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Research paper

Assessing groundwater quality using water quality index in semiarid region of Aurangabad district, central India

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Abstract

This paper presents a study on the influence of geochemical parameters on groundwater quality in GV-35 watershed of Aurangabad district, Maharashtra, India. Groundwater samples were collected from different locations and their physiochemical quality parameter were analysed. Water quality index (WQI) was determined on the basis of various physical and chemical parameters like pH, electrical conductivity, turbidity, total dissolved solids, total hardness, calcium, magnesium, sulphate, chloride, nitrate, sodium, potassium, carbonate, bicarbonate, fluoride and iron. These parameters were determined for the calculation of water quality index (WQI). During pre-monsoon, 4% of groundwater samples were excellent, 65% were good; 26 % were poor; and 4% were unsuitable for domestic suitability, whereas in post-monsoon, 65% of water samples were good; 26% were poor; 4% were very poor and 4% were unsuitable for domestic suitability .

Keywords: *GV-35 Watershed; Water Quality Index; Domestic Suitability; Aurangabad; India.*

1. Introduction

Ground water is one of the main sources of water requirement of people in India as well as other parts of the world. Pollution of water has been reported to cause 80% of human diseases and 30% of infant mortality. It is, therefore, important to monitor the quality of ground water pollution of various parts of our country (Singh & Parwana, 1992). Anthropogenic activities can alter the relative contributions of the natural causes and also introduce the effects of pollution (Whittemore et al,1989; Salve and Aher, 2016). Groundwater is the major source of water for domestic, agricultural and industrial purposes in many countries. India accounts for 2.2% of the global land and 4% of the world water resources and has 16% of the world's population. It is estimated that approximately one third of the world's population use groundwater for drinking (Nickson et al, 2005). Therefore, water quality issues and its management options need to be given greater attention in developing countries. Intensive agricultural activities have increased the demand on groundwater resources in India. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices (Ramesh & Elango, 2011; Deshpande et al, 2012; Marghade, et al, 2020). Groundwater is the main source that caters the need of inhabitants from rural part for daily activities, especially in a developing country like India (Gaikwad et al, 2018; Kumar et al, 2020; Kate et al, 2020). Water is the essence of life and nearly 165 billion liters of water needed per day in India (Gupta and Misra, 2018). Water quality is an imperative matter directly related to the welfare of the human race. Due to the shortage and contamination of surface water, the dependency on groundwater has been increased within a few decades to meet water requirements for drinking, irrigation, and other uses. The measure of the quality of water used for irrigated agriculture is essential for predicting its long-term usage while attaining enhanced productivity (Bauder et al, 2011; Wagh et al, 2018). All the agricultural practices carried out in the country are majorly dependent on this hidden natural resource (Srivastava and Parimal, 2020; Marghade, 2020; Verma et al, 2020). Specifically, in arid and semiarid provinces, subsurface water is mostly limited due to the scanty precipitation, high evaporation and surface runoff (Camacho Suarez et al, 2015; Kadam et al, 2020). While meeting the demands from various sectors, this precious resource is getting scarce, overexploited and contaminated in many parts of the country (Avvannavar and Shrihari, 2008; Vasanthavigar et al, 2010; 2012; Sharma and Kansal, 2011). Moreover, the ingestion of such polluted groundwater could upsurge the hazards of aquatic infection epidemic (Wu and Sun, 2016; Li et al, 2019). The degrading groundwater quality has become a serious universal issue for sustainable development (Adimalla and Wu, 2019). Hence, it is extremely important to understand the hydrogeochemical characteristics of groundwater for sustainable resource development and governance. The quality of ground water is the resultant of all the processes and reactions that have acted on the water from the moment it condensed in the atmosphere to the time it is discharged by a well. Therefore, the quality of ground water varies from place to place, with the depth of water table, and from season to season and is primarily governed by the extent and composition of dissolved solids present in it (Aher, 2012). The variations in major ion chemistry of groundwater lead to identification of geochemical processes that control the groundwater quality. Weathering of minerals within the rocks is an important process, regulating the concentration of dissolved ions in groundwater (Jacks, 1973; Bartarya, 1993; Rao and Rao, 2010). Groundwater is a vital natural resource for the reliable and economic provision of potable water supply in both the urban and rural environment. It thus plays a fundamental role in human well-being as well as that of aquatic and terrestrial ecosystems. In the background of preserving this most important natural asset, the water utility management is the key area that managers need to focus upon. Fresh and clean water is of fundamental importance to the survival, protection and development of human needs. The movement of groundwater is controlled by physical and geochemical properties of (i) contaminant (ii) the groundwater and (iii) the geological system through which the contaminated groundwater is flowing. Presence of some ionic contents beyond certain limits may make it unsuitable for irrigation, domestic or industrial uses (Purushtotham, et al, 2011; Aher and Deshpande, 2014). Poor quality of water adversely affects the plant growth and human health (US Salinity Laboratory Staff, 1954). The determination of physicochemical parameter has established role in evaluating the quality of groundwater, which is why these parameters have also been duly focused on. The chemical composition of water has evolved much interest during the last few decades because of several factors. The quality of groundwater is deteriorating mainly due to anthropogenic activity, irrigation return flow, excessive utilization of chemical fertilizers, municipal waste, unhygienic practices, septic tank effluent and landfills leachate (Srinivasmoorthy et. al, 2011; Aher and Dhumal, 2017). The agriculture is a dominant occupation in the study area, and groundwater demand in future will be very high. Along with the concern on the availability of this natural resource, it becomes extremely important to monitor and maintain its compositional value for safeguarding human's health while maintaining the fertility of soil. The Water Quality Index, indicating the water quality in terms of index number, offers a useful representation of overall quality of water for public or for any intended use as well as in the pollution abatement programs and in water quality management (Brown et al, 1972; Chatterjee & Raziuddin, 2007). Keeping this in view, the present study aims to calculate the water quality index (WQI) in order to assess the suitability water for domestic use.

2. Study area

The study area occupied by Bori Basin is located between latitude 19º45'05'' to 20º50'01'' N and longitude 74º45'00'' to 74º55'05'' E in Vaijapur block of Aurangabad District, Maharashtra, Central India (Fig. 1). Groundwater surveys and development agency nominated this watershed as GV-35 watershed (GSDA,2019). The area covers to extent of about 284.98 km^2 and is distributed in 25 villages and includes in the Survey of India topographical maps (46L/16 and 46I/13). The climate of the area is semi-arid, with minimum and maximum mean annual temperatures of 10.3°C in winter and 39.8°C in summer, respectively. The mean rainfall over a period of 50 years is about 540.85 mm. However, recently, the area has an acute shortage of surface water due to the frequent failures of monsoon. Agriculture is the main source of livelihood (Deshpande and Aher,2012a). Physio-graphically the area is a gradual plain with a gentle slope, which increases towards the north. The direction of the slope decreases towards the south east within the whole study area. The major part of the study is covered by black cotton soil or 'Regur' formed by the weathering of Deccan Trap Basalt. The drainage is dendritic, following the topography. The streams flow towards the south east. Streams are intermittent, except during rainy season (Aher,2017; Aher and Dhumal, 2017). Geologically the whole area covered by Deccan trap of the Late Cretaceous – Palaeogene (68-62 million years age) comprising lava flows of basaltic composition, the Deccan again divided into Lower Ratangarh and upper Ratangarh formations of Sahyadri group. The lower Ratangarh formation occurs in the middle part of the area having thickness of 360m, comprising mainly pahoehoe flows. Upper Ratangarh formation occupies a large part and comprises a sequence of 7 floes showing sparsely to moderately porphyritic character. The area constitutes a sequence of basaltic lava flows while alluvium occupies a small portion. There are two distinct hydrogeological units' i.e. fissured formations and porous formations (Aher, 2017). Utilization of groundwater is through dug wells and bored wells. The occurrence and movement of groundwater is controlled by variation in water bearing properties of these formations (Fig.2).

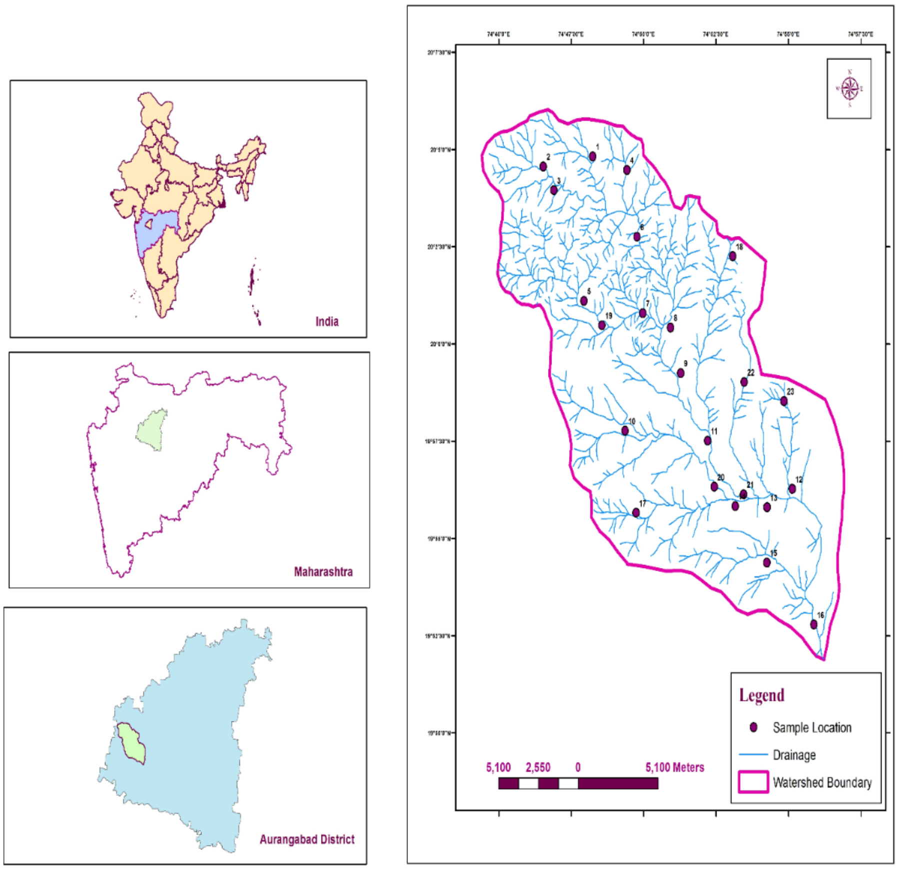

Fig. 1: Location Map of the Study Area.

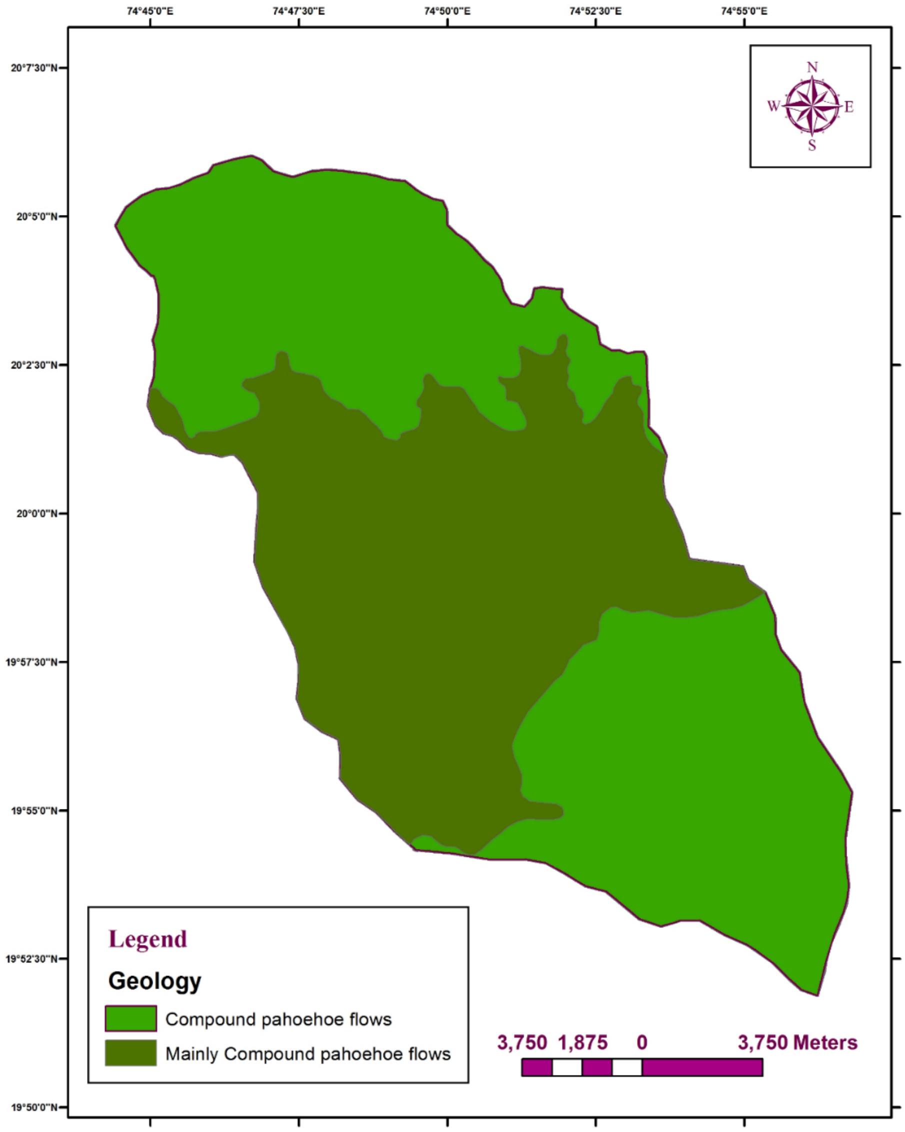

Fig. 2: Geological Map of the Study Area.

3. Methodology

The base map of the study area was scanned and digitized from the Survey of India (SOI) Toposheets No. 46L/16 and 46I/13 (1:50,000). ArcGIS: 10 is used to map and analyze the data for the evaluation of groundwater quality. Samples were collected from wells as shown in (Fig. 1.)

The groundwater samples were analysed for major ion chemistry, using of APHA (2017) standard water quality methodology. The physicochemical parameters viz. pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, total hardness, cations like calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K), and anions like Carbonate (CO_3), bicarbonate (HCO_3), total alkalinity, chloride (Cl), sulphate (SO_4), nitrate (NO_3) and fluoride (F). The pH and electrical conductivity (EC) of the groundwater samples were measured in the field. The TDS was calculated from EC adhering to the procedure of Hem (1991). The rest of the parameters were determined in the laboratory immediately after the groundwater sampling. For analytical precision of each groundwater sample, the concentrations of cations and anions were used to compute the ionic-balance-error, which was observed to be within the standard limit of ±10% (Domenico and Schwartz 1990). The suitability of groundwater for domestic purposes were evaluated by comparing the values of different water quality parameters with those of the World Health Organisation (WHO,2011) and Bureau of Indian standard (BIS,2012) guidelines values for drinking water.

3.1. Water quality index system

A water quality index, common with many other indices systems, relates a group of water quality parameters to a common scale and combines them into a single number in accordance with a chosen method of computation. The desired use of WQI is to assess water quality trends for management purpose even though it is not meant for an absolute measure of the degree of pollution or the actual water quality. WQI is defined as an index reflecting the composite influence of different water quality parameters which is considered and taken for calculation of water quality index. The standards for drinking purposes as recommended by BIS, (2012), WHO, (2011), and ICMR, (1975) have been used for the calculation of WQI, which involves three steps

In the first step each of the fourteen parameters like pH, EC, TDS, TH, Ca, Mg, SO4, Cl, NO3, Na, K, TA. F and Fe were assigned weights (w_i) ranging from 2 to 5, and its selection depends on their significance in quality of water for drinking purposes (Ramakrishnalah et al., 2009). In the second step is relative weights (W_i) are calculated through equation (1).

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

Where (W_i) is the relative weight, (w_i) is the weight of each parameter and (n) is the number of parameters Table 1. In the third step, quality rating scale calculation (Qi) for each individual parameter is computed by dividing its concentration for each groundwater sample with drinking water quality standards of and then multiplied by 100 using equation (2).

$$Q_i = (C_i / S_i) \times 100 \quad (2)$$

here Q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample in milligrams per litre (mg/L) and S_i is the drinking water standard guidelines for each chemical parameter. Eventuality, water quality sub-index (SIi) for each chemical parameter was computed by equation (3), and whole the WQI was determined by equation (4).

$$SI_i = W_i \times Q_i \quad (3)$$

$$WQI = \sum S\, I_{i-n} \quad (4)$$

Where,
SI_i is the sub-index of the ith parameter,
Q_i is the rating based on the concentration of ith parameter, and n is the total numbers of parameter?

4. Results and discussion

The statistics results of the physicochemical analysis in pre- and post-monsoon seasons are presented in table 1. The assigned weight and relative weight of physicochemical parameters for calculation of WQI are presented in Table 2, quality rating in Table 3 and 4, sub index values in Table 5 and 6, WQI values in Table 7, and Computation of water quality index for groundwater samples based on WQI in Table 8.

Table 1: Descriptive Statistics of Pre-Monsoon and Post-Monsoon Season of the Study Area

Parameter	pre-monsoon				post-monsoon			
	Minimum	Maximum	Mean	Std. Deviation	Minimum	Maximum	Mean	Std. Deviation
pH	7.01	9.27	7.72	0.65	6.50	8.76	7.21	0.65
EC	360	4360	1088	828	418	4418	1146	828
TDS	234	2834	708	538	272	2872	745	538
Turbidity	0.10	0.90	0.69	0.18	0.01	0.79	0.58	0.18
TH	112	1164	346	209	147	1199	381	209
Ca	14	115	70	29	32	133	88	29
Mg	6	217	41	42	19	230	54	42
Na	14	122	62	31	29	137	77	31
K	0.10	138.00	6.81	28.63	0.23	138.13	6.94	28.63
TA	56	756	230	136	92	792	266	136
CO_3	0.00	72.00	11.48	21.28	0.00	72.00	13.83	24.70
HCO_3	12	708	218	132	35	731	241	132
Cl	26	234	129	59	52	260	155	59
SO_4	19	289	60	56	48	318	89	56
F	0.07	1.92	0.74	0.58	0.08	1.77	0.59	0.58
NO_3	11	155	44	31	22	166	55	31
Fe	0.01	1.35	0.54	0.54	0.02	1.36	0.55	0.54
WQI	45.37	333.55	104.91	61.28	57.11	345.29	116.65	61.28

Table 2: The Assigned Weight and Relative Weight of Physicochemical Parameters

Sr. No.	Parameter	Units	Drinking water Standards (Si)	Recommending Agency	weight (wi)	Relative weight (Wi)
1	pH	-	6.5-8.5	ICMR/BIS	3	0.0625
2	EC	µ/cm	300	ICMR	3	0.0625
3	TDS	mg/L	500	ICMR/BIS	5	0.1042
4	TH	mg/L	300	BIS	3	0.0625
5	Ca	mg/L	75	ICMR/BIS	3	0.0625
6	Mg	mg/L	30	ICMR/BIS	3	0.0625
7	SO_4	mg/L	200	BIS	3	0.0625
8	Cl	mg/L	250	ICMR/BIS	4	0.0833
9	NO_3	mg/L	45	ICMR/BIS	5	0.1042
10	Na	mg/L	200	WHO	2	0.0417
11	K	mg/L	12	WHO	2	0.0417
12	TA	mg/L	200	BIS	3	0.0625
13	F	mg/L	1.5	BIS/WHO	5	0.1042
14	Fe	mg/L	1.0	BIS/WHO	4	0.0833
					∑ 48	∑1.00

4.1. pH

pH is one of the important factors of ground water. pH is ranging from 7.01 to 9.27 and 6.50 to 8.76 during pre- and post-monsoon seasons, respectively. The slightly increase of pH in pre -monsoon season can be attributed to the discontinued supply of CO_2 (Pondhe et al., 1997). 9% and 4% samples were exceeding the permissible limit in pre- and post-monsoon season, respectively prescribed by BIS (2012). The study indicating that groundwater is slightly alkaline in nature.

Table 3: Water Quality Rating (Qi) Values of Physicochemical Parameters (Pre-Monsoon Season)

Samples No	pH	EC	TDS	TH	Ca	Mg	TA	Cl	SO_4	F	NO_3	Na	K	Fe
1	85.88	266.67	104	134	123.73	29.16	106	56.8	21.96	72	50.11	4.37	3.33	9
2	82.59	280	109.2	156	87.47	119.88	100	60	38	34.67	80.82	17.98	0.83	6
3	84.71	273.33	106.6	142	68.27	126.36	124	43.2	13.5	52	54.83	18.95	7.5	7
4	84.35	160	62.4	98	29.87	113.4	70	10.4	21	73.33	50.99	17.01	3.33	11
5	96.94	389.33	151.84	226	117.33	187.92	100	65.6	32.9	16.67	131.52	28.19	8.33	122
6	98.24	636	248.04	264	136.53	220.32	128	83.2	59.79	23.33	170.01	33.05	13.33	132
7	96.47	291.67	113.75	180	102.4	136.08	98	53.6	24.83	27.33	54.14	20.41	7.5	49
8	90	503.33	196.3	244	119.47	213.84	128	79.2	28.56	20.67	127.98	32.08	4.17	107
9	109.06	120	46.8	80	25.6	90.72	30	23.2	14.5	26	90.57	13.61	48.33	51
10	105.65	293.33	114.4	176	83.2	158.76	104	57.6	20.67	4.67	109.77	23.81	0.83	94
11	82.71	296.67	115.7	148	110.93	71.28	98	46.4	22.2	6	80.33	10.69	2.5	101
12	85.76	576.67	224.9	196	91.73	178.2	194	89.6	35.53	6.67	154.26	26.73	1150	120
13	87.29	473.33	184.6	196	153.6	84.24	128	93.6	32.62	12	138.51	12.64	3.33	122
14	82.47	266.67	104	124	119.47	19.44	86	31.2	13.83	14	113.01	2.92	2.5	125
15	85.41	280	109.2	136	66.13	119.88	104	46.4	16.7	22.67	61.92	17.98	2.5	135
16	88.94	516	201.24	242	140.8	178.2	170	64.8	50.02	64.67	154.95	26.73	28.33	1
17	92.35	259.33	101.14	146	100.27	84.24	120	49.6	16.76	80	61.43	12.64	1.67	5
18	83.65	159.33	62.14	98	51.2	81	84	27.2	9.61	128	42.04	12.15	2.5	4
19	86.12	120	46.8	56	19.2	61.56	28	22.4	16.33	106	25.2	9.23	0.83	4
20	89.65	216.67	84.5	116	72.53	77.76	100	17.6	12	120	82.69	11.66	4.17	8
21	93.06	229.33	89.44	116	78.93	68.04	76	48.8	22.75	103.33	68.81	10.21	6.67	8
22	99.41	1453.33	566.8	582	145.07	722.52	378	80.8	144.5	58	344.65	108	1.67	11
23	98.59	283.33	110.5	124	113.07	29.16	90	36	20.98	61.33	24.22	4.37	0.83	12

Table 4: Water Quality Rating (Qi) Values of Physicochemical Parameters (Post-Monsoon Season)

Samples No	pH	EC	TDS	TH	Ca	Mg	TA	Cl	SO_4	F	NO_3	Na	K	Fe
1	79.88	286	111.54	151.5	147.73	72.49	124	67.2	36.46	62	74.55	10.87	4.42	10
2	76.59	299.33	116.74	173.5	111.47	163.21	118	70.4	52.5	24.67	105.27	24.48	1.92	7
3	78.71	292.67	114.14	159.5	92.27	169.69	142	53.6	28	42	79.28	25.45	8.58	8
4	78.35	179.33	69.94	115.5	53.87	156.73	88	20.8	35.5	63.33	75.44	23.51	4.42	12
5	90.94	408.67	159.38	243.5	141.33	231.25	118	76	47.4	6.67	155.97	34.69	9.42	123
6	92.24	655.33	255.58	281.5	160.53	263.65	146	93.6	74.29	13.33	194.46	39.55	14.4	133
7	90.47	311	121.29	197.5	126.4	179.41	116	64	39.33	17.33	78.59	26.91	8.58	50
8	84	522.67	203.84	261.5	143.47	257.17	146	89.6	43.06	10.67	152.42	38.58	5.25	108
9	103.06	139.33	54.34	97.5	49.6	134.05	48	33.6	29	16	115.01	20.11	49.4	52
10	99.65	312.67	121.94	193.5	107.2	202.09	122	68	35.17	5.33	134.21	30.31	1.92	95
11	76.71	316	123.24	165.5	134.93	114.61	116	56.8	36.7	4	104.78	17.19	3.58	102
12	79.76	596	232.44	213.5	115.73	221.53	212	100	50.03	3.33	178.71	33.23	1151	121
13	81.29	492.67	192.14	213.5	177.6	127.57	146	104	47.12	2	162.96	19.14	4.42	123
14	76.47	286	111.54	141.5	143.47	62.77	104	41.6	28.33	4	137.46	9.42	3.58	126
15	79.41	299.33	116.74	153.5	90.13	163.21	122	56.8	31.2	12.67	86.37	24.48	3.58	136
16	82.94	535.33	208.78	259.5	164.8	221.53	188	75.2	64.52	54.67	179.4	33.23	29.4	2
17	86.35	278.67	108.68	163.5	124.27	127.57	138	60	31.26	70	85.87	19.14	2.75	6
18	77.65	178.67	69.68	115.5	75.2	124.33	102	37.6	24.11	118	66.48	18.65	3.58	5
19	80.12	139.33	54.34	73.5	43.2	104.89	46	32.8	30.83	96	49.65	15.73	1.92	5
20	83.65	236	92.04	133.5	96.53	121.09	118	28	26.5	110	107.14	18.16	5.25	9
21	87.06	248.67	96.98	133.5	102.93	111.37	94	59.2	37.25	93.33	93.26	16.71	7.75	9
22	93.41	1472.6	574.34	599.5	169.07	765.85	396	91.2	159	48	369.1	114.9	2.75	12
23	92.59	302.67	118.04	141.5	137.07	72.49	108	46.4	35.48	51.33	48.66	10.87	1.92	13

Table 5: Calculated Sub Index (SIi) Values of Physicochemical Parameters (Pre-Monsoon Season)

Samples No	pH	EC	TDS	TH	Ca	Mg	TA	Cl	SO_4	F	NO_3	Na	K	Fe
1	5.4	16.7	10.8	8.4	7.7	1.8	6.6	4.7	1.4	7.5	5.2	0.2	0.1	0.7
2	5.2	17.5	11.4	9.8	5.5	7.5	6.3	5	2.4	3.6	8.4	0.7	0	0.5
3	5.3	17.1	11.1	8.9	4.3	7.9	7.8	3.6	0.8	5.4	5.7	0.8	0.3	0.6
4	5.3	10	6.5	6.1	1.9	7.1	4.4	0.9	1.3	7.6	5.3	0.7	0.1	0.9
5	6.1	24.3	15.8	14.1	7.3	11.7	6.3	5.5	2.1	1.7	13.7	1.2	0.3	10.2
6	6.1	39.8	25.8	16.5	8.5	13.8	8	6.9	3.7	2.4	17.7	1.4	0.6	11
7	6	18.2	11.9	11.3	6.4	8.5	6.1	4.5	1.6	2.8	5.6	0.9	0.3	4.1
8	5.6	31.5	20.5	15.3	7.5	13.4	8	6.6	1.8	2.2	13.3	1.3	0.2	8.9
9	6.8	7.5	4.9	5	1.6	5.7	1.9	1.9	0.9	2.7	9.4	0.6	2	4.2
10	6.6	18.3	11.9	11	5.2	9.9	6.5	4.8	1.3	0.5	11.4	1	0	7.8
11	5.2	18.5	12.1	9.3	6.9	4.5	6.1	3.9	1.4	0.6	8.4	0.4	0.1	8.4
12	5.4	36	23.4	12.3	5.7	11.1	12.1	7.5	2.2	0.7	16.1	1.1	48	10
13	5.5	29.6	19.2	12.3	9.6	5.3	8	7.8	2	1.3	14.4	0.5	0.1	10.2
14	5.2	16.7	10.8	7.8	7.5	1.2	5.4	2.6	0.9	1.5	11.8	0.1	0.1	10.4
15	5.3	17.5	11.4	8.5	4.1	7.5	6.5	3.9	1	2.4	6.5	0.7	0.1	11.2
16	5.6	32.3	21	15.1	8.8	11.1	10.6	5.4	3.1	6.7	16.1	1.1	1.2	0.1
17	5.8	16.2	10.5	9.1	6.3	5.3	7.5	4.1	1	8.3	6.4	0.5	0.1	0.4
18	5.2	10	6.5	6.1	3.2	5.1	5.3	2.3	0.6	13.3	4.4	0.5	0.1	0.3
19	5.4	7.5	4.9	3.5	1.2	3.8	1.8	1.9	1	11	2.6	0.4	0	0.3
20	5.6	13.5	8.8	7.3	4.5	4.9	6.3	1.5	0.7	12.5	8.6	0.5	0.2	0.7
21	5.8	14.3	9.3	7.3	4.9	4.3	4.8	4.1	1.4	10.8	7.2	0.4	0.3	0.7
22	6.2	90.8	59.1	36.4	9.1	45.2	23.6	6.7	9	6	35.9	4.5	0.1	0.9
23	6.2	17.7	11.5	7.8	7.1	1.8	5.6	3	1.3	6.4	2.5	0.2	0	1

Table 6: Calculated Sub Index (Sli) Values of Physicochemical Parameters (Post-Monsoon Season)

Samples No	pH	EC	TDS	TH	Ca	Mg	TA	Cl	SO_4	F	NO_3	Na	K	Fe
1	5	17.9	11.6	9.5	9.2	4.5	7.8	5.6	2.3	6.5	7.8	0.5	0.2	0.8
2	4.8	18.7	12.2	10.8	7	10.2	7.4	5.9	3.3	2.6	11	1	0.1	0.6
3	4.9	18.3	11.9	10	5.8	10.6	8.9	4.5	1.8	4.4	8.3	1.1	0.4	0.7
4	4.9	11.2	7.3	7.2	3.4	9.8	5.5	1.7	2.2	6.6	7.9	1	0.2	1
5	5.7	25.5	16.6	15.2	8.8	14.5	7.4	6.3	3	0.7	16.3	1.4	0.4	10.3
6	5.8	41	26.6	17.6	10	16.5	9.1	7.8	4.6	1.4	20.3	1.6	0.6	11.1
7	5.7	19.4	12.6	12.3	7.9	11.2	7.3	5.3	2.5	1.8	8.2	1.1	0.4	4.2
8	5.3	32.7	21.2	16.3	9	16.1	9.1	7.5	2.7	1.1	15.9	1.6	0.2	9
9	6.4	8.7	5.7	6.1	3.1	8.4	3	2.8	1.8	1.7	12	0.8	2.1	4.3
10	6.2	19.5	12.7	12.1	6.7	12.6	7.6	5.7	2.2	0.6	14	1.3	0.1	7.9
11	4.8	19.8	12.8	10.3	8.4	7.2	7.3	4.7	2.3	0.4	10.9	0.7	0.1	8.5
12	5	37.3	24.2	13.3	7.2	13.8	13.3	8.3	3.1	0.3	18.6	1.4	48	10.1
13	5.1	30.8	20	13.3	11.1	8	9.1	8.7	2.9	0.2	17	0.8	0.2	10.3
14	4.8	17.9	11.6	8.8	9	3.9	6.5	3.5	1.8	0.4	14.3	0.4	0.1	10.5
15	5	18.7	12.2	9.6	5.6	10.2	7.6	4.7	2	1.3	9	1	0.1	11.3
16	5.2	33.5	21.8	16.2	10.3	13.8	11.8	6.3	4	5.7	18.7	1.4	1.2	0.2
17	5.4	17.4	11.3	10.2	7.8	8	8.6	5	2	7.3	8.9	0.8	0.1	0.5
18	4.9	11.2	7.3	7.2	4.7	7.8	6.4	3.1	1.5	12.3	6.9	0.8	0.1	0.4
19	5	8.7	5.7	4.6	2.7	6.6	2.9	2.7	1.9	10	5.2	0.7	0.1	0.4
20	5.2	14.8	9.6	8.3	6	7.6	7.4	2.3	1.7	11.5	11.2	0.8	0.2	0.8
21	5.4	15.5	10.1	8.3	6.4	7	5.9	4.9	2.3	9.7	9.7	0.7	0.3	0.8
22	5.8	92	59.8	37.5	10.6	47.9	24.8	7.6	9.9	5	38.5	4.8	0.1	1
23	5.8	18.9	12.3	8.8	8.6	4.5	6.8	3.9	2.2	5.3	5.1	0.5	0.1	1.1

4.2. Electrical conductivity

The EC values ranges from 360 to 4360 µ/cm and 418 to 4418 µ/cm during pre- and post-monsoon respectively. The EC of the ground water sample in the post-monsoon season are higher as compare to the EC of pre-monsoon season which can be related to the dissolution of minerals (Ballukraya and Ravi, 1999). The maximum limit of EC in drinking water is prescribed as 1500 µ/cm as per WHO standard (2011). 22 % samples were exceeded the permissible limit, during pre- and post-monsoon season

4.3. Total Dissolves solids

Total dissolves solid is the concentration of all dissolved minerals in water indicating the general nature of salinity of water. It ranged from 234 to 3834 mg/L for pre -monsoon and 271 to 2871 mg/L in post-monsoon. Only 4 % samples were exceeding maximum permissible limit. prescribed by the BIS (2012) in both seasons. The TDS of ground water sample in the post-monsoon season was higher as compared to the pre-monsoon season which may be attributed due to leaching of salts from ground surface by recharge. TDS in ground water originate from natural sources and sewage (Kurian, 2001; Gaikwad et al, 2019). Higher concentration of dissolved solids may produce distress in cattle and livestock and a salty to water (Srivastava, et al, 2007).

4.4. Total hardness

Hardness values were recorded between 112 to 1164 mg/L and 147 to 1199 during pre- and post-monsoon seasons, respectively. In both the seasons only, one samples were exceeding maximum permissible limit prescribed by the BIS (2012). Sawyer and McCarty (1967) classified groundwater, based on TH, as follows groundwaters with TH <75, 75–150, 150–300 and >300 mg/L, has been designated as soft, moderately hard, hard and very hard, respectively. According to the above categorization, 4% belongs to moderately hard in both season; 52 % and 30 % belongs to hard and the remaining 43 % and 65% comprises very hard water in the area of this study during pre- and post-monsoon season respectively. The analytical result indicates that the water in the study area is moderately hard to very hard and such hardness is due to the presence of alkaline earths such as calcium and magnesium.

4.5. Turbidity

The values of turbidity are within 0.10 to 0.90 NTU and 0.0 to 0.79 NTU in pre- and post-monsoon season respectively. The permissible turbidity prescribed as a standard for drinking water is between 1 to 5 NTU (BIS, 2012), and all the samples are within prescribed limit.

4.6. Calcium and magnesium

The determination of calcium is usually required for potable water and Magnesium is an essential element for man. The values of calcium varied in the range of 14 to 115 mg/L and .32 to 133 mg/L in pre- and post-monsoon seasons respectively similarly magnesium values varied within range of 6 to 217 mg/L in pre-monsoon and 19 to 230 mg/L in post-monsoon seasons. Both calcium and magnesium are within limit in both seasons given by BIS (2012).

4.7. Sodium and potassium

Concentrations of sodium were found to vary within 14 to 122 mg/L and 29 to 137 mg/L during pre- and post-monsoon season respectively. Sodium values are within the limit given by BIS (2012), and only one sample of potassium are exceeding the maximum permissible limit of BIS (2012) in both pre- and post-monsoon season.

4.8. Total alkalinity, carbonate, and bicarbonate

Alkalinity is the measure of the capacity of the water to neutralize a strong acid. The Alkalinity in the water is generally imparted by the salts of carbonates, silicates, etc. together with the hydroxyl ions in free State. Most of the natural waters contain substantial amounts of dissolved carbon dioxide, which is the principal source of alkalinity (Trivedy and Goel,1984; Deshpande et al,2012)
The total alkalinity varies from 56 to 756 mg/L and 92 to 792 mg/L in pre- and post-monsoon season respectively, the carbonate values 0 to 72 mg/L during both seasons, and the bicarbonate alkalinity content of the groundwater ranged from 12 to 708 mg/L and 35 to 731 mg/L during pre- and post-monsoon season respectively.

4.9. Chloride

Concentrations of chloride were found to vary within 26 to 234 mg/L and 52 to 260 mg/L in pre- and post-monsoon seasons respectively. Though chloride concentration is high in ground water, but it is below permissible limit of BIS (2012).

4.10. Sulphate

The values of sulphate ranged within 19 to 289 mg/L and 48 to 318 in pre- and post-monsoon season respectively. The maximum values observed can be attributed to addition of septic tank water. Sulphate may have laxative effect if magnesium is present at an equivalent concentration (Chatterjee & Raziuddin 2002). In the present study sulphate in groundwaters is below permissible limit of BIS (2012).

4.11. Fluoride

Concentrations of fluoride were found to vary within 0.07 to 1.92 mg/L and 0.08 to 1.77 mg/L in pre- and post-monsoon seasons respectively. 17 % and 9% samples were exceeding the permissible limit in pre- and post-monsoon season, respectively prescribed by BIS (2012). Fluoride is higher during pre-monsoon season (1.92 mg/L) due to leaching from fluoride rich rocks and easier accessibility of rain water to weathered rock, long-term irrigation processes, semi-arid climate and long residence time of groundwater (Datta et al. 1996; Robinson and Edington 1946; Hem 1991; Srinivasamoorthy et al. 2008; 2012).

4.12. Nitrate

Nitrates are the end products of decomposition of organic matter present in fully oxidised waters and harmful above 45 mg/L. The recommended limit (BIS,2012) of NO_3 in drinking water is 45 mg/L and the concentration is higher in post-monsoon season (166 mg/L). 39 % and 57% samples were exceeding the permissible limit in pre- and post-monsoon season, respectively prescribed by BIS (2012). High concentration nitrate can cause for methemoglobinemia (an often-fatal disease in infants; the so-called blue baby syndrome). Thus, limited physiological problem (methemoglobinemia) may be associated with the use of groundwater in the study area. The origin of NO_3 is derived from agricultural areas due to leaching process from plant nutrient and nitrate fertilizers (Freeze and Cherry 1979; Madison and Brunett 1984).

4.13. Iron

The concentration of iron in ground water varies 0.01 to 1.35 mg/L in pre-monsoon and 0.02 to 1.36 mg/L in post-monsoon season. The Bureau of Indian Standards has recommended 0.1 mg/L as the limit for drinking water (BIS 2012). About 35 % and 4 % of the sample of the study area exceeds the maximum permissible limit of 1.0 mg/L during pre- and post-monsoon season respectively. High concentrations of iron generally cause inky flavour, bitter, and astringent taste. The high value may be due to rusting of casing pipes, non-usage of bore wells for long periods and disposal of scrap iron in open areas due to industrial and allied activity (Deshpande et al, 2013).

Table 7: Status of Water Quality Based on Water Quality Index (WQI)

Sr. No.	WQI	Category	pre-monsoon %	post-monsoon %
1	< 50	Excellent	4	0
2	50-100	Good	65	65
3	100-200	Poor	26	26
4	200-300	Very Poor	0	4
5	> 300	Unsuitable for domestic suitability	4	4

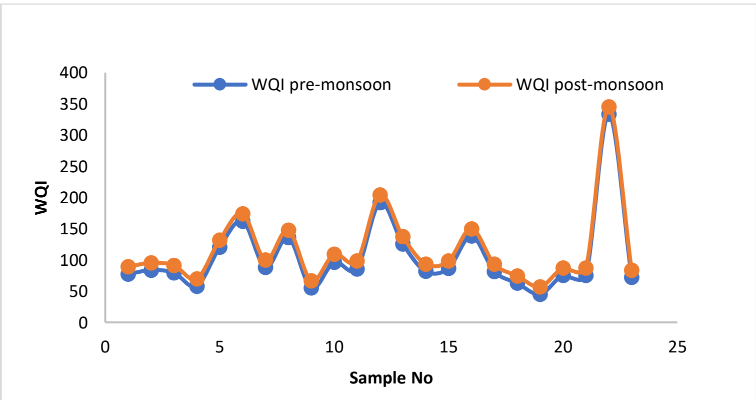

Fig. 3: Plot of Water Quality Index (WQI) Values for Pre-and Post-Monsoon Season.

Table 8: Computation of Water Quality Index for Groundwater Samples

Sample No.	WQI pre-monsoon	Water type	WQI Post-monsoon	Water type
1	77.33	Good	89.07	Good
2	83.69	Good	95.43	Good
3	79.53	Good	91.27	Good
4	58.13	Good	69.87	Good
5	120.31	Poor	132.05	Poor
6	162.28	Poor	174.02	Poor
7	88.14	Good	99.88	Good
8	135.91	Poor	147.65	Poor
9	55.15	Good	66.89	Good
10	96.35	Good	108.09	Poor
11	85.74	Good	97.48	Good
12	191.60	Poor	203.34	Very Poor
13	125.74	Poor	137.48	Poor
14	81.80	Good	93.54	Good
15	86.67	Good	98.41	Good
16	138.25	Poor	149.99	Poor
17	81.60	Good	93.34	Good
18	62.83	Good	74.57	Good
19	45.37	Excellent	57.11	Good
20	75.51	Good	87.25	Good
21	75.45	Good	87.19	Good
22	333.55	Unsuitable	345.29	Unsuitable
23	72.09	Good	83.83	Good

5. Water quality index (WQI) for domestic suitability

Quality of water is very significant to human because it has a direct link with human health and welfare (Chatterjee & Raziuddin, 2002; Srivastava, et al, 2007; Shaikh, et al, 2020). The water quality index (WQI) is an important tool to determine the drinking water quality in urban, rural and industrial area. Groundwater samples (n = 23) and its WQI values as well as its types are presented in Table 7 and fig .3. Thus, the WQI can be classified as excellent water type, if the WQI values are less than 50; good water type, if the WQI values ranged from 50 to 100; poor water type, if the WQI values ranged between 100 and 200; very poor water type, if the WQI values ranged from 200 to 300, and unsuitable for drinking water type, if the WQI values larger than 300. The WQI value and water type of the individual samples are presented in Table 8. The WQI ranges from 45.37 to 333.55 and 57.11 to 345.29 with an average of 104.91 and 116.65 for pre- and post-monsoon seasons respectively. During pre-monsoon, 4% (1 sample) of groundwater samples were excellent; 65% (15 samples) were good; 26 % (6 samples) were poor; and 4% (1 sample) were unsuitable for domestic suitability. In post-monsoon, 65 % (15 samples) of water samples were good; 26% (6 samples) were poor; 4% (1 sample) were very poor and 4% (1 sample) were unsuitable for domestic suitability (Table 6). Quality rating of the water is established from WQI as it is established from different physicochemical parameters in different seasons of the groundwater body. It is confirmed that majority groundwater samples from both seasons are good for drinking purpose as well as domestic suitability. At certain place poor quality of groundwater is mainly due to inputs from agricultural discharge.

6. Conclusion

This study is focussed on understanding the geochemistry of groundwater, its seasonal variation and degree of pollution. The study indicating that groundwater is slightly alkaline type. Electrical conductivity shows that 22 % samples were exceeded the permissible limit, during pre- and post-monsoon season. The TDS of ground water sample in the post-monsoon season was higher as compared to the pre-monsoon season which may be attributed due to leaching of salts from ground surface by recharge. Analysed physicochemical parameters like turbidity, total hardness, calcium, magnesium, sodium, potassium, total alkinity, chloride, sulphate is mostly in within limits. Nitrate ion content exceeds the recommended limit of drinking in many groundwater samples. Nitrate of groundwater samples shows that 39 % and 57% samples were exceeding the permissible limit in pre- and post-monsoon season and the origin of NO_3 is derived from agricultural areas due to leaching process from plant nutrient and nitrate fertilizers. Fluoride is higher during pre-monsoon season (1.92 mg/L) due to leaching from fluoride rich rocks and easier accessibility of rain water to weathered rock, long-term irrigation processes, semi-arid climate and long residence time of groundwater. Based on water quality index, it was inferred that 4% of groundwater sample is found unfit for drinking purpose in pre- and post-monsoon season. The precautionary measures should be adopted in advance, as well as by reducing the over exploitation of groundwater; construction and proper maintenance of rainwater harvesting structures for recharge will be helpful in preserving, maintaining and improving the groundwater quality.

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