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Limnological Study of Asan Wetland in Relation to Water Quality in Doon Valley, Uttarakhand, India

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Abstract: Asan wetland is one of the biodiversity hotspot and ecologically sensitive habitat in Doon valley and this important Bird Area has been notified as an 'Asan Conservation Reserve' in Uttarakhand, India. Its water is used for drinking, irrigation, boating and recreation. In view of the above, an attempt was made to study certain limnological parameters to assess the nutrient status for its suitability from ecological point of view, drinking and irrigation purpose. The limnological parameters were seasonally examined following standard methods. Total 72 water samples were collected from eight sampling stations. Study revealed that most of the parameters were in the limit of standard except some parameters like BOD and COD (higher in monsoon season). NO_3^- and PO_4^{3-} were found higher which can cause eutrophication in the water body. The wetland water was found to be slightly alkaline (pH 7.6) except in monsoon season and moderately hard (122.4 mg/l). Physico-chemical parameters indicate prevalence of good quality of water except in monsoon season in Asan wetland.

Key words: Asan conservation reserve, nutrients, wetland.

Introduction

Water is the universal solvent and the most precious life giving liquid on this planet essential for the survival of every living organisms. Freshwater is an indispensible resource and essential for life; 97% of water on earth is marine (salt water), while only 3% is fresh water. With regard to the fresh water, 79% is stored in polar ice caps and mountain glaciers, 20% is stored in aquifer or soil moisture and 1% is surface water (primarily lakes and rivers) (Pepper et al., 2006).

Wetlands are important water resource and one of the most productive ecosystem and crucial for biodiversity conservation. Wetlands are also important components of watersheds and provide many valuable functions to the environment and to society (Mitsch and Gosselink, 1993, 1994) and cover 58.2 million hectares area in India (Anon, 2007). They provide functions and values like biodiversity, nutrient cycling, purification of water, flood control, groundwater recharge, support in maintaining waterfowl population and also provide breeding habitat for some bird species (Brenson et al., 1981).

Environmental conditions experienced by organisms in wetlands are largely a function of physical and chemical properties of water and the sources and amount of water entering. Contamination of water bodies might lead to change in their trophic status and render them unsuitable for aquaculture, as many species of wetland's flora and fauna show extreme sensitivity to deterioration in the quality of their environment (Manon, 2004). Several physico-chemical or biological factors could act as stress and can adversely affect growth and reproduction of aquatic organism (Iwama et al., 2000). Good quality water is described by its physical, chemical and microbial characteristics, but

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some correlation were possible among these parameters and the significant one would be useful in indicating the quality of water (Kamble et al., 2009). Asan wetland is considered as an important aquatic habitat for birds due to its high productivity and nutrient enrichment. So far in Asan wetland, numerous studies on avifauna have been done but there was scanty study in relation to water quality. Hence, present study has provided detailed information on physico-chemical parameters of the Asan wetland water from eight different sites with the aim to assess the seasonal fluctuation in water quality. The study will contribute to management of wetland ecosystem.

Materials and Methods

Study Area

Asan wetland is one of the biodiversity hotspots and ecologically sensitive habitat in Doon valley and this important bird area has been notified as an Asan Conservation Reserve by the Government of Uttarakhand, India (Figure 1). It is a manmade wetland of about 3.2 km^2 area, located on Dehradun-Ponta road of the state of Uttarakhand in North India and lies between latitude 3028′°24′-30°N and longitude 7744′°40′-77°E. Asan wetland came into being due to the construction of Asan barrage at the confluence of Asan river and Yamuna canal. Feeding water in the wetland comes from the Asan river which exists in Doon valley, surrounded by the Himalaya and from Yamuna canal which originates from Yamuna river. The barrage is 287.5 m long and the river bed being 389.4 m above sea level with the minimum and maximum of water level at 402.4 m and 403.3 m above sea level respectively. Climatically, summer temperature ranges from 14°C to 38°C, while the winter temperature ranges from 2°C to 21°C and average rainfall is 250 cm (South-west monsoon) during June to September. Although the water level is controlled, it often fluctuates and goes down; thus swampy islands become distinct and attracts a variety of marsh-loving water birds.

Sampling Procedure and Analysis

Land use, vegetation, canal and river network information around the wetland was used to select water sampling station. Water samples were collected at seasonal interval from eight sampling stations during January, 2014 to December, 2014 and covered different seasons viz. pre-monsoon (PRM), monsoon (MON) and post-monsoon (POM). For physico-chemical analysis, water samples were collected in polyethylene containers. Some parameters like temperature, pH and dissolved oxygen were measured on the site and the collected samples were brought to the laboratory for the estimation of various physico-chemical parameters as per the procedures given in standard methods (APHA, 1998, 2005).

Result and Discussion

The quality of natural water is generally governed by various physico-chemical parameters. Comparative seasonal variation in water characteristic of Asan Wetland is presented in Table 1. The maximum, minimum and average values of various water quality parameters and their comparison with BIS standards for drinking water quality is presented in Table 2.

Figure 1: Location map of study area. (*Source:* Google map)

Table 1: Seasonal variation in water characteristics of Asan wetland, 2014

S. No.	*Water characteristics*	*Pre-monsoon (Mar.-Jun.)*	*Monsoon (Jul.-Oct.)*	*Post-monsoon (Nov.-Feb.)*
1	Temperature (°C)	24.01	27.19	19.46
2	pH	7.39	6.72	7.89
3	Conductivity (μ mhos/cm.)	294.94	358.83	326.79
4	Total hardness (mg/l)	115.40	104.63	149.02
5	Ca-hardness (mg/l)	62.16	56.33	83.41
6	Mg-hardness (mg/l)	53.23	39.91	65.61
7	Total alkalinity (mg/l)	132.56	113.55	142.79
8	DO (mg/l)	7.60	5.53	9.49
9	Chloride (mg/l)	57.31	71.34	58.58
10	Nitrate (mg/l)	0.85	1.09	1.72
11	Phosphate (mg/l)	0.13	0.12	0.06
12	Sulphate (mg/l)	14.49	15.50	14.74
13	Ca^{+2} (mg/l)	24.89	22.56	33.41
14	Mg^{+2} (mg/l)	12.94	9.70	15.94
15	Na^{+} (mg/l)	4.77	7.01	4.38
16	K^{+} (mg/l)	1.43	4.15	1.53
17	Free CO_2 (mg/l)	10.86	21.01	16.91
18	COD (mg/l)	7.06	26.31	10.00
19	BOD (mg/l)	2.56	8.46	3.14
20	TDS (mg/l)	198.94	238.03	159.12

The reported values refer to the mean value for various parameters of water samples. The seasonal variation of water quality parameters during the study is shown in Figure 2. The summary of the findings are given below.

Temperature

Temperature ranged from 16.55°C (post-monsoon) to 30.75°C (pre-monsoon) during study (Table 2). On seasonal basis average highest value was observed in monsoon and lowest in post-monsoon. Annual mean temperature was 23.56 ± 4.192°C, which shows the optimum range for growth of aquatic fauna and flora (Tables 1 and 2). This result agrees with the observation of Swaranlatha and Rai (1998) in Banjara Lake. Atmospheric temperature changes with change in seasons, results correspondingly change in the water temperature. It is found that seasonal fluctuation in wetland temperature is related to ambient temperature (Figures 2 and 3a).

pH

The pH value in samples were within the permissible level of 6.5 to 8.5, and it ranged from 6.43 (monsoon) to 8.5 (post-monsoon) (Table 2). On seasonal basis mean value of pH was observed to be highest in post-monsoon and lowest during monsoon, with annual mean value of 7.36 ± 0.605 (Tables 1, 2 and Figure 2).

Changes in the pH of water may be the result of various biological activities (Gupta et al., 1996). If the water body is neither highly alkaline nor highly acidic, the pH of water is generally governed by the carbon dioxide, bicarbonate, carbonate system (Hutchinson, 1975). In the present study, seasonal pH value was observed above the neutral scale (alkaline) which might be attributed by water level, concentration of CO_2, density of phytoplankton and increased dissolved oxygen level. The increasing acidic nature during rainy season is possibly due to higher concentration of CO_2, resulted into the formation of H_2CO_3, and NO_3^-, K^+, Cl^-, SO_4^{-2} and from addition of anthropogenic pollution (Figure 3b). The value of free CO_2 was found within the range of WHO standard.

Electric Conductivity and TDS

Electrical conductivity (EC) value ranged from 185.13 µmhos/cm (post-monsoon) to 402.83 µmhos/cm (pre-

Table 2: Comparison of water quality parameter with BIS standard for drinking water quality

Parameters	*Max.*	*Min.*	*Average*	*SD*	*WHO/BIS permissible limits (IS 10500: 1991)*
Temperature (°C)	30.75	16.55	23.56	4.192	30-35 (WHO)
pH	8.50	6.43	7.36	0.605	6.5-8.5
Conductivity (µmhos/cm)	402.83	212.13	323.42	64.745	750 (WHO)
Total hardness (mg/l)	190.67	71.67	122.44	36.365	300-600
Ca-hardness (mg/l)	170.21	38.06	67.91	27.428	100 (WHO)
Mg-hardness (mg/l)	82.87	20.45	51.67	18.203	-
Total alkalinity (mg/l)	191.33	75	127.23	34.712	200-600
DO (mg/l)	10.30	4.76	7.62	1.713	-
Chloride (mg/l)	80.94	42.56	61.98	10.336	250-1000
Nitrate (mg/l)	3.04	0.58	1.30	0.718	45-100
Phosphate (mg/l)	0.57	0.00	0.105	0.122	0.3 (WHO)
Sulphate (mg/l)	18.93	10.22	14.91	2.092	200-400
Ca^{+2} (mg/l)	68.17	15.24	27.19	10.984	75-200
Mg^{+2} (mg/l)	20.14	4.97	12.56	4.423	30-100
Na^{+} (mg/l)	13.13	1.87	5.28	3.545	-
K^{+} (mg/l)	4.60	0.83	2.35	1.370	-
Free CO_2 (mg/l)	24.20	9.53	16.37	4.840	22 (WHO)
COD (mg/l)	33.00	3.00	15.46	9.821	10 (WHO)
BOD (mg/l)	10.13	1.33	4.89	2.959	6 (WHO)
TDS (mg/l)	271.23	124.52	195.33	47.652	1000 (WHO)

SD – standard deviation

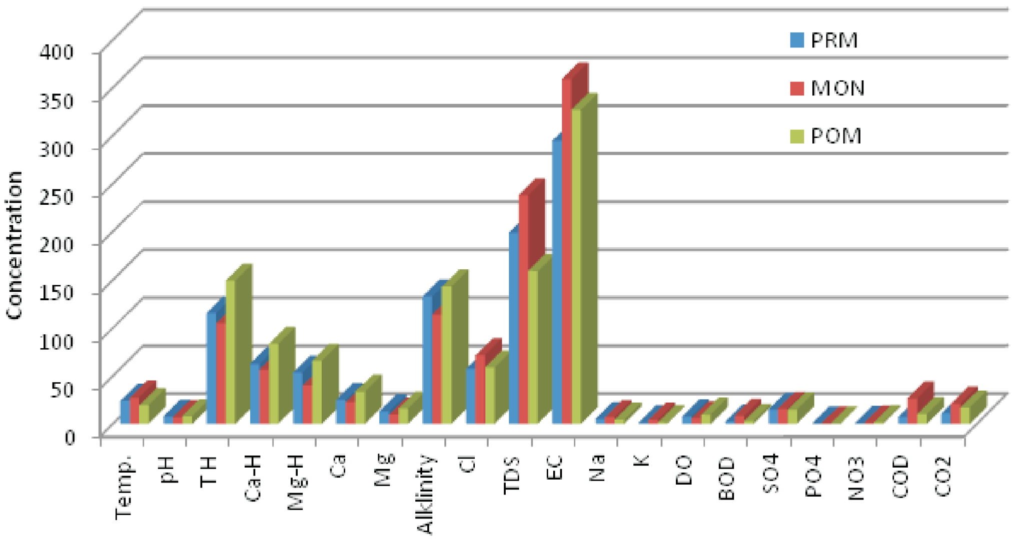

Figure 2: Seasonal variation of water quality parameter averaged over three seasons of year 2014.

monsoon) in water samples (Table 2). On seasonal basis, value was found high during monsoon followed by pre-monsoon and low during post-monsoon. Values showed marked seasonal variation (Figure 3d), while the annual mean concentration was recorded as 291.11 ± 73.04 µmhos/cm (Table 1 and Figure 2).

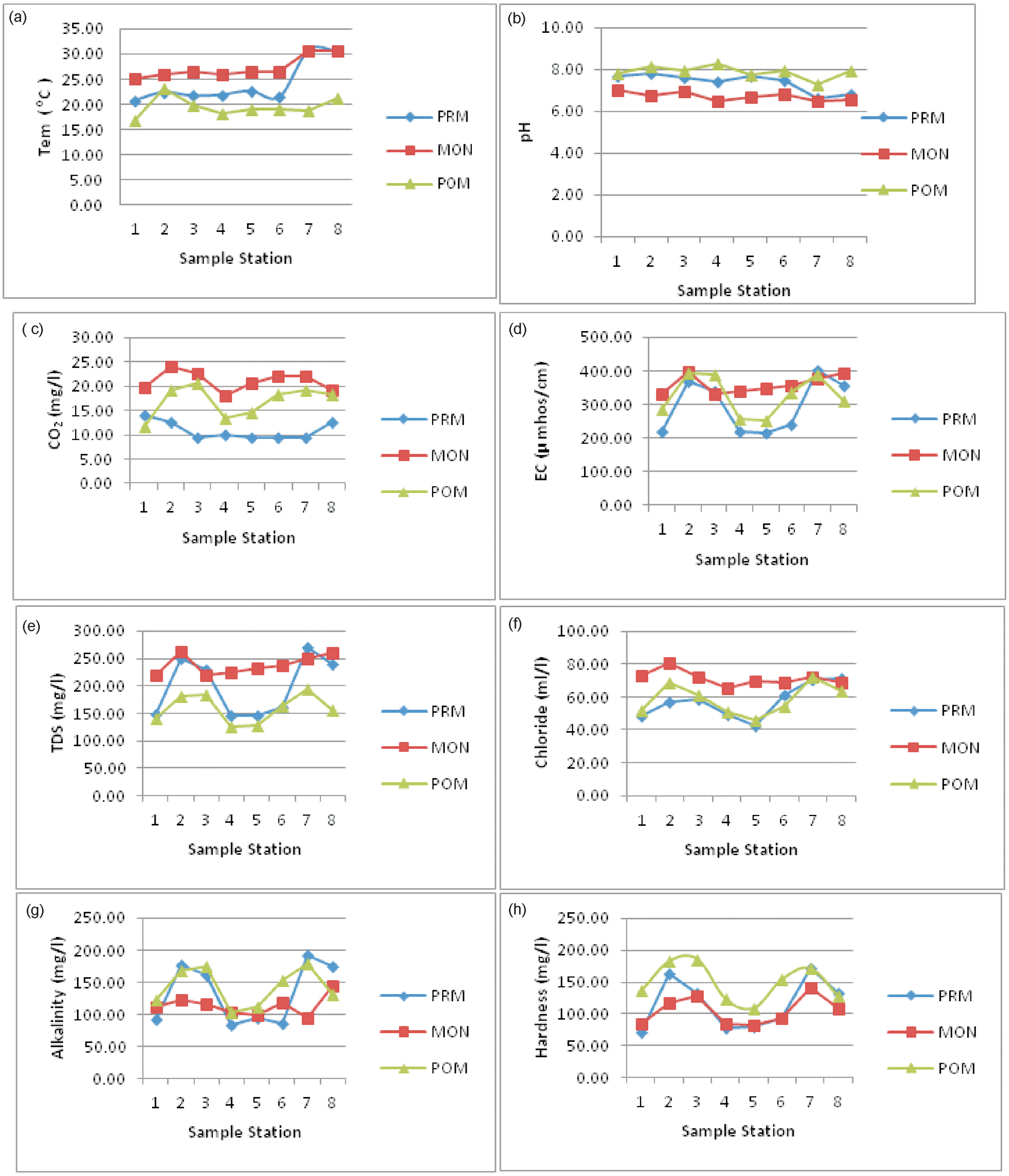

Figure 3 (a-h): Seasonal variation in concentration of water quality parameters in sampling stations of Asan Wetland.

TDS was found to fluctuate between 124.52 mg/l (post-monsoon) and 271.24 mg/l (pre-monsoon) as shown in Table 2. Seasonally, mean concentration was observed higher in monsoon and lower in post-monsoon period with an annual average value of 195.33 ± 47.652 mg/l (Table 1 and Figure 2).

The higher value of electric conductivity and TDS was observed during rainy season, associated with inflow of suspended impurities and ions from the mounting erosion, weathering and anthropogenic sources in catchment areas of wetland. Our results are supported by the report of Plass (1975) according to which, lake receiving direct runoff from watershed contains significant amounts of mineral precipitates that increase conductivity. Johnson (1988) also observed that TDS proportionately enhanced the electrical

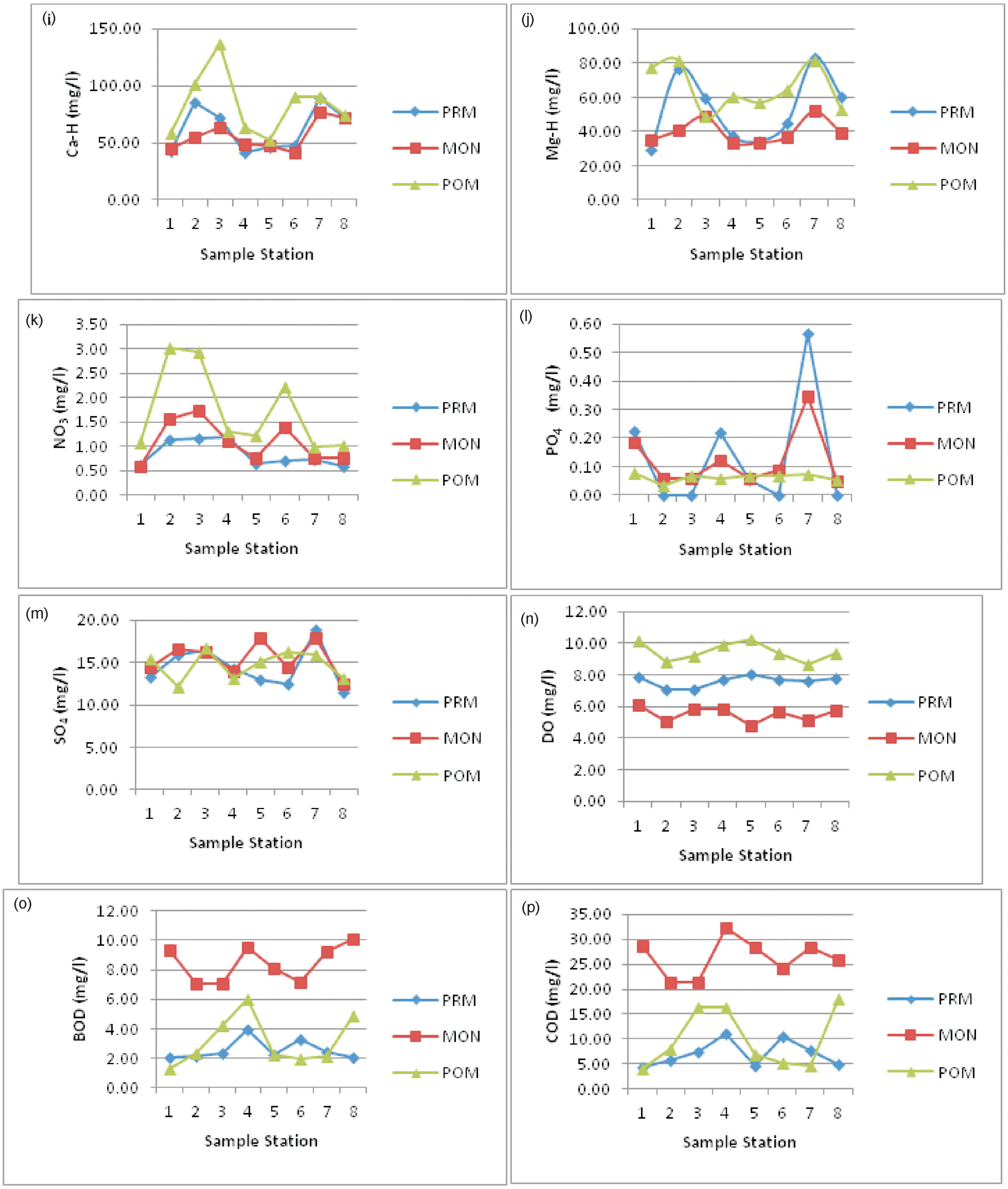

Figure 3 (i-p): Seasonal variation in concentration of water quality parameters in sampling stations of Asan Wetland.

conductance in water and ran parallel to each other (Figures 2 and 3e). The values of TDS and EC in study were observed in the limit of Bureau of Indian Standard (BIS) of drinking water quality.

Chloride

The chloride is found widely distributed in nature in salt form of sodium, potassium and calcium. The chloride concentration ranged from 42.56 mg/l (pre-monsoon) to 80.94 (monsoon) during study (Table 2). Seasonally, Cl^- content was found high in monsoon and low in pre-monsoon. The annual mean value was recorded as 61.98 ± 10.336 mg/l (Table 1 and Figure 2).

Higher value of chloride was during monsoon season which may be due to run off from surrounding catchment area and from anthropogenic sources like improper disposal of sewage, effluents and from drainage (Figure 3f). Excess of chloride over 5.5 mg/l in water was associated with contamination from animal organic matter (Khulbe, 1992; Jain et al., 1999). The National River Water Quality (NRWQ) standard ranges from 45 to 155 mg/l. In the present study the chloride values were found within the range of NRWQ standard and also in the limit of BIS standards of drinking water quality.

Total Alkalinity

Total alkalinity (TA) of water samples was recorded between 191.33 and 75 mg/l in pre-monsoon (Table 2). The mean seasonal concentration was found higher in post-monsoon and lower in monsoon, while the annual average was noticed as 127.23 ± 34.712 mg/l (Table 1 and Figure 2).

In the present study TA values showed variation with different seasons and in different sites (Figure 3g). Venkateswarlu (1969) and Michael (1969) attributed that there is an indication to suggest that alkalinity concentration is affected directly by rainfall. Higher TA in post-monsoon and pre-monsoon may be attributed to increased rate of decomposition, high photosynthetic rate and lower alkalinity in monsoon may be due to dilution of water. In the present investigation, all the values of alkalinity were found within the permissible limit BIS for drinking water quality.

Hardness

Total hardness (TH) was recorded between 71.67 mg/l (pre-monsoon) and 190.66 mg/l (post-monsoon) in the water samples (Table 2). Lower values for TH, Ca-hardness (Ca-H) and Mg-hardness (Mg-H) were recorded during monsoon and higher during post-monsoon. While annual mean value for TH was observed as 122.44 ± 36.365 mg/l, 67.91 ± 27.428 mg/l for Ca-H and 51.67 ± 18.203 mg/l for Mg-H in the study (Table 1 and Figure 2). Ca-H content ranged from 170.21 (post-monsoon) to 38.06 mg/l (pre-monsoon) in the wetland. Mg-H was observed between 82.87 (pre-monsoon) to 20.45 mg/l (post-monsoon) during the study (Table 2).

In the present study annual data indicates that the wetland water is moderately hard (Figures 3h to 3j). Hard water is believed to be more productive than the soft waters (Barrett, 1957). Higher hardness may be due to the weathering of carbonate rocks, limestone, dolomite and sandstone dominated in Himalayan and Shivalik river basin. Anthropogenic sources also contribute in the hardness of wetland water. Lower hardness in monsoon may be due to high precipitation. Water is often categorized according to degree of hardness as follows: 0-75 mg/l = soft, 75-150 mg/l = moderately hard, 150-300 mg/l = hard, above 300 mg/l = very hard (WHO). Since calcium and magnesium bond with carbonates and bicarbonates, alkalinity and water hardness are closely interrelated and produce similar measured levels in study.

Nitrate-nitrogen (NO_3^--N)

The nitrate level ranged from 3.04 (post-monsoon) to 0.58 mg/l (pre-monsoon) during the study (Table 2). The seasonal data was recorded as 0.85 mg/l in pre-monsoon, 1.09 mg/l in monsoon and 1.72 mg/l in post-monsoon, with annual concentration of 1.30 ± 0.718 mg/l (Table 1 and Figure 2). Nitrate amount did not vary significantly during the seasonal changes.

Study revealed that annual nitrate content was lower, which might be due to its utilization by phytoplankton and macrophytes. Though nitrate was in lower concentration, they were found somewhat higher during post-monsoon (Figure 3k). Similar findings have been made by Kaur et al. (1997). Although NO_3^- was below the permissible limit of BIS standard for drinking water quality but value was found higher than the value set for eutrophication (0.015 mg/l) by Sawyer (1947).

Phosphate (PO_4^{-3})

In the present study, phosphate content ranged from 0.00 to 0.57 mg/l in pre-monsoon (Table 2). Seasonally PO_4^{-3} value varied as 0.13 mg/l in pre-monsoon, 0.12 mg/l in monsoon and 0.06 mg/l in post-monsoon season, while the annual average was observed as 0.105 ± 0.122 mg/l (Table 1 and Figure 2).

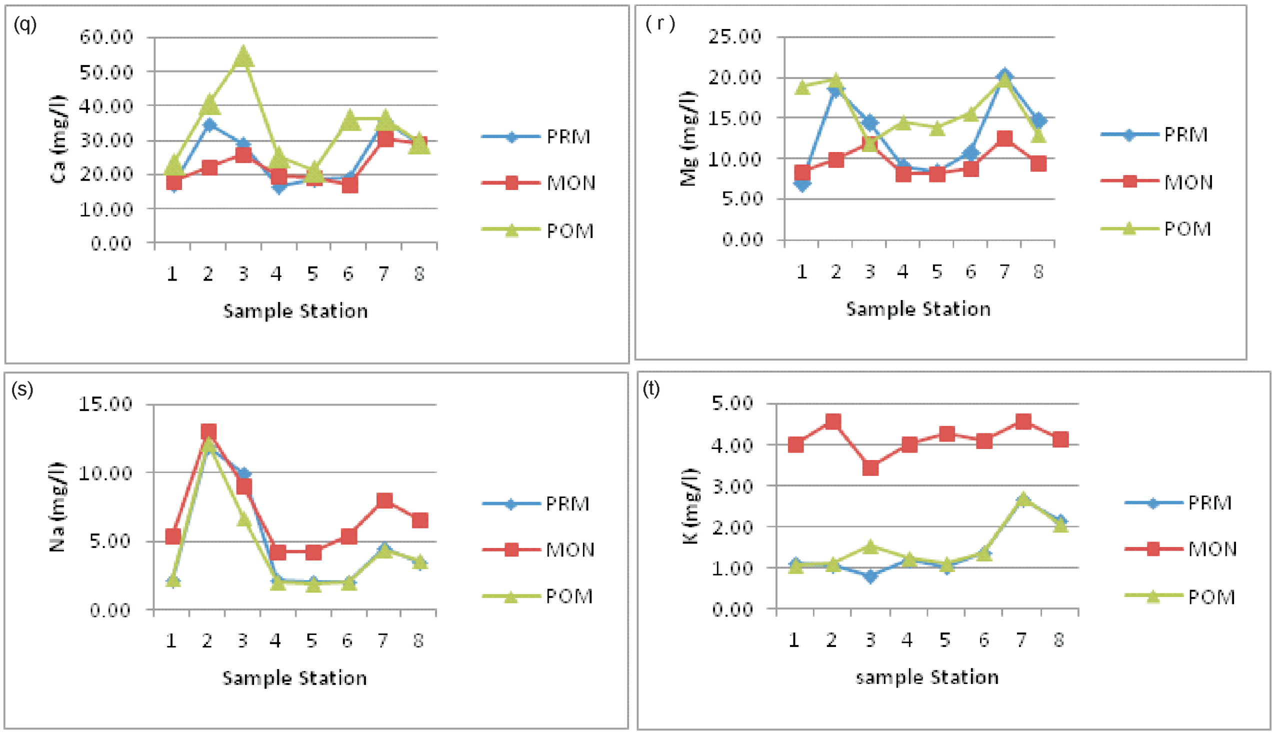

Figure 3 (q-t): Seasonal variation in concentration of water quality parameters in sampling stations of Asan Wetland.

The higher values of phosphate were recorded at disturbed sites as compared to undisturbed sites during monsoon and pre-monsoon season (Figure 3l), which might be due to anthropogenic activities and rain drainage with the nutrient-rich soil deposits from the catchment areas of wetland. Several workers (Vollenweiders, 1968; Carlson, 1977; Anon, 1986) have considered a value of >10 µg/l of PO_4^{-3} as indicative of eutrophication. In the present water body, phosphate concentration (0.105 ± 0.122 mg/l) was recorded higher than this critical limit of eutrophication. Both nitrate and phosphate ions were found within the permissible limit of BIS and WHO standards.

Sulphate (SO_4^{-2})

The sulphate concentration varied from 18.93 (pre-monsoon) to 10.22 mg/l (post-monsoon) in the study area (Table 2). Seasonally average value varied as 14.49 mg/l in pre-monsoon, 15.50 mg/l in monsoon and 14.74 mg/l in post-monsoon season. The annual mean value was recorded as 14.91 ± 2.092 mg/l (Table 1 and Figure 2).

In the present study, sulphate concentrations were observed to be almost constant during different seasons (Figure 3m). Sources of SO_4^{-2} in the wetland are possibly due to weathering of gypsum bearing carbonate rock, limestone, dolomite rock and leaching either from dissolution of gypsum or from oxidation of pyrite or from anthropogenic sources. Sulphate concentration was found within the limit of BIS standard of drinking.

Dissolved Oxygen (DO)

DO play an important role in aquatic environment and is essential for growth and productivity of aquatic organism. It is considered important factor that reflect the biological activity. DO value ranged from 10.30 (post-monsoon) to 4.76 mg/l (monsoon) in the present investigation (Table 2). The mean seasonal concentration was noticed higher in post-monsoon and lower in monsoon, while the yearly average was observed as 7.62 ± 1.713 mg/l (Table 1 and Figure 2). Nature of variation of DO is almost inversely related to that of seasonal variation of temperature, BOD and COD during study (Figure 3n). The lower value of DO during pre-monsoon and monsoon may be attributed to high temperature due to which the oxygen holding capacity of water decrease and excessive use by bacteria, phytoplankton and algae.

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

BOD varied between 10.13 mg/l (monsoon) to 1.33 mg/l (post-monsoon) in the wetland (Table 2). Higher seasonal value was found in monsoon and lower in pre-monsoon, with an annual concentration of 4.89 ± 2,959 mg/l (Table 1 and Figure 2). However, COD varied from 4.00 mg/l (post-monsoon) to 33.00 mg/l (monsoon) in study (Table 2). Seasonally, higher value was found in monsoon and lower value in pre-monsoon, whereas the annual value was observed as 15.46 ± 9.82 mg/l (Table 1 and Figure 2).

BOD is a widely accepted parameter in determining water quality and an important indicator of water pollution level. In the present study, BOD concentration was noticed higher during monsoon and lower in pre-monsoon as well as in post-monsoon (Figure 3o). Similar findings were also observed for COD value (Figure 3p). The maximum value of COD and BOD in monsoon indicates the higher degree of pollution associated with rain runoff, compared to other seasons. The COD of water increases with increasing concentration of organic matter (Boyd, 1981).

Calcium, Magnesium, Sodium and Potassium

In aquatic environment, calcium serves as one of the micronutrients for most of the organisms. Calcium concentration varied between 68.17 mg/l (post-monsoon) and 15.24 mg/l (Pre-monsoon) in present study (Table 2). Magnesium is essential for chlorophyll, growth and acts as a limiting factor for the growth of phytoplankton (Dagaonkar and Saksena, 1992). Mg^{+2} content ranged between 20.14 mg/l (pre-monsoon) and 4.97 mg/l (post-monsoon) in present investigation (Table 2). Ca^{+2} and Mg^{+2} content showed high value in post-monsoon and low in monsoon in the wetland (Table 1 and Figure 2). Concentration of calcium was found greater than that of magnesium as also observed by Venkatasubramani and Meenambal (2007). Calcium ions make the major contribution to the hardness although magnesium also contributes in present study. In Asan wetland the calcium and magnesium values were found to be in desirable limit of BIS standard (Table 2).

Na^+ content varied between 13.13 mg/l (monsoon) and 1.87 mg/l (post-monsoon) in water samples of Asan wetland (Table 2). K^+ ion ranged from 4.60 mg/l (monsoon) to 0.83 mg/l (pre-monsoon) during the study (Table 2). Seasonally, high value was found in monsoon for both Na^+ and K^+ contents (Table 1 and Figure 2). Yearly average value for Na^+ ion was 5.28 ± 3.545 mg/l and for K^+ ion, 2.35 ± 1.370 mg/l (Table 1 and Figure 2). Sodium was found to have higher values than potassium throughout the study; it may be due to high solubility of sodium than most of cations. Sedimentation and utilization of potassium by biota caused decrease in its content (Garg et al., 2006a and b).

Conclusion

The abovesaid study revealed that the parameters such as temperature, pH, EC, total hardness, Ca-Hardness, alkalinity, chloride, nitrate, sulphate, calcium, magnesium and TDS of Asan wetland water are under permissible limit of BIS and WHO standard for drinking water quality. However, the parameters like BOD, COD and free carbon dioxide crossed the permissible limit of WHO standard during comparative seasonal study which were observed to be higher in monsoon. Water chemistry of Asan wetland is attributed by carbonate weathering from Himalayan region and also affected due to pollutant discharge from anthropogenic sources near the catchment.

The study elicits that water quality of Asan wetland is of the good quality for irrigation and aquaculture purposes. Water is also suitable for drinking, followed by the conventional treatments and disinfection except in monsoon season, although there is a need for continuous monitoring on sewerage discharge and waste disposal in feeding water sources to maintain and improve the quality of water. It is utmost needed to protect the wetland, from ecological, socio-economic and aesthetic point of view.

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