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Assessment Of Spring Water And Soil Quality In Zanskar Valley, Ladakh, India

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Abstract
Drinking water quality assessment is an essential and crucial process to ensure whether the water is safe for consumption and other uses, especially in remote regions where there is a lack of periodic assessment. The study evaluated pH, turbidity, total hardness, chloride, fluoride, nitrate, dissolved iron, free chlorine, alkalinity, and salinity using the AE103 Drinking Water Combination Test Kit. Water samples were collected from six springs across different villages in Zanskar and analysed to determine their compliance with BIS (IS 10500:2012) and WHO drinking water standards. The findings indicated that most springs meet permissible limits for essential parameters, though some show elevated nitrate, hardness, and dissolved iron levels, likely due to natural geological conditions and limited anthropogenic influence. Recommendations include periodic monitoring, community awareness programs, and low-cost filtration solutions to ensure sustainable water quality management.
Keywords: *Spring water, Aquasol Kit, Soil Parameter, Physicochemical Analysis, Zanskar Valley.*

INTRODUCTION

Water and soil are fundamental natural resources that sustain life, support ecosystems, and influence agricultural productivity (1–4). In remote and fragile ecosystems like the Zanskar Valley in Ladakh, these resources are of critical importance due to the region's arid climate, extreme temperatures, and dependence on glacial and spring-fed water systems. The Zanskar Valley, located in the Indian Trans-Himalayan region, is characterised by its high-altitude desert environment, where freshwater availability is largely dependent on seasonal snowmelt and natural springs (5,6) . These springs serve as the primary source of drinking water, irrigation, and livestock sustenance for local communities. However, increasing anthropogenic activities, climate-change-induced glacial retreat, and tourism pressure pose significant risks to water and soil quality in the region. (7–10)

Soil quality, on the other hand, is vital for sustaining agriculture, the mainstay of the local economy in Zanskar. The valley's limited arable land is heavily reliant on the nutrient content and stability of its soil, which is susceptible to erosion, salinisation, and contamination from improper waste disposal and agricultural runoff. Assessing the physicochemical properties of both spring water and soil is essential to determine their suitability for human consumption, irrigation, and long-term ecological health (11).

Despite its ecological significance, there remains a scarcity of comprehensive studies on the water and soil quality of Zanskar Valley. Existing research has primarily focused on glacial hydrology, while spring water systems and soil health have received less attention (12). This study aims to bridge this gap by evaluating the quality of spring water and soil through sampling and analysis of key parameters. This finding will provide policymakers, environmentalists, and local communities with critical baseline data to implement sustainable water and land management practices.

Furthermore, this research has broader implications for understanding the impacts of climate change and human activities on high-altitude ecosystems (6,13–15). By identifying potential contamination sources and degradation trends, the study will contribute to the preservation of Zanskar's fragile environment while ensuring water and food security for its inhabitants.

MATERIALS & METHODS

Study area and sampling sites

In this study, water samples were collected from the springs in six villages in Zanskar Valley. Zanskar is situated in the north of India, shown in Fig. 1. The region is located roughly between 32°52'30" N and 33°52'30" N latitude and between 76°14'5" E and 77°32'4" E longitude. The name and geographic coordinates of the sampled springs are listed in Table 1. Zanskar is a high-altitude semi-desert lying on the northern flank of the Himalayan range with long, cold winters and short, mild summers. (16)

Sampling and sample analysis

The water samples were collected from six different spring water sites sourced from glacial water during only one period. Sampling was undertaken in the month of September 2024. The samples were analysed for several parameters with the AE103 drinking water combination test kit, which is designed for basic water quality analysis and ideal for remote areas like Zanskar Valley, where lab access is limited. It provides instant approximations for critical parameters. It is suitable for preliminary screening. It uses globally accepted techniques like EDTA titration for hardness and DPD for chlorine. Limitations are that the colourimetric tests are subjective and depend on user interpretation for colour charts. Titration-based tests may have ±5-10% error due to drop size variability. For pH and salinity, the Aquasol digital meter was used. (17,18)

Fig. 1: Map of Zanskar Valley in India

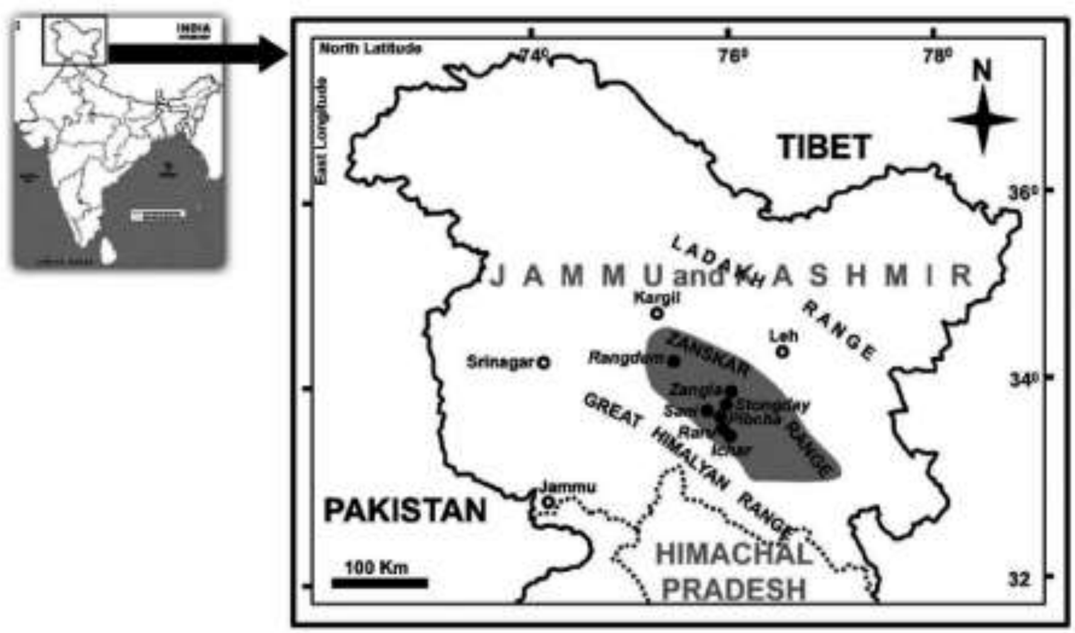

Table 1: The name and geographic coordinates of the sample springs

S.No.	Village Name (Sites)	Location
1.	Stongday Gompa	Latitude: 33.51° Longitude: 76.9869°
2.	Mila Chumig	Latitude: 33.5205° Longitude: 76.9849°
3.	Sani Chumig	Latitude: 33.5051° Longitude: 76.8126°

4.	Stongday Jal Jeevan	Latitude: 33.5177° Longitude: 76.9712°
5.	Barden Water Pump	Latitude: 33.3959° Longitude: 76.9212°
6.	Kumik Chumig	Latitude: 33.49° Longitude: 76.95°

RESULTS AND DISCUSSION

The spring water quality of six springs in Zanskar Valley was analysed using the AE103 Drinking Water Combination Test Kit. The results are summarised below and compared with the Bureau of Indian Standards (BIS) IS 10500:2012 and World Health Organisation (WHO) standards. (19,20)

Table 4: Water Quality Parameters of Zanskar Valley Springs:

S. No.	**Parameter**	**Stongday Gompa**	**Mila Chumig**	**Sani**	**Jal Jeevan**	**Barden**	**Kumik**	**BIS Limit**	**WHO Limit**
1	pH	8.0	8.5	7.96	8.0	8.0	8.0	6.5-8.5	6.5-8.5
2	Turbidity (NTU)	3	5	5	5	5	1	≤1	≤5
3	Total Hardness	20	100	150	60	110	180	≤300	≤500
4	Chloride (ppm)	20	10	30	20	10	10	≤250	≤250
5	Fluoride (ppm)	Nil	Nil	4.5	1.0	Nil	3.0	≤1.5	≤1.5
6	Nitrate (ppm)	5	10	1	1	0.5	2.5	≤45	≤50
7	Dissolved Iron (ppm)	Nil	Nil	0.5	0	0	0	≤0.3	≤0.3
8	Free Chloride (ppm)	Nil	Nil	Nil	Nil	Nil	Nil	0.2 - 1	0.2-5
9	Alkalinity (ppm)	110	60	70	60	90	60	≤200	No strict limit
10	Salinity (ppm)	428	115	159	117	141	189	-	≤500

Physicochemical Parameters of Spring Water Samples

pH refers to the measurement of acidity or basicity of a solution using the pH logarithmic scale. It shows how many hydrogen ions (H^+) are present in a solution. Lower pH suggests more acidity, whereas higher pH indicates more basicity or alkalinity. Seven is neutral, less than seven is acidic, and more than seven is basic on the scale, which runs from 0 to 14. The ideal range is between 6.5 and 8.5. Low pH solutions can be corrosive and leach metals, whereas high pH solutions taste harsh and cause pipe scaling. The pH of all spring waters was within the acceptable range of 7.96 to 8.5, suggesting that there were no serious problems. The highest pH (8.5) was found in Mila Chumig, most likely because of geogenic processes such as rock leaching.(21–24)

Turbidity describes how cloudy or hazy a liquid is due to suspended particles like silt, clay, organic debris, etc. The ideal turbidity range is below 5 NTU. Turbidity measurement is essential for evaluating water quality, especially in drinking water and wastewater treatment, as it can reveal the presence of contaminants and impact how well disinfection procedures work. Excessive turbidity harbours germs and decreases the effectiveness of disinfection. There was discernible turbidity in the spring waters, since their turbidity was within permissible bounds. Soil erosion or sediment flow from glacier melt are two potential causes of turbidity. (25–28)

Total Hardness, represented as calcium carbonate (CaCO3), is the amount of dissolved calcium and magnesium ions in water. Hard water can alter the flavour of beverages, produce scaling in pipes and appliances, and cause problems with soap lathering. Although hard water is not thought to be harmful to health, the calcium and magnesium it contains can help with mineral consumption in general. Sani Chumig (150 ppm) and Kumik Chumig (180 ppm) came close to the BIS threshold (330 ppm); however, all samples are below acceptable levels (20-180 ppm). It suggests that while moderately hard water could lead to scaling, there are no health hazards. (29,30)

Fluoride, a naturally occurring mineral, is essential for dental health, especially for preventing tooth decay and strengthening tooth enamel. Water, soil, and a variety of foods all naturally contain it. Dental fluorosis, which causes teeth to become mottled or discoloured, can occasionally result from excessive fluoride exposure, particularly in young people. The BIS (1.5 ppm) and WHO (1.5 ppm) limitations were surpassed by Sani Chumig (4.5 ppm) and Kumik Chumig (3.0 ppm). Long-term exposure can lead to dental, skeletal and dental fluorosis. Installing activated alumina filters or mixing them with low-fluoride water are two mitigation techniques. (31–33)

Chloride, a negatively charged ion, is a vital electrolyte in the body, affecting fluid balance, acid-base balance, nerve and muscle function, and aiding digestion. It is found in many foods and indicates salinity or sewage contamination in water samples. All spring samples are in the range of the permissible limit. (34,35)

Nitrates, naturally present in water, can increase due to human activities like agricultural runoff, wastewater, and landfills. High concentrations can be harmful, especially to infants and can cause certain cancers. Beyond permissible levels, methemoglobinemia occurs, and excessive nitrates can cause algal blooms and water quality issues in aquatic ecosystems, impacting biodiversity and recreational activities. All samples are well below limits (0.5 - 10 ppm). No agricultural or sewage contamination is detected that could affect concentration. (36–39)

Dissolved iron, a colourless and tasteless iron, can cause staining, metallic taste, and aesthetic issues in drinking water. It can leach from rocks or soil. Only Sani Chumig (0.05 ppm) had detectable iron, but it is within limits. (40–42)

Free chlorine in water is an active, undissociated form of chlorine that disinfects water and kills pathogens. It is essential for safe drinking water, but maintaining levels and avoiding byproducts is crucial. If free chlorine is absent in springs, it increases the risk of microbial contamination. Free chlorine is absent in all springs, indicating no disinfection. It's important to promote chlorination or boiling for microbial sterilisation. (43–45)

Alkalinity measures a water body's buffering capacity, primarily based on bicarbonates, carbonates, and hydroxides, which maintain stable pH levels in aquatic environments. It protects organisms from harmful changes, but high alkalinity can cause a bitter taste and reduce disinfectant effectiveness. (46)

Salinity, measured in ppt or ppm, is the salt content in water. Fresh water typically is less than 0.5 ppt, while seawater averages around 35 ppt. Stongday Gompa and Kumik Chumig have elevated salinity levels, possibly due to mineral leaching or glacial influence. (47,48)

Physicochemical Parameters of Soil

The soil samples were analysed for pH, organic carbon, nitrogen (N), phosphorus (P), and potassium (K) using standardised field-testing methods. The soil was taken after the harvest in the month of September. (12,49–52)

Table 5: Soil Nutrient Levels and Their Significance:

S. No.	Parameter	Test Result	Optimal Range	Interpretation
1	pH	6.8 (slightly acidic)	6.0-7.5 (Neutral)	Ideal for most crops; ensures nutrients Availability.
2	Organic Carbon (%)	0.9% (moderate)	0.8-1.2% (Good)	Supports water retention and microbial activity.
3	Nitrogen (kg/ha)	80 kg/ha (low)	250-500 kg/ha (High)	The deficiency observed may limit leafy growth. Requires urea/compost amendment.
4	Phosphorus (kg/ha)	60 kg/ha (moderate)	25-60 kg/ha Adequate	Sufficient for root development but may need supplementation for fruiting crops.
5	Potassium (kg/ha)	250 kg/ha (Adequate)	125-250 kg/ha (Good)	Optimal for photosynthesis and disease resistance.

CONCLUSION

The present study is undertaken to assess physicochemical parameters and determine whether the water is safe for consumption and the soil is healthy for cultivation. There has been a lack of water quality testing in such regions due to limited anthropogenic activities, and the sources are mainly glacier water, which is clean and safe for drinking without any treatment.

Most springs meet drinking water standards except for High fluoride in Sani Chumig and Kumik Chumig. There is no chemical disinfection (free chlorine) that can increase the risk of microbial contamination. Recommendations for the site include fluoride mitigation by installing fluoride removal filters in the affected villages. Train locals in chlorine tablet use or solar disinfection (SODIS). Long-term monitoring is essential to see the changes and take necessary precautions, as the Zanskar Valley is currently facing rapid urbanisation with an increase in pollution and scarce water resources.

The sampled soil has balanced pH, adequate potassium and moderate organic carbon. It is a nitrogen deficiency and borderline phosphorus levels. Overall, the soil is suitable for cultivation but requires targeted fertilisation. To boost or increase nitrogen availability, apply urea (100 kg/ha) or compost before planting. Incorporate crop residues or vermicompost annually. Re-test the soil every 2 seasons to monitor nutrient dynamics.

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