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Article

Application of Relative Weight Method for Groundwater Quality Assessment in Northeastern part of Y.S.R District, Andhra Pradesh, India

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ABSTRACT

The present study intended to determine ground water quality index (WQI) using arithmetic weight methods to establish groundwater quality assessment in and around northeastern part of Y.S.R District. The calculation of WQI for various parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), and major cations and anions. Most of the groundwater samples are exceeding the permissible limits with respect to pH, EC, TDS, TH, and fluoride. Calculated WQI values range from 162 to 568. This classification reveals that 8% of the groundwater samples fall into Class C: Poor water, another 40% fall in Class D: Very poor, and 56% fall in Class E: Unsuitable for drinking category. From this study, it is clear that groundwater quality is very poor and proper monitoring and management techniques are needed to maintain and improve water quality standards and health of local community.

Key words: Water quality index, Ground water, Northeastern part of Y.S.R District, Andhra Pradesh.

1. INTRODUCTION

Ground water is one of major important natural resources required for human consumption for various purposes such as domestic, irrigation, industrialization, and urbanization. Groundwater motion along its flow paths below the ground surface is governed by the concentration of chemical constitutions [1-8]. Therefore, groundwater chemistry aids in knowing the geochemical history of aquifers and its suitability for various purposes [9-12]. Groundwater quality as well as quantity and its suitability for several purposes also depends on mode of weathering, quality of recharge of groundwater and other sources apart from water rock interaction [13-15]. When the intense growth of the population in the country has led to huge scale of groundwater usages causes groundwater depletion which occur especially in semi-arid regions of India and these water resources are at a risk not only in India in other parts of the world also. Fallowed intense agricultural practices and urban development have one of the major causes of high demand on groundwater resources at greater risk to contamination [16-18]. Water quality index (WQI) is determined considering the suitability of groundwater for human consumption [19,20]. The objective of the present study was to interpret the WQI based on the physicochemical parameters at village level in northeastern part of Y.S.R District.

1.1. Study Area

The study area is situated in the northeastern part of Y.S.R district and the area covering an area of 164.08 km^2. The study area located in between $15^0\,10'\,30''$ N latitude and $78^0\,49'\,30''$ E longitude with a mean elevation of 138 m intended boundary falling in Survey of India (SOI) topographic sheet 57 J/13 on 1:50,000 scale, as shown in Figure 1. Geologically, the study consists of Banganapalle quartzite and Cumbum shale with dolomites and shale with phyllites. The geomorphologic view the area consists of Residual hills and Structural hills. In post monsoon season temperature varies from 38 to 41°C.

2. MATERIALS AND METHODS

Twenty-five groundwater samples were collected in November 2018 in and around northeastern part of Y.S.R district, Andhra Pradesh. Global positioning system device was used for recorded sample in the study area. The samples were collected in pre-cleaned and well-dried polyethylene bottles. The samples were collected from bore wells in pre-cleaned polyethylene bottles and stored at 35°C room temperature. The groundwater samples were analyzed by different parameters such as electrical conductivity (EC), pH, total dissolved solids (TDS), and major cations such as calcium, magnesium, and anions such as bicarbonate, carbonate, chloride and fluoride, and adopting the standard methods [21,22]. All the experimental were carried out in triplicate and the results were found reproducible with in a ±3% error limit.

2.1. Laboratory Analysis

The chemical analysis of water samples was performed at the Geochemistry Laboratory in Department of Geology, Yogi Vemana University. Water samples were taken at the end of the constant rate pumping tests for each of the boreholes and analyses were performed approximately 24 h after sampling. The methods used include titrimetry using the standard methods as suggested by the American Public Health Association, 2007 [23]. The physical characteristics determined include turbidity and color. Table 1 shows analytical results of groundwater samples.

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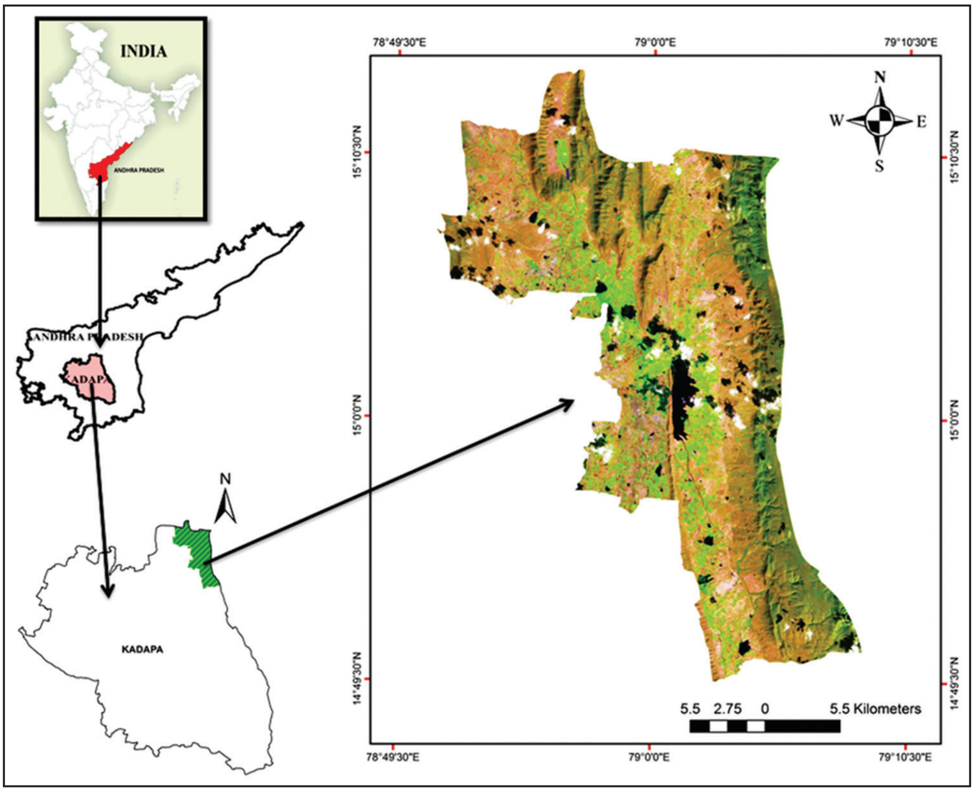

Figure 1: Location map of the study area.

2.2. Relative Weight Method

2.2.1. Calculation for water quality rating

The WQI calculations constitute three consecutive steps [4,11,24]: Step – 1: "Weight assigning" of the each of the parameters depends on its relative significance. Step – 2 "calculation of relative weight" by the equation given below:

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

The third step is "rating of quality (qi)"

$$qi = \left(\frac{Ci}{Si}\right) \times 100$$

where Ci is the concentration of each parameter in each water sample, Si is the WHO recommended value for each parameter. Finally, the Wi and qi were used to determine the SIi for individual parameters and hence WQI can be determined by the equation given below:

$$SIi = Wi \times qi$$

$$WQI = \sum_{i=1}^{n} SIi$$

Where *SIi* is the sub index of each parameter. The computed procedure values of the sample 1, as shown in Table 2.

3. RESULTS AND DISCUSSION

Analytical results of groundwater samples are shown in Table 1. Table 3 reveals the comparison of groundwater quality with standards for drinking water WHO 2011.

3.1. Chemistry of the Groundwater Samples

3.1.1. pH

pH is very important parameter in groundwater media to provide important piece of information of geochemical equilibrium. Desirable limit of pH in drinking water is specified as 6.5–8.5 (Table 1). Most of the samples of pH fall within the desirable limit and 4% of the samples exceeding permissible limit (Table 3). From the above result reveals that most of the groundwater samples had alkaline nature.

3.1.2. EC

The permissible limit of the EC in groundwater is suggested as 1500 mS/cm by W.H.O, 2011.

EC of the groundwater varies in between 1650 to 7920 µS/cm with a mean of 3332 µS/cm (Table 1). All samples are exceeding the permissible limit of EC (Table 3). Extensive agricultural practices might have caused higher EC in the study area.

3.1.3. TDS

In the study area, the TDS value varies between a minimum of 700 mg/L/l and a maximum of 3730 mg/L (Table 1) indicating that 28% of the groundwater samples exceeding the maximum permissible limit of TDS (Table 3). High concentration of TDS in the groundwater sample is due to leaching of salts from soil may percolate into the groundwater which may lead to increase in TDS values.

3.1.4. Total hardness (TH)

The minimum desirable limit of the 100 mg/L and maximum desirable limit of TH for drinking water are 500 mg/L as per the W.H.O, 2011. TH ranges in the study area in between 100 and 560 mg/l (Table 1). The acceptable limit of TH (as $CaCO_3$) is 300 mg/L, if non availability of alternate water source it can be extend up to 600 mg/L. According to this ground water is categorized as hard: 75–150; medium hard 150–300; very hard: >300 categories; and 60% of the sample groundwater belongs to hard category (Table 4).

Table 1: Physicochemical parameters of groundwater of the study area.

S. No	pH	EC	TDS	TH	Ca^{2+} mg/L	Mg^{2+} mg/L	TA	Cl^{-}mg/L	F^{-}mg/L
1	8.57	2600	1190	400	60	30	210	27	1.44
2	8.33	2110	840	140	20	17	220	128	0.9
3	8.34	1650	700	140	20	12	121	99	0.7
4	8.52	1740	760	160	20	13	170	92	1.03
5	7.98	3650	1790	140	40	20	182	426	0.9
6	8.17	2560	1060	160	80	40	146	213	0.6
7	8.06	3440	1580	280	28	20	134	518	0.5
8	8.43	7920	3730	180	60	35	72	135	0.8
9	8.39	3990	1580	180	23	20	78	227	2.2
10	7.87	2960	1350	200	40	6.8	84	57	1
11	8.06	2770	1200	140	40	17.9	90	263	1.4
12	8.72	1920	800	160	10	29.6	90	71	1.7
13	8.03	2220	1020	160	30	16.7	97	206	1.3
14	7.84	3910	1740	220	60	20.4	109	362	1.4
15	7.48	7370	3350	560	30	8	146	859	0.8
16	8.21	4500	1840	160	50	7.5	182	248	1.3
17	8.02	2790	1180	200	40	20.8	133	298	0.9
18	7.8	3030	1380	200	30	9.4	121	376	1.5
19	8.25	2470	1050	120	60	5.8	133	163	0.8
20	7.99	2390	1050	280	60	5.8	85	213	1.9
21	8.57	2360	1030	120	60	8.7	109	170	0.5
22	8.66	2660	1180	200	20	14	133	298	0.9
23	7.98	4950	2170	220	60	10.2	97	611	1.7
24	8.54	2780	1120	140	30	8	121	121	0.9
25	8.6	1660	720	100	30	5.5	72	120.7	1
Min	7.4	1650	700	100	10	5.5	72	27	0.5
Max	8.7	7920	3730	560	80	40	220	859	2.22
Average	8.19	3332	1475	208	40.4	16.5	126.9	266	1.1

TDS: Total dissolved solids, TH: Total hardness, EC: Electrical conductivity, TA: Total alkalinity

Table 2: Sample 1 water quality index.

Chemical parameters	Weight(wi)	Relative weight (Wi)	Si	Ci	qi	Sli
pH	3	0.103448	8.57	7.52	87.7	9.07
EC µs/cm	4	0.137931	2600	5620	216.1	29.8
TDS mg/L	2	0.068966	1190	2600	218.4	15
TH mg/L	2	0.068966	400	520	130	8.9
Ca^{2+} mg/L	3	0.103448	60	80	133.3	13.7
Mg^{2+} mg/L	3	0.103448	30	106.9	356.4	36.8
Cl mg/L	3	0.103448	27	405	1500	155
TA mg/L	4	0.137931	210	732	348.5	48
F mg/L	5	0.172414	1.44	1.09	75.6	13
	29	1				329

TDS: Total dissolved solids, TH: Total hardness, TA: Total alkalinity, EC: Electrical conductivity, TA: Total alkalinity

3.1.5. Total alkalinity

Total alkalinity in the groundwater is varying from 72 to 220 mg/L with an average value of 126 mg/L, respectively (Table 1). The alkalinity of natural waters is due to the salts of carbonates, bicarbonates, borates, silicates, and phosphates along with hydroxyl ions in the free state. The permissible limit of bicarbonate in drinking water is 150 mg/L (Table 3).

3.1.6. Calcium Ca^{2+}

Calcium concentration in groundwater ranges in between the 10 mg/L and 80 mg/l with average value of 40.4 mg/L. The maximum value of calcium was recorded as 88 mg/L and minimum was 8 mg/L. The maximum desirable limit for calcium is 200 mg/L. All the samples are within the permissible limit in the study region (Table 4).

3.1.7. Magnesium (Mg^{2+})

Magnesium in the groundwater of the study area is varying from 5.5 to 40 mg/L and the average value is 16.5 mg/L (Table 1). The required permissible limit of magnesium in groundwater for drinking purpose is 30 mg/L [22] and the concentrations are found to be within the permissible limits (Table 3).

3.1.8. Chloride (Cl^-)

Chloride concentration in the study area varies from 27 mg/L to 859 mg/L with a mean of 266 mg/l. The desirable limit of Cl^- in potable water is 250 mg/L and the permissible limit is 600 mg/L [22]. Cl^- concentration in groundwater may be due to leaching of the upper soil layers due to industrial and domestic activities and dry climate [26].

3.1.9. Fluoride (F^-):

Fluoride concentration varies from 0.24 mg/L to 2 mg/L with a mean of 1 mg/L. The desirable limit of fluoride in drinking water is between 0.5 and 1.5 mg/L. The permissible limit in drinking water 1.5 mg/L. Out of the total sample analysis, 12% of the samples are above the permissible limit of 1.5 mg/L. Volcanic intrusions observed at these villages might have contributed fluoride contamination in groundwater. The residents in the village that rely purely on ground water for drinking purposes and the people in study area are exposed to higher levels of fluoride contamination in groundwater. The groundwater of these study area is alkaline and observed that increase in the alkalinity made a similar increase in the fluoride concentration [27]. In the alkaline environment, F^- ions can be easily liberated and OH^- and F^- ions have similar radiant easily exchange with each other. The presence of fluoride bearing minerals and their interaction with water in dry climate is considered to the major cause of fluoride concentration. It can be concluded that fluoride bearing water is usually high in the alkalinity and low in hardness and chloride, sulfate.

Table 3: Comparison of groundwater quality with standards for drinking water of WHO 2011.

Water quality parameter	WHO max accept limit	WHO max allow limit	Concentration in study area	Percent compliance in %
pH	7	8.5	7.4–8.7	4
EC (µS/cm)	400	1500	1650–7920	100
TDS (mg/L)	500	1500	700–3730	28
TH (mg/L)	100	500	100–560	4
Ca^{2+} (mg/L)	75	200	October-80	Nil
Mg^{2+} (mg/L)	50	150	5.5–40	Nil
TA	-	-	72–220	-
Cl^- (mg/L)	200	600	27–859	8
F^- (mg/L)	0.6	1.5	0.2.2	12

TDS: Total dissolved solids, TH: Total hardness, EC: Electrical conductivity, TS: Total alkalinity

Table 4: Groundwater classification based on TH.

Parameter	Classification	Range	Number of samples	% of samples	References
TH	Safe	<75	Nil	Nil	[25]
	Moderate	75–150	3	32	
	Hard	150–300	20	60	
	Very Hard	>300	3	8	

TH: Total hardness

Table 5: Correlation matrix of the ground water sample parameter.

	pH	EC	TDS	TH	Ca^{2+} mg/L	Mg^{2+} mg/L	TA	CL^- mg/L	F^- mg/L
pH	1								
EC	−0.39594	1							
TDS	−0.40666	0.994208	1						
TH	−0.44764	0.497374	0.504163	1					
Ca^{2+} mg/L	−0.20109	0.254493	0.256498	0.06939	1				
Mg^{2+} mg/L	0.2375	0.151472	0.166908	0.0277	0.21972748	1			
TA	0.061834	−0.10899	−0.11015	0.20543	−0.01372714	0.11279174	1		
CL^- mg/L	−0.69509	0.58239	0.579328	0.575893	0.03576517	−0.162725	0.037521	1	
F^- mg/L	-0.0516	0.003394	−0.03415	0.059663	−0.04247552	−0.0143639	−0.29822	−0.02367	1

TDS: Total dissolved solids, TH: Total hardness, TA: Total alkalinity, EC: Electrical conductivity

Table 6: Water quality index at individual sampling stations.

S. No	Water quality index	Water quality status
1	330	Unsuitable
2	291	Very poor
3	332	Unsuitable
4	245	Very poor
5	246	Very poor
6	288	Very poor
7	339	Unsuitable
8	341	Unsuitable
9	322	Unsuitable
10	457	Unsuitable
11	231	Very poor
12	568	Unsuitable
13	427	Unsuitable
14	378	Unsuitable
15	416	Unsuitable
16	323	Unsuitable
17	173	Poor
18	285	Very poor
19	162	Poor
20	307	Unsuitable
21	278	Very poor
22	275	Very poor
23	239	Very poor
24	247	Very poor
25	326	Unsuitable

Table 7: Water quality classification based on WQI value.

Class	WQI value	Water quality status	% of samples in the study area
A	<50	Excellent	Nil
B	50–100	Good water	Nil
C	100–200	Poor water	8
D	200–300	Very poor water	40
E	300	Water unsuitable for drinking	56

WQI: Water quality index

3.2 Correlation Matrix

From Table 5, we observed that a positive correlation in between EC and TDS (0.9) [28].

The calculated WQI values range from 162 to 568 in this study (Tables 2 and 6). This can therefore be grouped into five classes: Excellent, Class A (<50); good, Class B (51–100); good water, Class C (101–200); poor water, Class D (201–300); very poor, and Class E (>300) unsuitable for drinking. According to the WQI classification, 8% of the northeastern part of Y.S.R region groundwater samples fall into Class C: Poor, another 40% fall in Class D, very poor, and 56% fall in Class E, unsuitable for drinking, as shown in Table 7 [24]. WQI's high value may be due to higher levels of TDS, EC, TH, and fluoride in the study area [24,29].

4. CONCLUSION

Groundwater quality assessment for drinking purpose in northeastern part of the Y.S.R district was examined by various physicochemical parameters such as pH, EC, TDS, calcium, magnesium, total alkalinity, chloride, and fluoride. The suitability for drinking purpose is determined by comparing with Indian and WHO standards. Major cations and anions are within the permissible limit except fluoride. Fluoride concentration (0.2–2 mg/L) is observed in different places of the northeastern part of the Y.S.R district. From the study reveals that children are highly prone to the health risks caused by dental fluorosis through the intake fluoride water. Therefore, the study indicates that the frequent monitoring of groundwater is a vital step to avoid human health risks and that groundwater must be tested before consumption to avoid health risks, especially in children. According to WQI classification 8% of samples fall in Class C: Poor water; 40% belongs to Class D: Very poor category, and 56% of the samples are in Class D: Unsuitable for drinking criteria. Hence, it may be concluded that the quality of groundwater in certain parts of study area is affected and not fit for human consumption. In the study area, many of ionic concentrations in the groundwater are at higher levels indicating that they are problematic in one way or the other, if they are consumed without proper treatment. It is significant to note that ground waters of variable quality exist in this area and the quality of the groundwater is being deteriorated in some parts. This is mainly because of percolation from sewage, waste disposal sites, and industrial effluents. Therefore, it is advisable that constant monitoring and proper treatment of groundwater are essential, as prerequisite for use of these waters for drinking purpose.

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