Trophic Status of Kashmir Himalayan Lakes as Depicted by Water Chemistry

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ABSTRACT

Six Kashmir Himalayan lakes located at different altitudes and depicting varied human interference in their catchment areas, were investigated for various limnological parameters so as to classify them with respect to trophic status. The best chemical indicators of the trophic state of these aquatic systems were found to be the total phosphorus and total dissolved inorganic nitrogen in the epilimnetic layer. The two mountain lakes, the Gangabal and the Nundakol, were oligotrophic in nature. The rural lakes, the Manasbal and the Malpursar, were mesotrphic, while the semi-urban Anchar Lake typified the eutrophic habitats of the region. The urban Khushhalsar lake belonged to the hypertrophic category.

Keywords: Himalayan lakes; water chemistry; trophic status

INTRODUCTION

The Valley of Kashmir, situated in the midst of the Himalayan range of mountains roughly between 33^0 , 01′ and 35^0, 00′ N and 73^0, 48′ and 75^0, 30′E, has been famous for its crystal clear tarns and lakes throughout the world. However, during the recent past many of these waters have started showing signs of instability and in some of them even the red euglenoid blooms, a rare phenomenon in freshwater lakes, were evinced. Although the increased fertility of lakes with ageing is a natural phenomenon, but the pace at which the lakes of this part of the Himalayas have shown this phenomenon clearly indicates that human interference in the catchment areas as well as within the basins of the aquatic system has greatly increased.

In order to devise methods for the conservation of these and other similar water bodies of the region, it is imperative to have a clear picture about their present trophic status. A perusal of the literature shows that although a large number of reports are available on the water chemistry of the lakes of the Himalayan region (Kaul, 1977; Qadri and Yousuf, 1978, 1979; Das and Pandey, 1978; Vass, 1980; Zutshi *et al*, 1980 a & b; Khan and Zutshi, 1980; Kaul & Hando, 1980; Purohit and Singh, 1981; Singh *et al*, 1982; Trisal, 1985, 1987; Wani and Subla, 1990; Pandit, 1993), most of these are inconclusive in respect of trophic assessment. In some cases

the authors have assigned several trophic states of a single water body on the basis of different parameters (Kaul 1977; Pandit, 1993). This thing in mind, six lakes, viz. Gangabal, Nundakol, Malpursar, Manasbal, Anchar and Khushhalsar, representing different habitat types of the valley of Kashmir were selected for a detailed limnological study during April 1987 – May, 1989. The present article is based on the data collected on their water chemistry and discusses the trophic condition of these aquatic systems.

MATERIAL AND METHODS

The geographical and morphometric data of the selected water bodies are presented in Table 1. The methods used for the analysis of different chemical parameters include:

i. pH – Toshniwal CL 46 digital pH meter

ii. ii) Chloride –titrimetric method using 0.141 N silver nitrate (APHA, 1985)

iii. Sulphate – turbidimetric method (APHA, 1985)

iv. Silicate – molybdosilicate method (APHA, 1985)

v. Ammonia–nitrogen – nesslerization method (CSIR, 1974)

vi. Ammonia–nitrogen – sulphanilic acid method (CSIR, 1974)

vii. Phosphorus (Total phosphorus, Hydro–P and Ortho–P) – ascorbic acid method (APHA, 1985)

All the statistical tests employed were computed in accordance with Zar (1984).

RESULTS AND DISCUSSION

According To Vollenweider (1968) the chemical conditions in a water body are a reflection of the geology and cultural activity in the catchment. The nutrient import from the catchment is a principal contributor to the man – induced enrichment of lake systems. Based on this observation the lakes included in the present study are easily divisible into two groups.

(i) *Mountain lakes*: These are above the upper tree line and show least anthropogenic activity in their catchment. Included in this category are the Gangabal and the Nundakol lakes. Both these water bodies lie above 3,500 m a.s.l. and are surrounded on almost all sides by lofty mountains covered with snow throughout the year. The Gangabal Lake mainly receives melt water

from the glaciers and the excess water from it leaves by a channel which joins the Nundakol lake, a much smaller water body than and located above one km away from the former.

(ii) *Valley lakes*: These are located in rural and urban areas of Kashmir within a narrow altitudinal range of 1580 – 1600 m a.s.l in close vicinity of human settlements. These water bodies show varied human activity in their catchment areas (Yousuf, 1995). The group includes the remaining four water bodies, viz., Manasbal, Malpursar, Anchar and Khushhalsar lakes. The Manasbal has its catchment spread over forest, agricultural land and rural human settlements. The Malpursar is surrounded mainly by the agricultural land and human settlements. Both these water bodies have no permanent inlets. While the former receives its water mainly as ground water from the springs spread over its basin, the latter receives a significant quantity of water from adjoining agricultural fields. The Manasbal joins the river Jhelum through a channel, while the Malpursar is connected with the Sindh nallah, a tributary of the Jhelum. The Anchar is a semi-urban water body mainly fed by the Sindh nallah, which deposits large quantities of silt brought from its upper reaches. The lake also receives large quantities of agricultural run-off and domestic sewage from the surrounding areas. The Khushhalsar is a typical urban aquatic system surrounded on all sides by human settlements from which large quantities of domestic sewage enter it.

The influence of the catchment characteristics are well depicted in the water chemistry of these water bodies. All the nutrients recorded their minimum values in the mountain lakes, while the maximum values were observed in the urban lake (Table 2). In the two mountain lakes near-neutral pH values (generally on the acidic side of the scale) were recorded. In the other four lakes the pH showed considerable variations from near-acidic to highly alkaline values. According to Whitemore (1984) the acidic pH (< 6.5) is usually a feature of oligotrophic lakes, while the circum – neutral (6.5 – 7.5) and alkaline pH (> 7.5) is mainly exhibited by eutrophic and mesotrophic lakes. As per this classification Khushhalsar belongs to the eutrophic category and the other five pertain to the mesotrophic group. However, this categorization is not so specific to be useful for the classification of the present waters.

The gradation in the concentration of chloride content of the six water bodies shows clearly the role of catchment characteristics of the systems. The catchment of the mountain lakes is least exposed to the human interference because of inaccessibility, the only interference being in the form of sheep and cattle grazing

Table 1. Morphometric data of the investigated lake.

Parameter	Gangabal	Nundakol	Malpursar	Manasbal	Anchar	Khushhalsar
Altitude (m.a.s.l)	3570	3507	1585	1584	1584	1584
Latitude (North)	34.51	34.48	34.10	34.15	34.00	34.02
Longitude (East)	74.79	74.78	74.25	74.40	74.12	74.06
Area (ha)	172.5	42.5	0.28	280	680	123
Periphery (m)	7050	2700	310	8500	15600	6250
Max. Length (km)	03.00	01.25	00.01	03.05	06.00	02.25
Max. Breadth (km)	0.95	00.05	00.04	01.05	2.76	0.75
Marsh land (ha)	Nil	Nil	00.08	25	380	83

Table 2. Average values of the limnological parameters of the six Himalayan lakes.

Parameter	Gangabal	Nundakol	Malpursar	Manasbal	Anchar	Khushhalsar
Water temp. (°C)	10.90	11.70	14.10	15.40	13.50	13.50
pH	6.85	6.98	7.82	7.94	08.01	07.46
Chloride (mg/l)	10.37	13.75	20.44	21.09	35.91	39.97
Ortho.-P-(µg/l)	02.56	3.75	09.01	11.06	11.66	55.25
Hydro.-P (µg/l)	05.31	06.50	13.30	16.25	20.47	83.02
Total P (µg/l)	08.50	10.00	23.28	23.53	32.03	135.37
Amonia –N (µg/l)	24.53	36.42	87.41	189.09	87.41	425.91
Nitrate-N (µg/l)	37.75	60.50	376.01	106.21	207.44	1314.17
Nitrite-N (µg/l)	90.37	105.00	88.78	98.99	173.11	1113.25
Total DIN (µg/l)	153.84	174.90	533.49	339.49	652.29	2869.90
Silicate (µg/l)	35.02	194.20	618.37	465.91	660.50	1010.31
Sulphate (µg/l)	315.94	508.00	2094.83	1344.86	1920.03	4395.22

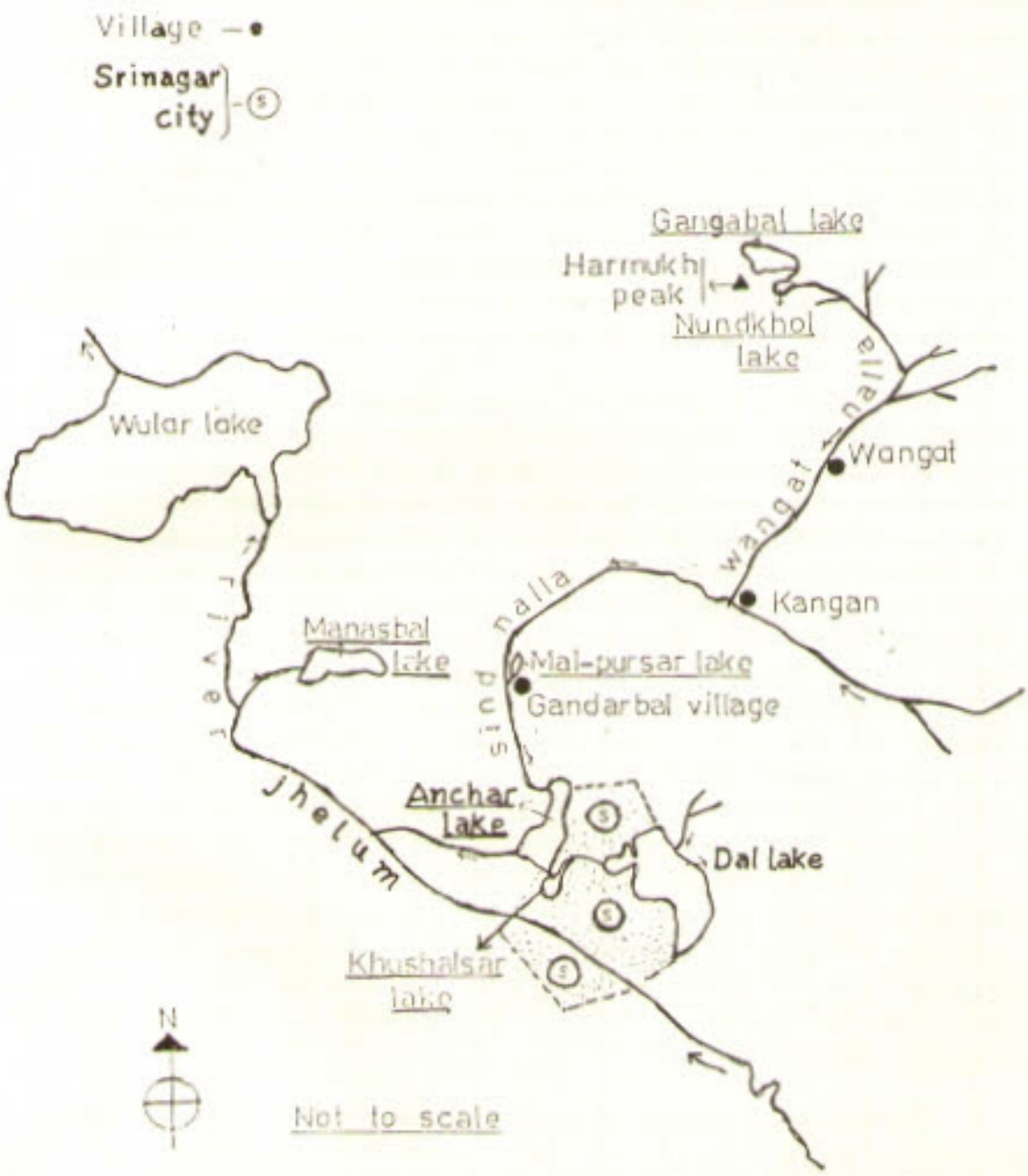

Fig.1. Location of the six lakes selected for the limnological investigations.

during summer months. The chloride content snowed the minimum values in these systems. The other four waters depict varied interference in their catchment and in proportion to the role of the human society the chloride concentration also recorded a gradual increase, the least values within the group being recorded by Malpursar and the maximum by the Khushhalsar. The Manasbal and the Anchar recorded intermediate values, with the former having lesser quantity. The gradation shown by the silicate and sulphate ions also recorded a similar trend. Since chlorides, sulphates and silicates are generally present in appreciable concentrations in freshwater systems (Henderson – Seller and Markland, 1987) and seldom act as limiting factors, they are not used for assessing the trophic status of a water body. This leaves one with only two other nutrients, nitrogen and phosphorus, for classifying the lentic systems.

Phosphorus is regarded as a key element in eutrophication process (Vollenweider, 1972). During the present study very low concentrations of all the three forms of phosphorus (Ortho – P, Hydro –P and Total P) were recorded in the two mountain lakes, while in the valley lakes the concentration was appreciably higher and recorded a gradual increase from Malpursar through Manasbal to Anchar. The Khushhalsar recorded the highest values of all the six waters, being several times higher than found in any of the other three valley lakes. Generally the total phosphorus content of water bodies has been used for categorization of aquatic habitats. Toerien and Walmsley (1974), for example, suggested that 25 – 30 µg/l total P be regarded as the border line for eutrophy. Thornton and Nduku (1982) proposed two sets of the values for delimiting the lower boundary of eutrophy, 30 µg/l for temperate and 50-60 µg/l for tropical lakes. Wetzel (1983) recognized five groups of lakes on the basis of total P concentration. As per this system the Gangabal (mean total P = 8.5 µg/ l) and (mean TP= 23.5 µg/l), Malpursar (Mean TP = 23.3 µg/l) and the Anchar (mean TP = 32.0 µg/ l) to the mesotrophic category, while the Khushhalsar (mean TP = 135.00 µg/ l) belongs to the hypertrophic group. Application of Carlson's (1977) trophic state index on phosphorus content (Table 3) also reveals a similar pattern. A slightly better picture of the trophic sate of these water bodies is obtained if OECD (1982) guidelines are followed using the epilimnetic total P content (Table 4).

The three forms of dissolved inorganic nitrogen (nitrate, nitrite and ammonia) also recorded a clear cut gradation in their concentration in the present lakes (Table 2). While the minimum values (153.8 µg/ l for Gangabal and 174.0 µg/ l for Nundakol) were recorded in the mountain lakes, the maximum concentrations were evinced in the Khushhalsar (mean DIN = 2.870 mg/l). OECD (1982) classification on the DIN content ranked these water bodies in nearly the same order as that based on

TP (Table 4). Similar results are obtained when Carlson's index on DIN is employed (Table 3). While applying OECD categorization of these lakes on the basis of TP and DIN, some difficulty was felt as the terminology used therein is rather complicated and very narrow ranges are set for different categories. Further it is an established fact that trophic status is a dynamic concept rather than a static one and a water body may reveal different trophic condition at different times during the course of a year. Even the same concentration of a nutrient may be regarded as indicating different trophic levels in different water bodies. For example Henderson – Sellers and Markland (1987) have shown that for a mean chlorophyll 'a' concentration of 10 mg/m there is an approximately 55% chance for the lake to be classified as eutrophic, and 35% chance to be a mesotrophic one. Further about 8% and 2% chances are there for the lake to be hypertrophic and oligotrophic respectively. This being so, these authors have suggested that the trophic boundaries set by OECD need not be applied rigidly. OECD report itself recommends that the boundaries set should be handled with caution and need not be applied to cases which lie outside the ranges and situations covered by the programme. Keeping these observations in mind the OECD classification was slightly modified so as to suit the local aquatic habitats (Table 5). The classification was directly applied to the mean monthly values of different study sites rather than to the overall mean concentration of the nutrients concerned in a water body. On this basis the number of times a lake appeared in a particular trophic state was expressed as a percentage of whole. For example, there were three sampling stages in Anchar lake and each was sampled twelve times. Thus a total of 36 recordings were made. On 27 occasions the concentration of TP fell in the eutrophic range, while on nine occasions it was within mesotrophic state. This when expressed in percentage revealed that 75% samples were of eutrophic nature. The results obtained from these calculations are given Table 6. These data reveal a relatively better picture of the trophic state of a waterbody. The two mountain lakes are alithrough in the oligotrophic range, whereas the other waterbodies show different stage or different trophic condition at different times of a year. A perusal of Table 6 reveals that the Malpursar and the Manasbal both fall mainly in mesotrophic level. However, the former shows more proximity to eutrophic category. The Anchar is ranked as a eutrophic water system, having quite advanced in its trophy than the Malpursar and the Manasbal. Both the TP and DIN placed the Khushhalsar in the hypertrophic category without any doubt.

In order to see whether the conclusions regarding the trophic state of the present lakes are valid, Tucker's test of multiple comparison was applied (Table 7). It clearly indicated that there was the highest similarity in the abiotic components between the two mountain lakes, while the two lakes showed least similarity with the Khushhalsar. These inferences are also confirmed by the biological data of these

Table 3. Values of Carlson Index for the six lakes based on total phosphorus (TP) and total dissolved inorganic nitrogen (DIN).

	Lakes					
Index based on	**Gangabal**	**Nundakol**	**Malpursar**	**Manasbal**	**Anchar**	**Khushhalsar**
TP	28.52	31.69	43.53	43.87	48.25	68.75
DIN	56.81	58.57	73.89	67.68	76.64	96.99

Table 4. Categorization of six Kashmir Himalayan lakes as per OECD ranges of TP and DIN.

	OECD		Range	
Lake type	Total P µg/l	Example	Total DIN µg/l	Example
Ultra-oligotrophic	<5		<200	Gangabal Nundakol
Oligo-mesatrophic	5-10	Gangabal Nundakol	200-400	Manasbal
Meso-eutrophic	10-30	Malpursar Manasbal	400-650	Malpursar
Eutrophic	30-100	Anchar	650-1500	Anchar
Hypertrophic	>100	Khushhalsar	>1500	Khushhalsar

Table 5. Proposed classification of Kashmir Himalayan lakes on the basis of total phosphorus and total dissolved inorganic nitrogen content of epilimnetic water.

	PROPOSED RANGE	
Lake Type	Total P	Total DIN
Oligotrophy	<10	<250
Mesotrophy	10-30	250- 600
Eutrophy	30-100	600-1500
Hypertrophy	>100	>1500

Table 6. Frequency of occurrence of the six Kashmir Himalayan lakes in different Trophic categories. (Based on Total P and Total DIN Content).

(a) on Total Phosphorus:

Lakes	Oligotrophy	Mesotrophy	Eutrophy	Hypertrophy
Gangabal	100	-	-	-
Nundakol	100	-	-	-
Malpursar	01.23	85.18	13.58	-
Manasbal	1.98	78.57	19.14	-
Anchar	-	44.55	55.55	-
Khushhalsar	-	-	40.19	59.80

(b) on Total dissolved inorganic nitrogen:

Lakes	Oligotrphy	Mesotrophy	Eutrophy	Hypertrophy
Gangabal	100	-	-	-
Nundakol	100	-	-	-
Malpursar	-	72.50	27.50	-
Manasbal	18.65	63.88	17.46	-
Anchar	-	25.00	75.00	-
Khushhalsar	-	-	13.84	86.15

Table 7. Similarity (%) in the limnological parameters of the Kashmir Himalayan lakes as per Tuckey's Test.

Lakes	Gangabal	Nundakol	Malpursar	Manasbal	Anchar
Nundakol	100				
Malpursar	53.2	73.00			
Manasbal	40.00	66.66	56.20		
Anchar	40.0	60.00	68.70	62.00	
Khushhalsar	0	1.14	06.25	12.50	12.50

water bodies. While the Khushhalsar in infested throughout its basin with submersed as well as free floating macrophytes and the fish, except for the mirror carp, have completely been driven out of the system, the Gangabal and the Nundakol waters are free of any macrophytes and the plankton community is also very low, as is characteristic of nutrient-poor waters. Schizothoracine and salmonid fishes are a characteristic feature of these habitats. In the other three lakes, viz., Manasbal, Malpursar and Anchar, the submersed vegetation is conspicuous but the free floating macrophytes are restricted to only certain areas, being at highest density in the Anchar. Both schizothoracine and cyprinine fishes are found in these habitats, but salmonids are totally absent.

ACKNOWLEDGEMENTS

The present article is based on a part of the data collected during the tenure of a research project No. 37 (39) 786-EMR II awarded by the CSIR, New Delhi to the second author. The authors take this opportunity to thank the CSIR authorities for releasing the grants with punctuality which facilitated the collection of data, especially from the snow-bound water bodies. Thanks are due also to the Head, P. G. Department of Zoology, The University of Kashmir, for laboratory facilities.

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