsoon season and at site-I and II during the summer and during winter at site-II.

Table 1: Seasonal Variation of Physico-Chemical Properties at SITE-I (2006 & 2007)

YEAR	2006				2007			
PARAMETERS	SUMMER	MONSOON	WINTER	AVERAGE	SUMMER	MONSOON	WINTER	AVERAGE
Temp.	28.17 ±2.42	27.1 ±2.08	23.95 ±0.73	26.4 ±2.19	28.7 ±2.71	28.35 ±1.56	25.37 ±1.090	27.47 ±1.82
pH	8.05 ±0.29	7.85 ±0.44	7.97 ±0.18	7.95 ±0.10	7.83 ±0.09	7.175 ±0.10	7.68 ±0.188	7.56 ±0.34
Trans.	44.05 ±1.64	37.33 ±7.41	42.85 ±2.15	41.41 ±3.58	44.41 ±3.34	35.65 ±0.285	38.18 ±2.23	35.41 ±4.50
TDS	290 ±233.53	315 ±66.08	250 ±177.01	285 ±32.78	450 ±129.09	245 ±102.46	320 ±121.10	338.33 ±103.72
DO	7.0 ±2.01	6.00 ±0.77	7.90 ±1.44	6.96 ±0.950	7.75 ±0.759	7.2 ±1.23	9.50 ±0.253	8.15 ±1.20
CO2	3.17 ±0.57	1.67 ±0.35	3.53 ±0.32	2.79 ±0.986	4.05 ±0.310	3.95 ±0.544	4.47 ±0.221	4.15 ±0.275
Total Alkalinity	166.5 ±55.54	133.75 ±37.66	203.5 ±82.43	167.91 ±34.89	187 ±37.49	155.75 ±42.40	145 ±8.71	162.58 ±21.81
Total Hardness	143.0 ±37.25	105.5 ±31.29	123 ±30.30	123.84 ±18.76	130.5 ±43.278	102 ±26.93	90 ±10.83	160.5 ±20.80
Calcium	30.6 ±6.80	34.5 ±12.71	30.55 ±8.05	31.85 ±2.26	27.25 ±4.05	27.4 ±10.91	23.2 ±1.95	25.95 ±2.38
Mg	16.226 ±5.24	4.758 ±1.79	11.222 ±4.57	10.735 ±5.74	17.092 ±9.87	8.174 ±5.27	7.808 ±2.90	11.0246 ±5.25
BOD	16.875 ±3.52	12.87 ±1.93	11.125 ±1.49	13.623 ±2.94	23.5 ±10.700	19.375 ±12.76	19.125 ±5.83	20.666 ±2.45
COD	32.4 ±7.17	23.4 ±10.23	22.1 ±4.07	25.96 ±5.60	31.32 ±5.23	26.2 ±6.89	20.6 ±1.36	26.04 ±5.36
Sulphate	15.25 ±4.38	13.6 ±7.73	4.55 ±2.46	11.13 ±5.76	14.45 ±5.68	10.1 ±4.550	6.3 ±2.41	20.28 ±4.07
Phosphate	0.6 ±0.21	0.55 ±0.27	0.185 ±0.06	0.445 ±0.22	0.605 ±0.194	0.51 ±0.199	0.21 ±0.06	0.441 ±0.20
Nitrate	0.1749 ±0.03	0.1328 ±0.05	0.1521 ±0.06	0.1532 ±0.02	0.2037 ±0.026	0.1184 ±0.044	0.1605 ±0.016	0.1608 ±0.042

Table 2: Seasonal Variation of Physico-Chemical Properties at SITE-II (2006 & 2007)

YEAR	2006				2007			
PARAMETERS	SUMMER	MONSOON	WINTER	AVERAGE	SUMMER	MONSOON	WINTER	AVERAGE
Temp.	29.35 ±2.41	28.32 ±1.40	24.1 ±0.503	27.25 ±2.78	29.12 ±0.798	29.1 ±1.790	25.36±1.418	27.86 ±2.16
pH	7.76 ±0.122	7.41 ±0.076	7.94 ±0.132	7.70 ±0.269	7.77 ±0.328	7.30 ±0.088	7.56 ±0.384	7.54 ±0.235
Trans.	55.36 ±2.89	42.5 ±5.83	76.26 ±6.78	58.04 ±17.03	45.51 ±0.342	39.83 ±3.50	42.42 ±1.706	42.58 ±2.84
TDS	105 ±44.34	145 ±55.07	94 ±44.347	115 ±26.45	105 ±30.00	146 ±41.23	95 ±34.156	115 ±26.45
DO	9.875 ±1.192	6.35 ±0.420	8.97 ±1.41	8.39 ±1.830	9.3 ±0.496	7.05 ±0.655	8.25 ±0.50	8.2 ±1.12
CO2	3.85 ±0.341	3.87 ±0.680	3.65 ±0.341	3.79 ±0.121	3.45 ±0.310	4.4 ±0.081	3.7 ±0.476	3.85 ±0.49
Total Alkalinity	181.55 ±27.19	181.50 ±16.901	155.75 ±32.93	172.91 ±14.86	194.25 ±29.227	162 ±48.57	174.25 ±16.82	176.83 ±16.27
Total Hardness	95.75 ±22.98	107.5 ±26.96	86.75 ±22.58	96.66 ±10.40	108.5 ±25.33	93.75 ±40.111	98 ±9.201	100.08 ±7.59
Calcium	27 ±6.00	26.4 ±5.38	23.6 ±5.24	25.66 ±1.814	28.9 ±6.98	22.5 ±10.902	24.7 ±3.272	25.36 ±3.25
Mg	6.893 ±2.185	10.126 ±3.708	6.771±2.67	7.93 ±1.902	8.840 ±2.45	9.15 ±3.300	8.845 ±1.851	8.94 ±0.176
BOD	5.70 ±1.860	3.175 ±0.722	5.72 ±1.278	4.865 ±1.463	4.4 ±1.416	5.325 ±2.131	5.425 ±1.960	5.05 ±0.565
COD	11.68 ±1.906	7.12 ±1.890	10.15 ±1.532	9.65 ±2.320	11.24 ±2.195	11.04 ±1.814	12 ±2.07	11.42 ±0.506
Sulphate	12 ±3.88	12.75 ±3.021	5.65 ±1.738	10.13 ±3.900	14.6 ±6.42	12.65 ±9.369	5.05 ±2.002	10.76 ±5.04
Phosphate	0.48 ±0.165	0.475 ±0.192	0.2 ±0.081	0.385 ±0.160	0.526 ±0.173	0.445 ±0.254	0.39 ±0.103	0.4536 ±0.068
Nitrate	0.1583 ±0.029	0.1107 ±0.047	0.1428 ±0.040	0.1372 ±0.024	0.6504 ±1.035	0.1329 ±0.071	0.1805 ±0.0276	0.321 ±0.268

Table 3: Seasonal Variation of Physico-Chemical Properties at SITE-III (2006 & 2007)

YEAR	2006				2007			
PARAMETERS	SUMMER	MONSOON	WINTER	AVERAGE	SUMMER	MONSOON	WINTER	AVERAGE
Temp.	29.47 ±2.332	29.4 ±1.33	26.2 ±0.84	28.35 ±1.86	29.37 ±2.75	29.02 ±1.68	25.92 ±1.114	28.13 ±1.89
pH	7.91 ±0.072	7.61 ±0.34	7.76 ±0.25	7.76 ±0.15	7.85 ±0.095	7.75 ±0.17	7.67 ±0.141	7.75 ±0.090
Trans.	73.26 ±4.697	47.51 ±1.71	60.8 ±3.81	60.52 ±12.87	69.12 ±5.55	57.147 ±3.410	58.4 ±3.069	61.55 ±6.580
TDS	125 ±19.14	180 ±36.51	115 ±10.00	140 ±35.00	135 ±19.14	175 ±19.14	80 ±16.32	130 ±47.69
DO	8.475 ±1.327	5.95 ±0.310	8.7 ±1.324	7.70 ±1.52	9.425 ±1.347	6.625 ±0.655	9.325 ±1.087	8.45 ±1.58
CO2	3.725 ±0.330	4.05 ±0.544	3.525 ±0.47	3.76 ±0.26	3.625 ±0.427	4.2 ±0.0816	4.15 ±0.556	3.991 ±0.318
To. Alka.	144.75 ±24.58	166.5 ±22.09	117.5 ±8.34	142.91 ±24.55	121 ±18.93	146 ±16.53	112 ±14.165	126.33 ±17.61
To. Hard.	119.75 ±31.96	127.25 ±10.99	87.25 ±6.70	111.41 ±21.26	101.75±21.91	120.25 ±12.78	83.75 ±11.814	101.91 ±18.25
Calcium	27.1 ±7.320	29.5 ±3.771	18.3 ±2.07	24.96 ±5.89	25.3 ±7.55	29.05 ±3.70	19.4 ±4.137	24.58 ±4.864
Mg	12.688 ±3.689	13.054 ±3.294	10.126 ±0.42	11.956 ±1.59	9.3937 ±3.58	11.346 ±4.24	8.601 ±1.168	9.780 ±1.412
BOD	4.2 ±1.224	3.8 ±0.673	3.735 ±0.262	3.79 ±0.415	3.775 ±1.456	3.675 ±0.394	3.625 ±0.853	3.691 ±0.076
COD	9.52 ±0.672	8.8 ±0.666	9.44 ±1.605	9.2533 ±0.394	8.48 ±1.085	7.32 ±0.963	7.64 ±1.456	7.813 ±0.599
Sulphate	4.3 ±1.949	5.05 ±1.738	4.1 ±2.08	4.48 ±0.500	4.15 ±1.50	3.779 ±0.518	2.60 ±0.588	3.5096 ±0.809
Phosphate	0.405 ±0.0869	0.36 ±0.124	0.2733 ±0.094	0.3461 ±0.066	0.365 ±0.050	0.325 ±0.055	0.20 ±0.0489	0.2966 ±0.086
Nitrate	0.1096 ±0.026	0.0742 ±0.017	0.0941 ±0.028	0.0926 ±0.017	0.110 ±0.034	0.10078 ±0.038	0.1029 ±0.011	0.1046 ±0.004

Saxena and Chauhan, (1993) reported that pH was nearly neutral during monsoon which become alkaline during summer and winter in river Yamuna, Agra. Lower values of pH during the monsoon season in the all three ecosystem may be due to carrying heavy load of runoff and diluting water as collection sites do not seem to be polluted any appreciable source of pollution. However the higher value at site-I and III during summer may be attributed to increase utilization of CO_2 during photosynthesis as these sites are well infested with aquatic weeds. The site-II receives the domestic sewage from some part of the town Armori and therefore shows higher pH in winter season. Thus in the present observation the pH at all the sampling sites are alkaline throughout study period.

Transparency: In the present investigation at all the sites minimum transparency was recorded in the monsoon season which may be due to the large inflow of runoff and due to fine silt held in suspension. At site-I, the maximum transparency was observed during summer due to the settling of the fine silt, plankton growth and reduced level of water flow, whereas at site-II, the maximum transparency was observed during the winter season, i.e. in the month of January.Adebisi, (1981) from upper Ogun river reported that minimum of Secchi disc transparency occurs between August and October and water was most transparent in February and reported that fine silt held in the suspension when the water was lotic, was probably responsible for extremely low transparency in August and December, as soon as water turns lentic in January, it becomes relatively clearer. The gradual decrease in transparency after this transitional period of maximum transparency may be due to increase in plankton abundance in river Sokato. Datta *et al*., (1988) pointed out that high amount of sand and silt carried by the river during rainy seasons results with consequent decrease in transparency.

In the present investi- gation in all the ecosystem minimum transparency recorded during monsoon was due to large amount of silt being carried along with runoff and at site-I and III the maximum transparency during summer was due to settling of silt and suspended matter and low water level. Likewise at site-II, the maximum transparency during winter was due to low depth and shallow bed at the collection site.

TDS: In the present investigation higher values of TDS were recorded during the summer season at site-I and during monsoon at site-II and III where as minimum value were recorded during monsoon at site-I and during winter at site-II and III. Pande and Sharma, (1998) reported high values of TDS in summer and rainy season and low values during winter season in Ramganga River at Moradabad (UP). Sinha *et al*., (1989) reported the low values 212.50 mg/l in winter season and higher 526.33 mg/l in summer season in river Ganga at Kalakankar (Pratapgarh). In the present investi-gation maximum of TDS 640 mg/l was recorded in the month of April at site-I minimum of 60 mg/l; were recorded at site-II and III in the month of October and November respectively. Bansal, (1989) reported wide range of fluctuation in different in the range of 37 to 266 mg/l, minimum values were reported in June and maximum in December in river Betwa at Vidisha (MP). Sharma and Pande, (1998) reported low value of TDS in winter and high values during summer in Ramganga River at Moradabad. In the present investigation also the higher value of TDS were recorded during summer sat site-I which might be due to more rate of evaporation with consequent saturation of dissol-ved solids in water and less flow of water, whereas at site-II and III the more values of TDS during monsoon may be due to the high input of runoff containing the organic and waste from the habita-tion and also the runoff from the agriculture fields. However at site-II and III minimum value were recorded during winter month might be due to the sedimentation and dilution due to high value level and also due to the assimilation of carbonates and bicarbonates during winter. At site-I in contrast to above minimum TDS were recorded during monsoon season which might be due to flooding during monsoon months.

DO: In the present investigation the higher values of DO were recorded during winter at site-I and during summer at site-II and III whereas lower values were recorded during the monsoon at all the sites. Arvindkumar and Singh (2002) in the river Mayurakshi recorded high value of DO in winter season and reported to be due to its increased solubility with reduction in the water temperature. According to Biswas *et al*., (1975) large quantity of water in the river, dilute the organic matter, the organic matter from surface runoff, sewage discharge and domestic activities, and flooded river lowers the level of dissolved oxygen in the monsoon season. Zafar, (1991) reported higher concentration in winter and lower in summer. This trend was also reported by Bodola and Singh, (1981) in the river Alaknanda and Khanna, (1993) in the river Ganga. In the present investigation, the lower values were recorded during monsoon which might be due to high organic load carried with runoff and with their consequent decomposition, whereas higher values of DO in winter may be due to increased solubility of DO with fall in temperature at site-I and also due to increased photosynthetic activity of phytoplankton and macrophytes. Contrary to the above reports the higher value of DO was also recorded at site-II and III. This stretch of river (including collection site) is temporarily dammed during summer and water is stored for irrigating the agriculture field for the late varieties of paddy. As more water level with lentic conditions favour the phytoplankton and macrophytes growth and their enhanced photosynthetic activity may be responsible for higher values of DO at these sites during summer.

Free CO_2: In the present investigation minimum free CO_2 was observed at site-I during monsoon, at site-II during summer and at site-III in winter, however maximum value was recorded at site-I during winter and at site-II and III in the monsoon. At site-III the min. value was recorded in winter which may be attributed to enhanced CO_2 utilization through photosynthetic activity by phytoplankton and macrophytes, whereas higher values in monsoon may be due to agricultural runoff from the nearby agriculture fields (Koshy and Nayar, 1999).

At site-II the minimum free CO_2 level was recorded during summer which might be due to higher temperature and very low biodegradable material at the bottom, where as its higher value during monsoon may be due to high organic load from agriculture runoff and domestic wastes at site-I. The minimum free CO_2 was recorded during monsoon season which may be due to less biodegradable matter therein, whereas higher values in winter may be due to more photosynthetic activity by phytoplankton and macrophytes. Adebisi, (1981) recorded minimum CO_2 in monsoon season where as maximum during summer season in upper Orun river. Sinha *et al*., (1989) recorded minimum CO_2 in monsoon season and maximum in summer season in the river Ganga at Kalakankar. Shyamsunder, (1988) reported peak of CO_2 in summer months which might be due to accelerated rate of decomposition of organic matter by microbes in the bottom resulting in the rapid production of free CO_2.

Total Alkalinity: In the present investigation, at the site-I minimum values were recorded in July and maximum in December in the year 2006 and in the next year minimum was in July and maximum in June. At site-II minimum alkalinity was recorded in January and maximum in May in the year 2006 and minimum in August and maximum in June in the year 2007. At site-III the minimum alkalinity was in January and maximum in August in the year 2006 and minimum in January and maximum in September in the year 2007. Hukumat Rai, (1974) while studying the limnology of river Yamuna at Dehli reported that bicarbonate alkalinity was highest during summer and winter due to reduction of river flow and proportionately greater effect of sewage effluent outfalls. The Total alkalinity was low during monsoon and highest in the winter. Hannan *et al*., (1979) in Gaudalupe River in Texas reported the alkalinity values were influenced by inflow, photosynthesis and coincided with periods of increased flow during April, May, July, November, December and January and decreased in June and August during the time of peak by photosynthesis indicating that the decrease was caused by the photosynthetic utilization of bicarbonate by phytoplankton. In the present investigation the alkalinity was minimum similar to above reports in winter at site-II and III but at site-I it was minimum during the monsoon season minima at site-I might be due to dilution of pollutants with increased flow of water due to flooding, however seasonally maximum value is not uniform at all the sites under study. At site-I the seasonal maxima was observed during winter, which may be due to richness of salts in the water (carbonates and bicarbonates), excess of free CO_2 and so on. whereas at site-II, the seasonal maxima was recorded during summer due to reduction of flow of water and accumulation of large quantity of bicarbonates due to the excess production of free CO2 in the process of decomposition of bottom deposits, and at site-III, maximum value recorded during monsoon might be due to the runoff bringing more salts from the domestic wastes from the nearby village as well as from agriculture fields.

Total Hardness: In the present investigation at all sites, minimum values were recorded during winter and maximum, at site-I and II during summer and at site-III during monsoon. The monsoon maxima at site-III may be due to the runoff containing calcium and magnesium salts carried from surrounding catchment area and weathering of rocks due to heavy rainfall and summer maxima at site-I and II may be due to reduction in river flow with consequent concentration of water. The winter minima at all sites are due to the utilization of carbonate and bicarbonates by aquatic plants and due to sedimentation. Koshy and Nayar, (2000) reported that the hardness of water is mainly due to its calcium and magnesium salts and recorded the high values of hardness during post monsoon and pre-monsoon. Mohanta and Patra, (2000) reported seasonal fluctuation in hardness; minimum values were recorded during monsoon season and maximum during summer season. High values are probably due to regular addition of large quantities of sewage, detergents and large scale human use. Bansal, (1989) reported the minimum value of 62 mg/l to maximum of 184 mg/l in the river Betwa. Mishra and Tripathi, (2001) reported high value of 295 mg/l during monsoon season.

Calcium and Magnesium: From the table, it is evident that Ca and Mg ranged between 12 mg/l to 48.0 mg/l and 2.44 mg/l to 27.816 mg/l respectively, in the three ecosystems under study. Reginna and Nebi, (2003) recorded minimum calcium of 4.0 mg/l during the month of September and maximum of 46 mg/l during the month of June and magnesium with minimum of 4.0 mg/l during the month of July and maximum of 32.0 mg/l during the month of April in Bhavani River. Kulkarni *et al*., (2002) recorded the values of calcium ranging from 56.90 mg/l to 101.70 mg/l whereas magnesium ranged from 6.21 mg/l to

24.30 mg/l in the Khushawati River at Quepem, Goa. In the present investigation, from the table no. 4.7 to 4.9, it is clear that at site-I and III the maximum calcium was recorded during monsoon which may be due more leaching of calcium containing rocks during the rainy season and their subsequent entry into the ecosystem along the runoff from catchment area, however, at site-II the maximum calcium was recorded during summer which may be due to very less water accumulated in a little pool at a sampling site. The minimum values of calcium were recorded at site-I and III during the winter which may be due to its precipitation and utilization by the phytoplankton and at site-III during monsoon which may be due to dilution. As far as the magnesium is concerned the higher values are recorded during summer at site-I and during monsoon at site-II and III. The higher values at site-I may be due to the less flow of water whereas at site-II and III during monsoon may be due to leaching of magnesium bearing rocks in the catchment area. The lower values of magnesium were recorded at site-II and III during winter probably may be due to sedimentation and utilization by aquatic flora and at site-I during monsoon due to dilution during flooding.

BOD: In the present investigation the maximum values of BOD were recorded during summer season at site-I and III and during winter at site-II whereas minimum values were recorded during winter at site-I and III and during monsoon at site-II. higher BOD values in summer at site-I and III may be due to high organic load and reduced water flow whereas higher values during winter at site-II may also be due to decay of plant and animal matters in the river. The lower values during monsoon at site-II and during winter at site-I and III may be due to more flow of water which dilutes the organic pollutants and decreasing microbial activity due to low temperature in river water. This result is in conformity with Koshy and Nayar, (1999) in river Pamba. Pande and Sharma, (1998) in river Ramganga at Moradabad.

COD: In the present investigation minimum value of COD were recorded during the monsoon at site-II and III and during winter at site-I whereas maximum values were recorded at site-I and III during summer and during winter at site-II. Shah, (1988) reported minimum value of COD during April and maximum during December and stated that high values in winter were probably, as a result of death and decay of plants during winter with the consequent increase in organic matter. Dakshini and Soni, (1979) reported that domestic sewage and industrial waste mainly responsible for the increase in the chemical oxygen demand in river Yamuna. In the present investigation, the maximum value of COD was recorded at Site-I and site-III during the summer and may be due to reduced flow of water and due to domestic and agricultural discharge from nearby areas, however at site-II the maximum value was recorded during winter which may be due to the release of organic pollutants from domestic effluence and death and decay of plants with consequent increase of organic matter. At site-II and III the minimum values recorded during monsoon which might be due to dilution effect and the minimum values recorded during winter at site-I may also be due to dilution effect, as this site has been comparatively deeper containing more water in the winter.

Sulphate: In the present investigation, the maximum values of Sulphate were recorded at site-I and II during the summer and at site-III in the monsoon, and minimum values were recorded during winter at all the sites. Kulshresta *et al.*, (1992) reported maximum value of Sulphate during monsoon which they believed to be due to rain water bringing in high input of Sulphate from area in Manas sarovar reservoir, Bhopal (M.P.). Singh and Singh, (1990) reported maximum value during monsoon months due to municipal sewage in Subernarekha river at Ranchi, Bihar. Flushing of these ions into the river from surface runoff, during spring rains and decrease during dry period was also observed by Quadri and Shah (1984). In the present investigation the maximum value of Sulphate were recorded in summer at site-I and site-II and during monsoon at site-III whereas minimum values were recorded during winter at all the sites during the study. Monsoon maxima at site-III may be due to the rain water bringing high input of Sulphate from catchment area and input of agriculture runoff, however summer maxima at site-I and II may be due to high rate of evaporation and low flow of water where as minimum values at all the sites during winter may be due to high water level and sedimentation in the post monsoon period and also as all the sites do not receive any appreciable organic waste input by domestic or other sources.

Phosphate: In the present investigation maximum values of phosphates were recorded during the summer at all the collection sites and minimum during winter. Imevbore, (1978) recorded the phosphate content of flowing waters to change slightly from time to time, while that of stagnant waters is more or less constant. Prakasam and Johnson, (1992) reported maximum values of phosphate at all the stations due to discharge of domestic sewage and wastes. Tuzen *et al.*, (2002) observed that, the use of fertilizer and detergents are supposed to be responsible for the high concentration of this nutrient in the lotic ecosystem. In the present investigation the lower values were recorded during winter month may be due to rapid utilization by aquatic plants and also due to assimilation by phytoplankton while summer maxima may be due to low water level and inflow of agricultural runoff after paddy cultivation.

Nitrate: In the present investigation, minimum value of nitrate was recorded during monsoon months at all the three sampling sites, whereas maximum values were recorded during summer.

Kumar and Singh, (2002) reported high values of nitrate during rainy season due to influx of nitrogen rich flood water that brings large amount of contaminated sewage water. Similar findings were recorded by Badge and Verma, (1985). From the table, is evident that the site-III showed the lower values ranging from 0.0742 mg/l to 0.1103 mg/l while site-I and site-II between 0.1184 mg/l to 0.2037 and 0.1107 mg/l to 0.6504 mg/l respectively. Ray and David, (1966) recorded nitrate range from 5.7 to 7.3 mg/l in river Ganga at Kanpur, receiving city sewage. Pandit *et al.*, (1994) reported a value of 3.39 mg/l for river Damodar at Sundarghat receiving sewage. The highest value was recorded during monsoon season and lowest during summer. The highest value during monsoon may be attributed to heavy rain fall, land runoff, weathering of rocks and oxidation of ammonia form of nitrogen to nitrite and consequently to nitrate. The lowest value during summer may be attributed to utilization of it by the phytoplankton as evidenced by high photosynthetic activities. In the present investigation, minimum values of nitrates were recorded during monsoon season at all the three sampling sites. This may be due more quantity of water in the river diluting the runoff, and decrease activities of microbes during monsoon, however the summer maxima at all sites may be due to low water level and other anthropogenic activities.

CONCLUSION

Having a glimpse of values of physico-chemical characteristics such as BOD, COD, Nitrate, Phosphate, Alkalinity, DO, CO2 etc. all the three rivers have more or less similar ecological status. The region of the site-I and site-II are somewhat disturbed by the anthropogenic activities while site-III with less or undisturbed by the same. It is clear that all the three ecosystems under investigation are mildly polluted.

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