Renuka Lake ecosystem and wetland protection, Lesser Himalaya, Himachal Pradesh, India

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Abstract The oval-shaped Renuka Lake is located at an elevation of 620m above msl in Himachal Pradesh. The lake follows a riparian course between steep hill slopes on both the sides with thick forest. The lake is alkaline, Ca^{2+}+ $Mg^{2+}$are the major cations and $HCO_3^-$and SO_4^{2-} are the major anions. The high SO_4^{2-} in the lake water is derived from black carbonaceous shale and gypsum of the lithology. The total hardness of lake water exceeds the prescribed limits hence unfit for drinking, washing, and agriculture. The Na, K, and Cl are deficient in Renuka Lake. The variation in the chemistry of the lake water is primarily due to anthropogenic activity and the riparian course of lake. The drop of trashes by the tourists and seepage of inlets of domestic and municipal sewage has resulted in the growth of the macrophytes particularly in the extreme west of Renuka Lake where tourist lodge, temples and bathing ghats are located. The growth of weeds causes deficiency of D.O leading to eutrophic conditions and consequent fish mortality in the lake. The lake water in contact with soil in the riparian zone show variation in some major and trace elements. The vegetation in riparian zone affect both the quantity and quality of water. The wetland sediment chemistry shows enrichment in Al_2O_3, Fe_2O_3, K_2O,TiO_2 and trace elements Y, Zr, Ni, Th, U and Nb compared to lake sediments and the latter shows similarity with Post Archean Australian shale(PAAS) indicating higher clay fraction in wetland. Therefore, the variation in water chemistry of riparian zone is soil controlled. The higher Zr/Hf ratio of lake sediments and wetland suggests that these elements are controlled by zircon. The higher Zr/Yb and Zr/Th ratios in wetland sediments compared to lake sediments show mineral sorting (fractionation) during process of lighter particles (clays) being trapped in the wetland soil concentrating heavy minerals in sediments. This shows wetland control in the flow of nutrients and metal ions in the lake basin. The removal of plant cover, road construction and widening have accelerated silting in lake (3.3mm/yr).In order to reduce silt flow dredging has been carried out successfully in the wetland.

Key words Alkaline, Dredging, Himachal Pradesh, Renuka Lake, Riparian course, Soil control.

1.Introduction

The lake ecosystem is disturbed by various factors such as natural and man made. The natural factors may include climate, acid rain, nuclear fall out, land slide, etc. But impact of man made factors, in most of the fresh water lakes, are pronounce and detrimental. Discharge of pollutants from point and non-point source, deforestation, extensive cultivation, building construction, road construction and widening, setting of industries, discharge of untreated effluents, domestic sievage etc. not only pollutes the water body but also causes increased silt flow in the lake basin making it shallow hence cutting short the life span of the lake.

The Riparian zones have the capacity to buffer surface water bodies from non-point source run off from agriculture, urban or other land uses. It even absorbs sediment, chemical nutrients and other substances in non-point source run off. Riparian zones are instrumental in water quality improvement for both surface and water flowing into water bodies through sub-surface or ground water flow. The wetland riparian zones shows a particularly high rate of removal of nitrate entering a stream and thus has a place in eutrophication management. Because of there prominent role in supporting a diversity of species, riparian zones wetland are often the subject of national protection in a Biodiversity Action Plan.

Renuka Lake having a riparian course and a wetland shows water quality control, soil conservation, their biodiversity and influence on aquatic ecosystem. To establish these characters a comprehensive study of water quality, lake and wetland sediment geochemistry, isotope chemistry to determine rate of sedimentation, and survey of flora and fauna distribution have been carried out. The lake is unique in lesser Himalaya and is under Ramsar Convention Environment Act.

2. Methodology

The water samples were collected in pre-washed 1L polythelene bottles filling it to the capacity. Within 5-6 hours of collection pH, E.C, D.O, TDS etc. were measured using portable field kit. The samples were filtered using 0.45 µm Millipore filter membranes. A part of this was used for measurement of carbonate and bi-carbonate by acid titration, choride by $AgNO_3$ titration, sulphate by $Ba(ClO_4)_2$ titration after passing the samples through cation exchange resin, phosphate by an ascorbic acid spectrophotometry, silicate by molybdenum blue spectrometry. Na, K by flame photometer and Ca and Mg by AAS 2100(Perkin Elmer Atomic Absorption Spectrophotometer).

The sediment samples carefully selected were collected from lake and wetland, dried and processed. The samples were ground to -200 mesh size in agate mortar and were used for making pellets. These pellets were subjected to X-ray fluorescence spectrophotometer (energy dispersive, Phillips EXAM-6 system) and major and trace elements were estimated. The accuracy was checked by running USGS sediment standards SDO1, SCO1, GSD9 and SO1. The major element accuracy is ~2.5%. The REE's were measured on ICP-MS using G2 and SDO1 standards in the University of Kiel, Germany. As the REE.s are present in minor quantities in the matrix elements, therefore, elements have to be separated as a group so that the spectral interference from the matrix elements can be avoided. The precision of data is better than 5% except for Ce and Nd, which have precision of about 10% and for REE (<10%).

3 .Geomorphic features of Renuka Lake

The oval shaped lake at an elevation of 620m above msl in the lesser Himalaya has water spread of 670ha and bound by $30^0 36' 30''$ N latitude and $77^0 27' 6''$ E longitude. The lake follows a riparian course between two steep hill slopes with forests and this and its detached part Parasram Tal are along the abandone course of Giri River which got separated due to tectonic up liftment (Fig.1). These lakes are fed from watersheds, rainwater run off from catchment and underground seepage. Parasram tal also receives over flow of Renuka through its outlet discharging in the former after passing through the population, market carrying more pollution to the Tal.

The average rain fall in the region is between 150-199.9 cm per annum (Joshi, 1984)[1]. The Renuka Lake is 10.50m in length and 204m in breadth with a maximum depth of ~13m and catchment area is ~254.3ha.

The catchment rocks of Renuka are dark carbonaceous shales and slates, closely interbedded with thin slaty quartzite belonging to Infra Krol Group. The slaty quartzites, or clay slates are frequently calcareous and consists of quartz, carbonate, sericite and pyrite and in some cases chlorite. The green-gray calcareous shale and argillaceous limestone with variable gradation are of Krol A Group. The purple-red shales with intercalation of green-shales and thin dolomitic cherty limestone belong to Krol B Group. The well bedded grayish-white limestone with shale represents Krol C. The rock formation belongs to neo-Proterozoic – Proterozoic age. (Auden, 1934)[2]. The soil composition of the region also show a heterogeneous mixture of carbonate rocks, sandstones, shales, siltstone in various proportion (Srikantia and Bhargava,1998)[3]. The soil cover is thin due to weathering-limited conditions (Stallard and Edmond, 1987)[4] as physical erosion has been stronger due to uplifting Himalaya.

4. Water quality of Renuka Lake

The lake water is alkaline, pH ranges between 8.21 to 8.55 in the month of March-April. The carbonate alkalinity is 2.45 meq/l average. Ca^{2+} and Mg^{2+} are the major cations and contribute 38.57 to 48.93% and 44.71 to 54.16% of the total cation budget, respectively. The HCO_3^- and SO_4^{2-} are the major anions contributing 36.97b to 51.90 and 43.25 to 51.91% to the anion budget, respectively. The high Ca^{2+} + Mg^{2+} and HCO_3^- in water indicate dissolution of limestone in the lake basin which is supported by $(Ca^{2+}+Mg^{2+})$:HCO_3^- equivalent ratio of ±2.55.The high SO_4^{2-} in the lake is derived from black carbonaceous shale and gypsum in the lithology. During weathering process rocks exposed to the atmosphere come in contact with dissolved O_2 (rain water) that reacts with pyrite resulting in oxidative decomposition producing H_2SO_4 by the following reactions:

$4FeS_2+15O_2+ 8H_2O \rightarrow 2Fe_2O_3+ 8H_2SO_4$

$H_2SO_4 \rightarrow 2H + SO_4^{2-}$ (Berner and Berner, 1987)[5]……………………(1)

As water draining rocks where sulphide oxidation is taking place, the presence of carbonate minerals neutralizes acid and hence the pH of lake water remains alkaline (Das and Parkash, 2001)[6]. The contribution of Na and K is between 4 and 7% of the major ion budget of the lake. The low $(Na+K)/T_Z^+$ ratio (0.058) indicates that there is no significant contribution of cations to the lake water from the degradation of alumino-silicates. The depletion in K compared to Na may be due to its resistance to weathering and that K^+ is utilized in the formation of clay mineral illite. As the hardness of water exceeds the prescribed safe limit hence unfit for drinking, domestic and agriculture use. The variation in chemistry of water is related to anthropogenic activity and riparian wetland zone. It is observed that PO_4^{2-} and in some cases SO_4^{2-} in water samples in contact with wetland are depleted (1.5 to 3.5µg/l and 120 to 135 mg/l, respectively) where as there concentration is enhanced in samples taken from wetland (12.0 to 13.5 µg/l and 150 to 160 mg/l, respectively).The variation shows that these nutrients are adsorbed in vegetation/soil thus protecting the lake water from further pollution. The trace element content of Renuka water show higher concentration of Fe and Pb in samples close to the hotel, temples, bathing ghat where human activity viz-a-viz pollution is maximum (Fig.2; Table 1). In comparison to lake water, samples along the contact of wetland and riparian zone show depletion in metal ion concentration except relative enhancement of Sr. The latter may indicate higher carbonate in water as Sr has chemical affinity with carbonate minerals and enter into lattice structure of calcite. Other metal ions Cu, Cd etc. do not show significant variation.

4.1 Water quality and phytoplankton

The phytoplankton being the primary producers constitute the basic food source of the lake which supports fish and other aquatic animals. As the lake is rich in nutrients it supports a high biological diversity(Melkania,1988)[7].The macrophytic vegetation covers an area of 39,969 sq. m in Renuka lake. According to Singh and Mahajan (1987)[8] the chief macrophytic genera are Phragmites, Acorus, Typha, Carex, Pontederia and Veronica which totals to 42 in number. It is observed that the total number of phytoplankton were higher in April and October which are indicators of pollution. In addition blue green algae developed in large number in October when the temperature of lake water was between 19^0 to 24^0C but their number decrease in August when the temperature of water increased. It is observed that the number of Myxophycean members were directly correlated to the concentrations of nitrate-nitrogen (NO_3-N) and inorganic phosphate phosphorus. Phosphorous and nitrogen are transported into the lake through soil particles from agriculture lands, animals dung, sewage discharge, and cultural activities. The higher concentrations of dissolved inorganic phosphate phosphorus was recorded in April and October and low in June and August which corresponds to the high and low number of phytoplankton population in the lake (Singh and Mahajan, 1987)[8]. Weed infestation also leads to oxygen depletion and consequent fish mortality particularly in morning hours.

5. Sediment geochemistry of Renuka Lake and wetland

Among the major elements Al_2O_3, Fe_2O_3, K_2O and TiO_2 are enriched in wetland compared to lake sediments and as these show positive correlation with Al_2O_3 in both the cases, it indicates a common source viz., phyllosilicates. The trace elements Y, Zr, Ni, Th, U and Nb are enriched in wetland compared to lake and show similarity with Post Archean Australian Shale (PAAS) indicating clay rich sediment in the wetland. A high Zr/Hf ratio of 30 for lake sediments and 33 for wetland suggests that these elements are controlled by zircon since these values are similar to those reported by Murali et al (1983)[9] from the analysis of zircon crystals. The Zr/Yb, Zr/Th ratio are higher in wetland sediments as compared to lake sediments though these ratios are expected to be higher in sandstones than in shales but as the wetland is enriched in alumina it indicates more of shale component. This shows mineral sorting (fractionation) during process of lighter particles (clays) being trapped in the wetland soil concentrating heavy minerals (zircon) in sediments. This is also reflected from negative correlation of Gd_N/Yb_N with Al_2O_3 and a strong positive correlation with SiO_2 in wetland sediments. This shows that the wetland restricts the flow of nutrients, metal ions to the lake basin during catchment run off, due to precipitation in the monsoon season and also checks the flood water flow in the lake (Das, Birgit and Parkash, 2008)[10].In addition grazing and road construction and similar other human activities accelerate the silt flow in the water body which has been measured 3.3 mm/Yr by Pb^{210} isotope method (Das and Kaur, 2001)[6]. During rainy season silt flow will increase with such anthropogenic activities. This shows that the anthropogenic intervention is the main cause of environmental degradation of Renuka Lake. The study shows, over the years, the human activities have increased many fold throughout the Himalaya as a consequence most of the water bodies in lesser Himalaya are eutrophic and/or in advanced stage of trophic evolution. In Higher Himalaya population is sparse hence situation is some what different except glacial silt flow in the water body is likely.

6. Renuka wetland protection

The problem of degradation of lakes and wetlands can be controlled effectively by adopting technical and socio-economic conditions of local people. An integrated program involving measures to combat unplanned growth of settlements and land use may be a lasting solution.

The Himachal Pradesh Government has taken steps for dredging the wetland to protect from further silt flow to the basin, control water pollution, save aquatic life and people, check flood water. Besides this afforestation and planting of soil binding trees are being carried out to hold the soil from rapid erosion. Some important measures to be followed for protection of wetland are (i) throwing of household garbage in the water body be prevented by law, (ii) construction of building roads etc. should be restricted to the minimum necessity, (iii) periodical cleaning of open drains and selective harvesting of macrophytes, particularly the emergent and sub-merged , at the time of peak growth can substantially reduce nutrients from the lake sediments,(iv) harvesting of weeds should be increased to control excessive weed growth ,(v) public awareness should be propagated for their involvement to protect their own property,(vi) water quality parameters should be checked from time to time for its pollution.

Tab. ;1 Trace elements content of water samples of Renuka Lake (µg/l)

Sample No	Pb	Cu	Cr	Zn	Co	Fe	Cd	Sr
Rn 1	100	10	40	10	-	80	10	770
Rn 2	100	10	30	-	-	40	20	650
Rn 3	100	10	20	10	10	60	10	620
Rn 5	100	10	30	10	10	30	10	690
Rn 6	100	-	10	20	30	30	10	610
Rn 11	100	-	10	20	20	70		630
Rn 16	200	10	20	-	10	120	10	600
Rn 17	100	-	20	10	20	80	10	590
Rn 19	100	10	30	30	20	70	-	610
Rn 20	300	10	30	20	30	50	-	560
Rn 21	200	10	20	10	30	60	-	630

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of
selected
Table 2. Rare Earth Elements (REE) in sediments
(REE) Data (data (ppm) samples sediment
of Renuka Lake and
Wetland

Sample No.	LAKE				WETLAND			
	GR I	GR II	GR III	GR VII	NGR I	NGR IV	NGR V	NGR VI
La	35.4	25.1	28.4	24.9	44.6	46.3	41.6	43.1
Ce	72.8	51.7	58.8	50.4	88.8	94.9	85.1	87.3
Pr	8.08	5.8	6.5	5.75	10.3	10.3	9.51	9.91
Nd	30.5	21.9	24.4	22.1	39.1	38.9	35.9	37.8
Sm	6.24	4.49	5.07	4.48	7.87	8.06	7.62	7.84
Eu	1.18	0.85	0.97	0.92	1.61	1.55	1.43	1.57
Gd	5.48	3.98	4.54	4.36	7.44	7.23	6.95	7.2
Dy	4.81	3.58	3.7	3.81	6.79	6.51	6.36	6.69
Ho	0.98	0.75	0.74	0.77	1.4	1.35	1.3	1.35
Er	2.72	2.02	2.13	2.1	3.75	3.8	3.49	3.69
Tm	0.41	0.29	0.29	0.29	0.53	0.56	0.51	0.52
Yb	2.67	1.99	2.14	2.03	3.6	3.78	3.51	3.62
Lu	0.41	0.31	0.33	0.32	0.56	0.59	0.54	0.58
∑REE	171.67	122.75	138.01	122.23	216.35	223.83	203.81	211.17
LaN/YbN	8.96	8.52	8.97	18.29	8.37	8.28	8.01	8.05
Ce/Ce*	1.03	1.03	1.04	1.01	0.99	1.04	1.03	1.01
Eu/Eu*	0.62	0.62	0.62	0.64	0.7	0.62	0.6	0.64
CeN/ YbN	7.07	6.73	7.12	6.43	6.39	6.51	6.28	6.25
CeN/ SmN	2.82	2.78	2.8	2.72	2.72	2.84	2.7	2.69
GdN/YbN	1.66	1.62	1.72	1.74	1.42	1.55	1.6	1.61
∑LREE	153.02	108.99	123.17	107.63	190.67	198.46	179.73	185.95
∑HREE	17.47	12.91	13.88	13.68	24.07	23.82	22.65	23.65
∑LREE/∑HREE	8.76	8.44	8.88	7.87	7.92	8.33	7.93	7.86