Asian Journal of Water, Environment and Pollution, Vol. 19, No. 4 (2022), pp. 63-72.
DOI 10.3233/AJW220057

Evaluation of Groundwater Quality by Water Quality Index During Successive Periodic Intervals in the Selected Villages of Gara Mandal of Srikakulam District in Andhra Pradesh

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Received September 18, 2020; revised and accepted November 11, 2021

Abstract: The quality of groundwater is assessed using the Water Quality Index method and it is pertinently helpful to transfer the complex data into usable data. In this research study the WQI values have been estimated for each water sample (in total, 66 samples have been collected) based on 9 water quality parameters at periodic intervals in May 2015, 2016 and 2017 in the villages of Gara Mandal of Srikakulam District in Andhra Pradesh. The overall results disclosed that 50-54% of the groundwater samples (WQI lies between 100-200) showed poor quality and 10-13% of water samples (WQI lies between 200-300) showed very poor quality in successive periodic intervals. An assessment of measured physicochemical parameters of 66 sample sites has shown that the majority of the groundwater samples have a high concentration of calcium, magnesium, sodium, chloride and sulfate ions beyond the desirable limits of BIS and WHO standards. Correlation matrix show a strong positive correlation existing between the calcium, magnesium, sodium, chloride and sulfate ions pointing out that groundwater in this region has been contaminated more by these components due to anthropogenic activities and over-exploitation. Hence, in the study region, suitable treatment of water is necessary before consumption, this is because maximum parts of the sampling points have a high WQI value.

Key words: Groundwater, water quality index (WQI), calcium, magnesium.

Introduction

The earth is known as “Water planet” since about 75% of the earth’s surface is covered by frozen water. It is the principal constituent of all living beings and the most valuable and abundant source for subsistence on earth. Freshwater is the prime need for human beings, and it is considered an essential factor that is directly or indirectly connected with economic growth. Despite being a limited freshwater source as well as bad quality of available surface water, both the quantity and quality of water are under remarkable pressure because of rapid universal changes. Hence, an alternative source of water is very significant to ensure the water supply that meets the demand. Groundwater represents about 30% of the world’s fresh water and it is an essential asset for our planet (Roy et al., 2017). It is an essential source of freshwater for agriculture, human use, and manufacturing industries in most countries of the world (Omid and Palangi, 2018), but the groundwater is mainly considered to be prone to physicochemical pollution caused by a lack of compact adjacent

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drainage system, seepage from discharge bearing water body and contaminated by industrial waste discharge, applied fertilisers in cultivation, etc. This difference in the quality occurs due to profundity, and also over geographic distances (Mishra and Nagda, 2020) and might be due to several processes that influence the groundwater under different conditions. The presence of certain toxic chemical constituents, such as heavy metal ions in water, has drawn widespread attention due to their carcinogenic nature (Subbarao and Dhilleswararao, 2013). As a limited resource, groundwater needs continuous monitoring through the assessment of quality and management for sustainable use.

The Water Quality Index (WQI) technique is highly capable of communicating the water quality data (Zejin et al., 2020) and is regularly utilised for the assessment of water contamination of various quality parameters on the overall water quality (Khan and Qureshi 2018; Imanhomayoonnezhad et al., 2019; Srinivas et al,. 2020). It is a single number that rates the water quality by totaling different water quality parameters. The WQI procedure has been generally associated to evaluate both groundwater and surface water quality. Henceforth, it has turned out to be the most supportive and fertile method (Claudia Alejandra et al., 2020) for the evaluation of water quality globally, especially when considering the opportunity of including drinking water standards.

In this way, checking the quality of groundwater at regular intervals has been essential. Hence, a detailed study on physicochemical parameters of the groundwater in the villages of Gara Mandal of Srikakulam district has been carried out periodically once a year i.e. in May 2015, 2016, and 2017 to know the quality of water. It is to be noted that, preceding this work,, no significant examination of groundwater quality by utilising water quality index methodology at periodic intervals was done in the study region.

Materials and Methods

Study Area

Gara Mandal is situated 19 kilometres far from the head office of the Srikakulam district and is near the gulf of the Bay of Bengal. Gara Mandal lies within the coordinates of longitude between 83.8920 °E and 84.9345 °E and latitude between 18.2484 °N and 18.4010 °N. Gara Mandal covers about 157 sq.km of area and has 24 major villages. According to the 2011 census, the population is 79617, and the density of population per sq.km is 509. Gara Mandal normally receives about 1099.9 mm of rain per year.

Collection of Water Samples

In the field trip, oral inputs from villagers are taken on the quality of water in terms of physical properties; and sites are selected from the villages of Gara Mandal. Specific sampling points are chosen depending on the objectives of the study. Sampling site selections are determined by two fundamental criteria: accessibility/ safety and upstream-downstream locations of pollutant releases. The water samples are taken from bore wells, hand pumps and open wells. The sample containers are thoroughly cleaned before the collection and are rinsed two or three times with the sample before it is filled. A total of 66 water samples (Figure 1) are taken from different locations (Table 1) periodically once a year in May 2015, 2016 and 2017. Water samples are collected and preserved (water samples are acidified by 50% HNO_3 of $pH<2$ for cationic analysis, whereas for anionic analysis samples are not acidified) as said by standard methods (APHA, 2005) and the analysis part is performed by AR-analytical reagent grade chemicals. The different physicochemical parameters are measured based on standard methods **(**APHA, 2005) and these are compared with water standards as per BIS-2012 (BIS, 2012**)** and WHO-2011 (WHO, 2011**)**.

Evaluation of Water Quality Index (WQI)

The fundamental objective of WQI is to transfer complex data into useable information. The WQI is ascertained for the quality of groundwater in the study area, and it is a valuable method for the assessment of overall water quality for drinking purposes (Kumari and Rai, 2020).

To estimate WQI, the following steps have been considered. The assigned and relative weights of each parameter as per WHO (2011) standards are shown in Table 2. The highest assigned weight of 5 has been given to TH and TDS as a result of their emphasis on the assessment of groundwater quality. The allocated weights of the remaining parameters are between 1-4 relying upon their emphasis in the assessment of groundwater quality.

In the preliminary step, some analysed parameters are taken and weightage (w_i) is given mathematically from 1 to 5. In the subsequent step, the relative weight (W_i) (Claudia Alejandra et al., 2020; Dolly et al., 2019) is measured using the formula given in Eq. (1):

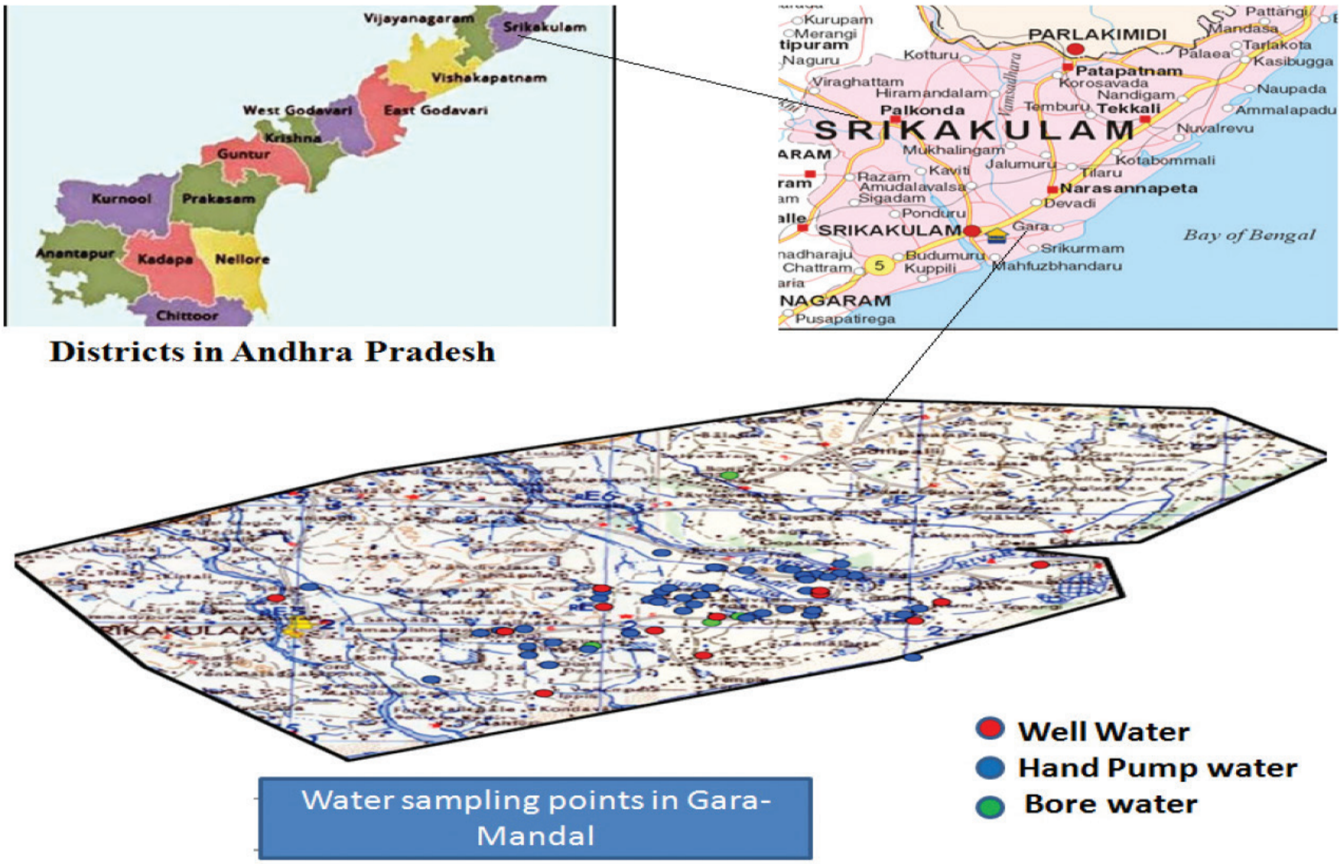

Figure 1: Location of sampling points in the Gara Mandal of Srikakulam District.

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

here, 'w_i' represents the assigned weight of an individual parameter and 'n' represents the number of examined parameters. In the next step, a quality rating scale (Q_i) is determined for every parameter according to the expression as Eq. (2).

$$Q_i = \frac{c_i}{S_i} \times 100 \quad (2)$$

here, 'c_i' represents the concentration of each analysed parameter in the water sample. 'S_i' is the standard value, as stated by the guidelines of WHO-2011 as per an analysed parameter.

Finally, the WQI is determined using the expression as Eq. (3).

$$\text{WQI} = \Sigma W_i \times Q_i$$

here, 'W_i' represents the relative weight and 'Q_i' represents the quality rating scale.

Results and Discussions

Assessment of Water Quality Parameters in periodic Years

During the 3-year study period (May-2015, 2016 and 2017), the yearly variation in the concentration of physicochemical parameters in the groundwater samples has been studied, and a statistical précis of these data is presented in Table 3.

Physicochemical Parameters

pH is a very important parameter and is related to other water quality parameters as aqueous chemical equilibrium always involves hydrogen ions. Groundwater in this study region is neutral to slightly alkaline in nature, as the pH recorded ranged from 6.5 to 8.5, during periodic intervals and is within the desirable limits according to WHO and BIS standards in almost all sites. Electrical Conductivity (EC) is a valuable parameter of groundwater quality for representing salinity risk and gives a sign of the total solids in surface water and groundwater samples. EC values

Table 1: Groundwater sample locations in the study region

Sam. No	*Location site*	*Source*	*Latitude*	*Longitude*	*Sam.No*	*Location site*	*Source*	*Latitude*	*Longitude*
1	Vatsavalasa colony	A	18.2923	83.9989	34	Ramachandrapurani-Domaveddi	B	18.2906	83.9497
2	Vastavalasa (Muncipal Primary School)	B	18.2905	83.9921	35	Ramachandrapuram- near Rama temple	B	18.2935	83.9621
3	Vatsavalasa-House	C	18.2815	83.9812	36	Simmaneta Junction	A	18.2917	83.9566
4	Amadalapadu-vatsavalsa Panchayati office)	C	18.3023	84.0230	37	Deepavali-Bus stand Street	B	18.2840	83.9702
5	Pedatulugu -Segidiveedi	B	18.3034	84.0430	38	Deepavali -Primary School	B	18.2812	83.9630
6	Peddatuhigu-Gollaveedi	B	18.3063	84.0437	39	Deepavali- Sondipeta (Sai baba temple)	B	18.2683	83.9691
7	Chinnatulugu Main road	A	18.3175	84.0456	40	Deepavali- Lankapeta (shiva temple)	B	18.2794	83.9802
8	Chinnatulugu -Muncipal primary school	B	18.3071	84.0359	41	Gonti -Entrance	B	18.2752	83.9633
9	Nizamabad-Road point	B	18.3028	84.0268	42	Sunkarapalem	A	18.2484	83.9676
10	Nizamabad-Kaalingapeta road point	B	18.3012	84.0249	43	Jalluvalasa-SC colony	B	18.3202	84.0420
11	Nizamabad -SC colony	C	18.2980	84.0150	44	Jalluvalasa (Anjanava temple)	B	18.3184	84.0456
12	Nizamabad -Primary school	B	18.3046	84.0294	45	Jalluvalasa (Anjanava temple)	A	18.3201	84.0456
13	Sattivada-Main road Point	B	18.3196	84.0009	46	Komi(Anjanava temple)	B	18.3389	84.0515
14	Sattivada- Rama Temple	A	18.3020	84.0165	47	Komi(Srisainaveedi)	A	18.3122	84.0799
15	Sattivada-Pedalapur Street	C	18.4010	84.0200	48	Komi-SC colony	B	18.3078	84.0736
16	Sattivada-Gangu Street	B	18.3106	84.0100	49	Komi-SC colony	A	18.3384	84.1077
17	Raghavapuram- Near anjanava swamy temple	B	18.3220	84.0145	50	Korlam-Mainroad	B	18.3035	84.0693
18	Raghvapuram -Mangala street -school	B	18.3152	84.0071	51	Korlam Main Road (anadarao house)	B	18.2735	84.0718
19	Raghavapuram-SC-colony	B	18.3061	84.0070	52	Korlam (Anjanava temple)	A	18.2991	84.0724
20	Syrigain -Polaki Street	B	18.3147	83.9990	53	Gara-Primary school	B	18.3308	84.0554

21	Syrigam -Grama Panchayati Office	B	18.3139	83.9977	54	Gara-Secondary school	B	18.3325	84.0513
22	Svrigam-Sai ram temple Arangipeta	B	18.3125	84.0000	55	Gara-Boravanipeta bus stand primary	B	18.3317	84.0442
23	Rama krishnapurani-Road point	B	18.3172	84.0120	56	Salihundam Board	B	18.3298	84.0479
24	Rama krishnapuram-Primary School	B	18.3220	84.0029	57	Garakothapetta-Primary school	B	18.3297	84.0410
25	Ampolu Colony	B	18.3149	83.9833	58	Kothapetta Primary school	B	18.3310	84.0410
26	Ampolu bus stand street - panchayati office	A	18.3218	83.9839	59	SalihundamPrimary school	B	18.3356	84.0357
27	Ampolu-kothapeta	A	18.3089	83.9845	60	Salihundam SC colony	B	18.3350	84.0378
28	Ampolu-kothapeta	B	18.3194	83.9841	61	Konkenapetta -Salihundam	B	18.3281	84.0419
29	Reddy peta	B	18.3229	83.9014	62	Kolluvalasa(near srirama temple)	A	18.2749	84.0126
30	Reddy peta	A	18.3150	83.8920	63	Kollivalasa	B	18.3345	84.0248
31	Vadada- Pangala street	B	18.2683	84.9345	64	Ambalavalsa-Jonnadaveedi	B	18.3362	84.0167
32	Vadada-Chipiri veedi	B	18.2581	83.9358	65	Ambalavalsa-Anjanaya temple	B	18.3364	84.0157
33	Ranachandrapuram- Primary school	B	18.2924	83.9555	66	Booravelli -Ammavari temple	B	18.3467	84.0010

A = Well water, B = Hand pump and C = Bore water

Table 2: Assigned as well as relative weights of the parameters to estimate the WQI

S. No	*Chemical parameter*	*Weight (w_i)*	*WHO standards (S_i)*	*Relative weights (W_i)*
1	TDS	5	500	0.1612
2	Total Hardness	5	300	0.1612
3	Chloride	4	250	0.1290
4	Fluoride	4	1.5	0.1290
5	Total Alkalinity	3	200	0.0967
6	Calcium	2	75	0.0645
7	Magnesium	2	50	0.0645
8	Sodium	4	200	0.1290
9	Potassium	2	12	0.0645
		$\Sigma w_i = 31$		

Table 3: Statistical data of determined physicochemical parameters in water samples collected during May – 2015, 2016 and 2017 years

Parameter	*2015*			*2016*			*2017*		
	Mean	*Median*	*SD*	*Mean*	*Median*	*SD*	*Mean*	*Median*	*SD*
pH	7.01	7.01	0.31	7.12	7.12	0.33	7.12	7.12	0.30
Turb	0.064	0.05	0.057	0.096	0.08	0.078	0.103	0.08	0.084
EC	1596	1356	1087	1607	1377	1094	1611	1367	1088
TA	270.5	284.2	101.6	269.1	283	99.1	272.6	288	102.3
TDS	1020	867	695.5	1027	882.5	700.5	1032.7	879	697.9
TH	578.9	517	336	583.2	520	338.6	584.3	526.5	333.3
Ca^{2+}	110.7	97	62	111	90.5	63.7	112.4	96	64.5
Mg^{2+}	70.1	56.5	49.6	70.07	54.5	51.01	70.78	53.5	49.9
F^-	0.487	0.42	0.33	0.502	0.42	0.326	0.498	0.415	0.318
Cl^-	280.4	192.5	212.9	282.1	198	213	283.8	203	211
SO_4^{2-}	188.5	154	132	187.6	156.5	126.2	183.9	161.5	121.6
Na^+	98.04	67	98.45	110.2	72	94.1	122	90.5	95.1
K^+	25.65	13	32.13	25.84	13.9	31.9	25.4	13.7	32.1

in water samples during periodic intervals range from 291-6350 m mhos cm^{-1}, 314-6438 and 367-6408 m mhos cm^{-1}, respectively. Many of the groundwater samples have a high concentration of EC indicating the higher quantity of dissolved minerals in water samples. The turbidity in the groundwater samples is within the permissible limit at respective periodic intervals. The total alkalinity (TA) of water is primarily because of carbonate, bicarbonate and hydroxide ions. It is a quantification of the capability of water to neutralise acids. The impacts of excess alkalinity in water include gastrointestinal problems, reduction of natural stomach acidity, etc. The TA is ranging from 71 mg L^{-1} to 525 mg L^{-1}, 68-502 mg L^{-1} and 65 mg L^{-1} to 525 mg L^{-1} in the respective periodic intervals. By comparison with standard values, some of the water samples are noticed to have excess alkalinity than the desirable limits. The TDS is due to the presence of inorganic components and little amount of organic components. The TDS in water is greater than 1000 mg L^{-1} and is said to be brackish. TDS stimulates toxicity through enhancing salinity and increases in salinity cause shifts in limited biodiversity and chronic effects. In the present study area, the TDS was obtained from 190 mg L^{-1} to 4062 mg L^{-1}, 201-4120 mg L^{-1} and 234 mg L^{-1} to 4097 mg L^{-1} in periodic intervals, respectively. Approximately 74% of the water samples are found in excess TDS values than desirable limits. The higher amounts of TDS in many of the samples might be due to the groundwater contamination when wastewater is discharged from residential sectors into open lanes which permeated down to the groundwater table (Swati and Khan, 2020). Hard water is helpful in the growth of children if within the desirable limit; however, a high concentration of hardness in the drinking water can cause severe diseases like anencephaly, nervous system defects, prenatal mortality as well as various kinds of cancer have also been correlated with high hardness of the water. The total hardness (TH) values ranged from 130 mg L^{-1} to 1618 mg L^{-1}, 149-1657 mg L^{-1} and 148-1646 mg L^{-1}, respectively, at successive periodic intervals. Approximately 75% of the water samples were found to have excess TH values than the desirable limits of WHO-2011. This represents that water samples in most of the selected sites are hard to very hard water. The high concentration of TH is mainly because of mineral deposition in the study region and reported to have minerals like quartz and apatite (Pavankumar et al., 2017). The calcium (Ca^{2+}) ion is an essential component for bone growth and is the most abundant ion in groundwater. However, excessive amounts of calcium intake may cause bladder stone development, scaling and abdominal infirmities, etc. As per the obtained results, the calcium concentrations were obtained to range from 26 mg L^{-1} to 309 mg L^{-1}, 26 -298 mg L^{-1} and 22-303 mg L^{-1}, respectively, in the successive time intervals. Magnesium (Mg^{2+}) is a basic component in a human being. Consumption of high concentrations of Mg^{2+} possibly will cause a purgative impact as its deficiency causes utilitarian changes. The data relating to these ion concentrations range from 14 mg L^{-1} to 253 mg L^{-1}, 13-268 mg L^{-1} and 16 mg L^{-1} to 271 mg L^{-1}, respectively, in periodic intervals. The experimental data reveal that the majority of the samples have high Mg^{2+} concentration than Ca^{2+} concentration at periodic intervals which might be due to the leaching and weathering of magnesium salts. Fluoride is necessary for human at lower concentrations and aids to shun tooth rotting in youth. In groundwater, the presence of fluoride is due to weathering and leaching of fluoride-bearing minerals from rocks and sediments and also the nature of soil. The excess intake of F^- for a long period causes health problems such as mottling of teeth, softening of bones, and dental fluorosis. The fluoride concentration is obtained to range from 0.09-1.4 mg L^{-1}, 0.12-1.4 mg L^{-1} and 0.12-1.42 mg L^{-1}, respectively, at successive periodic intervals. All water samples at periodic intervals have fluoride concentrations within the desirable limits. Chloride (Cl^-) is another essential component that keeps the proper blood pressure and volume of a cell. The obtained results in the samples at periodic intervals are 77-1230 mg L^{-1}, 68-1265 mg L^{-1} and 72-1246 mg L^{-1}, respectively. The sulfate concentrations are ranged from 24-547 mg L^{-1}, 31-553 mg L^{-1} and 29-497 mg L^{-1}, respectively, at periodic intervals. The sodium ion is an important constituent in the body and sufficient levels of sodium are needed for good health. The Na^+ concentrations obtained are 10-450 mg L^{-1}, 25-485 mg L^{-1}, and 27-500 mg L^{-1}, respectively. Potassium is a necessary constituent in humans. The potassium (K^+) and sodium (Na^+) ions are responsible to keep the normal osmotic pressure in cells. The K^+ concentration range from 0.2-120 mg L^{-1}, 0.8-116 mg L^{-1} and 0.39-123 mg L^{-1}, respectively, in periodic intervals. There is not much difference in the concentrations of physicochemical parameters during the periodic intervals.

Evaluate the Groundwater Quality Using WQI

For calculation of WQI values of each water sample, nine parameters (Table 2) in the water samples have been considered. The WQI values have been calculated individually (Figure 2) at periodic intervals in May 2015, 2016 and 2017. Following the water grading standards of WQI, the groundwater is classified into five categories and the category of each water sample at periodic intervals is shown in Table 4. The calculated WQI values in 2015 represent that 7.57% of the samples in the study region represent excellent water, 25.75% represent good water, 54.54% belong to poor water and 10.6% very poor water whereas, in 2016, WQI values indicate 3.03% of the groundwater samples represent excellent water, 33.3% belong to good water, 50% poor water, 12.12% very poor water and in 2017 WQI values reveal that 3.03% of the samples represent highly pure water, 31.81% pure water, 50% impure water and 13.63% stale water. In all periodic intervals, 1.51% of the groundwater samples show unfit for drinking in

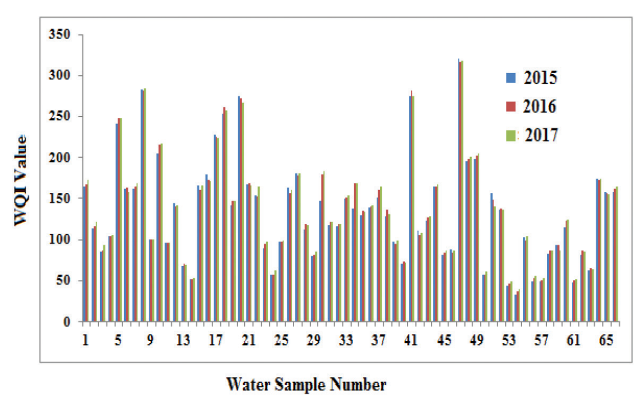

Figure 2: WQI values of each groundwater sample during periodic intervals of the years 2015, 2016 and 2017.

Table 4: Identification of category of each water sample during May-2015, 2016 and 2017 based on WQI values in the study region

WQI range category		*2015*		*2016*		*2017*	
		Groundwater sample number	*% Category of water quality*	*Groundwater sample numbers*	*% Category of water quality*	*Groundwater sample number*	*% Category of water quality*
< 50	Excellent Water	53,54,56,57,61	7.57%	53,54	3.03%	53,54	3.03%
50.1 - 100	Good Water	3,11,13,14,23,24,25,29,39 ,40,45,46,50,58,59, 62,63	25.75%	3,9,11,13,14,23,24,25,29,39 ,40,45,46,50,55,56,57,58,59 ,61, 62,63	33.33%	3,9,11,13,14,23,24,25,29,3 9,40,45,46,50,56,57,58,59, 61, 62,63	31.81%
100.1- 200	Poor Water	1,2,4,6,7,9,12,15,16,19,21 ,22,26,27,28,30,31,32,33, 34,35,36,37,38,42,43,44,4 8,49,51,52,55,60,64,65,66	54.54%	1,2,4,6,7,12,15,16,19,21,22, 26,27,28,30,31,32,33,34,35, 36,37,38,42,43,44,48,51,52, 60,64,65,66	50%	1,2,4,6,7,12,15,16,19,21,22, 26,27,28,30,31,32,33,34,35, 36,37,38,42,43,44,51,52,55, 60,64,65,66	50%
200.1 - 300	Very Poor Water	5,8,10,17,18,20,41	10.63%	5,8,10,17,18,20,41,49	12.12%	5,8,10,17,18,20,41,48,49	13.63%
> 300.1	Unfit for Water	47	1.51%	47	1.51%	47	1.51%

the study area. The variations in the WQI values in the samples are negligible differences during periodic intervals.

It was noticed that the WQI value is lowest for water sample-53, 54 and highest for water sample-47 in the study area. The water sample-47(well water) has a high WQI value and the reason might be that the well was lined with poorly sealed brick with an unsealed cover, which allowed the migration of polluted surface and as well as leached water into the well. Hence, this sample was reported to have very high concentrations of magnesium, calcium, sodium, chloride, and sulfate. Most of the groundwater samples showed poor quality, which might be due to release of solid waste, agricultural chemicals, septic tanks, etc. into the water. This may be due to improper drainage system in many of the locations in the study area.

Correlation Matrix of Various Physicochemical Parameters

Pearson's correlation analysis is an approach that gives instinctive similarity correlation between any one sample and an entire data set**.** On the other hand, the correlation coefficient (represented 'r') is typically utilised to identify the connection between the variables. Usually, 'r' can attain the values from –1.0 to 1.0. Where 0.0 has no correlation, –1 has an inverse correlation (perfect negative) and 1.0 has a perfect positive correlation. The r > 0.5 or < –0.5 between the parameters are to be vital. Based on the experimental results in May-2015 correlation matrix of physicochemical parameters of groundwater are determined and is shown in Table 5. A similar trend of correlation between the parameters is followed in the year May-2016 and May-2017. The obtained Pearson's correlation data indicate a close considerable positive correlation of EC with calcium, magnesium, sodium, chloride and sulfate representing high conductivity of water samples owing to the presence of these ions. In all periodic intervals, correlation data reveal that there is a strong positive correlation of magnesium and calcium with chloride and sulfate ions indicating that groundwater in the study area has been contaminated more by these components by the application of anthropogenic activities.

Conclusion

In this study, the variations in the WQI values are examined and there is a negligible difference at periodic intervals. The water sample-47 (well water) has a high WQI value and the reason might be that the well was lined with poorly sealed brick with an unsealed cover, which allowed the migration of polluted surface & as well as leached water into the well. Hence, this sample was reported to have very high concentrations of dissolved salts. Most of the sampling locations are of poor quality since the WQI value lies between 100 and 200 and might be due to the improper drainage system in many of the locations in the study region. In this regard, the procedure adopted in this investigation can undoubtedly be connected to other regions for the development and definition of capable groundwater

Table 5: Correlation matrix between the physicochemical parameters in the present study area (according to data from May-2015)

	pH	*Turb*	*EC*	*TDS*	*TH*	*Ca^{2+}*	*Mg^{2+}*	*Na^{+}*	*K^{+}*	*TA*	*F^{-}*	*Cl^{-}*
pH	1											
Turb	0.042	1										
EC	0.006	0.100	1									
TDS	0.006	0.099	0.999	1								
TH	0.028	0.141	0.799	0.794	1							
Ca2+	-0.08	0.184	0.745	0.745	0.870	1						
Mg2+	0.002	0.107	0.723	0.724	0.941	0.684	1					
Na+	-0.08	0.237	0.539	0.539	0.504	0.535	0.412	1				
K^{+}	0.067	0.093	-0.02	-0.023	-0.016	0.065	-0.06	0.150	1			
TA	0.003	0.010	0.006	0.007	0.007	0.0006	0.012	0.008	-0.06	1		
F^{-}	0.151	-0.054	-0.30	-0.302	-0.199	-0.260	-0.15	0.110	-0.012	0.016	1	
Cl^{-}	0.083	0.308	0.672	0.672	0.747	0.706	0.677	0.572	-0.01	-0.001	-0.082	1
SO_4^{2-}	0.102	0.196	0.618	0.618	0.858	0.732	0.824	0.432	-0.023	0.016	-0.104	0.738

usage and administration approach to ensure legitimate use and to avoid groundwater quality deficiency.

Acknowledgement

The authors thank the organisation of the GMR Institute of Technology for giving the facilities to do this work.

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