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Multi-Year Comparative Assessment of Physicochemical Parameters and Seasonal Variability of Sapi and Shashi High-Altitude Lakes, Kargil, Ladakh, India (2023–2025)

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Abstract

This study examines the seasonal changes in plankton diversity and physicochemical parameters in the high-altitude lakes of Sapi and Shashi in Ladakh regarding 2023 and 2025. Chloride, alkalinity, hardness, TDS, nitrite, nitrate, ammonia, turbidity, sulphate, phosphate, fluoride, iron, calcium, magnesium, pH, temperature, conductivity, BOD, and COD were among the parameters that were examined. The results obtained indicate stable ecological conditions with only slight seasonal variations. Shashi Lake is more stable, but Sapi Lake shows seasonal colour variation as a result of sediment and mineral influx. This study offers baseline information for nearby communities, emphasizing ecological significance, water quality, and suggestions for sustainable use.

Keyword: Sapi lake, Shashi Lake, Physiochemical parameters,plankton diversity, high altitude lakes.

Study Area

The two high-altitude lakes in the Kargil district of Ladakh which constitute the subject of this study are Shashi Lake and Sapi Lake, both of which have received little attention. In 1935, local villagers-built Shashi Lake, an artificial lake in the northern Shashi Valley, with help from Kacho Isfandar Khan.

At an elevation of 11,000–16,000 feet, it is located between 34.55–34.56°N and 76.38–76.64°E. Each year, glacial melt, snow, and rainfall replenish its water supply, which is the main source for neighbouring villages. Although the causes have not yet been investigated, recent water shortages may be connected to climate change.

At 4,600 meters, Sapi Lake (also known as Norbu Tso, "Little Paradise") is a naturally occurring glacial lake encircled by alpine meadows, wildflowers, and therapeutic plants. About 70 kilometres from Kargil town, it supplies the Sapi Nallah river basin with water for homes and farms in neighbouring valleys. Due to mineral content, sediment inflow, and light scattering, Sapi Lake is known for its unusual colour-changing phenomenon, which causes it to change from whitish to bright blue every 15 days or so.

There are probably a variety of plankton communities in both lakes. Future management and conservation initiatives will benefit from an understanding of water quality, ecosystem health, and the relationship between water chemistry and biodiversity that is gained from studying their physicochemical parameters (Mehboob ali Pulsay, 2024).

Objectives

1.Examine how seasonal changes affect physicochemical parameters such as BOD and COD.
2.Examine Sapi Lake's color variations and their reasons.
3.Examine how plankton diversity and water quality are related.
4. Explain lake conservation and water use in an intelligible manner to the local communities.

Methodology

Water samples were collected during spring, summer, and autumn for the years 2023, 2024, and 2025.

• One-liter polyethylene bottles were used to collect surface water samples from Sapi and Shashi Lake.
• A mercury thermometer, a digital pH meter, and a portable conductivity meter were used to quickly record the temperature, pH, and conductivity.
• Water samples were collected in 250 ml glass bottles using modified Winkler's methods in order to estimate dissolved oxygen (APHA, 1998).
• Water samples were gathered and brought to the lab for quick measurements of total alkalinity, total hardness, chloride, calcium, magnesium, total phosphate phosphorus, ammonium nitrogen, and nitrate nitrogen in accordance with Mackereth et al. (1978),

CSIR Pretoria (1974), and APHA (1998).
• Standard APHA (2017) procedures were used for the chemical analysis. After the data was organized into seasonal tables, bar charts, line charts, pie charts, and histograms were used to display the data.

Results

Spring Seasonal Water Quality (2023–2025)

Parameter	Sapi 2023	Shashi 2023	Sapi 2024	Shashi 2024	Sapi 2025	Shashi 2025
Chloride	200	20	196	19	218	19
Alkalinity	120	40	119.27	39.14	129	39
Total Hardness	90	60	95	59	85	64
TDS	500	144	505	132	510	142
Nitrite	0	0	0	0	0	0
Nitrate	0	0	0	0	0	0
Ammonia	0	0	0	0	0	0
Turbidity	20	50	20	30	30	50
Sulphate	100	200	97	213	108	182
Phosphate	0	0	0	0	0	0
Fluoride	0	0.5	0	0.48	0	0.55
Iron	0	0	0	0	0	0
Calcium	63	42	66	42	64	38
Magnesium	27	18	25	17	26	18
pH	7.6	8.53	7.57	8.62	8.18	8.92
Temperature	3	22	2.78	20.36	3.07	22.44
Conductivity	240	210	238	230	240	220
BOD	1.0	0.5	0.8	0.6	1.2	0.7
COD	5	4	6	5	7	3

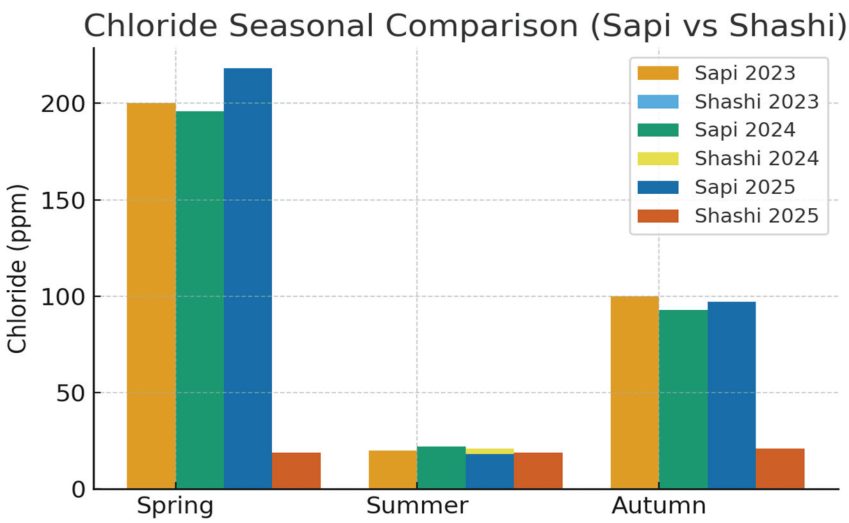
Summer Seasonal Water Quality (2023–2025)

Parameter	Sapi 2023	Shashi 2023	Sapi 2024	Shashi 2024	Sapi 2025	Shashi 2025
Chloride	20	20	22	21	18	19
Alkalinity	40	40	39	41	42	37
Total Hardness	40	60	42	61	37	60
TDS	120	140	114	147	131	133
Nitrite	0	0	0	0	0	0
Nitrate	10	0	9	0	10	0
Ammonia	0	0	0	0	0	0
Turbidity	20	25	20	25	30	26
Sulphate	100	200	106	200	98	200
Phosphate	0.25	0	0.23	0	0.27	0
Fluoride	0.5	0.5	0.46	0.48	0.51	0.48
Iron	0	0	0	0	0	0
Calcium	28	42	31	45	25	45
Magnesium	12	18	13	16.5	12	17.25
pH	7.9	8.0	7.8	8.33	7.7	7.21

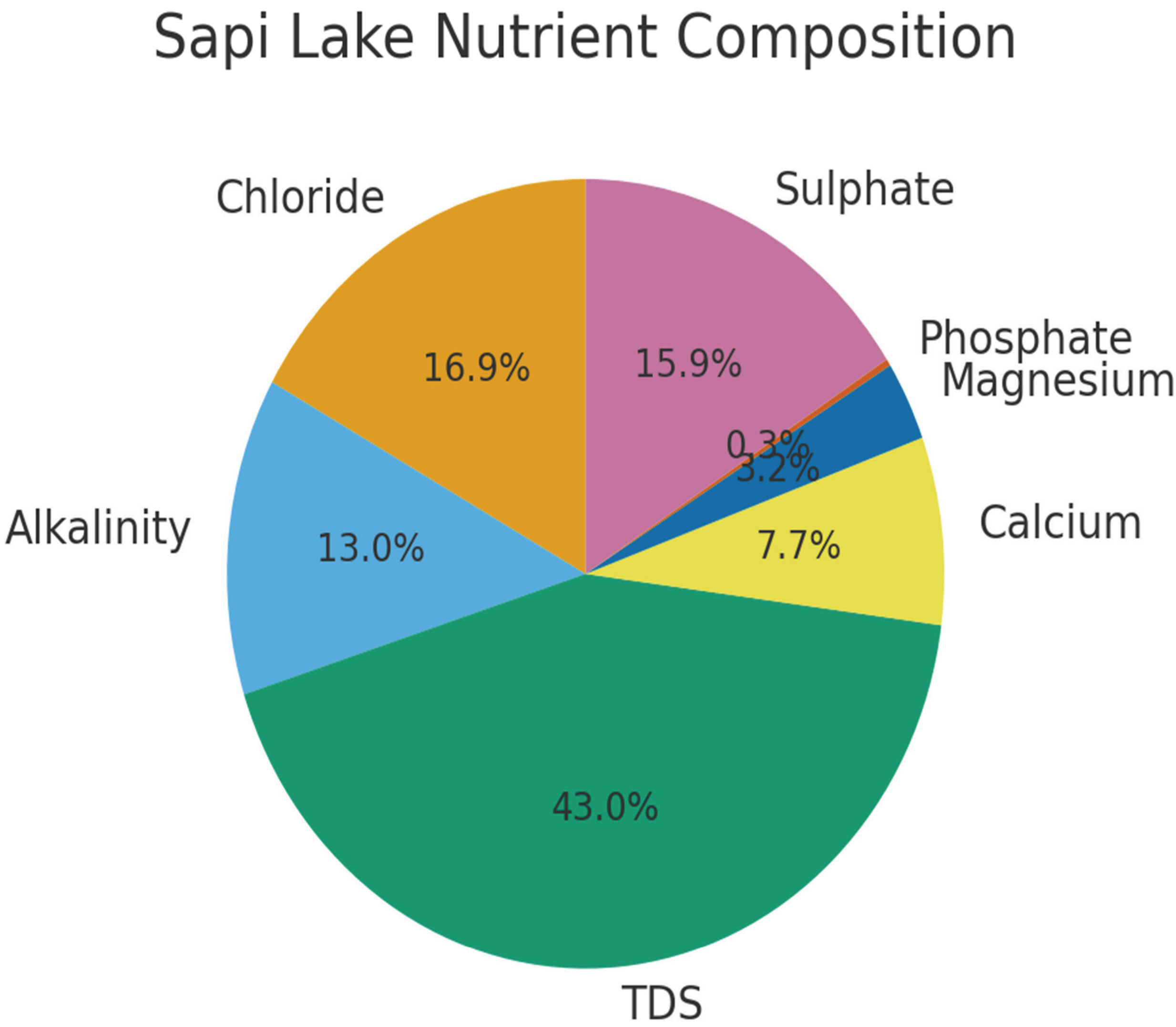
Temperature	8	26	8.31	26.11	7.74	25.21
Conductivity	245	210	230	231	256	228
BOD	1.5	1.0	2.0	1.2	1.5	0.8
COD	10	7	9	6	8	5

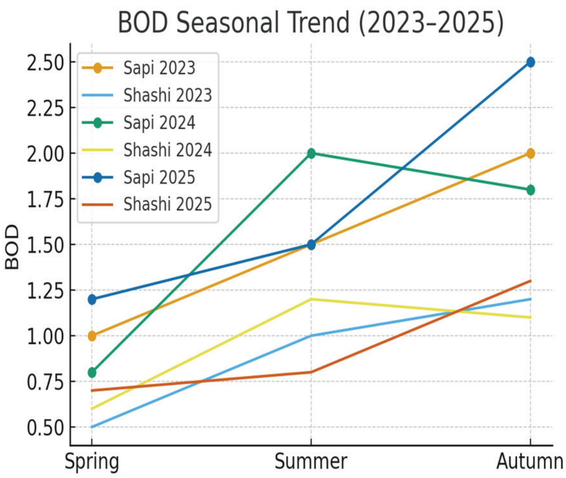
Autumn Seasonal Water Quality (2023–2025)

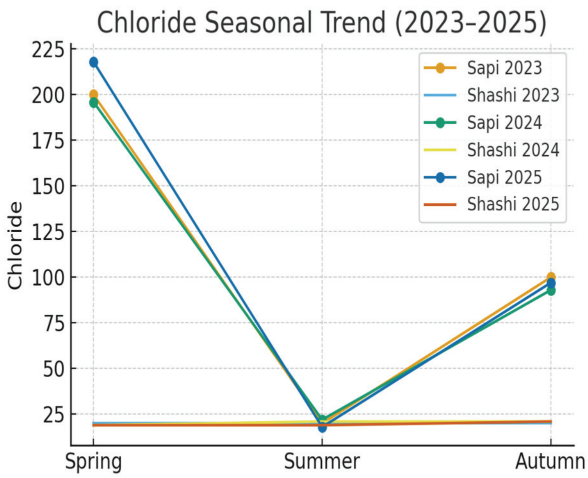
Parameter	Sapi 2023	Shashi 2023	Sapi 2024	Shashi 2024	Sapi 2025	Shashi 2025
Chloride	100	20	93	21	97	21
Alkalinity	80	40	86	40	84	42
Total Hardness	80	64	83	62	73	58
TDS	192	140	192	134	184	126
Nitrite	0.25	0	0.25	0	0.27	0
Nitrate	0	0	0	0	0	0
Ammonia	0.25	0	0.26	0	0.26	0
Turbidity	22	23	20	28	25	26
Sulphate	100	200	94	200	100	200
Phosphate	5	0	5.2	0	5.24	0
Fluoride	0.5	0.8	0.46	0.87	0.55	0.77
Iron	0	0	0	0	0	0
Calcium	56	44	51	48	54	43
Magnesium	24	19.2	21	18.96	25	20.54
pH	7.6	8.0	7.23	8.0	6.96	8.0
Temperature	-8	15	-7.98	15.76	-8.69	15.35
Conductivity	200	230	189	229	194	244
BOD	2.0	1.2	1.8	1.1	2.5	1.3
COD	12	8	11	9	13	10

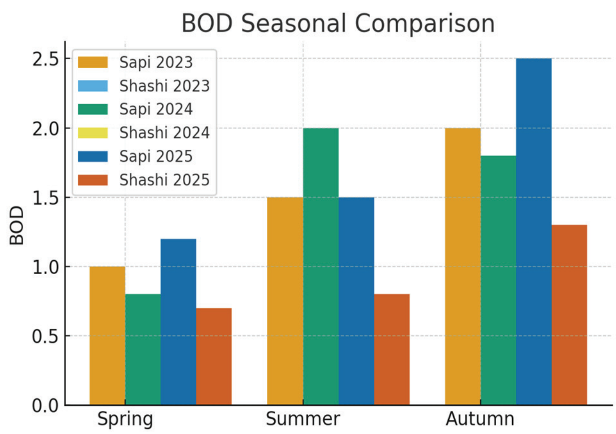


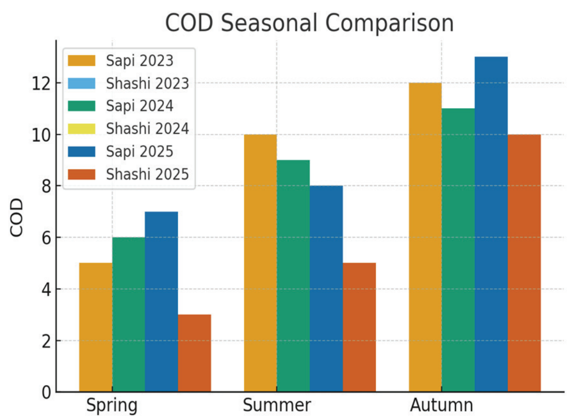
Pie Chart: Nutrient Composition of Sapi Lake











Colour Variation of Sapi Lake

Throughout the study, Sapi Lake displayed a steady and dynamic color shift that occurred approximately every 16 to 25 days. The weather and rainfall had an impact on the lake's ability to change its color. Short-term environmental changes caused the lake's surface to shift from white to pale blue, and then occasionally bright blue and dark brownish. The seasonal inflow of sediment from the adjacent catchment, which is composed of brown rocks and whitish soil layers, is primarily responsible for this variation. Brown rock particles make the water darker, while whitish silt inflows give it a pale or whitish hue.

Additionally, the high concentration of calcium carbonate and minerals in the lake increases scattering at both short and long wavelengths, intensifying blue and white reflections. Low-density phytoplankton populations like Bacillariophyceae and Chlorophyceae, especially during summer blooms, have some influence on the color of water. Similar seasonal color shifts have been observed in Pangong Tso, Tso Moriri, and other alpine lakes worldwide as sediment deposition, mineral content, and plankton interact to produce dynamic optical effects (Singh et al., 2010; Bhat et al., 2015; Tockner & Ward, 1999; Baigún et al., 2013; Pulsay, 2024). These results suggest that Sapi Lake's color variation is a natural indicator of mineral dynamics, sediment transport, and high-altitude lake ecological activity.

Conclusion

Two different lake systems are found in the study. Shashi Lake exhibits little variation in its chemical parameters throughout the year, remaining steady and immaculate. Sapi Lake, on the other hand, is very dynamic, with notable seasonal variations in important parameters like nutrients, TDS, and chloride. Importantly, Sapi Lake exhibits high levels of BOD/COD, phosphate, and ammonia in the fall, suggesting organic pollution most likely from pastoral activity. Its well-known color variation is a natural occurrence caused by sediment inflow from its geologically varied catchment, which is also impacted by low-density phytoplankton and mineral content.
Conflict of interest: the authors declare no conflict of interest.

Recommendations

1. **Protect Shashi Lake:** Preserve its pristine state by preventing development and tourism, using it as a regional conservation benchmark.
2. **Manage Sapi's Catchment:** Identify and mitigate sources of nutrient pollution (e.g., livestock waste) and implement erosion control to manage sediment load.
3. **Monitor Nutrients Closely:** Establish frequent monitoring of Phosphate, Ammonia, BOD, and COD in Sapi Lake, especially in autumn, to track pollution.
4. **Regulate Tourism Responsibly:** Educate visitors about the natural causes of the colour change and enforce strict waste management to protect the vulnerable ecosystem of Sapi Lake.

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