Physico-Chemical Characteristics and Nutrient Dynamics of Lake Tso Moriri, a Ramsar Site in Ladakh, India

M.D. Mahdi

Associate Professor, Department of Zoology, Government Degree College Boys Pulwama-192301
Corresponding Author Email: *dilgeermahdi[at]gmail.com*

Abstract: ***Lake Tso Moriri, located in the Changthang region of Ladakh, India, at an altitude of 4,569 m above sea level, is a high-altitude brackish lake designated as a Ramsar site. This study investigates the physico-chemical parameters and nutrient dynamics of the lake and its tributaries. The lake, characterized by its endorheic nature and arid climate, exhibits high salinity with a pH of 8.7, categorizing it as brackish water. Ionic progression in the lake follows Mg > Na > Ca > K, differing from its tributaries (Ca > Na > Mg > K), due to precipitation of calcium carbonate in the alkaline environment. Elevated total dissolved solids (TDS) and total hardness exceed drinking water standards, reflecting significant salt accumulation driven by evaporation. Nutrient levels, including nitrogen and phosphorus, remain low due to minimal anthropogenic and agricultural activities in the catchment. The lake supports a unique ecosystem, hosting rare and endangered migratory birds such as the black-necked crane and bar-headed goose. However, increasing tourism and grazing activities threaten its ecological balance. This baseline data highlights the lakes unique limnological characteristics and underscores the need for conservation efforts to protect its biodiversity.***

Keywords: Tso Moriri, Ladakh, Ramsar Site, Physico-Chemical Parameters, Nutrients, Biodiversity

1. Introduction

Ladakh, a high-altitude cold desert situated between the Himalayas and the Karakoram Mountains, hosts Lake Tso Moriri, a brackish water body at 4,569 m above sea level ($32^0$54'N, $78^0$18'E). Declared a Ramsar site, the lake is renowned for its deep blue waters, snow-capped surroundings, and ecological significance, supporting rare migratory birds such as the blacknecked crane (Grus nigricollis) and bar-headed goose (Anser indicus). The lake Spanning around 120 kms with a maximum depth of 72 m, the lake is fed by glacial streams, including Gyoma, Karzuk, and Phersey, with no outlet, leading to water loss primarily through evaporation. This endorheic nature, combined with the arid climate (average rainfall 75 mm), results in high salinity and distinct physico-chemical characteristics compared to freshwater lakes in the region **[1].**

Despite its ecological importance, Lake Tso Moriri has received limited scientific attention due to its remote location and harsh climatic conditions, with temperatures ranging from -40 ^{0}C to 30^{0}C. Increasing tourism, mountaineering, and livestock grazing have disrupted the lakes ecosystem, affecting its biodiversity and ecological balance **[2].** This study aims to establish baseline data on the physico-chemical parameters and nutrient dynamics of Lake Tso Moriri and its tributaries, addressing the gap in scientific knowledge about high-altitude brackish water systems in the Himalayas.

2. Materials and Methods

Lake Tsomoriri is situated in the Nyoma district of Ladakh, within the Trans-Himalayan region, commonly referred to as Chumathong. The region experiences an average annual rainfall of approximately 75 mm, with fluctuating temperatures. The lake is approximately 230 kilometers from the main town of Leh and remains predominantly frozen for about three months, typically from mid-December to mid-March. Access to the lake is severely restricted during winter months, from mid-November to mid-April, due to the closure of the Srinagar-Leh National Highway and apprehensions of heavy landslides and cloudbursts along the route, making year-round sampling a challenging task.

The lake receives water from numerous snow-fed streams and glaciers from nearby peaks. Notably, the Gyoma stream enters the lake from the north through the pasture land of Pelado Laa, while the Karzuk stream feeds into the western bank. A larger stream, Phersey, flows into the lake on its southern side. The lake's surface typically remains calm during morning hours but experiences significant disturbances from fast currents and high winds in the afternoon.

For the purpose of this study, a total of 14 sampling sites were meticulously selected. Three of these sites were located in the main tributaries feeding the lake, while the remaining 11 sites were distributed across the lake itself at various latitudes and longitudes. Water samples were collected and subsequently analyzed in accordance with established standard methods, including those outlined by Welch **[3]** CSIR **[4],** Mackreth et al. **[5],** and APHA **[6],** as well as procedures listed by Bhat and Yousuf **[7]** Pandith and Yousuf **[8],** and Mahdi et al. **[9].** The physical and chemical parameters recorded were presented in average values.

3. Results and Discussions

The physico-chemical parameters of Lake Tso Moriri and its tributaries are summarized in Table 1. The lakes surface water temperature averaged 11^{0}C, while the bottom water was 8^{0}C, and tributaries averaged 7^{0}C, reflecting the influence of air temperature (mean 13^{0}C for the lake, 8^{0}C for tributaries).

S. No	Parameter	Lake Surface	Lake Bottom	Tributaries
01	Air Temp C	13	-	8
02	Water Temp C	11	8	7
03	Depth(m)	30	-	-
04	Transparency (m)	9	-	-
05	pH	8.70	8.79	8.52
06	Dissolved Oxygen (mg/l)	8	7	8
07	Caarbon dioxide (mg/l)	0	0	4
08	Conductivity	1399	1630	334
09	TDS (ppm)	582	516	199
10	Total Hardness(mg/l)	861	1022	351
11	Calcium (mg/l)	51	27	67
12	Magnesium (mg/l)	228	313	15
13	Chloride (mg/l)	32	28	31
14	Sodium (mg/l)	61	74	28
15	Potassium (mg/l)	22	22	14
16	Nitrate (µg/L)	222	280	241
17	Ammonia (µg/L)	46	37	52
18	T.P.P. (µg/L)	480	416	221
19	Total Alkalinity (mg/l)	374	434	156
20	CO_2 (mg/l)	68	77	17
21	HCO_3 (mg/l)	307	355	141
22	Sulphates (mg/l)	194	151	38
23	Silicates (mg/l)	8	13	6

The lake, with an average depth of 30 m and a maximum depth of 72 m, is classified as a cold monomictic lake **[10].** Dissolved oxygen levels were slightly higher in tributaries (8 mg/L) than in the lake (7.8 mg/L), attributed to greater turbulence in lake during afternoon hours and running water nature in lotic habitats. Transparency recorded as Secchi disc depth, averaged 9 m in the lakes central areas during calm morning hours but decreased in littoral zones during turbulence in afternoon due to sediment resuspension. Tributaries exhibited 100% transparency in late autumn and winter, reduced in summer due to silt-laden inflows, with Phersey stream being the least transparent. The lake water is highly alkaline (pH 8.78 to7.9), with no significant spatial variation, indicating a well-buffered system. Conductivity in the lake ranged from 1021 to 2390 µS/cm (mean 1399 µS/cm), significantly higher than in tributaries (215 to 416 µS/cm, mean 334 µS/cm), reflecting salt accumulation due to evaporation. TDS averaged 582 ppm in lake surface water, 516 ppm at the bottom, and 199 ppm in tributaries. Total hardness classified the lake as hard water (mean 861 mg/L surface, 1022 mg/L bottom), compared to 351 mg/L in tributaries. Cationic progression in the lake was Mg > Na > Ca > K, differing from tributaries (Ca > Na > Mg > K), due to calcium carbonate precipitation in the alkaline lake environment. Magnesium, being more soluble, accumulated in the water column. Chloride levels averaged 32 mg/L in the lake and 31 mg/L in tributaries, while sulphates were higher in the lake (194 mg/L surface, 151 mg/L bottom) than in tributaries (38 mg/L), linked to evaporative concentration **[11].**

Nutrient levels were low, with ammonia ranging from 6 µg/L -91 µg/L (mean 46 µg/L) and nitrate from 25 µg/L -674 µg/L (mean 222 µg/L) in the lake surface, slightly lower than in tributaries (mean 241 µg/L for nitrate). Total phosphorus averaged 480 µg/L in lake surface water, 416 µg/L at the bottom, and 221 µg/L in tributaries, reflecting inflows from the nutrient-rich catchment **[12].**

The high conductivity and TDS in Lake Tso Moriri, compared to its tributaries, underscore the impact of its endorheic nature and evaporative water loss, which concentrates salts and elevates hardness **[13].** The distinct cationic progression in the lake reflects the precipitation of calcium carbonate in its alkaline environment, while magnesium remains dissolved due to its solubility **[14].** The low nutrient levels, particularly nitrogen and phosphorus, are consistent with the sparse vegetation and minimal anthropogenic activity in the catchment **[15, 16].** However, the inflow of

Phosphorus rich water from the catchment contributes to elevated phosphorus levels in the lake. The lakes ecological significance is evident in its role as a habitat for rare and endangered species. However, increasing human activities, including tourism and grazing, pose risks to its biodiversity and ecological balance. The physico-chemical data indicate that Lake Tso Moriri is a unique brackish water ecosystem, distinct from freshwater lakes in the region, necessitating targeted conservation strategies to mitigate anthropogenic impacts.

This study provides critical baseline data on the physico-chemical and nutrient dynamics of Lake Tso Moriri, highlighting its brackish nature and ecological importance. The high salinity, driven by evaporation, and low nutrient levels reflect the lakes unique environmental conditions. The data underscore the need for conservation efforts to protect this Ramsar site from the growing pressures of tourism and grazing, ensuring the preservation of its biodiversity and ecological integrity.

References

[1] Alcocer, I., & Hammer, U. T. (1998). Saline lake ecosystems of Mexico. *Aquatic Ecosystem Health and Management*, *1*(3), 291-315.
[2] Hutchinson, G. E. (1937). A contribution to the limnology of arid regions: Primarily founded on observations made in the Lahontan basin. *Transactions of the Connecticut Academy of Arts and Sciences*, *33*, 47-132.
[3] Welch, P. S. (1952). *Limnological Methods*. Blakiston Co., Philadelphia.
[4] Council of Scientific and Industrial Research (CSIR). (1974). *Manual for Water Analysis*.
[5] Mackereth, F. J. H., Heron, J., & Talling, J. F. (1978). *Water Analysis: Some Revised Methods for Limnologists*. Scientific Publications Freshwater Biological Association, London.
[6] American Public Health Association (APHA). (1995). *Standard Methods for the Examination of Water and Wastewater*.
[7] Bhat, F. A., & Yousuf, A. R. (2002). Ecology of Periphytic Community of Seven Springs of Kashmir. *Journal of Research & Development*, *2*(1), 48-55.
[8] Pandith, J., & Yousuf, A. R. (2002). Studies on the limnology of some derelict waterbodies and their utilization for fish culture. *Journal of Research & Development*, *2*(1), 11-20. Press Information Bureau (PIB). (2023, May 30). *Records from lake sediments of Indus River Valley in Ladakh help reconstruct climate variation 19 to 6 thousand years ago*.

[9] Mahdi, M. D., & Yousuf, A. R. (2002). Limnological features of the River Jhelum and its tributaries in Uri, Kashmir. *Journal of Research & Development*, *2*(1), 1-10

[10] Arafat, S., Andrabi, S. M. H., Bakhtiyar, Y., Parveen, M., & Arafat, S. (2023). Multivariate statistical analysis of physicochemical parameters and fish assemblage in Manasbal Lake, Kashmir Himalaya. *Journal of Environmental Science and Engineering*, *65*(1), 1-10.

[11] Dar, G. H., Bhat, S. A., Pandit, A. K., & Ganai, A. H. (2021). Limnochemistry and Plankton Diversity in Some High Altitude Lakes of Kashmir Himalaya. *Journal of Applied and Natural Science*, *9*(1), 1-16. East Asia Forum. (2025, May 10). *Tourism in India's Ladakh border region reaches tipping point*.

[12] Gopal, B., Zutshi, D. P., & Kaul, V. (2002). Comparative Physico-Chemical Limnology of Two Lakes of Kashmir Himalaya. *International Journal of Multidisciplinary and Multilingual Research*, *1*(1), 1-10. Himalayan Geographic. (n.d.). *Amazing Tourism in the Himalayas*.

[13] Hutchinson, G. E. (1933). Limnological studies in Indian Tibet. *Nature*, *132*(3337), 567-568.

[14] Hutchinson, G. E., & Bowen, V. T. (1943). A quantitative study of the phosphorus cycle in Linsley Pond. *Ecology*, *24*(2), 204-221.

[15] Li, Y., Zhang, Y., & Li, Z. (2023). Hydrochemical Characteristics and Water Quality Assessment of Groundwater and Surface Water in the Alpine Desert Region of the Tibetan Plateau. *Water*, *15*(14), 2655.

[16] S., & Suri, B. L. (1975). Limnological studies on Dal Lake, Kashmir. *Journal of Research & Development*, *4*(2), 45-50.