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WATER QUALITY STATUS IN SACRED GROVES OF GARHWAL HIMALAYA, INDIA

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Abstract

Clean water is necessary to support the healthy living. Water is one of most important natural resources which supports several aspects of human development. Access to safe clean drinking water has a direct bearing on both quality and prosperity of human life. In Himalaya due to several natural and anthropogenic problems this precious natural resource is facing threat. The present study has attempted to form a water quality index (WQI) of three sacred groves located in Uttarakhand. Sacred grove is an age-old tradition where a forest patch or a water body is dedicated to local deity where cutting plants or killing animals are strictly prohibited, and is supposed to have high hydrological value. Water Quality Index is renowned effective method to express water quality in a simple, stable and reproducible unit of measure which communicates information of water quality to the concerned citizens and policy makers. Also a household survey was carried out in the year of 2015 in order to gather information regarding safe drinking water availability and sanitation. The results show that the water of all sacred groves is safe for different household purposes except for drinking as it needs treatment to make it perfect for this purpose.

Key words: correlation, sacred grove water, water quality index, water chemistry.

Introduction

Water is important in our daily life, used in several sectors like agriculture, industries and households. But worldwide consciously and unconsciously human being pollutes this precious natural resource on which its very existence is dependent. The problem is increasing day by day (Hidaka 2003, European communities 2002). In the last decade extensive decline in inland aquatic system's water quality has been recorded. In the 21st century anthropogenic activities are the topmost source for water quality deterioration. Health of human being is determined by easy availability of clean water. Water is supposed to be both source and support system for human development in every aspect. But today this resource even in Himalaya also faces several threats due to natural as well as anthropogenic issues. Sacred grove is an age-old tradition where a forest patch or a water body is dedicated to local deity and nobody is permitted to cut plants or kill animals or any form of life (Gaikwad et al. 2004). Sacred groves are associated with Sacred Natural Sites (SNS). IUCN defined SNS as ''Natural area of special spiritual significance to people and communities. They include natural areas recognized as sacred by indigenous and traditional people and institutionalized religions or faiths as places for worship and remembrance" (Ray et al. 2008). Sacred groves are well preserved forests and have high hydrological value. Some workers define sacred grove as a typical of small scale societies which are largely practicing subsistence economies (Gokhale et al. 1998, Gadgil and Berkes 1991). Gokhale (1998) mentioned sacred groves are self-organized conservation systems. Several studies have confirmed their watershed value which is accompanied by presence of perennial streams and springs. As sacred grove is an intact forest and covered with litter and humus, therefore, it is supposed to have better water infiltration capacity than grassland, scrub and rocky areas (Ramachandra et al. 2007). In Garhwal Himalaya exists a rich tradition to conserve the nature by socio-religious constraints on sustainable use of common property resources (Anthwal et al. 2006). A study has been undertaken to find out the water quality status in different sacred groves located in Uttarakhnd. Also one Water Quality Index is prepared for easy understanding of its quality status in those places.

Materials and Method

Study area

The present study has been conducted in three sacred groves of Uttarakhand viz. Tarkeshwar sacred grove, Hariyali devi sacred grove and Ravigaon sacred grove (Fig. 1). Tarkeshwar sacred grove is situated in Pauri district (N29°50′30″ to E78°47′31.6″, elevation 1779 m – 1834 m above MSL). The sacred grove is covering 20 ha area and has social catchment of about 22 villages. The sacred grove is dedicated to Lord Shiva and conserved by local village community. Hariyali devi is situated at the boundary of Rudraprayag and Chamoli districts (N30°14′44.9″ to E79°02′12.6″, elevation 2861 m – 2377 m above MSL). The grove is dedicated to Goddess Hariyali mata. It is covering an area of 205.5 ha. Here about 25 ha out of total 205.5 ha area is considered as the residence of deity. Therefore, a very strict community based protection is observed in this sacred grove. It has a social

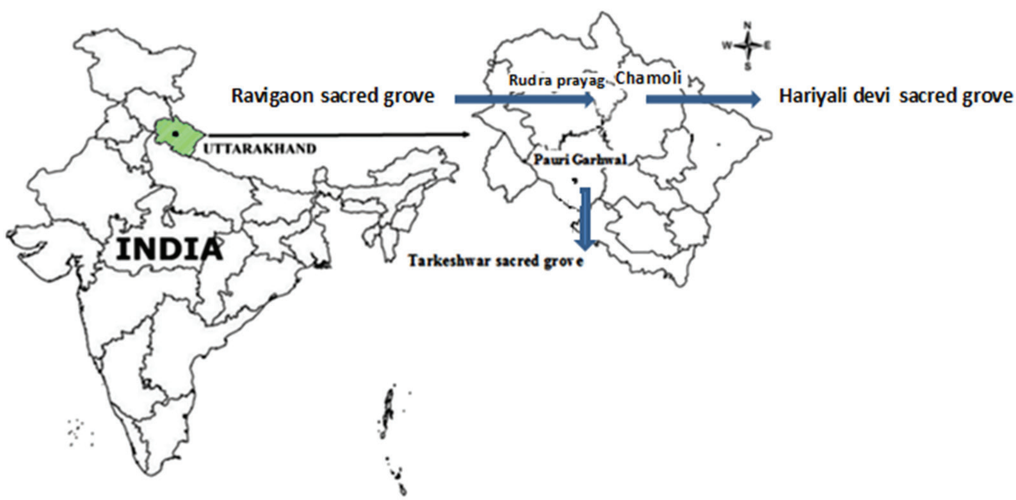

Fig. 1. Map of study area showing sample collection sites.

catchment of about 19 villages. Ravigaon sacred grove is situated in Rudraprayag district (N30°34′15.7″ to E79°02′43.9″, elevation 1727 m – 1834 m above MSL). Ravigaon covers an area of about 3.5 ha with a social catchment of about 20 villages. It is dedicated to Lord Triyugnarayan. All the three sacred groves are reserve forests but controlled mainly by village communities or temple authority.

Sampling and data analysis

Sampling was done during 2015. The year was divided into 3 seasons viz. Pre-monsoon (March–June), Monsoon (July–October) and Post-monsoon (November to February). Water samples were collected from 3 randomly selected stream spots of 3 sacred groves (Tarkeshwar, Hariyali devi and Ravigaon – figures 2–4) and their adjacent areas during the three seasons of 2015.

Samples were stored in 1 L plastic bottles; for dissolved oxygen (DO) a 300 ml BOD bottle (a glass bottle with a 'turtleneck' and a ground glass stopper) was used. The samples were analysed following the standard methodology of APHA (2005) for their physico-chemical quality i.e. pH, total hardness, calcium hardness, total alkalinity, DO, total dissolved solids

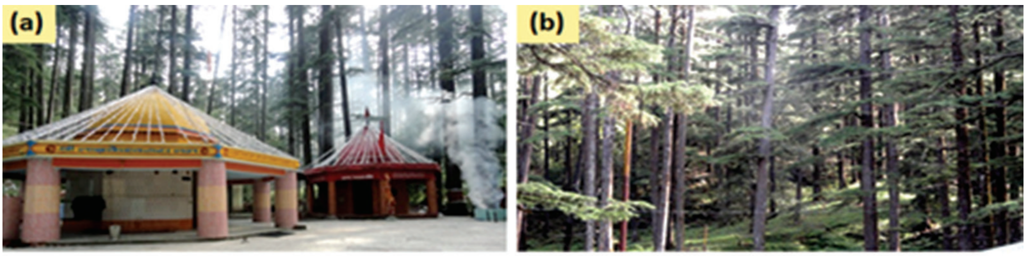

Fig. 2. Views from Tarkeshwar sacred groves: a) Tarkeshwar Temple; b) Temple surrounded forest (photos by Purna Jana).

Fig. 3. View from Hariyali devi sacred grove (photos by Purna Jana).

Fig. 4. Views from Ravigaon sacred grove (photos by Purna Jana).

(TDS), nitrate and chloride. The methods for each parameter have been described below.

(a) pH

Method/Procedure: by using Hanna (USA) combined pH and ORP meter.

(b) Total dissolved solids (TDS)

Method: Gravimetrical method.

Procedure:

1. Take 100 ml of sample water into a pre-weighed clean, dry porcelain dish.
2. Evaporate the water in the dish to dryness over the water bath or hot air oven.
3. Remove the moisture, cool and weigh.
4. The difference between the weights is the weight of total soluble salts.

Calculation: TDS (mg/L) = $(B–A)/100·10^6$, where: A = weight of empty porcelain dish in grams; B = weight of porcelain dish with residue; 100 = volume of sample taken.

(c) Dissolved oxygen (DO)

Method: Winkler method.

Reagent required:

1. Manganous sulfate solution: Dissolve 364 g $MnSO_4·H_2O$ in distilled water, filter through a 1.0 μm glass-fiber filter, and dilute to 1 L.
2. Alkali-iodide solution: Dissolve 500 g NaOH (or 700 g KOH) and 135 g NaI (or 150 g KI) in distilled water and dilute to 1 L.
3. Concentrated sulphuric acid.
4. Starch: Dissolve 0.5 g of starch powder in de-ionized water. Add this paste into 100 ml of boiling water. Allow to boil for few minutes. Cool and then use.
5. Standard sodium thio-sulphate (0.1 N): Dissolve 24.82 g $Na_2S_2O_3·5H_2O$ in 1000 ml distilled water. Preserve by adding 5 ml of chloroform per litre.

Procedure:

1. Collect water sample in a BOD bottle using DO sampler.
2. Add 1 ml of manganous sulphate followed by 1 ml of alkaline iodide reagent immediately after sample collection.
3. The tip of the pipette should be below the liquid level while adding these reagents, and close with the stopper immediately.
4. Mix well by inverting the bottle 4–5 times and allow the precipitate to settle down, leaving 150 ml clear supernatant.
5. Then add 1 ml concentrated sulphuric acid. Mix well till precipitate goes into solution.
6. Transfer 25 ml of sample into a clean conical flask and add starch indication, then titrate against standard sodium

thio-sulphate.

7. Disappearance of blue colour is the end point.

Calculation: DO (mg/L) in sample = ($N \cdot E \cdot 1000 \cdot V_t$)/$V_2 \cdot (V_1 - V/V_1)$, where: N = Normality of sodium thio-sulphate used; E = equivalent weight of oxygen = 8; V_t = volume of sodium thio-sulphate used for titration; V_1 = volume of sample bottle after placing the stopper; V_2 = volume of the part of the contents titrated; V = volume of $MnSO_4$ and KI added.

(d) Total alkalinity (TA)

Reagents:

1. Standard sulphuric acid (0.02 N): Prepare 0.1 N H_2SO_4 by diluting 3 ml of concentrated H_2SO_4 to 1000 ml, Standardize against standard Na_2CO_3 0.1 N. Dilute appropriate volume of H_2SO_4 (approximately 0.1) to 1000 ml to obtain standard 0.02 N H_2SO_4.

2. Phenolphthalein indicator: Dissolve 0.5 g phenolphthalein in 1:1 95 % ethanol and distilled water. Add drop wise 0.02 N NaOH till faint pink colour appears.

3. Methyl orange indicator: Dissolve 0.5 g of methyl orange in 1000 ml CO_2 free distilled water.

Procedure:

1. Measure the suitable volume of sample in 250 ml conical flask.

2. Add 2–3 drops of phenolphthalein indicator.

3. If the pink colour develops titrate against 0.02 N H_2SO_4, till the colour disappears, which is the characteristic of pH 8.3. Note down the volume of H_2SO_4 consumed.

4. Add 2–3 drops of methyl orange and continue titration with H_2SO_4 till the yellow colour changes to orange, which is the characteristic of pH 4.5. Note down the additional amount of H_2SO_4 required.

5. In case pink colour does not appear after addition of phenolphthalein continue with adding methyl orange.

Calculation:

Phenolphthalein Alkalinity (mg/L as $CaCO_3$) = [($A \cdot N$) of $H_2SO_4 \cdot 1000 \cdot 50$]/ml of sample Total alkalinity (mg/L as $CaCO_3$) = [($B \cdot N$) of $H_2SO_4 \cdot 1000 \cdot 50$]/ml of sample, where: A = ml of H_2SO_4 required to raise pH up to 8.3; B = ml of H_2SO_4 required to raise pH up to 4.5; N = Normality of H_2SO_4.

(e) Total hardness (TH)

Method: EDTA titrimetric.

Reagents:

1. Standard EDTA indicator: (0.01 M) Weigh 3.723 g of EDTA and dissolve in 1000 ml of distilled water and standardize against standard calcium solution.

2. EBT Indicator: The powdery form of the Erichrome Black-T can be used for this purpose.

Procedure:

1. Take 25 ml of the sample (dilute it with distilled water if required) and add 1–2 ml of the buffer solution and 1–2 g of EBT indicator.

2. Then titrate against the EDTA, with continuous stirring; until the last reddish tinge disappears. At the end point the solution gives blue colour.

Calculation: Total hardness (EDTA) as mg $CaCO_3$/L = $A \cdot B \cdot 1000 \cdot$Dilution factor (if diluted) ml of sample, where: A = ml titrant required and B = mg $CaCO_3$ equivalent to 1 ml EDTA titrant.

(f) Calcium hardness (Ca-H)

Method: EDTA titrimetric.

Reagents:

1. Sodium hydroxide: (NaOH) 1 Normality.

2. Indicator: Murexide (Ammonium purpurate).

3. Standard EDTA indicator: (0.01 M) Weigh 3.723 g of EDTA and dissolve in 1000 ml of distilled water and standardise against standard calcium solution.

Procedure:

Sample preparation: Titrate immediately after adding alkali and indicator. Use 50 ml sample or a smaller portion diluted to 50 ml, so that the calcium content is about 5–10 mg. Analyse hard water with alkalinity higher than 300 mg $CaCO_3$/L by taking the smaller portion and diluting to 50 ml, or by neutralizing the alkalinity with acid, boiling 1 min and cooling before beginning the titration.

Titration:

1. Add 2 ml NaOH solution per volume sufficient to produce pH 12–13.

2. Stir well and add a pinch of indicator.

3. Add EDTA titrant slowly, with continuous stirring to the proper end point (pink to purple).

4. Run the blank along with the sample.

Calculation: Calcium hardness as $CaCO_3$ L^{-1} = $A \cdot B \cdot 1000 \cdot$Dilution factor (If diluted) ml of sample taken, where: A = ml titrant for sample and B = mg $CaCO_3$ equivalent to 1.0 ml EDTA titrant.

(g) Chlorides (Cl)

Method: Argentometric.

Reagents:

1. Potassium chromate indicator: Add 50 g K_2CrO_4 in little amount of water and dilute to 1000 ml.

2. Standard Silver nitrate (0.0141 N): Dilute 70.5 ml of 0.1 N $AgNO_3$ in distilled water to 500 mL (1 ml = 0.5 mg Cl = 500 μg Cl). Standardize $AgNO_3$ against standard NaCl.

3. Standard Sodium Chloride (0.0141 N): Dissolve 824.0 mg NaCl (dried at 140°C) and dilute to 1000 ml (1 ml = 0.5 mg Cl = 500 μg Cl).

Procedure:

1. Use a 50 ml of sample or a suitable portion diluted to 50 ml.

2. Directly titrate samples in the pH range 7–10.

3. Adjust sample pH to 7 to 10 with H_2SO_4 or NaOH if it is not in this range.

4. Add 2 ml of K_2CrO_4 indicator solution.

5. Titrate with standard $AgNO_3$ titrant to a pinkish yellow colour end point.

6. For better accuracy titrate distilled water (50 ml) in the same way to establish reagent blank.

Calculation: Chlorides mg/L = $(A–B) \cdot N \cdot 35.45 \cdot 1000$ ml sample, where: A = ml $AgNO_3$ required for sample; B = ml $AgNO_3$ required for blank; N = Normality of $AgNO_3$ used.

(h) Nitrates (NO_3^{-1})

Method: Phenol disulfonic acid method.

Reagents:

1. Phenol disulfonic acid: Dissolve 25 gm of white pure phenol in 150 ml of concentrated H_2SO_4 and add 75 ml of fuming H_2SO_4. Heat for two hours on a water bath and keep in a dark bottle. In place of fuming acid 85 ml of concentrated H_2SO_4 can also be added.

2. Silver sulphate solution: dissolve 4.4 g of Ag_2SO_4 in distilled water to prepare 1 L of solution.

3. Liquid ammonia 30 %.

4. Standard nitrate solution (1 mg N/L): 0.72183 g of KNO_3 in distilled water and make up the volume to 1 L. This solution contains 100 mg N/L. Dilute it to 100 times to prepare a solution having 1 mg N/L (10→1000 ml).

Procedure:

1. Take 50 ml of sample (filter if necessary), evaporate the sample in a porcelain basin to dryness.

2. Cool and dissolve the residue in 2 ml phenol disulfonic acid and dilute the contents to 50 ml.

3. Add 6 ml of liquid ammonia to develop a yellow colour.

4. Take the reading at 410 nm.

5. Calculate the concentration of nitrate from the standard curve.

6. Prepare the standard curve between concentration and absorbance from 0.0 mg N/L to 1.0 mg N/L at the interval of 0.1. Find absorbance of the standard solution using the same procedure described for the sample.

Water Quality Index has been formed based on Harkins (1974) and Pandey et al. (2014) methodology. It is well known and effective method to express water quality in a simple, stable and reproducible unit of measure which communicates information on water quality to the concerned citizens and policy makers.

Water Quality Index (*WQI*)

$$WQI = \sum q_i \cdot W_i ,$$

where $q_i = \frac{100.(V_a - V_i)}{(V_s - V_i)}$ is water quality rating, when V_a = actual value present in the water sample, V_i = ideal value (0 for all parameters except dissolved oxygen which is 14.6 mg/L), and V_s = standard value; $W_i = \frac{K}{S_i}$, $K = \frac{1}{\sum_{i=1}^{n} \frac{1}{S_i}}$, where K is constant, S_i = permissible limit for the i^{th} parameters, and n = number of standard value.

Data on water availability (*L*) per household per day, distance travelled to fetch the daily needed water, etc. were collected following PRA method (household questionnaire survey and group discussion) by visiting 18 villages reside surrounding the Tarkeshwar sacred grove area, 18 villages reside surrounding the Hariyali devi sacred grove and 18 villages reside surrounding the Ravigaon sacred grove. For statistical analysis MS Excel has been used.

Result and Discussion

Result

Mean water quality data of three sacred groves in different seasons of 2015

All the water quality parameters (pH, DO, hardness, alkalinity, nitrate, chloride, etc.) remain within standard limits of World Health Organization (1984, 2011) (Tables 1 and 2) except in case of DO (the amount was lower than the WHO limit at Hariyali devi and its adjacent area during pre-monsoon season), pH (higher at Tarkeshwar adjacent area during monsoon) and calcium hardness (concentration was higher at Tarkeshwar and its adjacent area during post-monsoon season).

Table 2. Permissible limit list by WHO for water quality parameters.

Parameter	WHO Standard (2011)
pH	6.5 to 8.5
Dissolved Oxygen, mg/L	5
Total Hardness, mg/L	500
Calcium-Hardness, mg/L	75
Total Dissolved Solids, mg/L	500
Chloride, mg/L	200
Total alkalinity, mg/L	200
Nitrate, mg/L	50

Note: WHO – World Health Organization.

WQI of three sacred groves by using specific physico-chemical parameters

As per the formed WQI the quality of water has then been compared with the table given by Tyagi et al. (2013). According to the index during pre-monsoon, monsoon and post-monsoon its value in all spots was <50 except at Tarkeshawar sacred grove during monsoon. The quality was good (<50) during pre-monsoon and the grade of water was B according to comparison table of Tyagi (Table 3). But during

Table 1. Mean water quality data.

Parameters	Sea-son	Sampling site					
		TSG	TAD	HSG	HAD	RSG	RAD
		mg/L (Average ±SD)					
DO	1	9.73±0.25	9.27±0.97	4.83±0.91	3.61±0.24	8.51±0.21	8.10±0.00
	2	5.81±0.62	7.19±0.17	8.59±1.01	8.47±0.15	7.92±0.32	8.07±0.12
	3	11.29±0.83	11.71±1.04	8.17±0.06	8.13±0.23	8.33±0.58	9.00±0.00
pH	1	7.69±0.72	8.47±0.15	7.79±0.44	7.71±0.36	7.74±0.29	7.95±0.26
	2	7.68±0.57	8.58±0.11	7.93±0.51	7.82±0.24	7.70±0.10	7.96±0.30
	3	8.33±0.09	8.45±0.08	7.97±0.52	7.87±0.35	7.93±0.58	8.16±0.14
Cl	1	4.99±1.00	3.66±0.58	1.22±0.69	1.78±0.39	6.33±3.59	5.32±1.16
	2	2.83±1.89	2.16±0.76	1.70±0.61	1.55±0.69	2.38±0.58	1.71±0.24
	3	2.99±0.00	2.67±0.58	2.44±0.49	2.71±0.41	2.44±0.49	2.16±0.17
TH	1	71.22±52.03	95.67±8.50	32.42±21.73	48.99±32.34	42.67±6.03	37.00±1.00
	2	112.44±102.33	103.33±3.06	27.33±6.81	55.33±15.95	37.11±6.00	29.00±2.00
	3	156±100.41	124.11±18.55	36.33±2.52	60.33±18.58	43.78±5.01	36.33±2.96
Ca-H	1	42.33±24.38	70.33±2.08	17.98±11.56	22.99±15.30	23.33±3.51	20.00±2.00
	2	72.67±63.45	69.67±19.35	17.32±2.68	35.00±1.73	18.22±3.02	16.05±1.13
	3	91.5±68.59	93±24.33	18.67±2.52	36.67±4.04	25.11±2.01	17.56±2.04
NO_3^{-1}	1	0.08±0.02	0.09±0.015	0.85±0.085	0.80±0.06	0.59±0.41	0.13±0.005
	2	0.14±0.02	0.095±0.06	0.112±0.06	0.08±0.01	0.106±0.06	0.09±0.03
	3	0.06±0.001	0.08±0.008	0.12±0.07	0.08±0.02	0.05±0.03	0.07±0.017
TA	1	24.78±11.31	23.017±0.015	6.107±5.13	9.10±5.00	9.67±2.31	6.33±0.58
	2	12.67±6.43	14.07±4.31	11.33±0.33	19.23±2.01	9.22±2.16	8.83±1.61
	3	28.00±5.66	34.00±7.21	8.00±1.00	14.67±1.53	9.53±1.73	7.25±1.00
TDS	1	123±39.66	182.33±22.74	67.67±76.69	132.67±0.36	125.23±25.92	102.33±15.28
	2	276.67±75.88	275.00±31.22	117.33±12.58	130.67±17.56	132.67±50.52	158.33±36.89
	3	233.50±133.64	145.33±16.50	114.00±5.00	129.67±9.02	80.33±1.53	143.00±27.73

Note: TSG – Tarkeshwar sacred grove, TAD – Tarkeshwar adjacent area, HSG – Hariyali devi sacred grove, HAD – Hariyali devi adjacent area, RSG – Ravigaon sacred grove, RAD – Ravigaon adjacent area, SD – Standard deviation; Seasons: 1 – Pre-monsoon, 2 – Monsoon, 3 – Post-monsoon.

Table 4. WQI of three sacred groves by using specific physico-chemical parameters.

SA	Season	Parameters								WQI	Status*
		DO	Cl	TH	NO_3^{-1}	TDS	TA	Ca-H	pH		
TSG	1	12.53	0.02	0.04	0.00	6.08	0.08	0.35	14.20	33.29	Good
	2	22.63	0.01	0.06	0.01	13.68	0.04	0.60	14.19	51.20	Poor/Mod. poll
	3	8.52	0.01	0.08	0.00	11.54	0.09	0.75	15.38	36.37	Good
TAD	1	13.73	0.01	0.05	0.00	9.01	0.07	0.58	15.64	39.10	Good
	2	19.06	0.01	0.05	0.00	13.60	0.04	0.57	15.85	49.19	Good
	3	7.44	0.01	0.06	0.00	7.19	0.11	0.76	15.61	31.18	Good
HSG	1	25.15	0.00	0.02	0.04	3.35	0.02	0.15	14.39	43.12	Good
	2	15.48	0.01	0.01	0.01	5.80	0.04	0.14	14.65	36.14	Good
	3	16.57	0.01	0.02	0.01	5.64	0.02	0.15	14.73	37.14	Good
HAD	1	28.31	0.01	0.02	0.04	6.56	0.03	0.19	14.24	49.39	Good
	2	15.78	0.00	0.03	0.00	6.46	0.06	0.29	14.45	37.07	Good
	3	16.65	0.01	0.03	0.00	6.41	0.05	0.30	14.53	37.98	Good
RSG	1	15.68	0.02	0.02	0.03	6.19	0.03	0.19	14.30	36.46	Good
	2	17.19	0.01	0.02	0.01	6.56	0.03	0.15	14.22	38.18	Good
	3	16.14	0.01	0.02	0.00	3.97	0.03	0.21	14.65	35.03	Good
RAD	1	16.74	0.02	0.02	0.01	5.06	0.02	0.16	14.68	36.71	Good
	2	16.82	0.01	0.01	0.00	7.83	0.03	0.13	14.71	39.55	Good
	3	14.42	0.01	0.02	0.00	7.07	0.02	0.14	15.08	36.76	Good

Note: SA – Sampling area, TSG – Tarkeshwar sacred grove, TAD – Tarkeshwar adjacent area, HSG – Hariyali devi sacred grove, HAD – Hariyali devi adjacent area, RSG – Ravigaon sacred grove, RAD – Ravigaon adjacent area; Seasons: 1 – Pre-monsoon, 2 – Monsoon, 3 – Post-monsoon; Status* – Status as per Tyagi et al. (2013).

monsoon, at Tarkeshwar sacred grove the water quality deteriorated slightly (>50) (Tables 3 and 4).

Table 3. Standard rating of water quality as per Weight Arithmetic WQI method (Tyagi et al. 2013).

WQI scale	Water quality rating (WQR)	Grading
0–25	Excellent water quality	A
26–50	Good water quality	B
51–75	Poor water quality	C
76–100	Very poor water quality	D
>100	Unsuitable water quality	E

Dependency of villagers on water from various sources and distance travelled to collect water

Dependency on natural water source was higher in Hariyali devi sacred grove (64.03 %) than in the other two ones. In Tarkeshwar sacred grove area water scarcity was severe than in the other two places. In Tarkeshwar sacred grove average distance travelled by villagers to fetch daily needed water was 0.5 km which increased during lean season and become 3–4 km in order to get daily needed water (Table 5).

Table 5. Status of household based on water availability.

A	B	C	D	E	F
Tarkeshwar	28.70	73.15	13.89	0.9 (max 3–4 km)	0.32
Hariyali devi	64.03	35.97	0.00	0.6 (max 1 km)	0.58
Ravigaon	26.89	73.10	0.00	0.3 (max 1 km)	0.26

Note: A – Name of Sacred grove, B – Percentage dependency on natural source of water, C – Percentage dependency on Government supply, D – Percentage dependency on tube-well, E – Average distance travelled for water collection during lean season (km), F – Average distance travelled for water collection during other seasons (km).

Correlation coefficient values of various physico-chemical parameters of streams from both sacred groves and their adjacent areas:

Karl Pearson correlation (*r*-values) estimated to quantify the relationship between various physical and chemical parameters which revealed that alkalinity was positively correlated with calcium. Hardness showed significant correlations with pH, calcium and DO. pH showed positive correlation with alkalinity, chloride, TDS, DO. Alkalinity showed correlation with DO. DO showed negative correlation with nitrate (Table 6).

Table 6. Correlation coefficient values (*r*-values) of physico-chemical parameters of streams from three sacred groves and their adjacent areas.

	DO	Cl	TH	Ca-H	NO_3^{-1}	TA	TDS	pH
DO	1							
Cl	0.306*	1						
TH	0.345*	0.103	1					
Ca-H	0.368#	0.085	0.966#	1				
NO_3^{-1}	-0.506#	0.103	-0.162	-0.203	1			
TA	0.599#	0.182	0.700#	0.759#	-0.26	1		
TDS	0.14	0.114	0.665#	0.653#	-0.182	0.384#	1	
pH	0.553#	0.208	0.356#	0.339*	0.026	0.347*	0.393#	1

Note: Level of significance *p = 0.05, #p = 0.01 (Pearson's rank correlation).

Discussion

Almost all water quality parameters at three sacred groves during all three seasons were within permissible limit as per WHO (1984, 2011) except DO (lower at Hariyali devi sacred grove and its adjacent area during pre-monsoon season), pH (shows alkaline pH all over but higher at Tarkeshwar adjacent area during monsoon) and calcium hardness (higher at Tarkeshwar and its adjacent area during post-monsoon season). Kumar et al. (2010) and Madan et al. (2013) have found that the rivers of Uttarakhand show alkaline pH. According to WQI the quality of water at Tarkeshwar was good during pre-monsoon but it gets deteriorated during monsoon. During monsoon several festivals, rituals, ceremonies take place in Tarkeshwar sacred grove to please Lord Shiva. For this reason a number of pilgrims come to visit it. Most of them are somehow related to this grove by birth but migrated long time ago. During these festivals lots of waste related to rituals, festivals are generated which is discarded directly to the water body. That is the reason of water quality deterioration during monsoon but the quality is revived during post-monsoon and turned into good one. Madan et al. (2013) also mentioned that water body plays central role in lots of religious activities all through year in India, even rivers of Uttarakhand in this regards are not untouched. Central Pollution Control Board (2005) also recorded and stated several hazardous effects on aquatic life due to religious and cultural activities. Therefore, during monsoon the water needs treatment before consumption. Apart from Tarkeshwar sacred grove the other two sacred groves have good water quality during all three seasons.

The regression equation with significant correlation coefficients is well-thought-out to be very suitable to estimate the concentration of other constituents' availability. Significant correlation was shown by alkalinity with calcium which revealed that the ground water is alkaline in nature chiefly due to the presence of calcium salts. Rao et al. (2011) also found alkalinity having significant correlation with calcium. It also showed positive correlation with DO. This result is supported by Khatoon et al. (2013). pH is positively correlated with alkalinity and TDS. Khatoon et al. (2013) also recorded positive correlation of pH and total alkalinity. Ishaq and Khan (2013) recorded positive correlation between pH and TDS. pH showed positive correlation with hardness and dissolved solids. Bhandari and Nayal (2008) also recorded positive correlation between pH and hardness. Matta and Kumar (2015) recorded positive correlation between pH and dissolved solid. Chloride is positively correlated with pH which is supported by Bhandari and Nayal (2008). Hardness showed positive correlation with DO. Matta and Kumar (2015) also recorded similar result. Hardness showed positive correlation with calcium. This suggested that total hardness of water samples is mainly due to the presence of calcium salt. DO is negatively correlated with nitrate. Khatoon et al. (2013) also found negative correlation of DO and nitrate.

Based on availability of water daily life also gets changed. Higher dependency on water source enhances the chance of water body to get polluted (Anonymous 2014, 2017). Water availability has effect on lavatory system. For example, each household of Tarkeshwar sacred grove area possesses lavatory facility but due to non-availability of water it has become store room and the villagers use open defecation. This is a real concerned issue and a matter of hygiene too for this area which has also adverse effect on local surface water as in most cases surface water is used in daily domestic use.

Conclusion

In all the three sacred groves water quality was good according to Water Quality Index. The overall water quality in all three sacred groves was safe for use in daily life except for drinking purpose; there is a need for treatment. In Uttarakhand during summer prominent water scarcity condition is prevailed although this state is the origin of several main rivers of India. In these sacred grove areas, particularly during pre-monsoon season (summer), also acute water scarcity is felt. However, due to presence of this sacred grove, though the supply is meagre but the villagers never run out of daily needed water supply which is also good in quality. Proper care should be taken to manage the sacred grove which can maintain further the water quality and quantity, flowing through it. To save the water of sacred grove strong rules must be implemented by government or local management committee during festivals. At this time people come from different parts of country but simply used to forget all the issues arise during post festival duration and keep on polluting the local water by simply throwing all the waste generated during the festival time. Even to support the huge amount of pilgrims during festivals lots of construction works are also undertaken. These activities also keep on polluting the sacred grove environment. Even the transport through which the pilgrims come to visit the place pollute the local atmosphere. Awareness is needed to protect the sacred grove. Therefore input of government, some NGOs or even local management committee is strongly recommended. In this regards some awareness programmes must be organized to save the sacred grove ecosystem.

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