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A Comprehensive Evaluation of Potability Standards of Surface Drinking Water Sources in Pithoragarh City, Uttarakhand

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ABSTRACT
The definition of water quality encompasses physical, chemical, and biological aspects. However, there are geographical and temporal alterations in the water quality that occur naturally. The objectives of our study were the evaluation of water quality in Pithoragarh, Uttarakhand, with a specific focus on surface drinking water sources. Monthly collection of water samples from three distinct potable water sources was performed over the course of two years and rigorous physicochemical (pH, turbidity, conductivity, TDS, total hardness, total alkalinity, calcium, magnesium, nitrate, chloride, sulphate, fluoride, iron) and bacteriological parameters (total coliform) were studied and statistically analysed using standard methods to compute the compliance of these water sources with potability standards. Our results showed that some parameters, notably conductivity, exceeded BIS standards, indicating potential issues. Additionally, all three water sources had high levels of total coliform bacteria, well above permissible limits, suggesting that the water may not meet safety requirements. The studied water quality characteristics showed positive and negative relations, indicating interactions and interrelationship among various water quality indicators. Despite some adverse findings the water quality index for most seasons at all three sites was rated excellent or good, except for autumn, where the index was bad at one site. By shedding light on the suitability of these sources for consumption, this research contributes valuable information for public health and underscores the significance of managing the region's water quality.
Keywords: Biological, BIS Standards, Chemical, Coliform, Physical, Water quality

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INTRODUCTION

Among all the Indian states, Uttarakhand is particularly significant since it supplies water to neighbouring states via the enduring rivers, Ganga, and Yamuna. For a very long time, the Indian state of Uttarakhand has relied heavily on its natural sources of water for high-grade water for drinking purpose [1]. Water resources of the mountainous state are being contaminated by the rapid expansion of the human population, industrial processes, and agricultural output during the past ten years [2]. For decision-makers at various administrative levels to design a water health strategy and assess the water quality of accessible sources, a variety of physico-chemical and bacteriological parameters are crucial [3]. Since excellent water quality is heavily dependent on physicochemical factors, as well as the amount and source of pollution load, monitoring of water quality parameters is crucial [4]. Since hydrogeochemical processes in the environment determine chemical composition of water, monitoring water quality indicators provides crucial data for the management of water [4]. To guarantee that drinking water is suitable for human consumption, the government regulates its quality. The Bureau of Indian Standards (BIS) and the World Health Organization (WHO) have developed criteria for the purity of drinking water. The highest permissible concentrations of different pollutants in drinking water are specified by these regulations [5,6]. The Water Quality Index (WQI) is a crucial approach for determining surface water purity and its acceptability for human consumption [7]. WQI is a metric that gives a composite effect of different water quality metrics on the overall state of the water at a particular location. It is used to evaluate water quality for numerous purposes, including drinking, bathing, and irrigation [8]. There are only a few brief studies about the monitoring of the potability of traditional surface water resources in different hilly areas of Uttarakhand [9,10], but no extensive research has been done. The aim of this research is to determine the water quality parameters in relation with potability standards of study area. This study holds significant importance as water quality assessment would lead to policy recommendation for water resource

management. It will also promote awareness towards the contamination of water and water borne diseases, which will eventually lead to long term environmental sustainability.

MATERIAL AND METHODS

To fulfil our objective the examination of the research area's water quality characteristics and water quality index was done.

Study area: Pithoragarh is a town situated at an elevation of 1645 meters above sea level and having coordinates 29.4° to 30.3° in latitude and 80° to 81° longitude along the eastern and southern parts of the central Himalayas. The study area consists of three sampling sites in Pithoragarh city. Residents in the area frequently use these places as water sources. Table 1 and Fig. 1 provide the sampling places' names and GPS coordinates.

Analysis of water quality parameters: Monthly collection of samples of water from three distinct potable water sources was performed during a period of two years from January 2022 to December 2023. In accordance with APHA [11], water samples were collected in plastic bottles, and their physicochemical properties were examined, like odour, color, taste, pH, turbidity, TDS, total hardness, total alkalinity, conductivity, nitrate, fluoride, sulphate, chloride, calcium, magnesium, and iron, according to standard methods [5,11,12]. Sterilized tarson bottles with a capacity of 125 ml were used to collect the water samples for bacterial examination [11] and its investigation was performed by the USEPA approved Colilert®-18 Quanti-Tray® method for the analysis of total coliform in ambient water [13]. The observed value of parameters was compared with permissible range of drinking water suggested by BIS, 2012 (Table 2).

Analysis of water quality index: Water's suitability for drinking purposes was determined by calculating the water quality index (WQI) using the weighted arithmetic index method [14]. The following first formula was used to generate the water quality index (WQI), where q_i is the i_{th} parameter's quality rating and W_i is the weightage factor of the i_{th} parameter.

$$WQI = \sum_{i=1}^{n} W_i q_i$$

$$q_i = \left[\frac{V_a - V_i}{V_s - V_i} \right] \times 100$$

The following equation can be used to compute qi, where V_a is the i_{th} parameter's actual value as found by laboratory analysis, V_s depicts the value of the i_{th} parameter as determined by a standard table, and V_i represents the ideal value (for pH is equal to 7, and zero for other parameters). The drinking water quality status is determined based on the WQI scale (Table 3).

Data analysis: The average value of water quality parameters was compared to the BIS,2012 standards. The surface water data were analyzed using descriptive statistics (mean, maximum, minimum, and standard deviation) and inferential statistics (Pearson's correlation) using the PAST software [15], in combination with Microsoft Office Excel 2019.

RESULTS

Water quality parameters: The average of two years of surface water parameters statistics of samples from all three sampling sites i.e., Mahadev, Panda and Madh are presented in Table 4 and Table 5. The taste, color, and odor of all the samples collected throughout the time period from all the three sampling sites were found to be agreeable, whereas the pH ranges 7.77 to 7.98 at all three sites. Turbidity values never exceeded 0.5 NTU in any of the sampling sites. Conductivity and TDS values were highest in Panda with the value of 821us/cm and 410.5mg/l respectively. The value of total alkalinity (314.83mg/l) and hardness (359.83mg/l) was highest in Madh. The observed average calcium concentration was highest at Panda (75.03mg/l), whereas magnesium concentration was highest at Madh (44.28mg/l). Chloride and nitrate concentration were highest at Panda (37.8 mg/l) and Madh (2.63mg/l) respectively. Sulphate concentration was highest at Madh (3.91 mg/l). Fluoride and iron concentration were observed to be <0.2mg/l and <0.1 mg/l in all the samples from all three sites. All the three sites demonstrated coliform contamination ranging between 0 and 461.1 MPN/100ml. Total coliform bacteria concentration ranged between 0-290.9, 7.5-181.1 and 2-461.1 MPN/100ml at all the three sites respectively, with maximum average number at Madh (118.59MPN/100ml) and minimum at Panda (54.5 MPN/100ml).

Pearson correlation: For a more accurate evaluation of how the water quality criteria relate to one another, Pearson's correlation matrix was computed (Table 6). TDS showed a high positive correlation with EC (r= 0.708). Total hardness depicted a high positive correlation with TDS(r=0.735), total alkalinity (r= 0.880), calcium (r= 0.775), and magnesium (r= 0.787). Positive correlation was also depicted between

nitrate and conductivity (r= 0.769). Similar positive correlation was seen between magnesium and alkalinity (r= 0.780). Calcium showed moderate positive correlation with conductivity (r=0.6658) and total alkalinity (0.614). Moderate positive correlation was also depicted by nitrate with TDS (r=0.648), total hardness (r=0.677), and magnesium (r=0.659). Total coliform bacteria showed a very low negative correlation with pH (r= -0.186), TDS (r= -0.047), alkalinity (r=-0.032), calcium (r= -0.155), chloride (r= -0.198), and sulphate (r= -0.13).

Water quality index: The WQI of samples varied between 20.16 to 64.82 (Table 7). In spring, the water quality status inferred by calculated WQI (Table 2) was found to be excellent at Mahadev (WQI: 20.16) and Panda (WQI: 20.85) whereas the status was good (WQI: 28.49) at Madh. The water quality in winter season was excellent at Mahadev (WQI: 21.20) and good at other two sites (WQI_{Panda}=26.13, WQI_{Madh}=31.68). In autumn the water quality status at Madh was poor (WQI: 64.82) whereas it was found good at Mahadev (36.53) and Panda (WQI: 41.59). The water quality status was good at all the three sites in summer season.

DISCUSSION

Water samples from all three sites exhibited a pH range of 7.42 to 8.1, which is within the BIS desirable limit, suggesting a slightly alkaline nature; a parallel study in North Lakhimpur Town, Assam, assessed drinking water quality parameters [16]. Turbidity was within the BIS limits (≤ 5 NTU) at all sites, while average electrical conductivity exceeded BIS agreeable limit across all sites and surpassed the permissible limit (800 µS/cm) at Panda, consistent with findings in Bageshwar District, Uttarakhand [17]. Mahadev site occasionally exceeded the TDS desirable limit (500mg/l), yet within permissible bounds, while the other two sites aligned with the desirable range, consistent with sukhnag stream in Kashmir Himalaya [18]. Total alkalinity and hardness exceeded the desirable limits (200 mg/l and 300 mg/l) at all three sites but remained within the allowable range (600 mg/l). A similar range was noted in water quality testing in Garhwal and Rudraprayag district of Uttarakhand [19]. Major cations (Ca^{2+} and Mg^{2+}) occasionally surpassed BIS desirable limits but remained within permissible levels (200 and 100 mg/l) at all three sites, aligning with Srikakulam district, Andhra Pradesh [20]. Anions (chloride, nitrate, sulphate) were within BIS desirable limits, consistent with potability analysis in Sumari village, Uttarakhand [21]. Fluoride and iron concentrations across all sites met BIS desirable limits, mirroring Sikkim's drinking water quality [22]. Total coliform concentration at all three sites exceeded the BIS-prescribed limit of 10 colonies/100 ml, with Madh recording the highest count of 461.1/100 ml. While these fecal bacteria don't directly cause diseases, they serve as indicators of potentially harmful organisms, as observed in other studies across Uttarakhand [21,23]. Our study found TDS strongly correlated with EC and total hardness, and positive correlations of total hardness with calcium, and magnesium, as seen in some of the previous studies [19,24]. Additionally, positive correlations of nitrate with conductivity and magnesium with alkalinity, along with moderate correlations of nitrate with TDS, total hardness, and magnesium, mirrored some previous observations [25]. Total coliform exhibited very low negative correlations with pH, TDS, alkalinity, calcium, chloride, and sulphate, echoing relations in other hilly districts of Uttarakhand [19]. Mahadev and Panda consistently had excellent or good water quality throughout the year, but Madh showed poor quality in autumn, reflecting a seasonal variation observed in other Uttarakhand hilly regions [17,21]. This indicates that water from Mahadev and Panda is suitable for drinking after disinfection, while Madh water requires treatment for drinking purposes.

Table 1: Sampling sites with geological information of the sampling spot.

S. No.	Sampling sites	GPS Coordinates of spots		
		Latitude	Longitude	Altitude
1	Mahadev	29°34′34″N	80°12′9″E	1540m
2	Panda	29°36′7″N	80°13′54″E	1510m
3	Madh	29°36′37″N	80°12′58″E	1591m

Table 2: Indian national standards for drinking water

			BIS	
S. No.		**Parameters**	**Desirable limit**	**Permissible limit**
1	Physical	Taste	Agreeable	-
2		Colour (hazen units)	5	25
3		Odour	Unobjectionable	-
4	Chemical	pH	6.5 - 8.5	No relaxation
5		Turbidity (ntu)	5	10
6		Conductivity (us/cm)	200	800
7		TDS (mg/l)	500	2000

8		Total alkalinity (mg/l)	200	600
9		Total hardness (mg/l)	300	600
10	Essential minerals (mg/l)	Calcium	75	200
11		Magnesium	30	100
12		Chloride	250	1000
13		Nitrate	45	No relaxation
14		Sulphate	200	400
15		Flouride	1	1.5
16		Iron	0.3	1
17	Biological	Total coliform (mpn/100ml)	absent	10

Table 3: Water quality classification based on WQI values for drinking.

Sr. No.	WQI value	Classification	Ranking
i	0 to 25	Excellent	A
ii	26 to 50	Good	B
iii	51 to 75	Poor	C
iv	76 to 100	Very poor	D
v	More than 100	Unsuitable for drinking	E

Table 4: Annual descriptive statistics of all water quality parameters from all sites.

Parameters	Site 1 (Mahadev)		Site 2 (Panda)		Site 3 (Madh)	
	Min/Max	Avg±SD	Min/Max	Avg±SD	Min/Max	Avg±SD
Taste	AG	AG	AG	AG	AG	AG
Colour	<0.10-<0.10	<0.10±0	<0.10-<0.10	<0.10±0	<0.10-<0.10	<0.10±0
Odour	UO	UO	UO	UO	UO	UO
pH	7.42-7.99	7.77±0.16	7.56-8.1	7.88±0.18	7.61-7.98	7.80±0.10
Turbidity	<0.5-<0.5	<0.5±0	<0.5-<0.5	<0.5±0	<0.5-<0.5	<0.5±0
Conductivity	272-880	523.6±155.1	632-928	821±115.34	544-912	760.6±112.5
TDS	192-544	292±103.4	316-464	410.5±57.67	272-456	380.33±56.29
T. Alkalinity	136-338	258.8±77.5	228-348	281.3±38.49	214-364	314.83±52.78
T.hardness	178-414	280.3±69.2	296-416	335.1±38.98	276-432	359.83±49.58
Calcium	36-96	59.9±18.9	64-92	75.03±7.71	40-96	71.33±13.03
Magnesium	21-47.14	32.36±7.26	29-45	36.57±4.52	28-69.01	44.28±11.70
Chloride	0.5-9.5	4.98±2.08	5.9-62.5	37.8±24.52	3.8-35.5	17.6±12.08
Nitrate	1.3-1.9	1.63±0.29	2.3-2.8	2.55±0.16	1.8-3.2	2.63±0.43
Sulphate	3-5	3.83±0.57	3-4	3.75±0.45	2-5	3.91±0.90
Flouride	<0.2-<0.2	<0.2±0	<0.2-<0.2	<0.2±0	<0.2-<0.2	<0.2±0
Iron	<0.1-<0.1	<0.1±0	<0.1-<0.1	<0.1±0	<0.1-<0.1	<0.1±0
T.coliform	0-290.9	57.97±96.01	7.5-181.1	54.5±60.93	2-461.1	118.59±129.8

AG: Agreeable UO: Unobjectionable

Table 5: Annual summary statistics of all parameters from the study area.

	Taste	Colour	Odour	Ph	Turbidity	Conductivity	Tds	T. Alkalinity	T.hardness	Calcium	Magnesium	Chloride	Nitrate	Sulphate	Flouride	Iron	T.coliform
N	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
Min	Ag	1	uo	7.42	<0.5	272	192	136	178	36	21	0.5	1.3	2	<0.2	<0.1	0
Max	Ag	1	uo	8.1	<0.5	928	544	364	432	96	69.01	62.5	3.2	5	<0.2	<0.1	461.1

Sum	Mean	Std. Error	Variance	Stand. Dev	Median	25 percentile	75 percentile	Mode	Skewness	Kurtosis	Geom. Mean	Coeff. Var
2772.85	77.023	16.874	10250.57	101.245	33.7	12.125	113.725	2	2.143	5.135	0	131.446
3.6	<0.1	7.037E-18	1.782E-33	4.222E-17	<0.1	<0.1	<0.1	<0.1	-1.044	-2.121	<0.1	4.222E-14
7.2	<0.2	1.407E-17	7.131E-33	8.444E-17	<0.2	<0.2	<0.2	<0.2	-1.044	-2.121	<0.2	4.222E-14
138	3.833	0.109	0.428	0.654	4	3.25	4	4	-0.467	0.895	3.773	17.077
81.8	2.272	0.089	0.291	0.539	2.4	1.725	2.775	NA	-0.26	-1.24	2.204	23.749
725.7	20.158	3.436	425.123	20.6185	8.55	5.15	30.375	5	1.038	-0.492	11.536	102.282
1358.8	37.744	1.591	91.162	9.547	35.635	32.07	45.877	33	1.004	1.786	36.656	25.296
2475.6	68.766	2.527	230.046	15.167	72	64	73.2	72	-0.690	0.773	66.826	22.056
11704	325.111	10.401	3894.044	62.402	318	296.5	376	384	-0.571	0.718	318.456	19.194
10260	285	10.238	3773.6	61.429	292	244	336.5	NA	-1.002	0.648	277.003	21.554
12994	360.944	14.9112	8004.454	89.467	393	289.5	440	NA	-0.256	-0.821	349.076	24.787
25264	701.777	30.125	32672.41	180.755	726	579	876	NA	-0.571	-0.620	674.893	25.756
18	<0.5	0	0	0	<0.5	<0.5	<0.5	<0.5	0	0	<0.5	0
281.61	7.82	0.026	0.025	0.159	7.83	7.72	7.95	NA	-0.37	-0.13	7.82	2.03
uo	uo	0	0	0	uo	uo	uo	uo	0	0	uo	0
36	1	0	0	0	1	1	1	1	0	0	1	0
Ag	Ag	0	0	0	Ag	Ag	Ag	Ag	0	0	Ag	0

AG: Agreeable UO: Unobjectionable

Table 6: Factor analysis of the correlation matrix between the parameters.

	Ph	Conductivity	TDS	T. Alkalinity	T.hardness	Calcium	Magnesium	Chloride	Nitrate	Sulphate	Flouride	Iron	T.coliform
Ph	1												
Conductivity	0.38731	1											
TDS	0.275771	0.708643	1										
T. Alkalinity	0.194383	0.588549	0.644452	1									
T.hardness	0.215204	0.782061	0.735143	0.880066	1								
Calcium	0.159782	0.665819	0.622818	0.614911	0.775538	1							
Magnesium	0.154133	0.586633	0.547106	0.780388	0.787847	0.236416	1						
Chloride	0.526752	0.582914	0.504922	0.121611	0.177247	0.145378	0.147817	1					
Nitrate	0.209926	0.769011	0.648803	0.514378	0.677674	0.415846	0.659504	0.495159	1				
Sulphate	0.162784	0.191873	0.422285	0.588265	0.390726	0.105316	0.489632	0.208391	0.180623	1			
Flouride	3.76e-15	2.84e-16	2.86e-16	0	-4.1e-16	0	2.87e-16	6.47e-17	-1.5e-16	7.64e-17	1		

T.coliform	-0.18167	0.023813	-0.04708	-0.03298	0.076611	-0.15575	0.281733	-0.19892	0.26745	-0.13023	2.25e-16	2.25e-16	1
Iron	3.76e-15	2.84e-16	2.86e-16	0	-4.1e-16	0	2.87e-16	6.47e-17	-1.5e-16	7.64e-17	1	1	

Table 7: Calculated WQI values at all the sampling sites.

Site	Season	Calculated WQI	Water quality status
Mahadev	Autumn	36.53	Good
	Winter	21.20	Excellent
	Spring	20.16	Excellent
	Summer	36.79	Good
Panda	Autumn	41.59	Good
	Winter	26.13	Good
	Spring	20.85	Excellent
	Summer	25.18	Good
Madh	Autumn	64.82	Poor
	Winter	31.68	Good
	Spring	28.49	Good
	Summer	40.85	Good

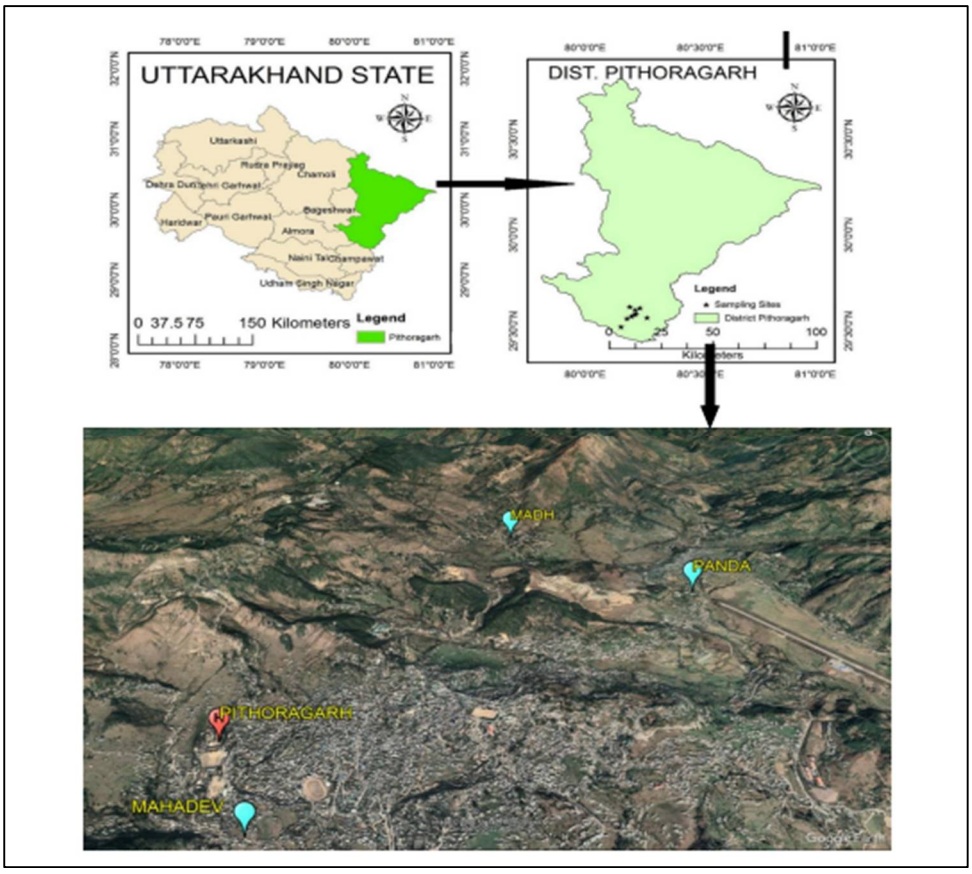

Fig. 1: Map representing sampling locations.

CONCLUSION

Through physicochemical and bacteriological investigations, the current study sought to assess the potability of natural surface water resources in Uttarakhand's mountainous regions. The study's key conclusion suggests that natural water sources can be safe for drinking if proper bacterial treatment

methods are employed; otherwise, they pose risks of waterborne diseases. The water quality index categorization underscores the need for management strategies to improve and preserve water quality.

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CONFLICT OF INTERESTS
The authors declare that there is no conflict of interests regarding the publication of this paper.

Author's Contribution
Joshi Apurva: Data Collection, original draft, data analysis.
Goswami Deepika: Conceptualization, supervision.
Verma Rakesh: Supervision, review, and editing.

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