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Spring water quality analysis using water quality index and geospatial technology in Takoli Gad Watershed, Tehri Garhwal, Uttarakhand, India

Nidhi Chhillar* and Varun Joshi

University School of Environment Management
Guru Gobind Singh Indraprastha University, Sector-16C, Dwarka, New Delhi 110078, India

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ABSTRACT

Water quality assessment in remote rural regions is regularly not taken on need as compared to metropolitan ones. On the other hand, domestic activities such as bathing, washing, and so on in close proximity to water sources might contaminate the water. Water quality must be assessed at periodic intervals in such circumstances in order to reduce the impact of water contamination. Samples of spring water were analyzed for pH, electrical conductivity, total dissolved solids, bicarbonate, sulfate, chloride, nitrate calcium, magnesium, sodium, potassium, and total hardness. The outcomes were validated by comparing with WHO and BIS criteria for drinking water quality. Spatial mapping of the spring water quality parameters was generated by utilizing the Inverse Distance Weighting interpolation tool. The geochemical attributes of spring water have been performed. Schoeller and Stiff diagram showed that Mg^{2+} and HCO_3^- are predominant ions among cations and anions. The piper trilinear diagram implied that Ca (Mg) HCO_3 type, bicarbonate type, and magnesium type as dominant water. According to the findings of the Water Quality Index (WQI), 36% of samples fall into the excellent category, while 57% of the spring samples fall into the good category making them ideal for drinking. Irrigation indices have shown that groundwater is ideal for irrigation. This investigation revealed that spring water of the Takoli gad watershed is mineralized, chemically consumable, and appropriate for irrigation. This study illuminates the pristine state of the spring water quality in the rural regions and consequently is suitable for water quality assessment in various rural communities.

Key words : *Spring, Water Quality Index, Groundwater, Irrigation, Drinking, Inverse Distance Weighting*

Introduction

For life, water is a fundamental and beneficial resource, a key factor in shaping the natural environment. Water has a critical role in the development of different economic sectors involving agriculture, domesticated animals, forestry, industrial usage, and supplementary revolutionary exercises (Kumar *et al.,* 1997; Ameen, 2019). Water can be obtained from many natural sources e.g. surface waters (streams, rivers, lakes, dams) and groundwater (springs, hand-dug wells, bore wells) (Batool *et al.,* 2018; Ameen, 2019).

The degrading quality of water is the serious concerns of the centennial (Kawo and Karuppannan, 2018). Ecological, geological and anthropogenic factors lead to certain changes. Water is currently jeopardized by the combination of over-abstraction and chemical toxicity due to increasing population, water demand, and infrastructural developments. As a result, many countries facing severe water scarcity and water quality issues (Kumar *et al.,* 1997; Joshi and Kothyari, 2003; Aminal, 2015). Groundwater appears to be potential vital resource capable of inverting the current situation (Taloor *et al.,* 2020).

The Himalayas are recognized as the "Water tower of the earth", and are essential wellspring of freshwater (Niti Aayog, 2017). In several mountain and hill areas, water is mainly taken from shallow wells (naula) and springs (dhara) for drinking and domestic utilization (Negi and Joshi, 2001). Springs are valuable renewable resource for the people living on the hills in most rural villages in developing countries, are found in almost all location, regardless of the elevation, incline and aspect, in the Himalayan states. Springs happen when slanting terrain and impervious layers converge by water table. In most cases, the authentic origin of springs is unconfined aquifers where the progression of water is beneath gravity. The events of springs depends primarily upon the attributes of the recharge area like porousness of soil, structure and profundity, the topography of the region, the incline of the terrain and land cover qualities (Kumar *et al.,* 1997; Lajci *et al.,* 2017; Ameen, 2019).

Continues drying up of springs, minimal discharge throughout dry season, and perpetual springs getting irregular all over the Himalayan mountains have been reported in recent decades (Negi and Joshi, 1996; Ives, 2012). Studies have demonstrated that the decrease in discharges of springs was associated with land use and land cover change biotic interference, development activities (road and building constructions, etc.), intense grazing, forest fires, decreased water maintenance limits of the catchments, declining precipitation in certain regions in the revive zone (Valdiya and Bartarya, 1991; Negi *et al.,* 2011; Negi and Joshi, 2004).

Various investigations all over the globe and India has considered the details of hydrochemistry and spring water quality in an alternate manner toward inspection of significant major ion chemistry, geochemical processes controlling water composition and different numerical and statistical methods have been utilized in the evaluation of water appropriateness used for household, irrigation and drinking purpose (Nazzal *et al.,* 2014; Batabyal and Chakraborty, 2015; Vilane and Dlamini, 2016; Gupta *et al.,* 2019; Khatri *et al.,* 2020; Kumar and Sangeeta, 2020). GIS is an intensive tool for evaluation and study of the spatial data associated with management of the resources The geospatial technique for mapping the physio chemical parameters of ground water are widely used by researchers (Kumar and Sangeeta, 2020).

Spring water is primarily used for drinking, rustic household, and irrigation purpose in Takoli Gad watershed. It is supposed to be scientifically analyzed and correlated with drinking water quality standards to ensure safe drinking water. The analysis of water quality provides the basic data on water security. The character of the water quality is dynamic and it could be changing through time along with different aspects. Therefore, careful tracking of water is necessary. Evaluation of spring water quality of the Takoli Gad watershed was studied in this research work by using physicochemical analysis, statistical method, water quality index (WQI) and geospatial approach.

Study Area

The investigation was done in Takoli Gad watershed of Kirti nagar block, Tehri Garhwal district, Uttarakhand (Fig. 1). The area, covering around 131.43 km^2 enclosed between 30^{0}14′ North to 30^{0}23′ North latitudes to 78^{0}37′ to 78^{0}46′ East longitudes in the Survey of India topographic map 53J/11, 53J/12, 53J/15 territories in height from 550 m to 2301 m above mean sea level (Negi *et al.,* 2011). The watershed originates in the upper catchment of the Alaknanda river. The Alaknanda river flows in southernmost part of the region boundary. Jakhand and Dagar Gad are the tributaries of the Takoli Gad. The watershed consists of roughly 68 villages with population density of 135 person/km^2 (Census data, 2011). The area fall within inner lesser Garhwal Himalayas and is characterized by gentle and mature topography. Maximum precipitation is recorded during the month of July to September and the average annual precipitation of the area is 1395 mm. The temperature ranges from 4.6 ^{0}C-19.6^{0}C in winters and 32 ^{0}C – 36.5 ^{0}C in summers (Bagchi and Singh, 2011).

Methodology

Following methods were adopted to complete the present research work

Sampling and analytical procedure

Sampling was conducted during May, 2019 for the pre-monsoon period (PREMON) and November,

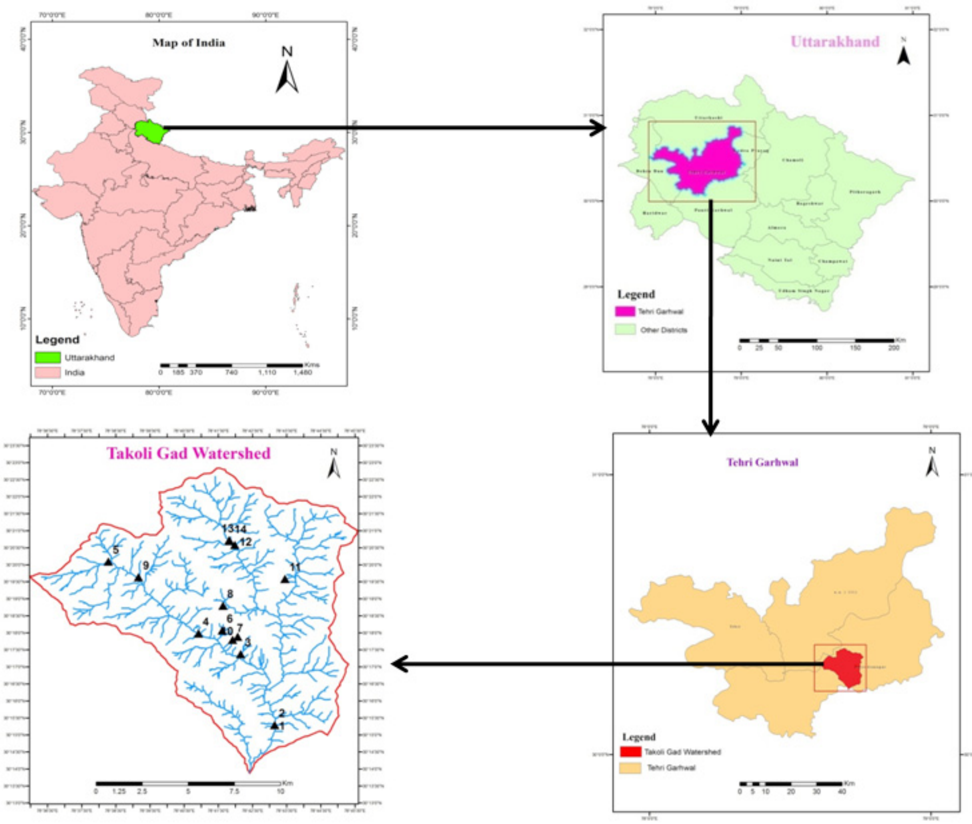

Fig. 1. Location map of the study area

2019 for the post monsoon (POSTMON) season to take into account seasonal variability. On the basis of feasible spring sites, best suitability, perennial nature, elevation and dependence of the local people on the natural spring water for drinking, irrigation and household purpose 14 natural springs of Takoli Gad watershed were selected (Table 1). Water samples were collected using standard techniques. Samples were marked and taken to the lab where they were stored and analyzed (APHA, 2012).

Table 1. Details of the sampling location of Takoli Gad watershed

No. of Sites	Spring no.	Elevation	Latitude	Longitude
1	1	661 m	N30^{0}15′18.25"	E078^{0}43′09.46"
2	2	656 m	N30^{0}15′18.34"	E078^{0}43′09.54"
3	3	785 m	N30^{0}17′23.38"	E078^{0}42′09.99"
4	4	803 m	N30^{0}17′59.74"	E078^{0}40′55.11"
5	5	1115 m	N30^{0}20′06.49"	E078^{0}38′17.07"
6	6	941 m	N30^{0}19′38.41"	E078^{0}39′10.45"
7	7	924 m	N30^{0}18′05.18"	E078^{0}41′37.71"
8	8	999 m	N30^{0}17′48.57"	E078^{0}42′55.38"
9	9	993 m	N30^{0}18′05.26"	E078^{0}41′37.82"
10	10	1111 m	N30^{0}17′53.90"	E078^{0}42′04.59"
11	11	1270 m	N30^{0}17′35.44"	E078^{0}42′27.28"
12	12	1116 m	N30^{0}20′35.71"	E078^{0}41′59.33"
13	13	1257 m	N30^{0}17′44.18"	E078^{0}41′49.94"
14	14	1238 m	N30^{0}17′44.24"	E078^{0}41′50.00"

Spatial water quality maps using GIS

The ArcGIS programming is applied to develop the spatial parameter map via Inverse Distance Weighting (IDW) tool. IDW is the basic method of interpolation. The physical and chemical parameter maps were formed by using IDW tool. A neighborhood around the interpolated point is defined, and the inspection esteems inside the neighborhood are taken from a weighted average. The weights are a diminishing function of distance. In addition to other options, the consumer has power above the statistical form of the weighting function, extent of the area (conveyed as a range or few focuses).

Water quality parameters and procedures

Spring water samples are analyzed using standard protocol for various physiochemical parameters i.e pH, Electrical Conductivity (EC), total dissolved solids(TDS), total alkalinity (TA), total hardness (TH) as $CaCO_3$, major cations such as Calcium (Ca^{2+}) , Magnesium (Mg^{2+}), Sodium (Na^+), Potassium (K^+), major anions such as Bicarbonates (HCO_3^-), Nitrate (NO_3^-), Sulfate (SO_4^{2-}), and Chloride (Cl^-) in the laboratory. pH, TDS and EC of the water samples were measured on site by multi parameter PC Testr 35. This was done to evade the unusual changes in the quality according to the regular protocol (WHO 2011; APHA 2012). Test techniques adopted are the basic protocols proposed by APHA, 2012. Water quality parameters for analysis and investigative techniques are showed in Table 2. The study samples were performed in triplicate and the average value were utilized in the water quality indices. The SPSS software was used for calculating mean and standard deviation.

Water Quality Index (WQI)

WQI is an algorithm that represents the qualitative condition of the water. Water quality index shall be considered from the perspective of groundwater suitability for human consumption. Horton (1965) developed the weighted arithmetic water quality index; using physicochemical parameters as contributions to a series of equations. Three steps must be followed to calculate the WQI. In the initial step, each one of the 12 parameters (pH, TDS, total hardness, Alkalinity, Na^+, K^+, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, Ca^{2+}, Mg^{2+}) a weight (wi) equable to its general significance is allotted to the overall quality of drinking water (Table 3). The weight of the utmost important parameters is 5 and the weight of the least important is 2. In the investigation, the highest weight of 5 was allocated to sodium, potassium, and nitrate due to their significant value in the measurement of water quality (Ramakrishnaiah *et al.,* 2009). The second stage involved computing the relative weight of the chemical parameters using the equation 1.

$$Wi = wi/\Sigma^{n}_{i=1} Wi \quad .. (1)$$

In the third stage, each parameter is allocated a quality rating scale (Qi) by dividing its concentration (Ci) in all spring samples by its particular standard (Si) as indicated by the rules (BIS, 2012 and WHO, 2011), and multiplying the outcome to 100 (Taloor *et al.,* 2020) (equation 2):

$$Qi = \frac{Ci}{Si} \times 100 \quad .. (2)$$

The sub index (SI) for every chemical parameter (equation 3) is calculated for computing WQI, which

Table 2. Physiochemical parameters for analysis of spring water

Parameters	Methods	References
pH	pH/EC/TDS meter (multi parameter PC Testr 35)	APHA(2012)
EC	pH/EC/TDS meter (multi parameter PC Testr 35)	APHA(2012)
TDS	0.64* EC	APHA(2012)
TA	Titrimetric	APHA(2012)
TH	EDTA titrimetric method	APHA(2012)
Ca^{2+}	EDTA titrimetric method	APHA(2012)
Mg^{2+}	Calculation	APHA(2012)
Na^+	Flame photometric methodAtomic absorption spectrophotometer (AAS)	APHA(2012)
K^+	Flame photometric method Atomic absorption spectrophotometer (AAS)	APHA(2012)
HCO_3^-	Titrimetric method	APHA(2012)
SO_4^{2-}	Turbidimetric method (UV spectrophotometer)	APHA(2012)
NO_3^-	UV spectrophotometer	APHA(2012)
Cl^-	Argentometric titration method	APHA(2012)

Table 3. Relative weight of chemical parameters

Chemical Parameters	Units	BIS (2012)	Weight (*wi*)	Relative weight Wi= wi/$\sum_{i=1}^{n}$Wi
pH	-	6.5-8.5	2	0.046512
TDS	mg/l	500	3	0.069767
TA	mg/l	200	3	0.069767
TH	mg/l	200	5	0.116279
Ca^{2+}	mg/l	75	5	0.116279
Mg^{2+}	mg/l	30	5	0.116279
Na^{+}	mg/l	200[a]	3	0.069767
K^{+}	mg/l	12[a]	3	0.069767
Cl^{-}	mg/l	250	2	0.046512
HCO_3^{-}	mg/l	244	3	0.069767
SO_4^{2-}	mg/l	200	4	0.093023
NO_3^{-}	mg/l	45	5	0.116279
Σwi= 43	**ΣWi= 1**			

Note: [a] WHO Standard (2011)

is used to compute WQI as given below (equation 4):

$$SI = Wi \times Qi \quad .. (3)$$

$$\mathbf{WQI} = \sum_{i=1}^{n} SIi \quad .. (4)$$

The figured WQI values are ordered into five classifications: excellent water (WQI, 0-25); good water (WQI, 26-50); poor water (WQI, 51–75); very poor water (WQI, 76–100); and water unsuitable for drinking (WQI, >100) (Chandra *et al.*, 2017).

Irrigation water quality

Irrigation water quality was figured by accompanying parameters sodium percentage, salinity hazard, alkalinity hazard.

Sodium percentage: Sodium concentration is one of the important parameters. Sodium content is generally stated as percentage of sodium which is described via equation (5):

$$\% Na = (Na^{+} + K^{+})*100/(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) \quad .. (5)$$

In which all ionic concentrations are represented in milli equivalents per litre.

Electrical Conductivity (EC): Is a strong salinity hazard indicator for crops as it is reflected in groundwater by the TDS. The essential impact of high EC decreases the plants osmotic action and consequently meddles with the intake of water and supplements from the soil.

Alkalinity hazard: This measures the extent of Na^{+} in a sample to Ca^{++} and Mg^{++} ions. The USDA's salinity laboratory suggests sodium adsorption ratio (SAR) because of its immediate connection to Na adsorption. The usage of water for irrigation, SAR,

Table 4. Physiochemical parameter analysis of spring water

Parameters	Pre monsoon (Premon)				Post monsoon (Postmon)			
	Range		Mean	Std. Dev	Range		Mean	Std. Dev
	Maximum	Minimum			Maximum	Minimum		
pH	7.9	6.45	7.139	0.3860	8.5	6.8	8.078	0.406
EC	478	222	343.28	102.50	377	167	260.920	88.230
TDS	398	155	280.64	87.368	341	143	233.142	72.324
Total Hardness as $CaCO_3$	204	32	99.642	48.164	314	100	204.571	73.209
Total Alkalinity	220	60	138.571	51.866	380	180	273.571	66.170
Ca^{2+}	100	23	60.785	23.178	194	60	119.285	43.270
Mg^{2+}	120	2	38.857	30.811	140	32	85.285	35.833
Na^{+}	16.921	2.4164	9.198	4.700	27.304	5.067	13.662	8.016
K^{+}	1.9676	0.3267	0.829	0.599	2.765	0.204	1.392	0.918
Cl^{-}	15.62	7.1	12.171	3.796	55.33	14.2	34.474	11.133
HCO_3^{-}	398	106	220.928	90.451	425	206	311.928	74.364
NO_3^{-}	34.8	4.6	14.885	8.503	28.6	1.8	9.978	7.751
SO_4^{2-}	58.1	16.4	28.478	12.299	45.2	11	22.607	10.963

which is a sort of Na hazard, was dedicated by equation (6) where all ionic concentrations are communicated in milli equivalents per litre.

$$SAR = \frac{Na}{[(\sqrt{Ca^{2+} + Mg^{2+}})]/2} \quad .. (6)$$

Results and Discussion

Assessment of water quality parameters

Natural processes or anthropogenic actions can both impair groundwater quality. The analysis of groundwater quality for drinking evaluates its viability for various purposes based on the specific standards issued by various agencies such as WHO (2011) drinking water standards and Indian drinking water standards (BIS, 2012). Physio-chemical parameters of spring water for pre monsoon and post monsoon season were analyzed in Table 4. From the study, pH of the samples ranged from 6.45 - 7.9 for PREMON and 6.8 - 8.5 for POSTMON (Table 5). These pH values were within safe limits prescribed by WHO and BIS ranges from 6.5 to 8.5 (Table 5) for human utilization. The pH trend in figure 7a shows that the maximum variation was reported for PREMON and POSTMON seasons, with higher values seen in the North West region for PREMON whereas for POSTMON entire region covering higher values except small patch is seen in the central region for lower values of pH. TDS value ranges from 155-398 ppm for PREMON and 143-341 ppm for POSTMON with the mean value of 280 ppm (PREMON) and 233 ppm (POSTMON). TDS values lies within permissible limit of WHO (500 mg/l) and BIS (500-2000 mg/l) (Table 5). As per the Freeze and Cherry, 1979 classification for the TDS parameter (Table 6) conveys that spring water samples were within freshwater category. Another classification was given by Davis and Dewiest in 1966 for the TDS (Table 6) parameter which shows that spring water samples found desirable for drinking water. The TDS distribution in figure 7b indicates lower values in the North region for PREMON and North East region for the POSTMON season. Maximum variation was reported in the Southern region of the study area for PREMON and POSTMON seasons.

The value of electrical conductivity (EC) in all sampling sites differs from 222 to 478 µS/cm (PREMON) and 167 to 377 µS/cm (POSTMON) (Table 4). EC shows significant correlation with vari-

Table 5. Comparison of spring water samples with drinking water standards

Parameters	BIS (2012) Desirable limit – Max Permissible limit (mg/l)	WHO (2011) (mg/l)	% Sample exceeding recommended value Pre Monsoon (PREMON)	% Sample exceeding recommended value Post Monsoon (POSTMON)
Essential parameters				
pH value	6.5 – 8.5	<8.0	100% within range of 6.5 – 8.5	100% within range of 6.5 – 8.5
Total hardness as $CaCO_3$	200-600	100-500	7.14% above 200, 92.85% below 200	64.29% above 200, 35.71% below 200
Cl^-	250-1000	250	100% below 250	100% below 250
Desirable Parameters				
Dissolved solids (TDS)	500-2000	600-1000	100% below 500	100% below 500
Ca^{2+}	75-200	250	21.42% above 75, 78.57% below 75	71.43% above 75, 28.57% below 75
Mg^{2+}	30-100	50	35.71% above 30, 28.57% above 50, 7.14% above 100	28.57% above 30, 28.57% above 50, 42.86% above 100
Na^+	-	200	100% below 200	100% below 200
K^+	-	12	100% below 12	100% below 12
SO_4^{2-}	200-400	250-1000	100% below 200	100% below 200
NO_3^-	45-100	50	100% below 45	100% below 45
HCO_3^-	200-600	-	64.28% above 200, 200 35.71% below	100% above 200 and below 600

ous parameters like pH, alkalinity, TH, TDS, chloride and calcium concentration of water (Patil *et al.*, 2012). Figure 7c depicts the electrical conductivity parameter which shows that the maximum variation was recorded in the Southern and North West region for both PREMON and POSTMON seasons, while the lower values in the North East region remains constant for both the seasons. Alkalinity ranges from 180 - 220 mg/l with mean value of 138.57 mg/l (PREMON) and 60 - 380 mg/l with mean value of 273.57 mg/l (POSTMON). Alkalinity has been found within safety limit value of WHO (200-600 mg/l) (Table 5).

Total hardness (TH) value ranges from 32- 204 mg/l with average value of 99.62 mg/l and 100-314 mg/l with mean value of 204.57mg/l for PREMON and POSTMON respectively (Table 4). Acceptable limit for TH in drinking water ranged within 200-600 mg/l by WHO and 300 mg/l given by BIS (Table 5). Swayer and McCarty classification (Table 7) for total hardness indicates that for PREMON 29% of the spring samples found under soft water class, 57% of the spring samples found in the moderately hard class. Moreover, 14% spring water fells in the hard water class. Although 36% of spring water for POSTMON found in moderately hard class, 57% of spring water was found in the hard water class and 7% of spring water fells under very hard water class.

Calcium content varies from 23 - 100 mg/l for PREMON and 60-194 mg/l for POSTMON (Table 4). The average value of calcium was 68.75 mg/l (PREMON) and 119.28 mg/l (POSTMON). The value of calcium was within standard limit of BIS (75-200 mg/l) but found little higher with the standard limit of WHO (75 mg/l) (Table 5). The chief source of Ca^{2+} in the study area is mineral ion exchange from rocks. This might possibly be related to the occurrence of $CaCO_3$, $CaSO_4$, $CaMg(CO_3)_2$ minerals and soils by water (Annapoorna and Janardhana, 2015). Problem with excessive concentration of calcium in water is that it leads to water hardness and scale formation. Magnesium concentration ranges from 2 - 120 mg/l for PREMON and 32- 140 mg/l for POSTMON (Table 4). Mg^{2+} have been found to be within safety limit value (Table 5) by WHO (150mg/l) but high as compared to desire limit value set by BIS (30mg/l). Mg^{2+} was most likely generated from the same source as Ca^{2+} (Annapoorna and Janardhana, 2015). In both the seasons no sample of the study area surpasses the maximum permissible limit approved for calcium

Table 6. Classification of water based on TDS by Davis and DeWiest (1966) and Freeze and Cherry (1979)

Parameters	Range	Class	No. of samples (Pre monsoon)	No. of samples (Post monsoon)	% of samples
TDS (mg/l)	<500	Desirable for drinking	14	14	100
Davis and DeWiest	500-1000	Permissible for drinking	-	-	-
(1966)	1000-3000	Useful for irrigation	-	-	-
	>3000	Unfit for drinking and irrigation	-	-	-
TDS (mg/l)	<1000	Fresh	14	14	100
Freeze and Cherry	1000-10,000	Brackish	-	-	-
(1979)	10,000-1,00,000	Saline	-	-	-
	>1,00,000	Brine	-	-	-

Table 7. Classification of water based on TH by Sawyer and McCarty (1967)

Parameters	Range	Class	No. of samples (Pre Monsoon)	% of samples (Pre Monsoon)	No. of samples (Post Monsoon)	% of samples (Post Monsoon)
TH (mg/l)	0-75	Soft	4	29	-	-
	75-150	Moderately hard	8	57	5	36
	150-300	Hard	2	14	8	57
	>300	Very hard	-	-	1	7
Total	14	100	14	100		

and magnesium (Table 5). The spatial patterns of calcium and magnesium are depicted in Figures 8a and 8b respectively.

The sodium and potassium levels varied from 2.4164 - 16.9216 mg/l and 0.3267 - 1.9676 mg/l respectively for PREMON. The sodium and potassium levels varied from 5.07 to 27.30 mg/l and 0.20 to 2.76 mg/l respectively for POSTMON (Table 4). Low K^+ and Na^+ might be because of its poor geochemical mobility (Mofor *et al.,* 2017). According to Annapoorna and Janardhana 2015, high level of sodium in the human body causes hypertension, congenial illness, renal problems and neurological disorders. Excessive levels of sodium in groundwater are caused by chemical weathering of feldspars or over-exploitation of groundwater resources and potassium in groundwater pose no concern. The spatial patterns of Na^+ and K^+ are illustrated in Figure 9a and 9b respectively.

Chloride value (Table 4) ranges from 7.1 - 15.6 mg/l (PREMON) and 14.2 - 55.33 mg/l (POSTMON) which lies within the permitted range of WHO limit (250 mg/l) and BIS (250-1000 mg/l) (Table 5). Chloride is a dominating anion in water and it gives a salty taste to water (Amanial, 2015). The chloride concentration may be due to household garbage or leaching from upper soil layers (Srinivasamoorthy *et al.,* 2008). The spatial pattern of chloride concentration distribution is depicted in figure 9c showed higher values during the PREMON season in the Southern and central parts but decreased in the central part during the POSTMON season.

In the sampling site, SO_4^{2-} concentration varied from 16.4 - 58.1 mg/l with an average value of 28.47 mg/l for PREMON while for the POSTMON SO_4^{2-} concentration varied from is 11 - 45.2 mg/L with average value of 22.60 mg/l (Table 4). All the samples fall within the desirable limit of 200 mg/l (Table 5). According to Jain *et al.,* 2010 the soluble salts of calcium, magnesium, and sodium makeup the majority of the sulfate concentration in the ground water which fluctuates substantially over time due to infiltration of rainfall and ground water recharge, which mostly occurs from stagnant water pools and surface runoff water collected in low-lying regions. The spatial pattern of sulfate concentration in figure 10a shows that higher values occupy larger region during the POSTMON season as compared with PREMON season.

The concentration of NO_3^- varies from 4.6 - 34.8 mg/l (PREMON) and 1.8 - 28.6 mg/l (POSTMON).

Table 8. WQI classification (Chandra *et al.,* 2017)

Water quality index level	Water quality status	Pre Monsoon (PREMON)			Post Monsoon (POSTMON)		
		No. of samples	% of samples	Spring no.	No. of samples	% of samples	Spring no.
<50	Excellent water quality	5	36	2,11,12,13,14	-	-	-
50-100	Good water quality	8	57	1,3,4,6,7,8,9,10	5	36	10,11,12,13,14
100-200	Poor water quality	1	7	5	9	64	1,2,3,4,5,6,7,8,9
200-300	Very poor water quality	-	-	-	-	-	-
>300	Undesirable for drinking	-	-	-	-	-	-
Total	14	100		14	100		

Table 9. Classification of spring water quality for irrigation purpose

Parameters	Range	Water class	No. of samples (PREMON)	% of samples (PREMON)	No. of samples (POSTMON)	% of samples (POSTMON)
Na % (as per Wilcox diagram)	<20	Excellent	14	100	5	36
	20-40	Good	-	-	9	64
	40-60	Permissible	-	-	-	-
	60-80	Doubtful	-	-	-	-
	>80	Unsuitable	-	-	-	-
SAR (Richards, 1954)	<10	Excellent	14	100	14	100
	10-18	Good	-	-	-	-
	18-26	Doubtful	-	-	-	-
	>26	Unsuitable	-	-	-	-

The average of NO_3^- value is 14.85 mg/l (PREMON) and 9.97 mg/l (POSTMON) with all samples falling within desirable limit of 45 mg/l (Table 5). Nitrate concentration in drinking water is considered significant for unfavorable health consequences (Jain *et al.,* 2010). The concentration of NO_3^- is due to the decaying organic waste, sewage and fertilizer from agricultural runoff (Annapoorna and Janardhana, 2015). The nitrate concentration distribution in figure 10b showed an almost similar pattern for both PREMON and POSTMON seasons while decreasing in the central part for the POSTMON season.

HCO_3^- is the dominant anion and the concentration is between 106 - 398 mg/l with mean of 220.92 mg/l for PREMON. For the POSTMON, HCO_3^- concentration ranges from 206 - 425 mg/l lwith mean of 311.92 mg/l (Table 4). All the samples fall within the maximum permissible limit of BIS (2012) for both seasons (Table 5). The spatial pattern of bicarbonate concentration distribution in figure 10c showed the maximum variation during PREMON and POSTMON seasons. In PREMON season the lower values in North and North East region and higher values in small patch of Central and South West region. Over the POSTMON season lower values covers narrow area of North region while higher values region increase in the Southern region.

In order to highlight the consistency of spring water quality, the Piper trilinear diagram (Piper, 1944), Schoeller diagram (Schoeller, 1967) and Stiff diagram (Stiff, 1951) have been plotted. The Piper plot (Fig. 2) comes in the domain of calcium bicarbonate type, magnesium type , calcium type and bicarbonate type which highlighting that alkaline earth dominates alkalies, weak acids exceeds strong acids in that order (Taloor *et al.,* 2020). The major ion chemistry is dominated by major cations $Mg^{2+} > Ca^{2+} > Na^{+} > K^{+}$ and major anions $HCO_3^- > CO_3^- > Cl^- >$

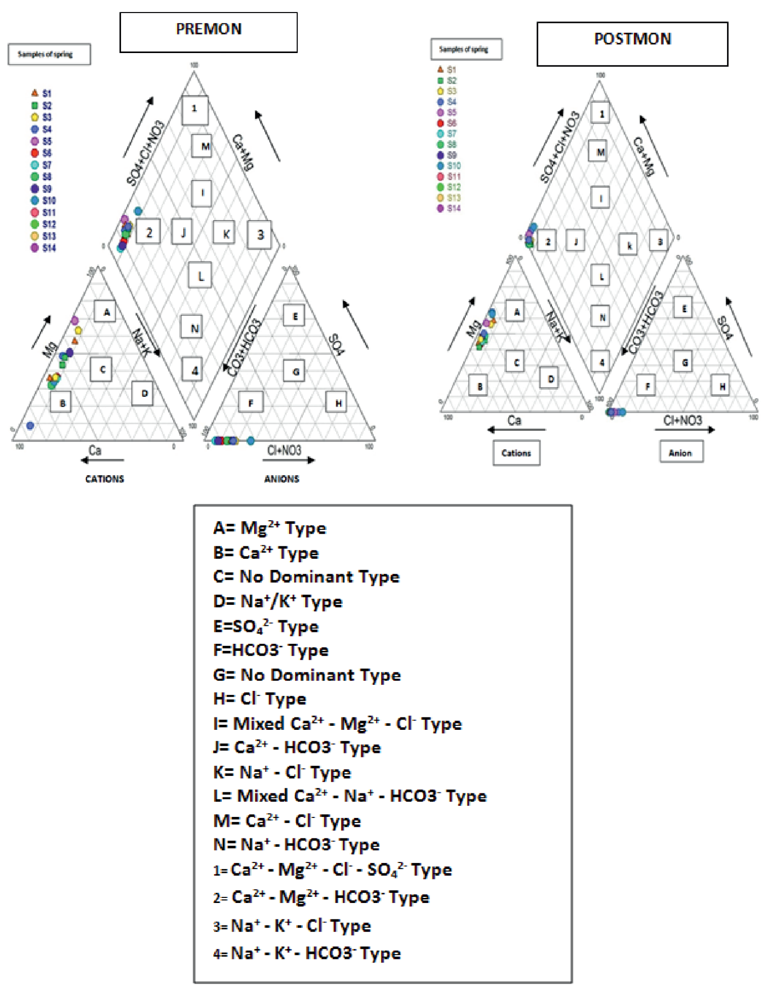

Fig. 2. Geochemical classification of spring water based on Piper-Trilinear diagram for PREMON and POSTMON

NO_3^- in the spring water. The disintegration of carbonate rocks enhances the water content of Ca^{2+} and Mg^{2+} ions. Schoeller outlines are utilized to display the overall groupings of anions and cations regularly expressed in milliequivalents per litre (Talabi *et al.,* 2015). Stiff diagram, is a graphical depiction of chemical analysis (Stiff, 1951). It is constructed by plotting the milliequivalents per litre of three or more anions and three or more cations. This method of graphical portrayal has the preferred position that, not at all like the trilinear diagrams, actual sample concentrations are shown and correlated about. In this study, the Schoeller (Fig. 3) and Stiff diagram (Fig. 4) both uncovered the predominance of Mg^{2+} and Ca^{2+} cations just as HCO_3^- and CO_3^- anions in the spring water of the watershed.

Suitability of spring water for Water Quality Index (WQI)

From WQI, spring water can be ordered into five classes based on WQI values. According to the categorization (Table 8), out of total samples analyzed 36% spring samples comes under excellent water class, 57% samples has a place with good water class where as 7% samples were in the category of poor water class for PREMON, while 36 % of samples belongs to good water category where as 64 % samples were found of poor water category for POSTMON (Chandra *et al.*, 2017). The spatial patterns of WQI for the study region are illustrated in figure 11. PREMON season shows that the majority part of the study area comes under the second category (good), with the exception of a small patch in the North West region. The POSTMON season shows that the excellent category area almost remains constant but good category gets decreases in relation with the PREMON season. This is indication of great changes in good category due to contamination of groundwater whereas an excellent category result remains constant for both PREMON and POSTMON seasons in NORTH EAST region.

Suitability of spring water for irrigation purpose

For the better comprehension of the irrigation water quality US Salinity Laboratory (USSL) diagram (1954), Sodium Absorption Ratio (SAR), Sodium percentage (Na %) were chosen to understand the suitability for irrigation purposes. The EC and Na^+ concentrations are significant in the classification of irrigation water (Taloor *et al*., 2020). SAR of irrigation water is measured as a sodium hazard index and is evaluated as the overall extent of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in water (Richards, 1954). The salinity hazard pa-

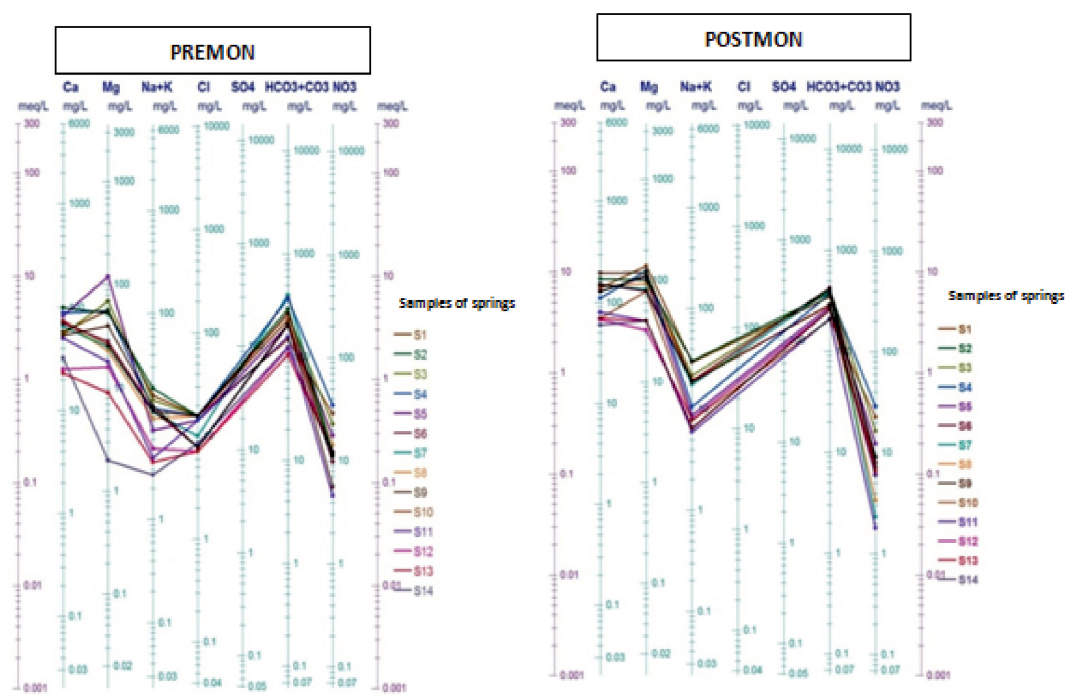

Fig. 3. Schoeller Plot showing the concentration of anions and cations in spring water of the Takoli Gad watershed for PREMON and POSTMON

rameter (EC) ranged from value of 222 to 478 µS/cm with mean value of 343.28 µS/cm for the PREMON and value of 167 to 377 µS/cm with mean value of 260.92 µS/cm for POSTMON. SAR values ranges 0.82 - 2.72, with a mean value of 1.82 for PREMON and 0.71 - 2.34, with a mean value of 1.322 for POSTMON. Na % value ranges from 3.50 to 12.22 for PREMON and 3.55 to 9.94 for POSTMON period. Mean value of Na% is 9.37 and 6.60 for PREMON and POSTMON respectively (Table 9).

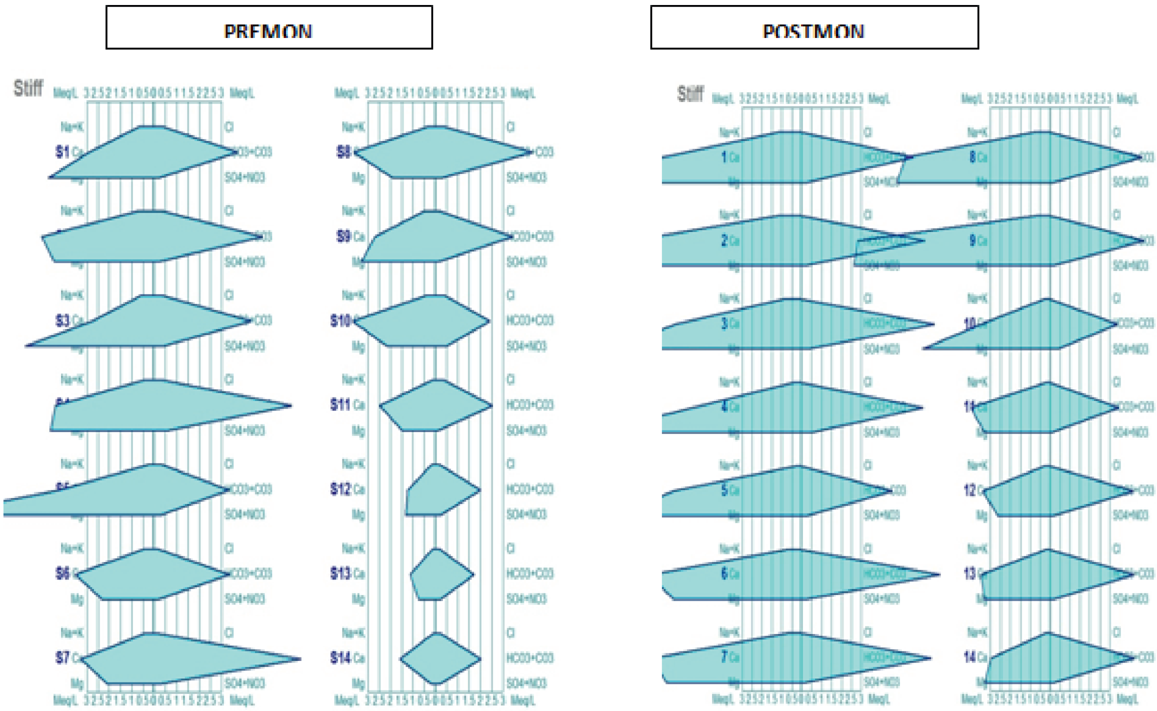

Fig. 4. Stiff Plot showing the chemical classification of spring water in the Takoli Gadwatershed for PREMON and POSTMON

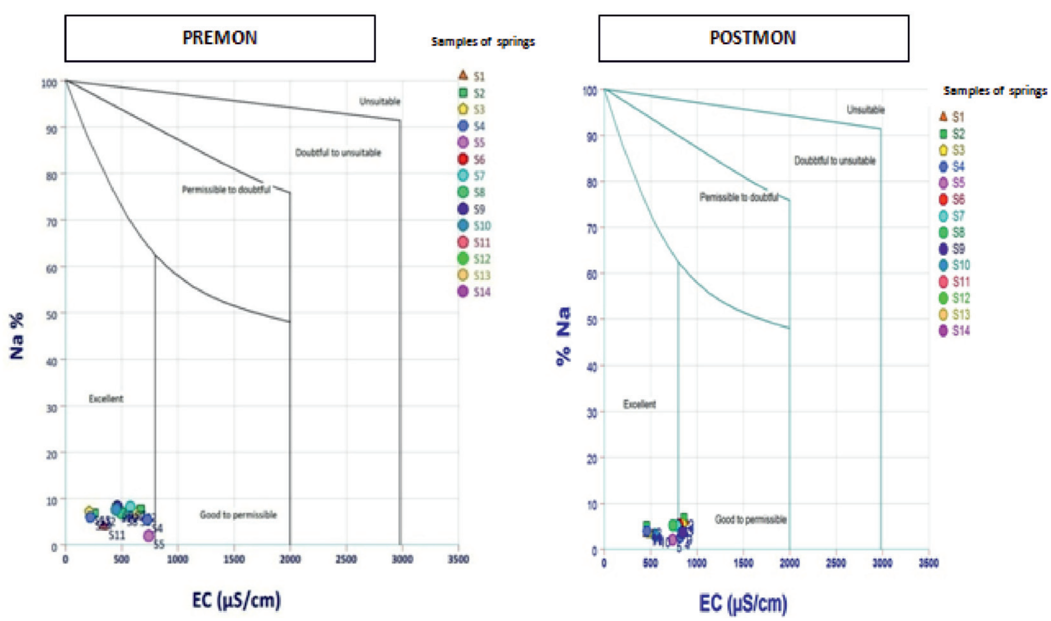

Fig. 5. Wilcox diagram for classification of irrigation water quality in Takoli Gad watershed for PREMON and POSTMON period

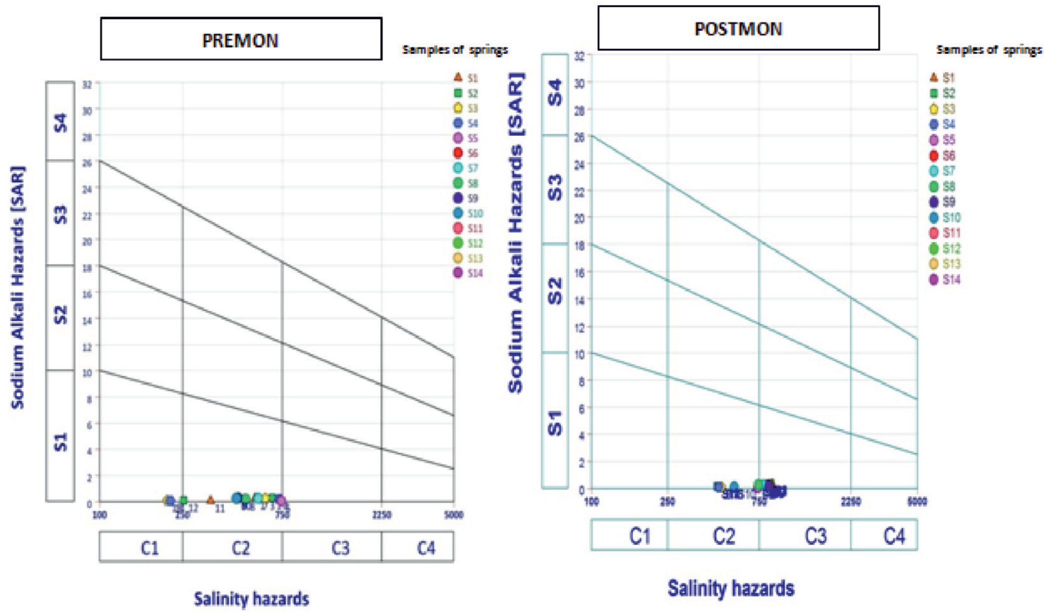

Fig. 6. USSL diagram for assessing irrigation water quality in Takoli Gad watershed for PREMON and POSTMON season

According to Wilcox diagram, 1955 all the spring samples found to be in excellent class for irrigation use (Fig.5). According to USSL classification (Fig. 6) of spring water for irrigation purpose 36% of the spring samples ware found to be of low salinity hazard, 64% of spring samples positioned under medium salinity hazard for PREMON as well for POSTMON. Sodium Adsorption Ratio (Richards, 1954) classification states that spring samples found in an excellent water quality, i.e. low sodium water category to medium sodium water category for PREMON and medium sodium water category to high sodium water category for POSTMON period.

Conclusion

Hydro-chemical investigation of spring water samples reveals that Ca^{2+} and Mg^{2+} are prevailing trailed by Na^+ and K^+ among cations. HCO_3^- is perhaps the most prevailing anion accompanied by Cl^- and NO_3^-. Examination of hydro-chemical facies demonstrates predominant facies on piper trilinear diagram Ca^{2+}–Mg^{2+}– HCO_3^- which portrays that the alkaline earth and weak acid dominate the water chemistry. As per the Indian Standards and WHO standard value of drinking water, spring water samples are in the acceptable cap. The Wilcox diagram reveals that for irrigation, spring water

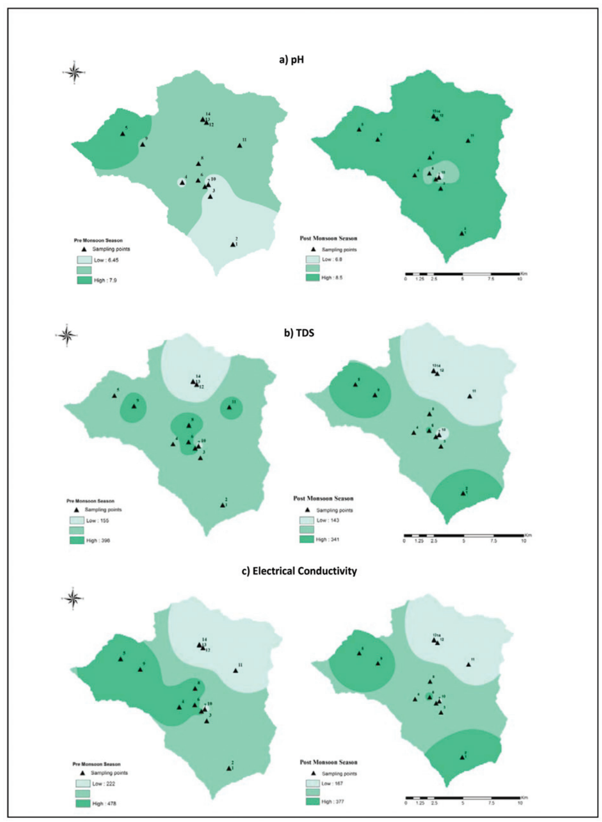

Fig. 7. Spatial distribution maps for PREMON and POSTMON a) pH b) TDS c) Electrical Conductivity

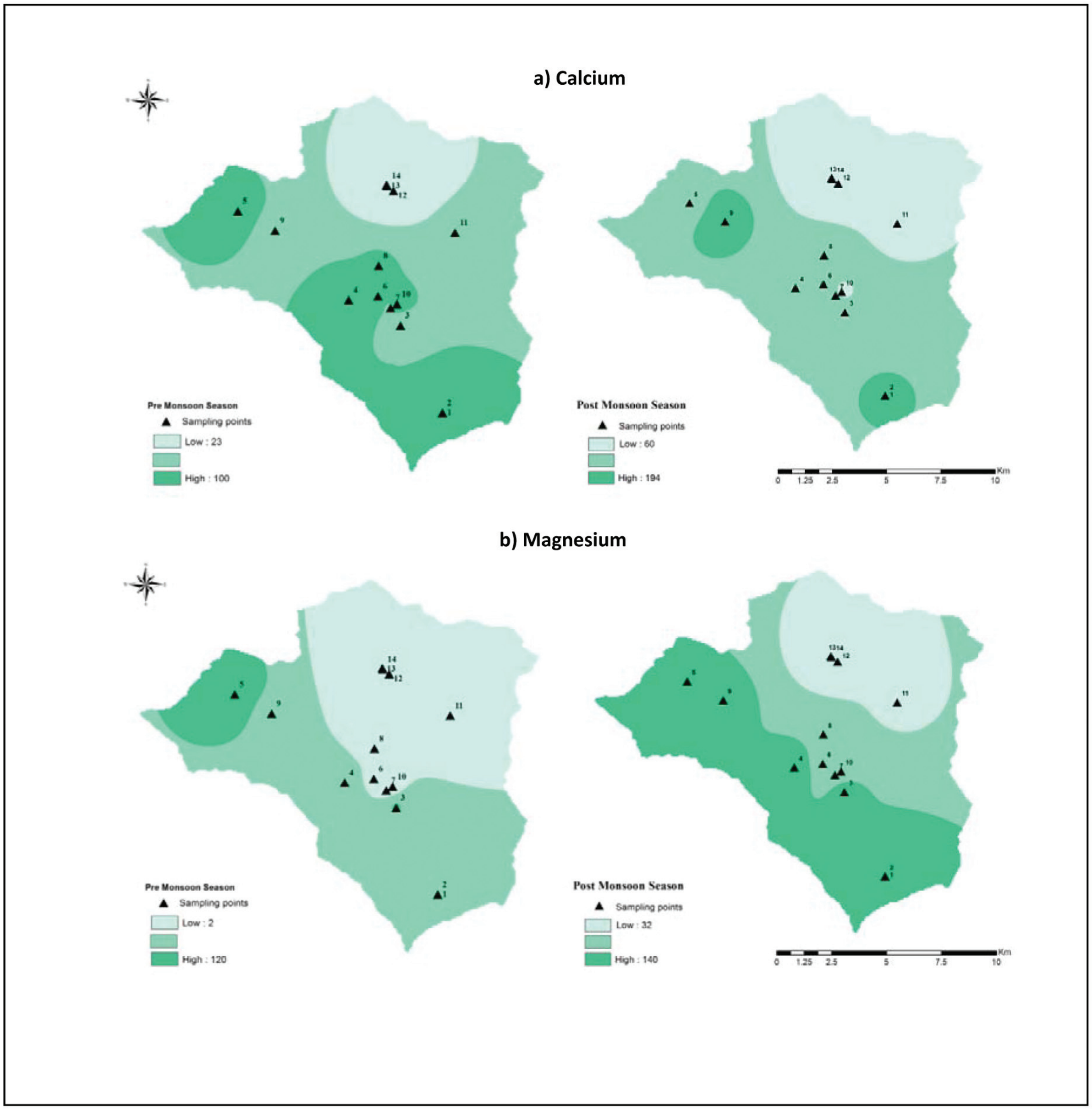

Fig. 8. Spatial distribution map for PREMON and POSTMON a) Calcium b) Magnesium

samples are in excellent class for PREMON and in between excellent to good class for POSTMON season (Table 9). The US Salinity Laboratory diagram (Fig. 6) for PREMON indicates that 64% of spring water samples belong to medium salinity (S1C2) which can be utilized for irrigation if mild leaching happens, regular salt resistant plant can be grown, whereas 36% of samples come under the low salinity water (S1C1) which is considered ideal for all crops types and all soil types. The USSL diagram for POSTMON season indicates that spring samples belong to medium salinity (S1C2) which comes in good category where regular salt lenient plants can be grown without a lot regulation of salinity and high salinity water (S1C3) which is not ideal for soil with minimal drainage. WQI was calculated and found that 93 % of spring water samples are in excellent to good category for PREMON and 36% of spring water samples are within good category for POSTMON. Spatial map of WQI reveals that the major parts of the study area fall under excellent to good category and a couple of stretches contain the poor spatial WQI where population in the Takoli Gad watershed is reliant on spring water for drink-

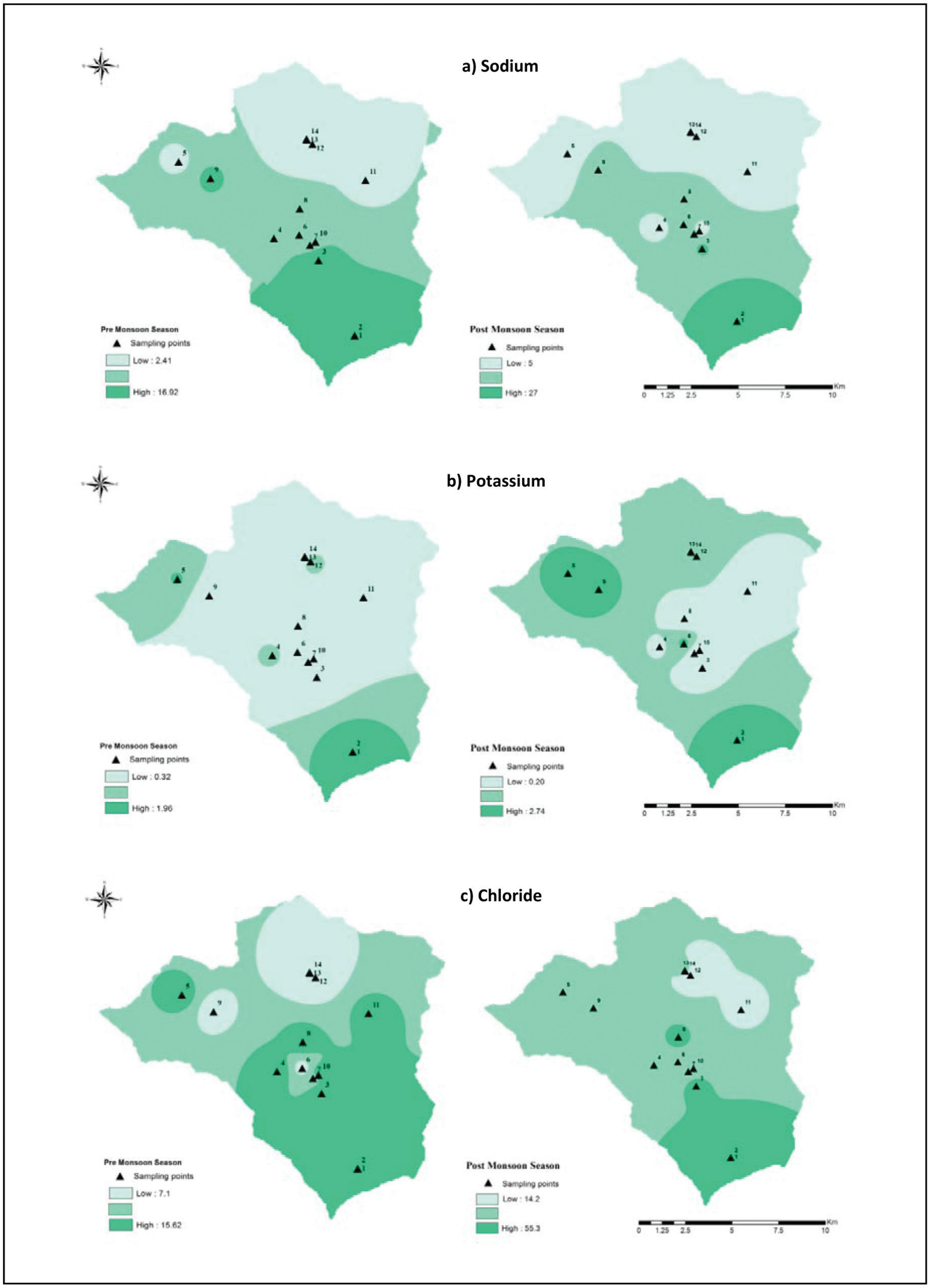

Fig. 9. Spatial distribution map for PREMON and POSTMON a) Sodium b) Potassium c) Chloride

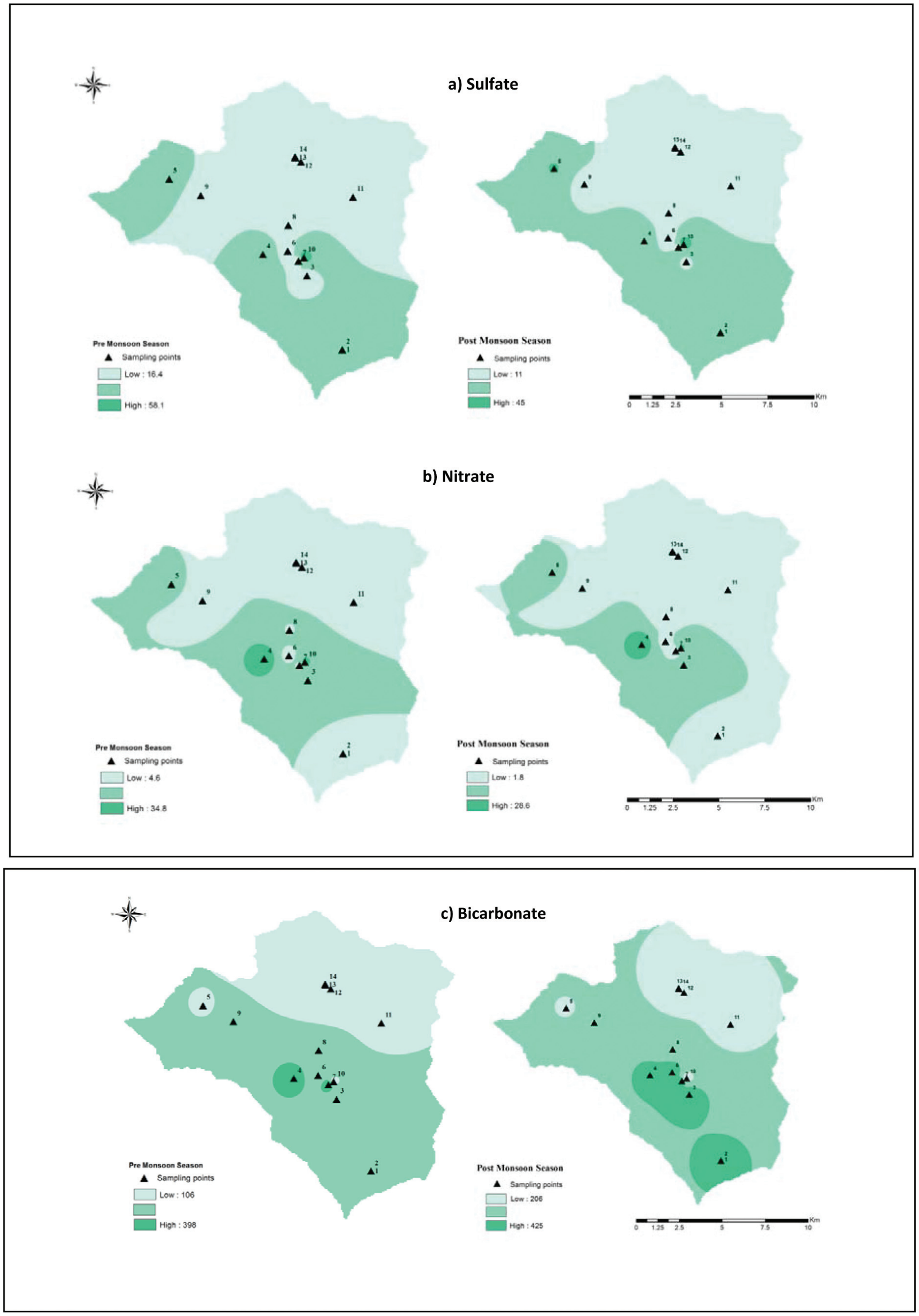

Fig. 10. Spatial distribution maps for PREMON and POSTMON a) Sulfate b) Nitrate c) Bicarbonate

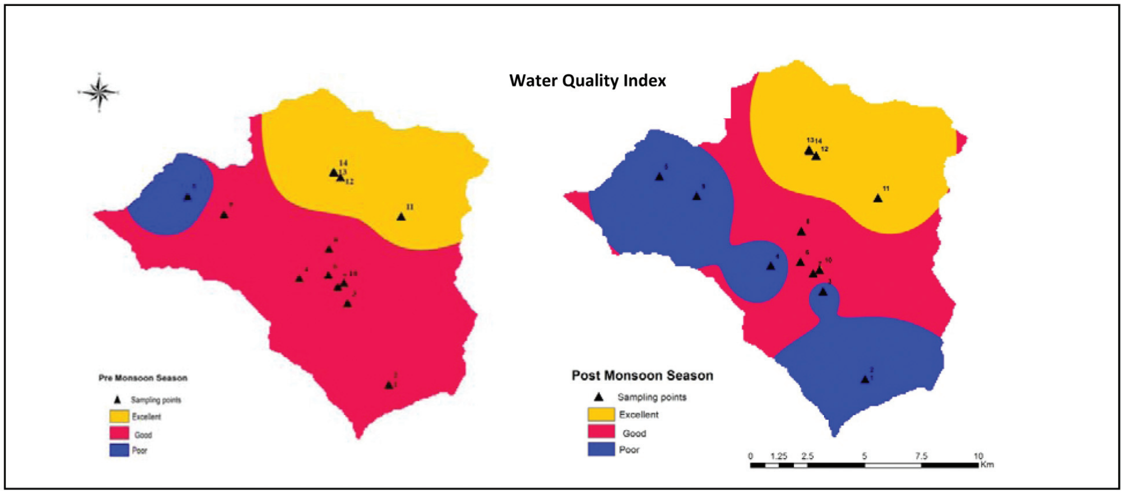

Fig. 11. Spatial distribution maps of water quality index (WQI) in the Takoli Gad Watershed for PREMON and POSTMON

ing and other household purposes. Spatial technology is helpful in assessing the best groundwater quality zone in the study area. Spatial distribution diagrams show a variation in PREMON and POSTMON period for various physiochemical parameters. During the post-monsoon season, accumulation of chemical effects slows down the process due to dilution process by rainfall therefore more samples fall under permissible limits. After post monsoon, the concentration in groundwater is expected to rise because to leaching process (Rawat and Singh, 2018). The overall situation of the spring water in the Takoli gad watershed of Tehri Garhwal is chemically consumable and appropriate for home-based and irrigation uses.

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