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LAKE LITTORAL WATER CHEMISTRY--AN INDICATOR OF CATCHMENT LAND USE: A CASE STUDY OF LAKE NILNAG IN KASHMIR HIMALAYA

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ABSTRACT

In the present study, the prospects of using littoral water chemistry to assess the catchment land use and sources of diffuse pollution was studied. Lake Nilnag situated at a distance of about 50km to the south of Srinag. . city, Kashmir in the foothills of the Pir Panjal range of Himalayan mountains at an altitude of 2180m a.s.l. and having an area of about 6.3hectares has a distinct difference in the land use in the immediate catchment. On north and northwestern side the land is under mixed agriculture and horticulture with interspersed forest and settlement patches while on the south and southeastern side, the pine forest is intact. Ten study sites each were selected on either of these sides in the littoral zone. Water sampling was conducted 1m inside from the waterline in the Lake during July, August and September 2006 and using standard methodology different physical and chemical parameters of water were analysed.

Highly significant differences were obtained for parameters pH, conductivity, acid neutralizing capacity, calcium, sodium, NH_4-N, NO_3-N, soluble reactive phosphorus, turbidity, dissolved organic carbon, sulphate, dissolved silica and total iron of littoral water of lake Nilnag toward forest side and agriculture side. These results clearly indicate that the littoral water chemistry acts as a good indicator of the catchment land use and influence of diffuse sources of pollution underlining the importance of monitoring littoral water chemistry for tracking diffuse sources of pollutants for better management of lakes.

Key words: Littoral water chemistry, catchment, land use, diffuse sources of pollution

INTRODUCTION

The littoral region is an interface zone between the land of the drainage basin and the open water of lakes. A number of workers have called attention to the importance of nutrients from the drainage basin in regulating metabolism in lakes. This gives an insight, what is commonly accepted now, that the lake ecosystem consists of the lake and its entire drainage basin (Wetzel, 2001).Water laden with inorganic and organic substances flows from higher elevations to the recipient lake basin both in ground and surface water. Chemical and biological reactions occur enroute that selectively modify the quality and quantity of nutrients and organic substances entering the lake. Surface flows often pass through the wetland-littoral complex and can further selectively lose or gain inorganic and organic compounds before reaching the open water (Wetzel, 2001). The activities on both nearby and more remote land areas in the drainage basin of lakes determine the features of lake shores (their vegetation, slopes etc.) and of water (the quantity and quality) (Pandit, 2002). In lakes of Kashmir Himalaya, the diffuse sources of pollutants have been recognized as a major threat to the lake ecosystems.

A number of studies worldwide have been oriented towards understanding elemental dynamics and quantifying diffuse sources of pollutants in catchments (Borman *et al*., 1969; Likens *et al*., 1970; Thomas and crutchfield, 1974; Omernik, 1976; Burton, *et al*., 1977). It is in this backdrop that the present study was carried out to assess whether the littoral water chemistry reflects the land use in the catchments of lakes.

STUDY AREA

Lake Nilnag is situated at a distance of about 50km to the south of Srinagar city, Kashmir in the foothills of the Pir Panjal range of Himalayan mountains at an altitude of 2180m a.s.l. The lake having an area of about 6.3 hectares (Yousuf *et al*., 1986) has a distinct difference in the land use in the immediate catchment. On north and northwestern side, the land is under mixed agriculture and horticulture with interspersed forest and settlement patches while on the south and southeastern side, the pine forest is intact. Given this dichotomy ten study sites each were selected on either of these sides in the littoral zone of the Lake (Figure 1).

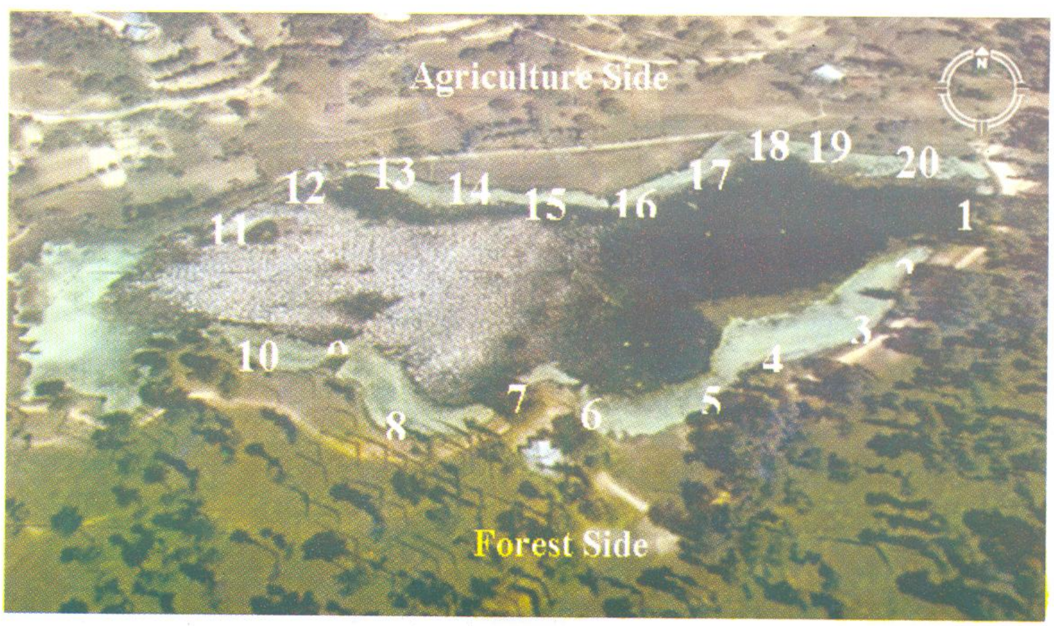

Figure 1. Lake Nilnag showing the location of study sites (source: http://earth.google.com)

MATERIAL AND METHODS

Water samples were collected between 10 a.m. and 1p.m., one metre inside from the waterline in the lake, in high density polyethylene bottles of one litre capacity. These were kept in dark at low temperature and carried to the laboratory for further processing. Sampling was conducted during July, August and September of 2006 and average values were obtained. The methods used for the analysis of different parameters are:

- pH by electrometric method (APHA, 1998)
- Conductivity by using digital conductivity meter (APHA, 1998)
- Acid neutralizing capacity by titration method (APHA, 1998)
- Chloride by argentometric titration method (APHA, 1998)
- Calcium and magnesium by EDTA titrimetric method (APHA, 1998)
- Sodium and potassium by flame emission photometric method (APHA, 1998)
- Dissolved oxygen by iodometric azide modification method (APHA, 1998)
- Ammonium nitrogen by phenate spectrophotometric method (Wetzel and Likens, 2000).
- Nitrate nitrogen by modified salicylate method (Yang *et al.*, 1998)
- Nitrite nitrogen by diazotization spectrophotometric method (APHA, 1998)
- Soluble reactive phosphate-phosphorus by ascorbic acid spectrophotometric method (Wetzel and Likens, 2000)
- Total phosphate-phosphorus by ascorbic acid spectrophotometric method after digestion by a combination of suphuric acid and nitric acid (APHA, 1998; Wetzel and Likens, 2000)
- Turbidity by nephelometric method (APHA, 1998)
- Dissolved organic carbon by spectrophotometric method (Collier, 1987)
- Sulphate by turbidimetric spectrophotometric method (APHA, 1998)
- Dissolved silica by molybdate blue spectrophotometric method (Wetzel and Likens, 2000)
- Total iron by phenanthroline method (APHA, 1998)

RESULTS AND DISCUSSION

Intensive agriculture uses contribute bio-available nutrients from chemical fertilizers and livestock waste (Clausen and Meals, 1989) as well as toxic synthetic organics, salts and metals to lakes (Wong, 1985). Several studies have shown that land use has a strong influence on river chemistry (Peierls *et al.*, 1991; Hunsaker and Levine, 1995; Pucket, 1995; Howarth *et al.*, 1996; Allan *et al.*, 1997). Strong relationships between land use and nutrient concentrations or export have been observed for phosphorus and nitrogen (Peterjohn and Correll, 1984; Lowrance *et al.*, 1985; Osborn and Wiley, 1988). Increased export of nitrite+nitrate and orthophosphate has been observed in predominantly agricultural and urban catchments compared with forested catchments (Omernik, 1976).

The data obtained in the present study shows a distinct influence of catchment land use on the water chemistry of the littoral zone in Lake Nilnag (Tables 1, 2 and 3 and Figure 2). The lower pH of water toward the forest side is a direct influence of the pine forest whose soils usually have an acidic pH (Brandtberg *et al.*, 2000; Sanborn, 2001). Higher values for nitrite-nitrogen and sodium may be because of the influence of lower pH toward forest side. Higher dissolved oxygen concentration toward forest side may be attributed to the lower demand by organisms and because of the shade effect of forest canopy keeping the water comparatively cooler. The higher values for ANC, calcium, potassium, ammonium-nitrogen, nitrate-nitrogen, soluble reactive phosphate-phosphorus, total phosphate-phosphorus, dissolved organic carbon, suphate, dissolved silica, total iron, conductivity and turbidity towards the agriculture side as compared to the forest side is a clear evidence of the direct influence of agricultural activities on the lake littoral water chemistry.

Highly significant differences have been obtained for parameters pH, conductivity, acid neutralizing capacity, calcium, sodium, ammonium-nitrogen, nitrate-nitrogen, soluble reactive phosphorus, turbidity, dissolved organic carbon, sulphate, dissolved silica and total iron of littoral water of lake Nilnag toward forest side and agriculture side (Table 3).

able 1 Average values of physical and chemical characteristics of littoral water on forest side of Lake Nilnag

Parameter	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8	Site-9	Site-10
pH	7.47	7.33	7.41	7.34	7.25	7.54	7.37	7.41	7.38	7.39
Conductivity μScm^{-1}	203	194	200	194	192	197	190	196	190	193
Acid Neutralising Capacity mgL^{-1}	156	144	152	144	142	146	138	146	138	142
Chloride mgL^{-1}	9	8	9	7	7	7	7	8	6	7
Calcium mgL^{-1}	34.1	28.1	32.1	31.1	30.1	34.0	30.0	34.0	30.0	32.0
Magnesium mgL^{-1}	12.9	9.9	11.9	11.4	10.9	12.4	10.4	11.9	9.9	10.9
Sodium mgL^{-1}	54	45	56	51	52	56	49	54	50	52
Potassium mgL^{-1}	14	12	13	10	12	14	10	13	11	12
Dissolved Oxygen mgL^{-1}	9.6	8.8	9.4	9	9.2	11.6	10.8	11.4	11	11.2
NH_4-N μgL^{-1}	116.2	101.2	111.2	120.1	117.6	120.8	110.8	171.1	161.1	166.1
NO_3-N μgL^{-1}	130	118	126	130	128	207.3	199.3	292	284	288
NO_2-N μgL^{-1}	44.4	29.4	39.4	30	27.5	31.6	23.3	33.3	23.3	28.3
Soluble Reactive PO_4-P μgL^{-1}	18.0	12.0	16.0	15.0	14.0	19.5	15.5	20.3	16.3	18.3
Total PO_4-P μgL^{-1}	349.8	319.8	339.8	306.6	301.6	466.2	474.4	750.3	730.3	740.3
Turbidity NTU	3.3	3	3.2	4	4.0	4.1	3.9	4.3	4.1	4.2
Dissolved Organic Carbon mgL^{-1}	3.1	2.5	2.9	3.5	3.4	3.8	3.3	3.7	3.3	3.5
Sulphate mgL^{-1}	4.0	3.4	3.8	3.9	3.8	4.3	3.9	4.7	4.3	4.5
Dissolved Silica mgL^{-1}	4.4	3.7	4.1	3.8	3.6	3.6	3.1	3.7	3.1	3.4
Total Iron μgL^{-1}	309	291	303	326.3	323.3	368.2	226.5	231	219	225

Table 2 Average values of physical and chemical characteristics of littoral water on agriculture side of Lake Nilnag

Parameter	Site-11	Site-12	Site-13	Site-14	Site-15	Site-16	Site-17	Site-18	Site-19	Site-20
pH	7.47	7.41	7.53	7.74	7.73	7.97	7.59	7.56	7.63	7.65
Conductivity μScm^{-1}	234	231	237	229	233	194	207	209	207	198
Acid Neutralising Capacity mgL^{-1}	176	172	180	168	174	144	152	154	152	150
Chloride mgL^{-1}	6.8	5.8	7.8	6.8	6.3	8.3	8.5	9	9.5	7.8
Calcium mgL^{-1}	42.1	40.1	44.1	40.1	43.1	33.0	33.5	34.5	33.5	34.0
Magnesium mgL^{-1}	11.6	10.6	12.6	10.6	12.1	10.9	11.0	11.5	11.0	11.4
Sodium mgL^{-1}	46	44	48	43	48	47	49	51	47	49
Potassium mgL^{-1}	14	14	16	15	16	11	11	12	11	12
Dissolved Oxygen mgL^{-1}	9.9	9.3	9.5	9.7	10.1	9.1	10	9.7	9.4	9.7
NH_4-N μgL^{-1}	150.5	145.5	155.5	162.4	169.9	166.3	144.8	147.3	144.8	152.3
NO_3-N μgL^{-1}	317.4	313.4	321.4	307.4	313.4	154	256.7	258.7	256.7	162
NO_2-N μgL^{-1}	28.9	23.9	33.9	25	32.5	31.4	28.1	30.6	28.1	33.9
Soluble Reactive PO_4-P μgL^{-1}	21.6	19.6	23.6	19.6	22.6	21.8	19.8	20.8	19.8	22.8
Total PO_4-P μgL^{-1}	551.7	541.7	561.7	333.2	348.2	261.7	819.2	824.2	819.2	475.3
Turbidity NTU	5.7	5.6	5.8	7.1	7.3	7.2	12.3	12.3	12.3	7.2
Dissolved Organic Carbon mgL^{-1}	3.9	3.7	4.1	3.4	3.7	3.8	3.5	3.6	3.5	3.9
Sulphate mgL^{-1}	9.7	9.5	9.9	9.1	9.4	6.5	7.2	7.3	7.2	7
Dissolved Silica mgL^{-1}	5.9	5.6	6.2	5.7	6.2	3.4	4.2	4.4	4.2	3.6
Total Iron μgL^{-1}	1691.3	1685.3	1697.3	1164	1173	392.3	1468.5	1468.5	1470	989.3

Table 3 Average values, standard deviations, T-test values and P-values for physical and chemical characteristics of littoral water towards forest side and agriculture side of Lake Nilnag (Based on Table 1 and Table 2)

	Forest Side		Agriculture Side			
Parameter	Average	SD	Average	SD	T- Test Values	P
pH	7.39	0.08	7.62	0.16	4.107	0.0005
Conductivity μScm^{-1}	194.5	4.2	217.6	16.3	4.336	0.0004
Acid Neutralising Capacity mgL^{-1}	144.6	5.8	161.7	13.0	3.788	0.0013
Chloride mgL^{-1}	7.6	0.9	7.6	1.2	N.S.	1.0000
Calcium mgL^{-1}	31.5	2.1	37.8	4.5	4.04	0.0008
Magnesium mgL^{-1}	11.2	1.0	11.3	0.6	N.S.	0.8679
Sodium mgL^{-1}	51.8	3.4	47	2.5	3.569	0.0022
Potassium mgL^{-1}	11.8	1.3	13	2.1	N.S.	0.1211
Dissolved Oxygen mgL^{-1}	10.2	1.1	9.6	0.3	N.S.	0.1322
NH_4-N μgL^{-1}	129.6	25.9	153.9	9.3	2.791	0.0121
NO_3-N μgL^{-1}	190.3	74.2	266.1	62.8	2.467	0.0239
NO_2-N μgL^{-1}	31.0	6.6	29.6	3.5	N.S.	0.5509
Soluble Reactive PO_4-P μgL^{-1}	16.5	2.6	21.2	1.5	5	<0.0001
Total PO_4-P μgL^{-1}	477.9	190.9	553.6	209.9	N.S.	0.4099
Turbidity NTU	3.8	0.45	8.3	2.86	4.918	<0.0001
Dissolved Organic Carbon mgL^{-1}	3.29	0.38	3.7	0.22	2.971	0.0087
Sulphate mgL^{-1}	4.0	0.41	8.2	1.33	9.567	<0.0001
Dissolved Silica mgL^{-1}	3.6	0.42	4.9	1.08	3.562	0.0023
Total Iron μgL^{-1}	282.2	53.0	1319.9	407.7	7.985	<0.0001

N.S. = no significant difference.

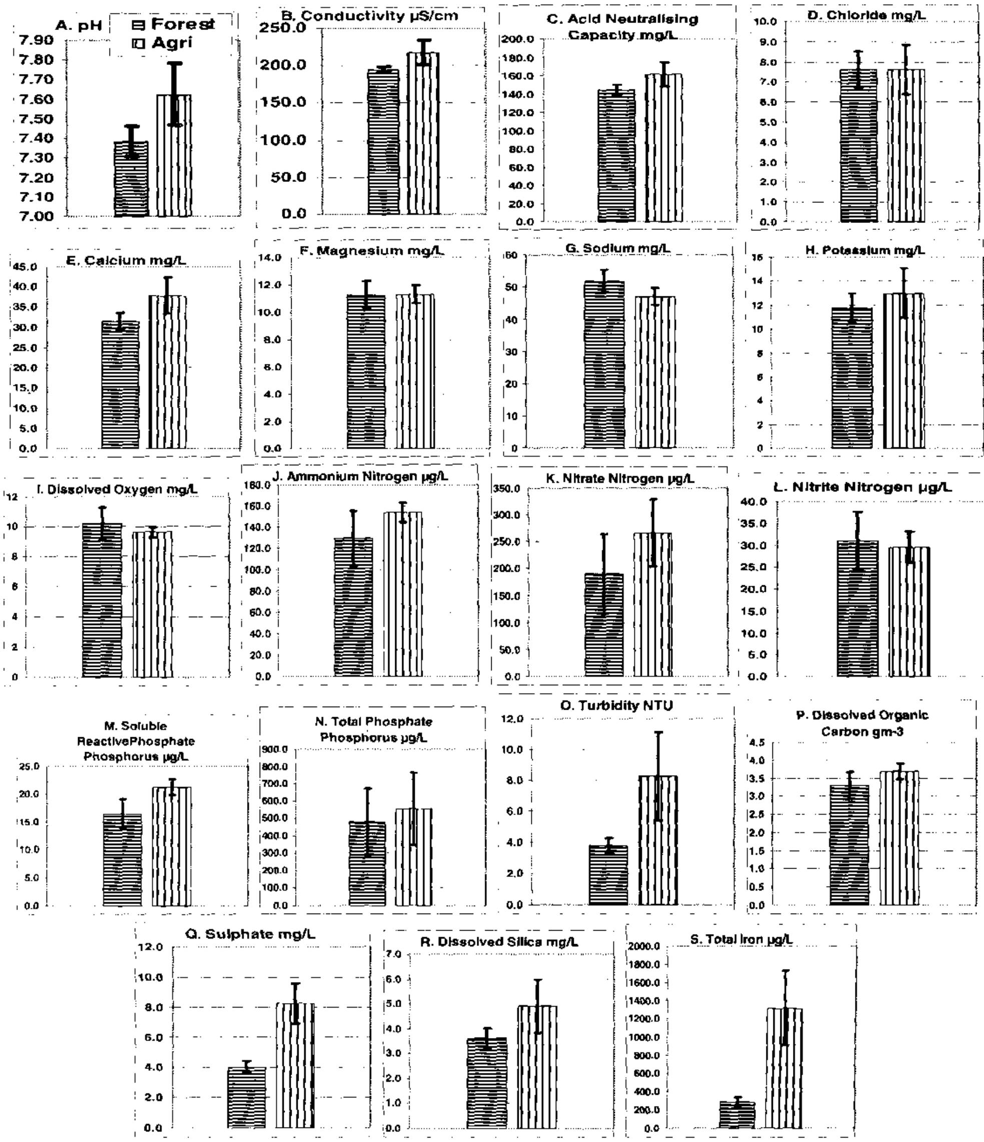

Figure2 (A to S). Comparison of various physical and chemical littoral water quality characteristics (average + standard deviation) of Lake Nilnag on forest side and agriculture side

CONCLUSIONS

From this study it may be concluded that the littoral water chemistry acts as a good indicator of the catchment land use and influence of diffuse sources of pollution. It underlines the importance of monitoring littoral water chemistry for tracking diffuse sources of pollutants for better management of lakes.

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