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IMPACT OF ANTHROPOGENIC ACTIVITIES ON PHYSICO-CHEMICAL PROPERTIES OF SEDIMENT OF HOKERSAR WETLAND: A PROTECTED WILDLIFE RESERVE (RAMSAR SITE NO.1570) OF KASHMIR HIMALAYA

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Abstract

Impact of anthropogenic activities on physico-chemical properties of sediment of Hokersar wetland was carried in summer, spring and autumn seasons. Sediment at Inlet site was having higher value for physico-chemical parameters *viz*; EC (0.509 dS/m), available nitrogen (109.86 mg/kg), available potassium (89.97 mg/kg), available phosphorus (10.18 mg/kg), Ca (352.53 mg/kg) and Mg (152.44 mg/kg) except pH which was highest (7.99) at Outlet. The values of all the physico-chemical parameters of sediment were found maximum in summer season and minimum in autumn except for pH which was higher (7.81) in autumn and lower in (7.16) in summer. Highest values for Fe (23.90 mg/kg), Mn (8.54 mg/kg), Cu (3.65 mg/kg) and Zn (2.77 mg/kg) in sediment were found at Inlet site and lowest values for Fe (11.82 mg/kg), Mn (3.52 mg/kg), Cu (0.97 mg/kg) and Zn (1.14 mg/kg) at outlet site. Further, these trace elements were observed in higher concentration during summer season as compared to autumn. This all may be due to the high rate of degradation of huge quantities of waste present in the Wetland.

Introduction

A wetland is a land area that is saturated with water, either permanently or seasonally, such that it takes the characteristics of a distinct ecosystem (Butler 2010). Wetlands play a number of roles in the environment, principally water purification, flood control, carbon sink and shore line stability. Wetlands have also been described as ecotones, providing a transition between dry land and water bodies. Some of the major wetlands in the world are Pantanal (Brazil, Bolivia and Paraguay), Camargue (France), Wasur National Park (Indonesia) and Kakadu wetlands (Australia).The wetland resources of India are estimated at 58.2 million hectare. The valley of Kashmir harbors a chain of wetlands occupying an area more than 7,000 hectares. Since the Kashmir valley wetlands are of great importance as biodiversity resources, waterfowl habitats have a great educational and research value (Prasad *et al.* 2002). There are nine wetlands in Kashmir, some of them are Hokersar, Mirgund, Shalbugh, Hygam and Narkara. Hokersar Wetland provides habitat and feeding ground for large number of migratory water fowl during winter that migrate from Siberia and the Central Asian region. But now from so many years it is losing this significant property. The threatened species in wetlands need special attention (Pandit *et al.*2007). Study by Khan *et al.* (2004) on the macrophyte community in relation to environmental stresses of Hokersar wetland reserves probably is the only long-term study carried out so far. The study indicates a shift in macrophyte community structure. The wetland has reduced from 1875.04 ha in 1969 to 1300 Ha in 2008 due to encroachments by farmers, sediment load carried by Doodh River

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and extension of willow plantations (Bano *et al.* 2021). The wetland is bordered by urban habitations on the northern side along the Srinagar-Baramulla highway. All kinds of waste generated by the people are dumped in the Wetland (Bano *et al*. 2018). These changes in composition and structure of wetland have affected its normal functioning and deteriorated its water and sediment quality (Romshoo and Rashid 2012). Thus the present study was aimed to study effects of anthropogenic activities on physico-chemical properties of sediment of Hakersar wetland.

Materials and Methods

Hokersar Wetland (34°06′N latitude, 74°05′E longitude) is situated in the Northern most part of Doodh Ganga catchment at an altitude of 1,584 m (amsl). It is a protected wildlife reserve area under control of the Directorate of Wildlife Protection and on 08/11/05 it was declared as a Ramsar site no.1570.. The wetland is fed by two inlet streams Doodh Ganga (from east) and Sukhnag Nalla (from west) (Pandit and Qadri 1990). It is a multi-basined wetland with inlet and outlet. It is differentiated into three varied zones, marshy and exposed area extending from north to north west, central deeper area, south eastern side covering most of the silted area. The North-Eastern zone comprises of diverse and dense macrophytic species. The central deep area is largely a free expanse of water. The marshy zone of the wetland and the open waters provide an efficient habitat to the migratory birds. Southern silted up portion acts as pasture land.

The present research work was conducted from 2018 to 2019 at Sheri- Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar (J & K).. For the study, the wetland was divided into four different sampling sites. The sampling sites were selected on the basis of inlet source of water, agricultural inputs, macrophyte abundance, and population pressure and outlet system of water in the wetland. The sampling sites were divided into four locations *viz*., I- Inlet location (the entry site of Doodh Ganga into the wetland near Hanjikh, the most polluted site, II- Outlet (Control site, near Sozieth), III- Centre (in the middle of the wetland near Soibugh) and IV- *Trapa* abundance site.

Sediment samples from selected sites were taken to laboratory, dried in shade, processed and stored at ambient room temperature. Standard methods were used foranalyzing physicochemical (pH, EC, N, P, K Ca, Mg, Zn, Fe, Cu, Mn) characteristics of sediment.The pH and Electrical conductivity of soil were determined according to Jackson (1973). Soil available nitrogen was determined by potassium permanganate method (Subbiah and Asija (1956). Available phosphorus by extracting phosphorus with 0.5M $NaHCO_3$ (Olsen *et al*. 1954). Available P (ppm) = concentration obtained from calibration curve × Dilution factorThe available potassium was extracted by ammonium acetate method (Jackson 1973) and determined with the help of flame photometer.

Available calcium and magnesium of soil were estimated by AAS from the extract developed during potassium extraction. The estimation of heavy metals like Fe, Mn, Zn and Cu was done by using the method outlined by Lindsay and Norvell (1978) using DTPA (Diethylene Triamine Penta Acetic Acid) extraction method with the help of atomic absorption spectrophotometer.

Results and Discussion

During spring season, the highest mean sediment pH (8.08 ± 0.009) was recorded in Outlet followed by *Trapa* abundance site (7.70 ± 0.005) and lowest in Inlet (7.18 ± 0.007). In summer, the maximum mean sediment pH (7.95 ± 0.004) was observed in Outlet followed by Centre (7.07 ± 0.004) and minimum (6.75 ± 0.002) in Inlet site. In autumn, the highest mean sediment pH was recorded in Outlet (7.94 ± 0.001) followed by Centre (7.90 ± 0.004) and minimum (7.59 ± 0.001) in *Trapa* abundance site. The overall site-wise highest mean sediment pH (7.99) was recorded in Outlet and lowest (7.38) in Inlet. However with respect to seasons highest mean sediment pH (7.81) was recorded during autumn followed by spring (7.63) and least (7.16) in summer season (Table 1). All sites and seasons were statistically significant from each other with respect to sediment pH. pH functions as a good indication of chemical nature of sediment and affect the

Table 1.Seasonal variation in Physico-chemical properties of sediment/soil in Hokersar Wetland.

Parameters	Seasons	Sites				Mean	C.D ($p \leq 0.05$)
		Inlet	Centre	Trapa abun-dance site	Outlet		
pH	Spring	7.18±0.007	7.58±0.006	7.70±0.005	8.08±0.009	7.63	Seasons(S): 0.043
	summer	6.75±0.002	7.07±0.004	6.88±0.003	7.95±0.004	7.16	Sites(S):0.050
	Autumn	7.82±0.003	7.90±0.004	7.59±0.001	7.94±0.001	7.81	Seasons ×Sites:0.086
	Mean	7.38	7.40	7.39	7.99		
Electrical conductivity (dS/m)	Spring	0.405±0.002	0.381±0.001	0.369±0.003	0.319±0.002	0.368	Seasons(S):0.017
	summer	0.797±0.001	0.491±0.004	0.473±0.008	0.446±0.006	0.552	Sites (S):0.020
	Autumn	0.326±0.002	0.263±0.003	0.227±0.001	0.139±0.002	0.239	Seasons ×Sites: 0.034
	Mean	0.509	0.374	0.361	0.301		
Nitrogen (mg/kg)	Spring	107.31±0.035	96.86±0.117	91.56±0.030	82.45±0.041	94.54	Seasons(S):0.395
	summer	119.62±0.027	102.76±0.077	96.25±0.095	92.41±0.090	102.76	Sites (S): 0.456
	Autumn	102.66±0.075	91.81±0.093	82.97±0.073	74.37±0.052	87.95	Seasons ×Sites:0.786
	Mean	109.86	97.14	90.26	83.07		
Phosphorus (mg/kg)	Spring	9.68±0.027	6.03±0.084	5.14±0.043	3.78±0.012	6.16	Seasons(S):0.255
	summer	13.98±0.400	9.88±0.001	8.89±0.002	7.70±0.001	10.11	Sites (S): 0.294
	Autumn	6.87±0.002	4.69±0.002	5.00±0.128	3.13±0.004	4.92	Seasons × Sites:
	Mean	10.18	6.87	6.34	4.87		0.510
Potassium (1×10^4mg/kg)	Spring	94.16±0.178	80.06±0.267	75.91±0.150	68.80±0.636	79.73	Seasons(S):0.514
	summer	98.73±0.412	84.66±0.237	78.46±0.618	73.58±0.138	83.86	Sites (S): 0.593
	Autumn	77.03±0.139	69.07±0.102	64.82±0.116	62.70±0.135	68.40	Seasons ×
	Mean	89.97	77.93	73.06	68.36		Sites:1.027
Magnesium	Spring	156.68±0.029	111.75±0.008	108.75±0.001	56.82±0.052	108.50	Seasons(S): 0.112
	summer	179.70±0.017	132.72±0.015	127.72±0.015	78.96±0.001	129.77	Sites (S): 0.129
	Autumn	120.96±0.001	90.42±0.002	84.95±0.004	43.96±0.008	85.07	Seasons ×Sites: 0.244
	Mean	152.44	111.63	107.14	59.91		
Calcium	Spring	342.87±0.002	181.72±0.004	179.80±0.001	126.87±0.002	207.81	Seasons(S):0.185
	summer	432.75±0.008	179.62±0.004	168.93±0.008	139.97±0.002	230.32	Sites (S):0.213
	Autumn	287.97±0.131	138.67±0.015	125.72±0.021	119.76±0.011	168.03	Seasons × Sites:
	Mean	354.53	166.67	158.15	128.87		0.370
Iron	Spring	25.04±0.004	13.97±0.001	12.66±0.002	9.75±0.006	15.35	Seasons(S):0.117
	Summer	35.85±0.003	33.95±0.005	29.48±0.007	16.97±0.010	29.06	Sites (S) :0.135
	Autumn	10.82±0.003	13.93±0.002	11.61±0.009	8.75±0.008	11.27	Seasons ×
	Mean	23.90	20.61	11.82	17.91		Sites: 0.234
Manganese	Spring	7.87±0.022	5.84±0.032	3.88±0.003	3.76±0.001	5.33	Seasons(S):0.339
	summer	11.93±0.007	8.68±0.019	8.13±0.043	3.95±0.005	8.17	Sites (S) :0.391
	Autumn	5.81±0.052	3.85±0.019	3.34±0.006	2.84±0.003	3.96	Seasons ×
	Mean	8.54	6.12	5.11	3.52		Sites:0.678
Copper	Spring	3.81±0.008	2.14±0.002	0.91±0.004	0.71±0.008	1.89	Seasons(S):0.110
	summer	6.89±0.004	4.98±0.001	2.77±0.005	1.72±0.001	4.09	Sites (S) :0.127
	Autumn	0.89±0.007	0.98±0.014	0.77±0.001	0.47±0.002	0.77	Seasons ×
	Mean	3.65	2.70	1.48	0.97		Sites : 0.221
zinc	Spring	2.82±0.006	2.21±0.004	1.48±0.004	0.95±0.001	1.86	Seasons(S):0.103
	Summer	4.07±0.005	1.86±0.008	1.27±0.001	1.96±0.002	2.29	Sites (S) :0.118
	Autumn	1.97±0.001	0.93±0.002	0.67±0.004	0.76±0.001	1.08	Seasons ×
	Mean	2.77	1.66	1.14	1.22		Sites: 0.205

mineralization and determines the soil fertility. pH influences the exchange of nutrients between water and sediment. In the present study pH varied significantly from 7.16 to 7.81 in three different seasons. Lower mean pH value recorded at Inlet may be attributed to the release of organic acids through decomposition of organic matter. In the present study high mean sediment pH was recorded during autumn and low mean values during summer season (Table 1). It might be due to the leaching process of exchangeable cations from the surrounding areas of the wetlands. Moreover the slightly low mean pH of the wetland may be due to the entrance of fresh water and dilution effects of rainwater into the aquatic ecosystems. Similar observations were reported by Latif *et al.* (1989) and Marathe *et al.* (2011).

During spring season, the highest mean electrical conductivity (0.405 ± 0.002 dS/m) was recorded in Inlet followed by Centre (0.381 ± 0.001 dS/m) and minimum (0.319 ± 0.002 dS/m) in Outlet. In summer, the highest mean sediment EC (0.797 ± 0.001 dS/m) was recorded in Inlet followed by Centre (0.491 ± 0.004 dS/m) and lowest (0.446 ± 0.006 dS/m) in Outlet. In autumn the maximum mean EC (0.326 ± 0.002 dS/m) was recorded in Inlet followed by Centre (0.263 ± 0.003 dS/m) and minimum (0.139±0.002 dS/m) in Outlet. The overall site-wise mean EC was observed highest (0.509 dS/m) in Inlet and lowest (0.301 dS/m) in Outlet. However with respect to seasons highest mean electrical conductivity (0.552 dS/m) was recorded during summer followed by spring (0.369 dS/m) and least (0.239 dS/m) in autumn season. All seasons and sites were statistically significant from each other with respect to electrical conductivity and interaction between sites × seasons was also found to be significant (Table 1).The mean electrical conductivity of Hokersar Wetland varied significantly from 0.239 to 0.552 dS/m. The highest sediment mean EC concentration (0.509 dS/m) was recorded at Inlet and lowest (0.301 dS/m) at Outlet. The higher mean EC at Inlet resulted from the fact that the wetland serves as a sink for different ion species and high level of EC recorded at Inlet site could be related to the intense human activities at the site. The maximum mean EC was recorded in summer (0.552 dS/m) followed by spring (0.368 dS/m) and lowest (0.239 dS/m) in autumn (Table 1). The higher mean EC in summer may be because of high temperature and high decomposition rate. Similar findings had also been reported by Saraswat *et al.* (2005) and Essien *et al.* (2009). pH and EC showed highly positive correlation with each other.

The maximum mean available nitrogen content (107.31 ± 0.035 mg/kg) was recorded in Inlet followed by Centre (96.86 ± 0.117 mg/kg) and least (82.45 ± 0.041 mg/kg) in Outlet during spring season ((Table 1). In summer the highest mean sediment available nitrogen content (119.62 ± 0.027 mg/kg) was recorded at Inlet followed by Centre (102.76 ± 0.077 mg/kg) and lowest (92.41 ± 0.090 mg/kg) at Outlet. In autumn, the maximum mean available nitrogen content (102.66 ± 0.075 mg/kg) was recorded at Inlet followed by Centre (91.81 ± 0.093 mg/kg) and least (74.37 ± 0.052 mg/kg) at Outlet. The site-wise highest mean available nitrogen content (109.86 mg/kg) was recorded at Inlet and lowest (83.07 mg/kg) at Outlet. However with respect to seasons highest mean available nitrogen content (102.76 mg/kg) was recorded during summer followed by spring (94.54 mg/kg) and least (87.95 mg/kg) in autumn season. All sites and seasons were statistically significant from each other with respect to available nitrogen content and interaction between sites × seasons was also found to be significant. Mean available nitrogen content varied from 87.95 to 12.76 mg/kg in three seasons and the maximum mean available nitrogen was recorded at Inlet and lowest at Outlet (Table 1). The higher mean nitrogen concentration at Inlet might be due to the higher waste water inputs from agricultural run-off, commercial and residential settlements. However, with respect to seasons higher mean available nitrogen content recorded during summer may be due to the oxidation of dead plant organic matter which settled on top layer. The low nitrogen levels observed during autumn may be ascribed to the slow rate of decomposition due to the low temperature. Similar findings have been reported by Krusement *et al.* (2000) Jeelani and

Shah (2006) and Rusu *et al.* 2012). Phosphorus is one among the chief nutrients in an aquatic environment. The capacity of sediment to retain or release phosphorus is one of the important factors, which influence the concentration of inorganic and organic phosphorus in the overlying waters. Much of the phosphorus in the soil is not available to plants as it is influenced by soil pH reactions. In the present study mean available phosphorus content varied significantly from 4.92 to 10.11 mg/kg. The highest mean value of phosphorus in sediment was recorded at Inlet and lowest near Outlet (Table 1). Discharge and subsequent sedimentation of suspended particulates from phosphate fertilizers and domestic wastes discharged into the wetland as a result of rainfall might have contributed to the increase in sediment phosphate contents at Inlet. Results in this study were consistent with those reported by Neal *et al.* (1999) and Rusu *et al.* (2012). Moreover high value of phosphorus during summer was due to the application of large quantities of synthetic fertilizers, commercial activities and domestic sewage (Krusement *et al.* 2000).

The maximum mean available phosphorus content (9.68 ± 0.027 mg/kg) was recorded at Inlet followed by Centre (6.03 ± 0.084 mg/kg) and least (3.78 ± 0.012 mg/kg) at Outlet during spring season (Table 1). In summer, the highest mean sediment available phosphorus content (13.98 ± 0.400 mg/kg)was recorded at Inlet followed by Centre (9.88 ± 0.001 mg/kg) and lowest (7.70 ± 0.001 mg/kg) at Outlet. In autumn, the maximum mean available phosphorus (6.87 ± 0.001 mg/kg) was recorded at Inlet followed by ***Trapa*** abundance site (5.00 ± 0.128 mg/kg) and least (3.13 ± 0.004 mg/kg) at Outlet. The site-wise highest mean available phosphorus content (10.18 mg/kg) was recorded at Inlet and lowest (4.87 mg/kg) at Outlet. However with respect to seasons highest mean available phosphorus content (10.11 mg/kg) was recorded during summer followed by spring (6.16 mg/kg) and least (4.92 mg/kg) in autumn season. All sites and seasons were statistically significant from each other with respect to available phosphorus content and interaction between sites × seasons was also found to be significant. Phosphorus is one among the chief nutrients in an aquatic environment. The capacity of sediment to retain or release phosphorus is one of the important factors, which influence the concentration of inorganic and organic phosphorus in the overlying waters. Much of the phosphorus in the soil is not available to plants as it is influenced by soil pH reactions. In the present study mean available phosphorus content varied significantly from 4.92 to 10.11 mg/kg. The highest mean value of phosphorus in sediment was recorded at Inlet and lowest near Outlet. Discharge and subsequent sedimentation of suspended particulates from phosphate fertilizers and domestic wastes discharged into the wetland as a result of rainfall might have contributed to the increase in sediment phosphate contents at Inlet. Results in this study were consistent with those reported by Neal *et al.* (1999) and Rusu *et al.* (2012). Moreover high value of phosphorus during summer was due to the application of large quantities of synthetic fertilizers, commercial activities and domestic sewage (Krusement *et al.* 2000).

The maximum mean available potassium content (94.16 ± 0.178 mg/kg) was recorded at Inlet followed by Centre (80.06 ± 0.267 mg/kg) and least (68.80 ± 0.636 mg/kg) at Outlet during spring season (Table 1). In summer, the highest mean available potassium content (98.73 ± 0.412 mg/kg) was recorded at Inlet followed by Centre (84.66 ± 0.237 mg/kg) and lowest (73.58 ± 0.138 mg/kg) at Outlet. In autumn, the maximum mean available potassium content (77.03 ± 0.139 mg/kg) was observed at Inlet followed by Centre (69.07 ± 0.102 mg/kg) and least (62.70 ± 0.135 mg/kg) at Outlet. The site-wise highest mean available potassium content (89.97 mg/kg) was recorded at Inlet and lowest (89.97 mg/kg) at Outlet. However with respect to seasons highest mean available potassium content (83.86 mg/kg) was recorded during summer followed by spring (79.73 mg/kg) and least (68.40 mg/kg) in autumn season All sites, seasons and their interaction was statistically significant from each other with respect to available potassium content. Potassium is an essential plant nutrient and plays a role in a wide range of physiological processes, from regulation of the stomata to enzyme activation. Potassium availability to plants in general is governed by different forms of K *viz.*, water soluble K, exchangeable K, fixed K and mineral K. Plants utilize not only the readily available K but also the non-exchangeable and mineral K during the crop growth. The potassium availability to plants is determined by the rate of change in the dynamic equilibrium between different forms of K in the soil which in turn is controlled by the mineral make up, rate of weathering and exchange properties of the soil. In the present study mean available potassium content in Hokersar Wetland ranged from 68.40 to 83.86 mg/kg (Table 1). Higher level of K was seen at Inlet and lower at Outlet during the entire study period. This may be attributed to the high discharge of effluents, domestic waste and agricultural output. The findings are in agreement with studies of Rusu *et al.* (2012). The increased mean potassium concentration during summer is due to the disposal of waste, discharge of untreated waste water and fertilizer output. These findings coincide with results reported by Malla and Totawat (2006), Ramesh and Ramesh *et al.* (2013) and Siraj *et al.* (2010).

The maximum mean magnesium content (156.68 ± 0.029 mg/kg) was recorded at Inlet followed by Centre (111.75 ± 0.008 mg/kg) and least (56.82 ± 0.052 mg/kg) at Outlet during spring season (Table 1). In summer, the highest sediment mean magnesium content (179.70 ± 0.017 mg/kg) was recorded at Inlet followed by Centre (132.72 ± 0.015 mg/kg) and lowest (78.96 ± 0.001 mg/kg) at Outlet. In autumn, the maximum mean magnesium content (120.96 ± 0.001 mg/kg) was observed at Inlet followed by Centre (90.42 ± 0.002 mg/kg) and least (43.96 ± 0.008 mg/kg) at Outlet. The site-wise highest mean magnesium content (152.44 mg/kg) was recorded at Inlet and lowest (59.91 mg/kg) at Outlet. However with respect to seasons highest mean magnesium content (129.77 mg/kg) was recorded during summer followed by spring (108.50 mg/kg) and least (85.07 mg/kg) in autumn season the mean magnesium content of sites and seasons was statistically significant from each other. In the present study Mg content varied from 85.07 to 129.77 mg/kg in three different seasons (Table 1). The higher value of Mg was reported at Inlet site compared to Outlet. The influx of pollution load in the form of domestic sewage, agricultural run-off could be reasons of high accumulation of Mg near Inlet. The highest concentration of Mg was found in summer followed by spring and least in autumn. The high concentration of Mg in sediment is associated with input of household waste, commercial residue and agricultural run-off. The results are in conformity with findings reported by Okbah and Hussein (2006); Bhuiyan and Gupta (2007) and Eid *et al.* (2010).

The maximum mean calcium content (342.87 ± 0.002 mg/kg) was recorded at Inlet followed by Centre (181.72 ± 0.004 mg/kg) and least (126.87 ± 0.002 mg/kg) was recorded at Outlet during spring season (Table 1). Highest mean calcium content (432.75 ± 0.008 mg/kg) was observed at Inlet followed by Centre (179.62 ± 0.004 mg/kg) and minimum (139.97 ± 0.002 mg/kg) at Outlet in summer season. In autumn, the maximum mean calcium content (287.97 ± 0.131 mg/kg) was found at Inlet followed by Centre (138.67 ± 0.15 mg/kg) and least (119.76 ± 0.011 mg/kg) at Outlet. The site-wise highest mean calcium content (354.53 mg/kg) was recorded at Inlet and lowest (128.87 mg/kg) at Outlet. However with respect to seasons highest mean calcium content (230.32 mg/kg) was recorded during summer followed by spring (207.81 mg/kg) and least (168.03 mg/kg) during autumn season. All sites and seasons were statistically significant from each other with respect to calcium content and their interaction was also found to be significant.

The mean concentration of Ca in Hokersar Wetland during the entire study period ranged from 168.03 to 230.32 mg/kg (Table 1). Calcium was having positive correlation with pH. Maximum concentration of Ca was observed at Inlet site, this may be attributed to the discharge of domestic sewage, agricultural runoff, weathering of bedrocks, household waste and dumping of solid waste. Similar findings are reported by Okbah and Hussein (2006), Shaltout and Khalil

(2005) and Eid *et al.* 2010. The highest mean concentration of Ca was observed in summer (230 mg/kg) followed by spring (207.81 mg/kg) and lowest (168.03 mg/kg) in autumn. Decrease in the volume of source water in Hokersar, least agricultural activities could be the reason of lower calcium values during autumn. The results are in accordance with the findings reported by Eid *et al.* (2010) and Okbah (2005). There was a positive correlation between calcium and magnesium as well (Table 2). The maximum mean iron content (25.04 ± 0.004 mg/kg) was recorded at Inlet followed by Centre (13.97 ± 0.001 mg/kg) and least (9.75 ± 0.002 mg/kg) at Outlet during spring season (Table 1). Maximum mean iron content was observed maximum (35.85 ± 0.003 mg/kg) at Inlet followed by Centre (33.95 ± 0.005 mg/kg) and minimum (16.97 ± 0.010 mg/kg) at Outlet in summer. In autumn, the maximum mean iron content (10.82 ± 0.003 mg/kg) was observed at Inlet followed by Centre (13.93 ± 0.002 mg/kg) and least (8.75 ± 0.008 mg/kg) at Outlet. The site-wise highest mean iron content (23.90 mg/kg) was recorded at Inlet and lowest (11.82 mg/kg) at Outlet. However with respect to seasons highest mean iron content (29.06 mg/kg) was recorded during summer followed by spring (15.35 mg/kg) and least (11.27 mg/kg) in autumn season. All sites and seasons were statistically significant from each other with respect to iron content and interaction between sites × seasons was also found to be significant. The mean concentration of Fe in sediment was found significantly varied between 11.27 and 29.06 mg/kg (Table 1). The highest concentration of Fe was found at Inlet due to the high anthropogenic activities, domestic waste and dumping of dead animals. Rather *et al.* (2022) also reported significantly higher values of Fe and while studying the impact of anthropogenic pressure on physico-chemical characteristics of forest soils of Kashmir Himalaya. Furthermore, the highest mean concentration of Fe was detected in summer (29.06 mg/kg) followed by spring (15.35 mg/kg) and least (11.27 mg/kg) in autumn. This could be because of the weathering of rocks due to high volume of water currents during summer season. The current results are in concordance with Bargagli (2000) who studied that metal and metal compounds are natural constituents of an ecosystem, moving between atmosphere, hydrosphere, lithosphere and biosphere. Iron showed positive correlation with all other elements except calcium (Table 2).

Table 2.Correlation between available nutrients of sediment/soil of Hokersar Wetland.

	pH	EC	N	P	K	Mg	Ca	Fe	Mn	Cu
EC	-0.755**									
N	-0.731**	0.852**								
P	-0.857**	0.921**	0.915**							
K	-0.808**	0.838*	0.920**	0.912**						
Mg	-0.847**	0.797**	0.956**	0.895**	0.934**					
Ca	-0.616*	0.712**	0.885**	0.797**	0.876**	0.857**				
Fe	-0.605*	0.794**	0.689*	0.846**	0.709**	0.592*	0.522			
Mn	-0.912**	0.879**	0.899**	0.947**	0.904**	0.906**	0.796**	0.739**		
Cu	-739**	0.868**	0.812**	0.914**	0.854**	0.750**	0.710**	0.939**	0.875**	
Zn	-0.607*	0.794**	0.876**	0.863**	0.873**	0.777**	0.872**	0.754**	0.827**	0.868**

*p<0.05 and **p<0.01.Where, EC= Electrical conductivity.

During spring, the maximum mean manganese content (7.87 ± 0.022 mg/kg) was recorded at Inlet followed by Centre (5.84 ± 0.032 mg/kg) and least (3.76 ± 0.001 mg/kg) at Outlet. Maximum mean manganese content (11.93 ± 0.007 mg/kg) was recorded at Inlet followed by Centre (8.68 ± 0.019 mg/kg) and minimum (3.95 ± 0.015 mg/kg) at Outlet during summer season (Table 1). In autumn, the maximum mean manganese content (5.81 ± 0.052 mg/kg) was found at Inlet followed by Centre (3.85 ± 0.019 mg/kg) at and least (3.34 ± 0.003 mg/kg) at Outlet. The site-wise highest mean manganese content (8.54 mg/kg) was recorded at Inlet and lowest (3.52 mg/kg) at Outlet. However with respect to seasons highest mean manganese content (8.17 mg/kg) was recorded during summer followed by spring (5.33 mg/kg) and least (3.96 mg/kg) in autumn season. All sites and seasons were statistically significant from each other with respect to manganese content and interaction between sites × seasons was also found to be significant. Manganese, a naturally occurring element found in rock, soil and water and crustal rock is a major source of Mn to the sediment and water. Mn content fluctuated from 5.33 to 8.17 mg/kg in sediment of Hokersar Wetland during different seasons (Table 1).The highest concentration of Mn was reported at Inlet site and least at Outlet site. The higher mean Mn content is mainly because of the natural contributions from sediment and use of fertilizers. Similar results were reported by Gupta *et al.* (1980) and Fonseca *et al.* (2007). The highest mean Mn content was reported highest in summer (8.17 mg/kg) followed by spring (5.33 mg/kg) and lowest (3.96 mg/kg) in autumn. Weathering of rocks and application of fertilizers and pesticides in agricultural fields may be the possible reasons of high value of Mn during summer (Giblin. 2009).Manganese showed positive correlation with all elements (Table 2).

The maximum mean copper content (3.81 ± 0.008 mg/kg) was recorded at Inlet followed by Centre (2.14 ± 0.002 mg/kg) and least (0.71 ± 0.008 mg/kg) at Outlet during spring (Table 1). Maximum mean copper content was observed (6.89 ± 0.004 mg/kg) at Inlet followed by Centre (4.98 ± 0.001 mg/kg) and minimum (2.77 ± 0.004 mg/kg) at Outlet during summer. In autumn, the maximum mean copper content (0.89 ± 0.007 mg/kg) was found at Inlet followed by Centre (0.98 ± 0.014 mg/kg) and least (0.47 ± 0.002 mg/kg) at Outlet. The site-wise highest mean copper content (3.65 mg/kg) was recorded at Inlet and lowest (1.48 mg/kg) at Outlet. However with respect to seasons highest mean copper content (4.09 mg/kg) was recorded during summer followed by spring (1.89 mg/kg) and least (0.77 mg/kg) in autumn season. Copper recorded at all sites and seasons was statistically significant from each other. The interaction between sites × seasons was also found to be significant. The mean concentration of Cu was found ranged from 0.77 to 14.09 mg/kg in three seasons. Highest mean Cu concentration was recorded at Inlet site and lowest at Outlet. This may be due to the highest pollution load from household sewage, agricultural inputs and weathering of rocks at the particular site entering the wetland. Trace metals enter in to the water bodies due to human activities (Saeed and Shaker. 2008). However, the highest mean Cu concentration was detected in summer (4.09 mg/kg) followed by spring (1.89 mg/kg) and lowest (0.77 mg/kg) in autumn (Table 1) It may be attributed to the maximum agricultural activities, weathering of rocks and high rate of decomposition and washing of vehicles during the summer season. The findings are in agreement with Zahran *et al.* (2015). Cupper showed positive correlation with all elements (Table 2).

The maximum mean zinc content (2.82 ± 0.006 mg/kg) was recorded at Inlet followed by Centre (2.21 ± 0.004 mg/kg) and least (0.95 ± 0.001 mg/kg) at Outlet during spring season (Table 1). Maximum mean zinc content (4.07 ± 0.005 mg/kg) was observed at Inlet followed by Centre (1.96 ± 0.008 mg/kg) and minimum (1.27 ± 0.002 mg/kg) at Outlet in summer. In autumn, the mean maximum zinc content (1.97 ± 0.001 mg/kg) was found at Inlet followed by Centre (0.93 ± 0.002 mg/kg) and least (0.67 ± 0.001 mg/kg) at Outlet. The site-wise highest mean zinc content (2.77 mg/kg) was recorded at Inlet and lowest (1.14 mg/kg) at Outlet. However with respect to seasons highest mean zinc content (2.29 mg/kg) was recorded during summer followed by spring (1.86 mg/kg) and least (1.08 mg/kg) during autumn season. The mean zinc content of sites and seasons was statistically significant from each other. The interaction between sites × seasons was also found to be significant. The mean concentration of Zn was found significantly fluctuated between 1.08 to 2.29 mg/kg during all the seasons (Table 1). The highest value of Zn was reported at Inlet site compared to other sites. Domestic sewage, washing of vehicles, dumping of hospital wastes lead to the higher values of Zn at Inlet site. Pollutants which are released from these sources are transported into the lake and finally accumulated into the sediment (Chen *et al*. 2007 and Simiyu and Tole, 2013) Furthermore, highest mean Zn content was seen during summer (2.29 mg/kg) followed by spring (1.86 mg/kg) and least in autumn (1.08 mg/kg). Zinc showed positive correlation with all elements (Table 2).

It may be concluded from the study that the physico-chemical parameters and elemental load was highest at Inlet followed by Centre then Trap abundance site and least was observed at Outlet, which could be attributed to enhanced anthropogenic activities and subsequent setting down of pollutants in sediment. The ever-increasing pace of urbanization has completely changed the natural set ups that have managed the functioning of ecosystems for hundreds of years (Dervash *et al.* 2018). So it can be suggested that management of wetland is very important as it endow with a variety of repairmen mechanisms naturally and behave as biofilters. Complete dryness of wetland needs to be avoided. Human encroachments and siltation have combined with natural processes to reduce the area of open water within the wetland. Various measures proposed for the conservation of the wetland include afforestation, control of grazing in the catchment area and installation of a sewage treatment system etc.

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