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Research paper

Spring water quality and discharge assessment in the Basantar watershed of Jammu Himalaya using geographic information system (GIS) and water quality Index(WQI)

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ABSTRACT

The demand for fresh spring water recently increased due to intensive domestic, industrial irrigation practices which typically caused depletion of water resources and deterioration of water quality. The spring water quality was analyzed for its major hydrochemistry and hydrochemical evolution of the spring water in the study area. A total of 60 spring water samples were collected from the three kinds of terrain (mountainous, hilly and plain) and analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), sulphate (SO_4^{2-}), chloride (Cl^{-}), nitrate (NO_3^{-}), and fluoride (F^{-}). The water quality of drinking purposes was plotted in the Piper trilinear diagram which reveals that spring hydrochemistry is dominated by the alkaline earth and weak acids. Gibbs diagram reveals that the spring water chemistry is primarily controlled by rock-water interaction in the investigated region. The water quality index (WQI), 45% of samples fall in the excellent category, 50% of spring samples fall in good categories for drinking purposes. The pH and TDS are within the permissible limit ranges from 7 to 8.4 and 123to 793 respectively. Based on chemical analysis of the various parameters such as non-carbonate hardness, sodium percentage sodium absorption ratio, residual sodium carbonate were calculated to define the quality of spring water for irrigation purposes. The discharge of spring water was also calculated during the pre-monsoon season and found that 70% of samples have discharge more than 20 L per second (Lps).

1. Introduction

Water scarcity in many parts of the world has become an unpleasant reality. Groundwater seems to be the potential natural resources capable to reverse this situation. Uncovering the spatial patterns of groundwater occurrence. The water economy of India is under the huge pressure and safe drinking water supply to 1.5 billion people by the end of next decade is one of the major challenge for the country. Himalayas being endowed with rich river water system may not able to cater the demands of water for agriculture, domestic and industrial uses in the coming years due to unscientific and improper use of water which led to acute shortage of water supply in many parts of India. Due to unavailability or inadequate quality of surface water, demand for ground water resources has increased over the years for drinking purposes in the world, especially in densely populated area particularly in the Indian sub-continent where two-third of the total population use groundwater for drinking purposes (Barakat et al., 2018; Bhat et al., 2019; Chen et al., 2019; Jasrotia et al., 2019a).

Springs is the main source of water for the people in the Himalayas both urban and rural chunk of large population depends on spring as a

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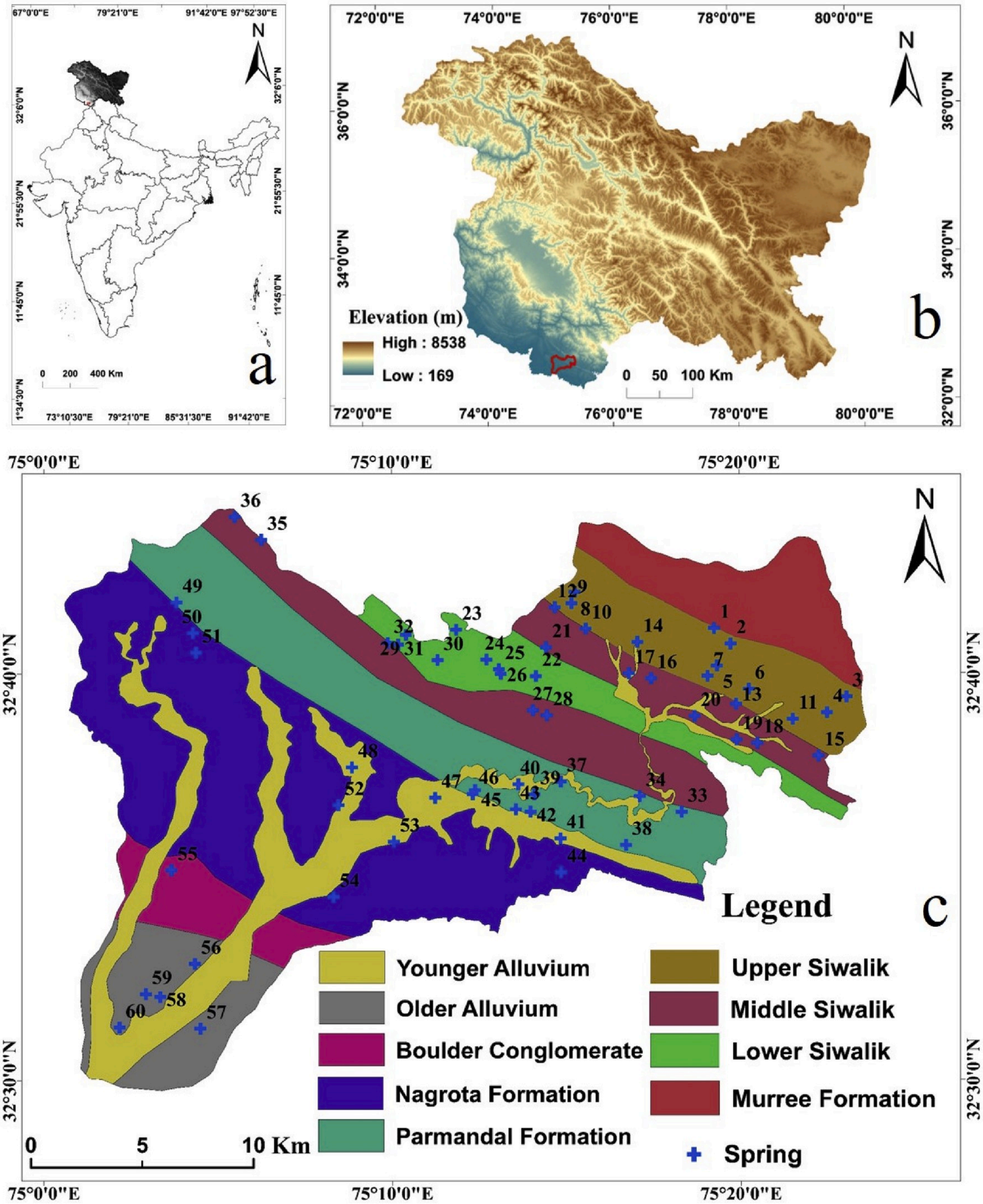

Fig. 1. (a) Location map of India, (b) location map of J&K depicting the location of Basantar watershed, (c) Geology map depicting the location of springs.

source of fresh water for the drinking, domestic and agricultural purposes and mostly used without prior water treatment in Himalayan villages (Bartarya, 1991; Bartarya and Valdiya, 1989; Negi and Joshi, 2004; Jasrotia et al., 2011, 2018; Bartarya and Bahukhandi, 2012). Himalayas being considered as water tower of the Asia and endowed with adequate rainfall, most part of Himalaya regarded as dry land as far as agriculture is concerned (less than 2% of land is irrigated), and water stressed region in terms of accessibility of drinking water to people (Singh et al., 2017; Adimalla et al., 2020).

Spring generally is a point at which water flows from an aquifer to the surface of the earth occur where ground surface and the impermeable rocks intersect with the ground water table. The occurrence mostly depends on rocks recharge characteristics, such as, lithology, porosity and permeability of the topsoil, hydrogeomorpholgy slope of the surface and precipitation (Joshi, 2006; Ansari et al., 2015; Haque et al., 2020). Besides the occurrence the management of springs is also a biggest challenge in the hilly regions of Himalaya due to over drafting of the water by hand pumps and tube wells in the small aquifers and pollution form the anthropogenic activities. The eco-geological labyrinth of Himalaya is under the grip of various natural dynamism, anthropogenic interventions. Due to climate change and global warming, melting of glaciers, reduced snowfall, more frequent heavy rainfall and widespread flooding has affected the water resources of Himalayas, consequently springs are widely affected. It is quite evident from the different sources that springs are drying up or their discharge is reducing throughout the Himalayas as it is mainly depending on rainfall pattern in the recharge

Table 1
Stratigraphic succession of the study area (after Ranga Rao et al., 1988).

Group	Sub Group	Formation	Lithology	Age
Jammu Alluvium ~~~~~~~~~	~~~~~~~~	Younger and Older Alluvium ~~Unconformity~~~	Fine to coarse grained sand, silt and clay, Fine to medium grained micaceous sand, silt and clay Coarse sand (cobble, boulder) Silt and clay in valley fill deposit ~~~~~~~~~~~~~~~~~~~	Recent to Upper Pleistocene ~~~~~~~~~~~~
Siwalik Group	Upper Siwalik	Boulder Conglomerate Nagrota Formation Parmandal Formation	Sand, silt and clay dominantly coarse- grained sandstone and pink grey mudstone	Pliocene to Middle Pleistocene
	Middle Siwalik		Medium to coarse-grained sandstones and subordinate grey brown mudstone	Upper Miocene
	Lower Siwalik		Red mudstone and fine medium- grained grey, green sandstone	Middle Miocene
–	–	–Thrust—————————————	–	–
Murree Group	Upper Murree		Monotonous grey sandstone and grey, brown to yellowish subordinate, mudstone, siltstone and clay	Early Miocene

area and variation in the amount of rain water that is able to in-filtrate the ground. The Himalayan ecosystem is quite fragile and susceptible to several changes caused due to natural and man-made problems. It is quite understood that if crisis persists it will affect livelihoods of millions of people in the Himalayas and particularly in the mountain belts (NITI Aayog, 2017).

Various researchers around the world and around India have studied the detail hydrochemistry and spring water quality in various to evaluate the major ion chemistry, radon concentration in water, geochemical processes controlling water composition and suitability of water for domestic, and drinking purposes (Brindha, and Elango, 2011; Bozau et al., 2013; Fonollosa et al., 2016; Al-Khashman et al., 2017; Barakat et al., 2018; Nnorom et al., 2019; Chen et al., 2019; Adimalla et al., 2020). In the recent studies use of GIS technology for spring potential mapping has also been well documented in many studies around the world (Ozdemir, 2011; Pourtaghi and Pourghasemi, 2014; Guru et al., 2017; Jasik et al., 2017; Rahmati et al., 2018; Jasrotia et al., 2019b; Adimalla and Taloor, 2020). The Basantar watershed is part of the Jammu plains and hilly stretch of Siwaliks in J&K, the scarcity of water is quite hilly nature of terrain and sloppy surface mostly rain-fed and lack of proper guidance and management has led to the dying of many springs.

In the current study region, 70% residents merely rely on the spring water for domestic uses, which increase the demand of monitoring of water quality and discharge of the spring. The major objective of the research is to understand the spring water quality through detail hydrochemistry in the study area, to determine the various classifications of water, for drinking and irrigation purposes.

2. Description of study area

The study area lies between latitude 32° 30′ to 33° 55′ N and longitude 75°1′ to 75°23′ E and covers a total area of 610 km^2. The study region is mostly covering of hilly terrain of Jammu Himalaya. The hydrogeomorphology, lithology, and slope play a major role in the evolution of the various types of drainage pattern in the study area. Basantar is the major river flowing in the northeast to southwest direction in watershed with Rui and Devak are its tributaries joins at the plains of Jammu Himalayas. The study area falls in subtropical to moist temperate climate with temperature ranges from 2° - 20 °C in winter and 30° - 47 °C in summer and average annual precipitation in the study area is 1208 mm (Jasrotia and Kumar 2014a).

Geologically study area is a part of the Siwaliks and Muree Formation lies in the hilly range of Lesser Himalaya from Early Miocene to Upper

Table 2
Instrumental, titrimetric and calculation methods used for chemical analysis of spring.

Parameters	Characteristics	Analytical method	Reagents	Unit	Reference
General	pH	pH/EC/TDS meter	pH 4, 7 and 9.2		APHA (2012)
	Electrical Conductivity (EC)	pH/EC/TDS meter	Potassium chloride	μS/cm	APHA (2012)
	Total dissolved solids (TDS)	Calculation	EC X (0.55–0.75)	mg/L	APHA (2012)
	Total hardness (as CaCO3)	EDTA titrimetric	EDTA, ammonia buffer and Eriochrome Black-T (EBT) indicator	mg/L	APHA (2012)
Major cations	Calcium (asCa^{2+})	EDTA titrimetric	EDTA, sodium hydroxide and murexide	mg/L	APHA (2012)
	Magnesium (asMg^{2+})	Calculation	MgH = TH-CaH; Mg=MgH X Eq.Wt of Mg X Normality ofEDTA	mg/L	APHA (2012)
	Sodium (asNa^{+})	Flame photometric	Sodium chloride (NaCl) and KCl	mg/L	APHA (2012)
	Potassium (asK^{+})	Flame photometric	NaCl and KCl	mg/L	APHA (2012)
Major anions	Bicarbonates (HCO_3^-)	Titrimetric	Hydrosulfuric acid (H2SO4), phenolphthalein and methyl orange	mg/L	APHA (2012)
	Chloride (Cl^-)	Titrimetric	Silver nitrate (AgNO3), potassiumchromate	mg/L	APHA (2012)
	Fluoride (F^-)	Fluoride (F−) ISE (Ion selective electrode; ThermoOrion)	TISAB III and NaF	mg/L	APHA (2012)
	Sulphate (SO_4^{2-})	UV visible spectrophotometer	HCl, ethyl alcohol, NaCl, barium chloride, sodium sulphate	mg/L	APHA (2012)
	Nitrate (NO_3^-)	UV visible spectrophotometer	Potassium nitrate (KNO3), Phenol disulponic acid, ammonia	mg/L	APHA (2012)

Pleistocene in age (Ranga Rao et al., 1988). The Siwaliks rocks mainly exposed in the study area, except the northernmost part of the study area where the Murree Formation of Early Miocene age found as Monotonous grey sandstone and grey, brown to yellowish subordinate, mudstone, siltstone and clay (Fig. 1c). The Siwaliks rocks as classified Lower, Middle and Upper Siwaliks are found in the study area, the Lower Siwalik composed of red mudstone and fine medium grained grey, green sandstone of Middle Miocene Age (Table 1). The Middle Siwaliks Upper Miocene Age composed of Medium to coarse-grained sandstones and subordinate grey brown mudstone with coarsening upward in sequence and comparatively softer to Lower Siwaliks. The Upper Siwaliks of Pliocene to Middle Pleistocene age study area further classified into three formation Parmandal Sandstone, Nagrota Silt, and Boulder Conglomerate which exquisitely found in the study area. The Jammu alluvium is the part of the Indo-Gangetic plains are part of the younger and older alluvium deposited plains of study area and mostly act as recharge cum discharge zone (Jasrotia and Kumar 2014b; Jasrotia et al., 2019a,b).

3. Data and methodology

3.1. Sampling and analytical procedures

Spring samples of 60 locations were collected and analyzed for various hydrochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH) as $CaCO_3$, calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), chloride ($Cl\_$), sulphate (SO_4^{2-}), nitrate (NO_3^-), fluoride (F^-). Environment sensitive index such as pH (hydrogen ion concentration), electrical conductance (EC), total dissolved solids (TDS) were measured in the field at the time of sample collection using a pH/EC/TDS meter. The detail analytical procedure for hydrochemical quality given in Table 2. The location of each spring was taken into the GIS environment, and the results of each parameter analyzed were added to the concerned wells.

3.2. Water quality index

The water quality index (WQI) was also evaluated to determine the suitability for drinking purposes (Horton, 1965; Ramakrishnaiah et al., 2009; Varol and Davraz, 2015; Saha et al., 2018; Adimalla and Taloor, 2020). The WQI is a mathematical effectual tool, which provides a comprehensive model of the groundwater quality and is used to present large quantities of water quality data into a single number developed by Horton (1965). WQIs are effective tool to estimate the overall water quality for drinking purposes by examining individual water quality parameters where all calculated cations, anions, pH, EC and TDS were taken into account to determine the water quality index by using the three set WQI calculations which includes (a) assignment of weights, (wi) (based on equation (1)) to each water quality parameter involved; (b) calculation of relative weights (Wi) and (c) quality rating scale calculation (Qi) (based on equation (2)):

$$\mathrm{Wi} = wi \Big/ \sum_{i=1}^{n} wi \tag{1}$$

$$\mathrm{Qi} = \frac{\mathrm{Ci}}{Si} \times 100 \tag{2}$$

where Qi is the quality rating for each chemical parameter i, Ci is the concentration of each chemical parameter i in each water sample (mg/L), n is the total number of parameters, and Si is the Indian drinking water standard (BIS, 2012) for chemical parameter i. Assigning the weights for each chemical parameter is the most important part, which determines the significance of a water quality parameter for drinking uses. Assigning the weights for each chemical parameter is the most important part, which determines the significance of a water quality parameter for drinking uses. For each of 11 parameters, a weight (wi) has been assigned according to its relative importance in the overall quality of drinking water, as shown in Table 3. The most significant parameters have a weight of 5 and the least significant have a weight of 2. In the study, the maximum weight of 5 has been assigned to total dissolved solids, nitrate and fluoride, due to their major importance in water quality assessment (Ramakrishnaiah et al., 2009). Then, water quality sub-indices (SIi) for each chemical parameter is computed by equation (3), and the WQI is determined by equation (4):

Table 3
Relative weight of hydrochemical parameters.

Chemical parameter	Units	BIS (2012)	Weight (wi)	Relative weight $Wi = wi/\sum_{i=1}^{n} Wi$
pH	–	6.5–8.5	3	0.075
TDS	mg/L	500	4	0.100
TH	mg/L	200	3	0.075
Ca^{2+}	mg/L	200	3	0.075
Mg^{2+}	mg/L	30	3	0.075
Na^+	mg/L	200	2	0.050
K^+	mg/L	12	2	0.050
F^-	mg/L	1.5	5	0.125
HCO_3^-	mg/L	120	3	0.075
SO_4^{2-}	mg/L	200	3	0.075
$(Cl^-$	mg/L	250	4	0.100
NO_3^-	mg/L	45	5	0.125
			$\sum$wi = 40	$\sum$Wi = 1

$$\mathrm{SIi} \;=\; \mathrm{Wi} \;\; \mathrm{x} \;\; \mathrm{Qi} \tag{3}$$

$$\mathrm{WQi} = \sum_{i=1}^{n} SIi \tag{4}$$

Based on the spatial statistical analysis in the GIS, using ARC Map 10.5 software. The quality maps of the different cations, anion, pH and TDS were prepared in the GIS environment using the inverse distance weighting (IDW, one of the highly used for the random sample data.

3.3. Irrigation water quality

Irrigation water quality was computed by the following as under.

For the irrigation water quality measurement Sodium absorption ration (SAR), which is a kind of sodium hazard in the use of water for irrigation was determined by equation (5) (Karanth, 1987)

$$\mathrm{SAR} = \frac{\mathrm{Na}^+}{\left(\sqrt{(\mathrm{Ca2} + +Mg^{2+})}\right)\Big/2} \tag{5}$$

The concentrations of cations are expressed in meq/L.

The sodium percent in water is another common parameter (Wilcox, 1955) which is extensively used to evaluate the water for irrigation suitability parameter computed to evaluate the suitability for irrigation computed by equation (6):

$$\mathrm{Na\%} = \;\; \times 100 \frac{\mathrm{Na}^+ + \mathrm{K}^+}{\mathrm{Ca2} + +\mathrm{Mg}^{2+} + \mathrm{Na}^+ + \mathrm{K}^+} \tag{6}$$

The concentrations of cations are expressed in meq/L.

The concentrations of cations are expressed in meq/L.

Besides this, irrigation water can also be classified based on RSC. When the sum of carbonate and bicarbonate is in excess over the alkaline earths chiefly calcium and magnesium, in excess of permissible limits affects irrigation adversely according to Eaton (1950) and Richards (1954).

$$\mathrm{RSC} = \;\; (\mathrm{CO32} - +\mathrm{HCO3} -) - (\mathrm{Ca2} + + \;\; \mathrm{Mg2} +) \;\; \mathrm{meq/L} \tag{7}$$

Table 4
Chemical composition of the spring water quality.

S No.	pH	EC	TDS	TA	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	F^-	SO^{2}_{4}	NO_3^-	Ionic balance	WQI
1	7.7	293	153	167	210	47.0	21.0	9.4	1.3	205.0	16.0	0.3	34.0	8.0	−1.63	40
2	7.5	520	280	276	280	84.2	16.0	30.0	1.6	334.0	18.5	0.5	27.0	25.0	−0.91	58
3	7.7	365	188	183	198	61.2	11.9	10.2	1.4	222.0	15.2	0.2	8.0	13.0	0.65	39
4	7.7	498	258	260	282	88.0	16.0	10.0	4.3	338.0	15.3	0.3	15.8	9.2	−1.67	53
5	7.5	292	153	158	200	42.0	25.0	9.4	2.3	195.0	15.2	0.5	37.4	4.2	1.34	41
6	7.8	285	148	133	174	42.6	18.3	11.3	1.4	172.9	7.8	0.2	42.5	8	0.97	36
7	7.5	254	133	118	164	40.6	17.1	10	1.4	154.6	10.9	0.4	37.6	11	1.04	36
8	7.7	742	388	278	384	90.7	40.2	34.8	2.5	349.8	64.6	0.1	34.7	63.9	0.51	78
9	7.7	723	398	353	404	10.5	93.7	34.2	5	441.3	43.3	0.1	38.1	31.4	0.44	87
10	7.7	1523	793	323	529	82.7	60	25	2	404.7	111	0.1	35	12	−2.32	107
11	7.7	562	289	163	269	88.7	13.5	22.1	9.2	209.5	18.5	0.1	120	11.6	0.67	50
12	7.9	532	279	278	244	62.6	23.2	25.8	1.4	349.8	11.4	0.1	2.2	4.5	0.09	50
13	7.8	620	320	243	289	88.7	18.3	36.4	6	307.1	64.6	0.2	24.6	13.2	0.51	57
14	7.4	472	247	208	249	22.5	48.7	28.1	3.9	264.4	18.5	0.1	71.5	0.9	0.67	52
15	7.5	543	284	288	259	22.5	51.2	46.5	2.1	362	32.7	0.1	20.2	2.6	0.59	58
16	7.2	712	367	118	224	76.6	9.8	85.8	7.8	154.6	175	0.1	41.1	9.9	0.46	49
17	7.3	582	305	273	289	38.6	48.7	15	5	343.7	25.6	0.2	10.7	2.1	0.67	58
18	7.2	612	315	298	344	108.7	19.5	10.4	16.2	374.2	11.4	0.1	56.5	11.1	0.51	63
19	7.6	333	169	158	214	56.6	19.5	10.7	1.6	203.4	14.9	0.1	44.3	10.5	0.85	40
20	7.7	763	398	328	374	114.7	23.2	42.4	59.6	410.8	64.6	0.1	112	2.1	0.38	90
21	7.6	1075	559	318	564	138.8	54.8	81.2	2.5	398.6	157	0.1	175	21.2	0.28	92
22	8.4	296	154	118	189	38.6	24.4	17.4	2.2	154.6	39.8	0.2	45.1	3.9	0.82	38
23	7.4	465	242	238	249	34.6	41.4	16.4	2.5	301	14.9	0.1	20.5	2.1	0.76	50
24	7.5	280	143	78	184	42.6	20.8	10	1.3	105.8	22	0.1	71.3	22.6	1.13	36
25	7	295	154	93	164	44.6	14.7	15.2	3.9	124.1	25.6	0.1	47	22.9	1.04	36
26	7.6	455	237	233	249	30.6	43.9	17.9	1	294.9	18.5	0.1	22.7	1	0.78	49
27	7.6	240	123	113	154	48.6	9.8	6	1.9	148.5	11.4	0.2	25.6	9.1	1.36	31
28	8.2	240	195	218	214	36.6	31.7	17.8	1.4	276.6	11.4	0.1	8.7	7.2	0.83	45
29	7.7	718	372	353	304	28.6	58.5	62.1	2.1	441.3	43.3	0.1	7.3	17.6	0.55	72
30	7.7	563	294	288	284	30.6	52.4	12	18.3	362	11.4	0.1	17.2	7.4	0.66	66
31	7.7	476	247	223	274	30.6	49.9	24.9	2.7	282.7	29.1	0.4	58.8	0.9	0.51	56
32	7.7	921	476	358	504	66.6	84	41.6	23.5	447.4	85.9	0.1	64	90.9	0.33	116
33	7.6	576	299	313	299	14.5	65.7	28.7	2.2	392.5	14.9	0.4	19.2	5.8	0.43	66
34	7.2	570	297	273	274	22.5	54.8	12.9	2.2	343.7	18.5	0.1	2.2	2.5	0.00	56
35	7.3	358	185	183	239	36.6	37.8	7.6	1.4	233.9	11.4	0.5	43.2	9.6	0.62	49
36	8.2	680	357	308	319	108.7	13.5	39.8	5.2	386.4	7.8	0.1	65.5	24	0.54	64
37	7.7	290	154	138	164	58.6	6.2	7.5	2	179	11.4	0.1	19	4.3	1.14	31
38	7.8	640	331	348	354	112.7	19.5	24.7	6.9	435.2	14.9	0.1	37.5	3.5	0.49	62
39	8	845	440	448	389	84.7	45.1	74	8.7	557.2	32.7	0.1	57.7	1.6	0.40	81
40	7.7	280	149	98	364	46.6	62.1	7.6	1.1	130.2	7.8	0.6	251	7.4	0.40	58
41	7.7	725	367	363	359	74.6	43.9	24.4	1.7	453.5	22	0.5	6.4	9.8	0.40	71
42	7.8	955	497	458	444	95	82	22	2	590	26	0.4	52	15.5	3.03	108
43	7.9	440	227	238	284	40.6	46.3	16.7	2.2	301	11.4	0.1	58.1	3.7	0.66	53
44	7.8	720	367	348	374	60.6	56	39.4	1.3	435.2	18.5	0.1	56.1	28.9	0.44	76
45	8	705	372	348	354	72.6	43.9	35.5	4.6	435.2	36.2	0.1	2	37.7	0.49	75
46	7.7	1305	679	178	189	74.6	3.7	93.3	6.5	227.8	61.1	0.3	17	139.9	1.03	87
47	7.7	385	206	188	199	32.6	30.5	10.4	1.6	240	7.8	0.1	16.1	2.8	0.97	41
48	7.5	685	357	368	404	42.6	74.3	16.3	9.9	459.6	14.9	0.1	51.5	4.8	0.49	78
49	7.8	270	142	148	143	26.5	20.6	8.6	3.3	191.2	7.8	0.1	2.2	2.2	0.50	33
50	7.7	354	185	143	191	24.5	33.5	6.9	2.6	185.1	7.8	0.1	36.1	15.5	0.97	42
51	7.2	512	269	228	206	56.6	17.5	9.9	13.8	288.8	7.8	0.1	2.2	0.9	0.28	47
52	7.6	260	137	123	119	44.6	3.8	14.7	1.6	160.7	11.4	0.2	5.9	3.1	1.25	28
53	7.9	296	156	133	115	26.5	13.6	6.8	43.2	172.9	7.8	0.1	31.7	2.6	1.06	48
54	7.7	233	123	103	124	26.5	15.9	10.8	0.9	136.3	14.9	0.1	11.8	8.5	1.31	29
55	7.8	300	158	93	115	34.6	8.7	25.9	5.1	124.1	25.6	0.1	40.3	0.9	1.15	29
56	7.7	270	141	113	172	32.6	24	9.6	2.4	148.5	18.5	0.1	47.1	3.1	1.09	34
57	7.7	302	161	78	177	40.6	20.3	9.4	2	105.8	7.8	0.1	73.7	35.5	1.08	40
58	7.7	260	137	98	153	30.6	20.5	10	0.9	130.2	18.5	0.1	38.6	7.1	1.27	32
59	7.8	440	227	138	201	26.5	34.6	28.1	1.5	179	36.2	0.1	44	29.2	0.76	48
60	7.5	656	333	310	314	110.5	14.8	41.5	5.3	388.2	8.7	0.3	67.2	26.9	1.26	65

All concentration in mg/l except pH and EC; location of the samples are shown in Fig. 1c; WQI: Water Quality Index.

3.4. Discharge measurement

The discharge of the spring water fluctuates seasonally and mainly depends on rainfall pattern in the recharge area and variation in the amount of rainwater that is able to in-filtrate the ground. In some studies, we have found that anthropogenic activity affects the spring discharge (Hao et al., 2016) where the measure of concentration discharge have also been well documented with arsenic occurrence (Reyes et al., 2015) We measure the discharge of spring during the summer (pre-monsoon) at that time the flow was quite low so we use this simple and accurate. The discharge measurement of the springs were also carried out using the container/stopwatch method, where flow (Q) can be captured into a container of known volume (V), one of the most straightforward methodologies for determining discharge is to time (t) the filling of the container and calculate flow using the discharge equation

$$Q = V/t \tag{8}$$

Table 5
Comparison of the quality parameters of spring water of the study area with WHO (1984) and BIS (2012) standard for drinking purpose.

S No.	Water Quality parameters unit	WHO (1984) Highest desirable limit	Maximum permissible limit	BIS (2012)Highest desirable limit	Maximum permissible limit	Concentration in the study area	Undesirable effect
1	pH	7.0	8.5	6.5	8.5	7–8.4	Cause skin, eye and mucous membrane irritation
2	TDS (mg/L)	500	1500	500	2000	123–793	Gastrointestinal irritation
3	Calcium (mg/L)	75	200	75	200	10.5–138.8	Scale formation
4	Magnesium (mg/L)	50	150	30	100	3.7–93.7	Diarrhea, abdominal cramping
5	Potassium (mg/L)			–		0.9–59.9	Bitter taste
6	Sodium (mg/L)		200	–	–	6–93.3	High blood pressure
7	Bicarbonate (mg/L)					105.8–590	Kidney failure internal bleeding
8	Chloride (mg/l)	200	600	250	1000	7.8–175	Salty taste
9	Sulphate (mg/L)	200	400	200	400	2–251	Laxative effect
10	Nitrate (mg/L)	45		45	–	0.9–139.9	Methaemoglobinaemia
11	Fluoride (mg/L)			1	1.5	0.1–0.6	Fluorosis
12	Total Hardness as $CaCO_3$ (meq/L)	100	500	200	600	115–864	Encrustation in water supply and adverse effect

Table 6
Water classifications on the basis of TDS (Freeze and Cherry, 1979; Davis and DeWiest, 1966) and TH (,b).

Parameters	Range	Water type/ Classification	No. of sample	% of samples
TH (mg/L) (,b)	<75	Soft		
	75–150	Moderately hard	5	8
	150–300	Hard	55	92
	>300	Very hard		
TDS (mg/L) (Davis and DeWiest, 1966)	<500	Desirable for drinking	57	95
	500–1000	Permissible for drinking	3	5
	1000–3000	Useful for irrigation		
	>3000	Unfit for drinking and irrigation		
TDS (mg/L) (Freeze and Cherry, 1979)	<1000	Fresh	60	100
	1000–10,000	Brackish		
	10,000–100000	Saline		
	>100,000	Brine		

4. Results and discussions

4.1. Assessment of spring water suitability for drinking purposes

It is essential to distinguish the quality of spring for drinking and other domestic purposes. Various water quality parameters and analytical results are presented in Table 4 and the values are compared with standard values of the Bureau of India Standards (BIS, 2012), as shown in Table 5. The pH value ranged from 7 to 8.4, with a mean of 7.66 (Table 4). The pH values range between 6.5 and 7.9 indicates the water is acidic to slightly alkaline in nature. The total dissolved solids (TDS) ranges between 123 and 793 mg/l within the highest desirable limit indicate the water is suitable for livestock. ,b) classification, based on the hardness the spring samples of study area falls under moderately hard (8%) to hard category (92%) (Table 6). Furthermore, TDS values were classified according to Freeze and Cherry (1979), as shown in Table 6, indicating all the spring samples were under fresh water category. The classification of (Davis and DeWiest, 1966) indicate that 95% samples are under desirable for drinking water and only 5% are under the permissible category. The calcium varies from 10.5 to 138.5 with 73% samples are under the desirable limit and 27% samples fall in the permissible limit (BIS, 2012). The magnesium varies from 3.7 to 93.7 with 53% fall in the desirable category and 47% fall in the permissible limit. The sodium varies from 6 to 93.3 and potassium varies from 0.9 to 59.9 in the study area. Among the anion bicarbonate is the dominant element varies from 105 to 590, chloride varies from 7.8 to 175, sulphate varies 2 to 251, nitrate varies 0.9 to 139.9 and fluoride varies from 0.1 to 0.6 in the study area.

The Piper trilinear diagram (Piper, 1953) and Gibbs diagram (1970) were plotted to accentuates the spring water quality. The Piper plot of the spring samples falls in the field 1 and 3 which highlights that alkaline earth exceeds alkalies, weak acids exceeds strong acids respectively (Fig. 2). The major ion chemistry is dominated major ion chemistry is dominated by Ca^{2+}, Mg^{2+}, $HCO_3^-$and $SO^4{}_{2\_}$ ions in the spring waters. The dissolution of carbonate rocks enriches the water in Ca^{2+} and Mg^{2+} ions. The Ca/Mg molar ratio of spring water indicates the dissolution of calcite and dolomite from the geological formation. In the Gibbs ratio the relation to three mechanisms i.e. evaporation dominance, rock dominance and precipitation dominance controlling water chemistry. The Gibb's ratio $Cl^-/(Cl^- + HCO_3^-)$ for anion (Fig. 3a) and ratio $Na^++K^+/(Na^++K^++Ca^{2+})$ for cation (Fig. 3b) exhibit that the water is mainly governed by rock dominance. The carbonate mineral dissolution may be diminished during the travel of groundwater from the recharge areas towards the thicker parts of the aquifer because of the lack of carbon dioxide.

4.2. GIS based spatial water quality

The GIS is an efficient tool to represent the data spatially ways and widely used by number of researchers around the world in the last four decades for mapping of the physical and chemical parameters. In the present study it found that the spatial spring water quality distribution of physical parameter PH(Fig. 4a) shows that most of the area under the desirable limit except a small patch in the southern part of the study area TDS (Fig. 4b) shows that except a small patch in the hilly area, the TDS is under the desirable limit. The spatial distribution of the chemical parameters (Fig. 4c–i) show that most of the area is under the desirable limit except a few pockets which are above the desirable/permissible limit.

4.3. Water quality index (WQI)

Groundwater samples (n = 60) and its WQI values are presented in Table 3. Therefore, the groundwater quality status can be categorized into five types (Ramakrishnaiah et al., 2009; Adimalla and Taloor, 2020) based on WQI values, namely excellent water (<150), good water (150–200), poor water (200–250), very poor water (250–300) and water unsuitable for drinking (>300) (Ramakrishnaiah et al., 2009). The computed WQI values ranged from 28 to 116 (Table 4). As per the

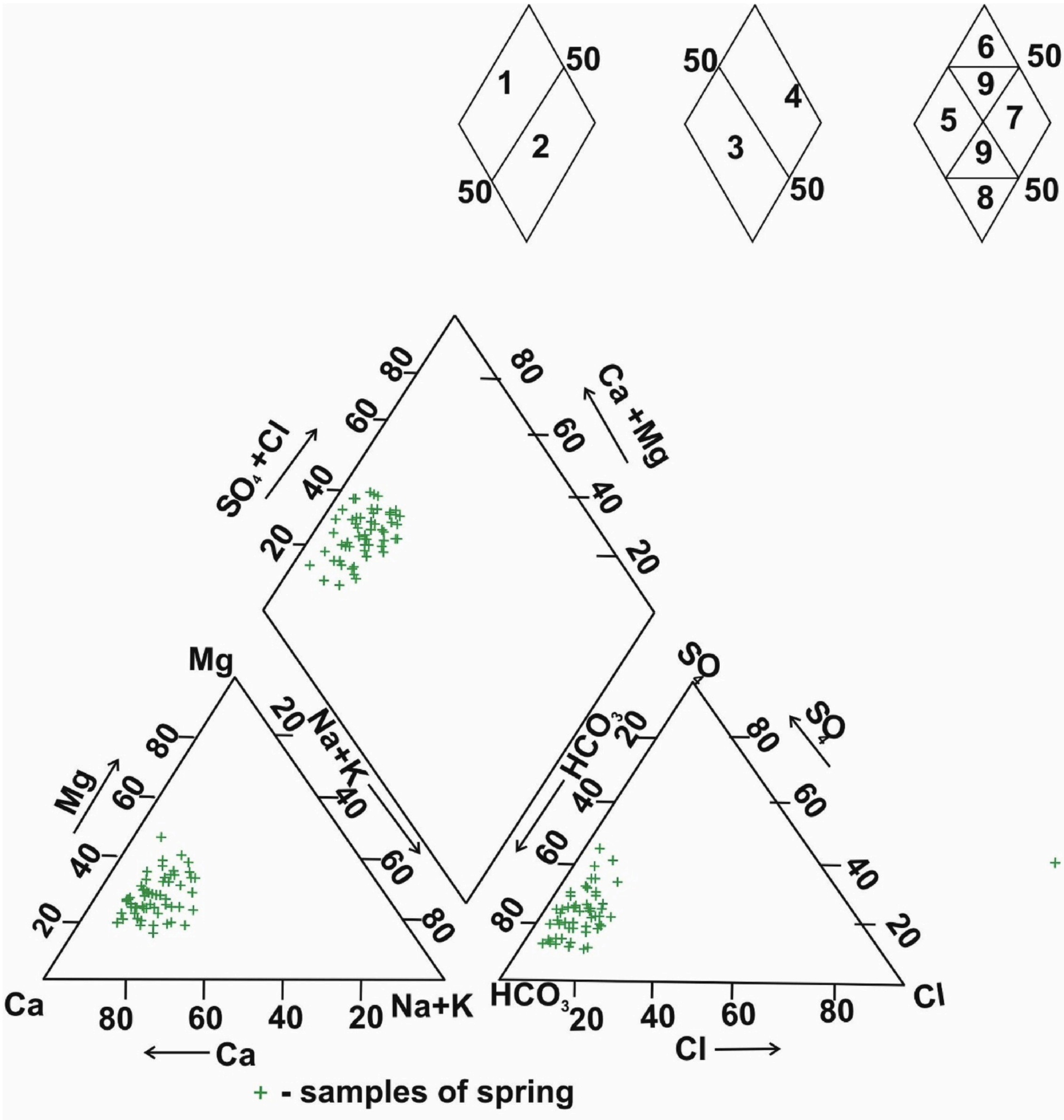

Fig. 2. Geochemical classification of groundwater based on Piper-Trilinear diagram.

classification of WQI 27% of the total spring samples fell under the excellent category, and 30% of the spring sample belongs to good water category for drinking purposes. Moreover, 3%of groundwater samples were found of poor water quality (Table 7). The GIS based spatial analysis were performed using kriging-interpolation to determine the spatial distribution water quality index (WQI) map of the study area (Fig. 5). The spatial map shows that most of the area falls under the excellent to good categories where two small pockets found in the north and north west are under the poor category. It is also found that no sample in the study area falls in the very poor and not suitable drinking water categories.

4.4. Evaluation of spring water suitability for irrigation purposes

Evaluation of spring water quality is an important and vital for the study area as the southern portion is completed dominated by the agriculture activities. For the better understanding of the irrigation water quality the well-established USSL diagram (1954), Sodium absorption ratio (SAR), Sodium percentage (Na%) and Residual sodium carbonate (RSC), were chosen to understand the suitability for irrigation purposes. The surplus amount of sodium concentration in water, leads to the formation of alkaline soil, and the high salt concentration, which results in the development of saline soil. Besides this, dissolved ion such as sodium, bicarbonate, and carbonate in irrigation water affects plants growth and reduce productivity of crops. The EC and Na^{+} concentration are important in classifying irrigation water. SAR of irrigation water is calculated as an index of sodium hazard and is quantified as the relative proportion of sodium (Na^{+}) to calcium (Ca_2^{+}) and magnesium (Mg_2^{+}) ions in water (Richards, 1954). SAR values ranged from 0.14 to 2.06, with an average of 0.52 (Table 9). The salinity hazard parameter (EC) ranged between 233 and 1523 μS/cm with an average value of 526 μS/cm (Tables 3 and 8), and both are used in the USSL (1954) diagram (Fig. 6). The USSL diagram shows that all the samples fall in the low alkali hazard zone where as the 3 samples (5%) falls under the low salinity hazard, 50 (83%) samples under the medium salinity hazard and 7 (12%) samples fall under the high salinity hazard zone. Sodium concentration reacts with soil to reduce or enhance its permeability. Sodium is one of the common element found in the water extensively used to evaluate

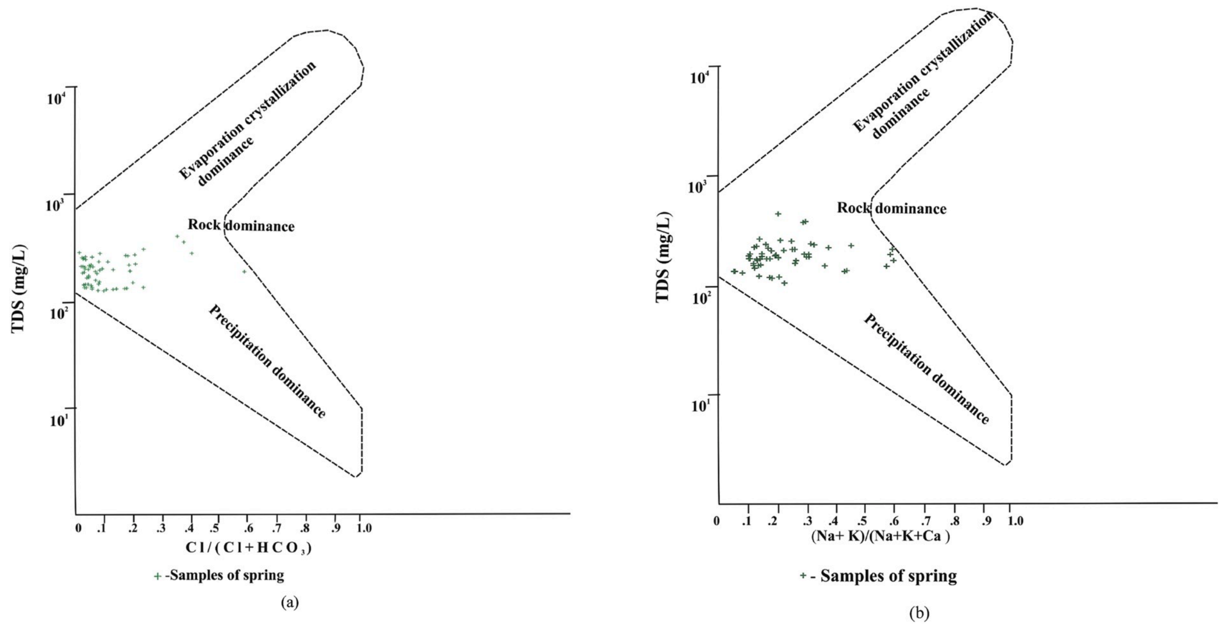

Fig. 3. (a) Gibbs ratio-I Cl/(Cl + HCO3) for anion. (b) Gibbs ratio II–Na + K/(Na + K + Ca) for cation.

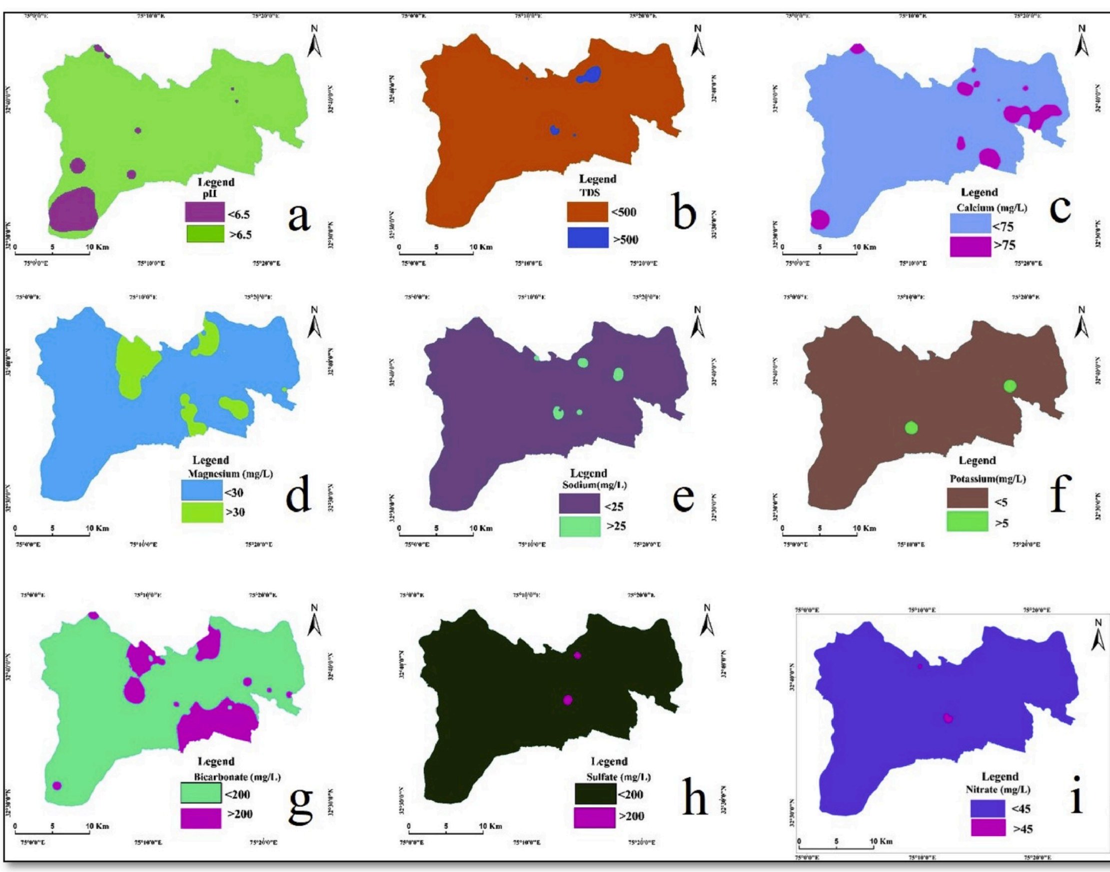

Fig. 4. Spatial distribution of different elements in the GIS environment.

irrigation water suitability. In the present study, the sodium percentage calculated through equation (6) for spring water in the study area, is plotted against EC in Wilcox diagram (Fig. 7). The spatial distribution map of the EC was prepared to know about the spatial distribution and it was found that most of the area under <250 EC, whereas three pocket in the northern area have 250–750 EC and a small area have a value > 2750 (Fig. 8). The value of Na% ranges from 0.002 to 45.93 with a mean of 16.34. The Wilcox diagram shows that 45 samples (75%) falls under the excellent category for irrigation use of water and 15 samples (25%) falls under the good category of sodium in the irrigation water for

Table 7
Water quality index value type of water and percentage of sample in the study area (Ramakrishnaiah et al., 2009).

WQI Range	Type of water	Samples	%
<50	Excellent	27	45
50 to 100	Good	30	50
100 to 200	Poor	3	5
200 to 300	Very poor	–	–
>300	Not suitable for drinking purposes	–	–

Table 9
Groundwater quality based on sodium percentage as per Wilcox diagram.

S. No.	Remark on quality	Percentage of sodium	No. of sample	% of sample
1	Excellent	<20	45	75
2	Good	20–40	15	25
3	Permissible	40–60		
4	Doubtful	60–80		
5	Unsuitable	>80		

irrigational purposes. The water containing a high concentration of carbonate and bicarbonate ions tends to precipitate calcium and magnesium as carbonates. As a result, the increase in the relative proportion of sodium decreases soil permeability. The residual sodium carbonate destroys the soil structure, as it restricts water and air movement through the soil. RSC is present in groundwater if the total concentrations of carbonate and bicarbonate ions exceed that of calcium and magnesium ions (Richards, 1954). The RSC value classified (Raghunath, 1987a) as >1.25 good water type for irrigation, 1.25 to 2.5 doubtful for irrigation,>2.5 unsuitable for irrigation. In the present study, the RSC values varies from −5.29 to 1.19 which shows that all the samples fall under the good category.

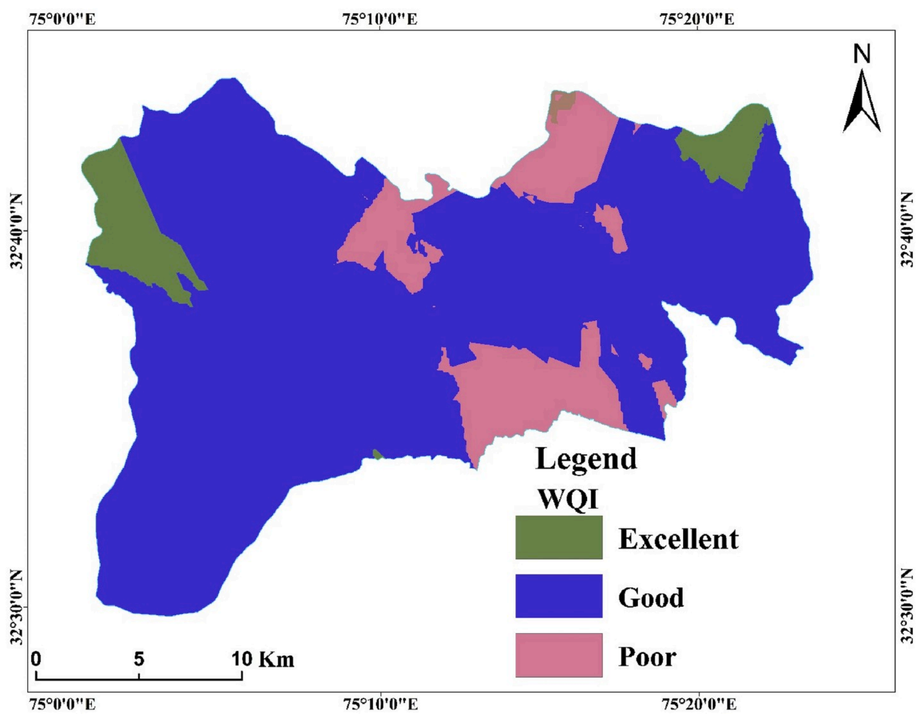

Fig. 5. Spatial distribution of water quality index (WQI) in the study area.

Table 8
Classification of groundwater quality for irrigation purpose based on SAR and EC.

Parameters	Water type	Quality	Suitability for irrigation	Range	No. of samples	% samples in study area
SAR (Richards 1954)	Low sodium water	Excellent	Suitable for all types of crops and all types of soils, except for those crops, which are sensitive to sodium	<10	60	100
	Medium Sodium water	Good	Suitable for coarse textured or organic soil with good permeability	10–18	–	
	High sodium water	Doubtful	Harmful for almost all type of soils, requires good drainage, high leaching gypsum addition	18–26	–	
	Very high Sodium water	Unsuitable	Unsuitable for irrigation	>26	–	
EC (Wilcox 1955)	Low salinity water (C1)	Excellent	Suitable for all types of crops and all kinds of soils	>250	3	5
	Medium salinity water (C2)	Good	Can be used, if a moderate amount of leaching occurs. Normal salt tolerant plants can be grown without much salinity control	250–750	50	83
	High salinity water (C3)	Doubtful	Unsuitable for soil with restricted drainage	750–2250	7	12
	Very high salinity water (C4)	Unsuitable	Unsuitable for irrigation	>2250		

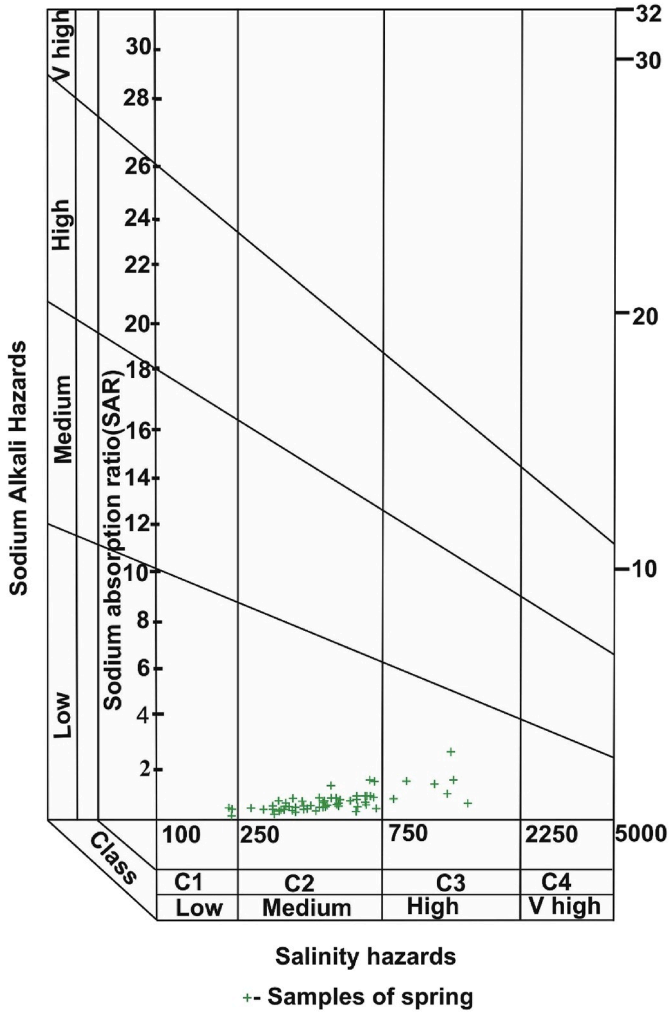

Fig. 6. Classification of irrigation water based on salinity hazards (USSL, 1954).

4.5. Spring discharge

Spring discharge is now a day for critical parameter for the suitable development and management of the springs. High discharge springs are considered as quite valuable and well maintained due to high utility of spring water. It is useful to embed the growing problem of spring water depletion within the context of mountain environmental systems, including the reference to mountain aquifers. Springs have provided water to the mountain communities for centuries and the revival of this traditional source of water is extremely important for the region's sustainable growth. At the same time, rivers are kept alive throughout the year, particularly in a monsoonal climate, primarily due to discharge from groundwater as springs and seeps along their river channels. In the present study area based on equation (8) the measurement of discharge indicates that 42 springs have discharge more than 20 L per minute second (Lps), 10 springs have discharge between 10 and 20 Lps, 5 springs have discharge between 2 and 10 Lps and 3 springs have discharge >2 Lps (Table 10).

5. Conclusion

Hydrochemical analysis of the spring water samples exhibit that Ca and Mg are dominant followed by the Na^+ and K^+ among cations. The bicarbonate is one of the most dominant anion followed by the Cl_ and NO3_. Analysis of hydrochemical facies reveals two dominant facies on piper trilinear diagram Ca^{2+}–Mg^{2+}– HCO_3- and Ca^{2+}–Mg^2– HCO_3^- – $SO^2{}_4$ type which depicts that the water chemistry is dominated by the alkaline earth and weak acids. The Gibbs plot shows that total dissolved solids, point towards rock dominance and suggests congruent dissolution of carbonate lithology. The high values of $HCO3^-$ in spring water samples illustrate the dissolution of carbonate rocks in the recharge area due to the acidic precipitation (CO^{2-}rich) and ionic enrichment. The fluoride is with the desirable limit whereas the nitrate is in the permissible limit except 3 (5%) samples. The Wilcox diagram revealed that most of the spring samples are good (25%) to excellent (75) category for irrigation. The US Salinity Laboratory diagram indicates that 83% of groundwater samples belong to medium salinity (S2) and low sodium hazards (C3S1), whereas only 12% samples falls under the high salinity water which considered as unsuitable for soil with restricted drainage. The water quality index of domestic uses was determined and found that 95% of the spring water samples are under excellent to good category which means that most of the springs are source of fresh drinking water where major chunk of the population in the study area is rely for drinking purposes. The spatial water quality index map shows that most of the study area are fall under excellent to good categories and a few pockets have the poor spatial WQI. The depletion of spring is one of the major problems in the Himalayas due to various socio-economic and political reasons which has arose the need of spring discharge measurement and in the study it was found that 70% of the springs dominated by the sandstone lithology have discharge rate of <20Lps whereas the spring in the boulder/sandstone area 17% springs usually have a discharge rate of 10–20 Lps and required a carefully attention for the revival and rejuvenations of the springs before it comes too late. The overall scenario of the spring water in the study area is chemically potable and suitable for domestic and agricultural uses.

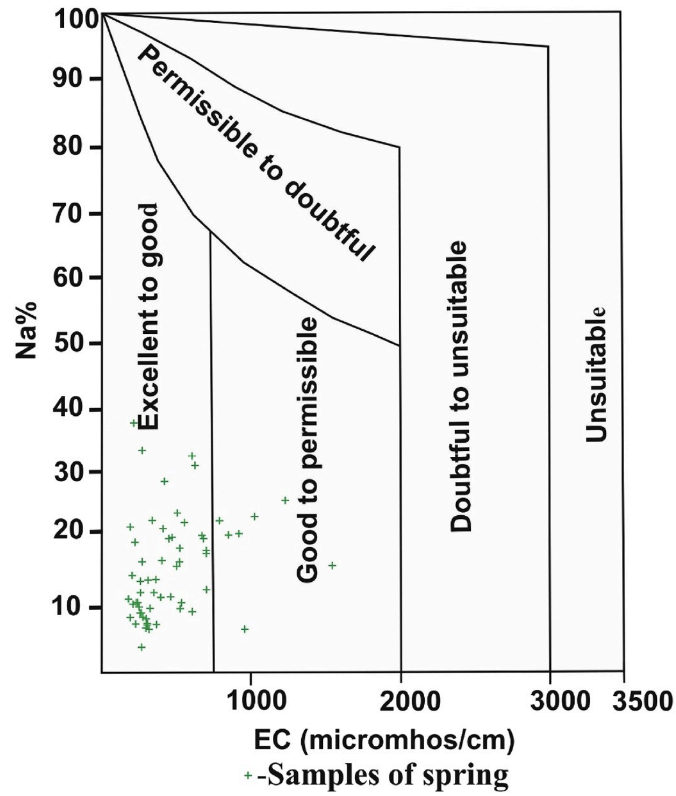

Fig. 7. Sodium percentage versus electrical conductivity (after Wilcox, 1955).

Declaration of competing interest

The authors declare that they have no known competing financial

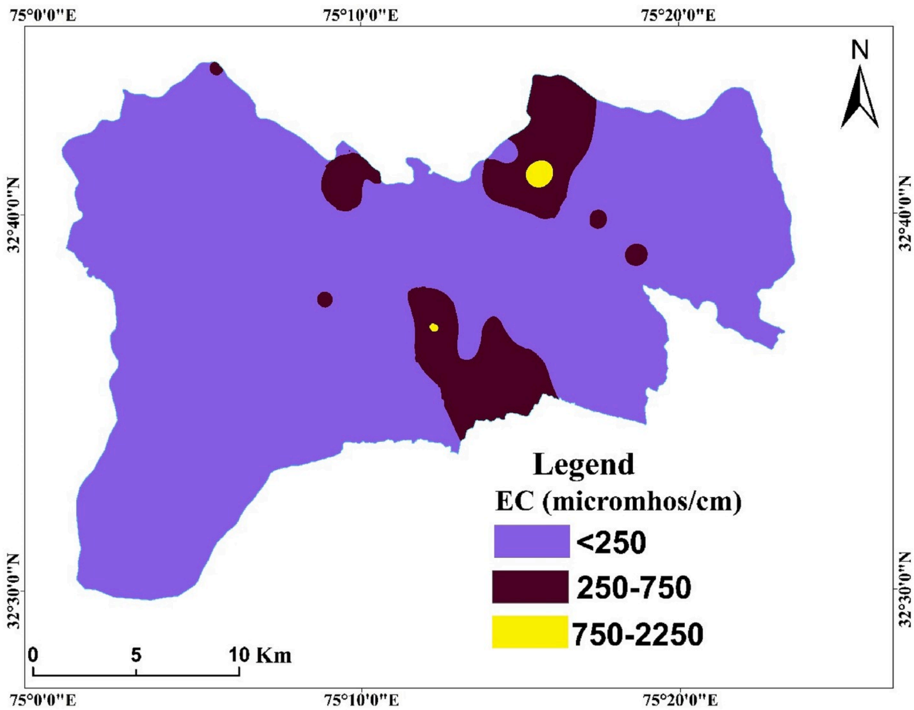

Fig. 8. Spatial distribution of electric conductivity (EC) in the GIS environment.

Table 10
Spring discharge in the study area in different formation.

Discharge (LPS)	No. of Samples	%	Discharge point	Formation	Structurally controlled
>20	42	70	Not at source	Sandstone	Thrust
10–20	10	17	Not at source	Boulder beds/ Sandstone	Fault
2–10	5	8	Not at source	Alluvium	Lineaments
<2	3	5	Not at source	Slit and clay dominated	Unable to identify

interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gsd.2020.100364.

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