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Calculation of water quality index (WQI) to assess the suitability of groundwater quality for drinking purposes in Vinukonda Mandal, Guntur District, Andhra Pradesh, India

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ABSTRACT

The objective of Water Quality Index (WQI) is to turn a complex water quality data into information that is clear and useful for the community. The present study is aimed to calculate WQI for the groundwater samples collected in Vinukonda Mandal of Guntur District. WQI is an effective tool to assess the suitability of groundwater quality for drinking purposes through providing a single number based on various physicochemical parameters. Twenty three groundwater samples are collected from the study area and 17 physicochemical parameters such as pH, EC, TDS, TA, TH, Turbidity, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, F^{-}, NO_3^-, HCO_3^-, SO_4^{2-}, PO_4^{3-} and DO are analyzed. WQI is calculated to know the overall groundwater quality status of the study area and the values ranges from 130.97 to 206.59. Then its quality is categorized based on different conditions including excellent, good, poor, very poor and unfit. The results show that the groundwater quality for the 22 samples is poor and for the other sample is very poor indicating that the groundwater is not fit for drinking purposes without treatment. The present paper reveals that the groundwater of the study area requires some extent of treatment before consumption.

Keywords: Groundwater samples, Vinukonda Mandal of Guntur District, Physicochemical Parameters, Water Quality Index (WQI)

INTRODUCTION

The excessive consumption of groundwater as drinking water in all over the world is due to the purification of groundwater in the soil column through anaerobic decomposition, filtration and ion exchange processes [1]. Hence, groundwater must carefully manage to maintain its purity within standard limits. Groundwater quality depends on the quality of recharged water, atmospheric precipitation, inland surface water and sub-surface geochemical processes.

Water pollution not only affects water quality but also threats human health, economic development and social prosperity [2, 3]. Water quality is a term used to describe the physical, chemical and biological characteristics of water, usually in respect to its suitability for a particular purpose [4, 5]. Hence, assessment of groundwater quantity and quality are important for the development of further civilization and for future water resources development strategies. The quality of groundwater may be based on its physical, chemical and micro-biological characteristics [6, 7] due to weathering from source rocks and anthropogenic activities. Potable or drinking water is defined as having acceptable quality in terms of its physical, chemical, and bacteriological parameters so that it can be safely used for drinking and cooking.

Therefore, it is necessary to assess the quality of surface and groundwater. The monitoring of water quality using the Water Quality Index (WQI) developed by Horten [8] helps in overall assessment and management of groundwater [9, 10] and effective way to communicate information on water quality to the policy makers and concerned citizens.

Ever since the Council on Environmental Quality in its 1972, Annual Report clearly indicated the need for environmental indexes, interest in such indexes has greatly increased throughout the world.

Water Quality Index is a numerical expression of the degree of pollution and increasing with the pollution. WQI is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption [11-13]. The WQI provides a comprehensive picture of the quality of surface or groundwater for most domestic uses and easily understandable for decision makers about quality and possible uses of any water body.

To avoid the ill effects of water pollution certain chemical quality standards have been established for evaluating the suitability of water for drinking, domestic, irrigation and industrial uses. In order to assure that such levels of water quality are maintained preferably by adapting the guidelines issued by the World Health Organization [14, 15] and also by various authorities including Central Pollution Control Board [16], World Bank [17], Bureau of Indian Standards [18-20], Indian Council of Medical Research [21], etc.

The chemical quality of groundwater is expressed in terms of various parameters like pH, EC, TDS, TA, TH, Turbidity, Ca^{2+} Mg^{2+}, Na^+, K^+, Cl^-, F^-, NO_3^-, HCO_3^-, SO_4^{2-}, PO_4^{3-} and DO. The present study deals with the calculation of Water Quality Index (WQI) of groundwater in Vinukonda Mandal of Guntur District of composite state of Andhra Pradesh, India, to assess the suitability of groundwater quality for drinking purposes.

EXPERIMENTAL SECTION

2.1.: Study Area:

The Vinukonda Mandal of Guntur District, composite state of Andhra Pradesh has rocks of Cryolite, a major source of fluoride and moreover, it has other deposits comprising of limestone (of cement grade), iron ore, copper and lead minerals, diatomaceous earth, gypsum, granite, kankar, quartz and white clays. The soils of this area are wetted by the famous Naguleru, a rivulet of Krishna River.

2.2: Water Samples Collection:

Twenty three groundwater samples were collected from 23 villages of the study area Vinukonda Mandal of Guntur District in composite state of Andhra Pradesh. The groundwater samples were collected carefully in one-liter capacity polyethylene bottles which were cleaned with acid water, followed by repeated washing with double distilled water [22, 23] to avoid unpredictable changes in characteristics as per standard procedures of APHA, [24]. The names of the villages in Vinukonda Mandal, where the groundwater samples collected were depicted in Table 1 and Figure 1.

Table 1: Names of the samples collected villages

S. No:	Sample Number	Village Name	S. No:	Sample Number	Village Name
1	1	Sivapuram	13	13	Dondapadu
2	2	Koppukonda	14	14	Vinukonda
3	3	Thimmayapalem	15	15	Gokana konda
4	4	Narasayapalem	16	16	Enugupalem
5	5	Brahmanapalli	17	17	Surepalli
6	6	Mada manchipadu	18	18	Ummadivaram
7	7	Andugulapadu	19	19	Perumallapalli
8	8	Tsoutapalem	20	20	Nayanipalem
9	9	Venkupalem	21	21	Settupalli
10	10	Nagulavaram	22	22	Vithamrajupalli
11	11	Peda kancherla	23	23	Neelagangavaram
12	12	Narasarayanipalem			

Figure 1: Location of samples collected villages in VINUKONDA Mandal

2.3: Sample Preservation and Handling:

Immediately after collection, in the present study the temperature of the groundwater samples was maintained at 4°C by keeping the sample in an ice-box and transported to laboratory for the chemical analysis. It is essential to protect water samples from change in composition and deterioration with aging due to various interactions. Sample collection, transportation and care of samples prior to analysis have great significance on the subsequent analysis [25]. The optimum sample holding times ranges from zero to 6 months. According to U. S. Environmental Protection Agency, [26], the preservation techniques of various parameters are summarized in Table: 2. Preservation is essential for retarding biological action, hydrolysis of chemical compounds and complexes, and reduction of volatility of constituents.

2.4: Methods of Analysis of Various Water Quality Parameters:

The drinking water quality depends on many physicochemical parameters and their concentrations [27]. For the assessment of groundwater quality, seventeen physicochemical parameters were selected and analyzed according to the standard methods of chemical analysis as prescribed in literature [15, 24] and the methods for each parameter were listed in Table 3. The average values of three replicates were taken for each determination.

Table 2: Recommendations for water samples preservation according to measurement

Measurement	Volume required (ml)	Container	Preservative	Holding Time
Conductance	100	P, G	Cool, 4°C	28 days
Color	50	P, G	Cool, 4°C	48 hours
Odour	200	G	Cool, 4°C	24 hours
Hardness	100	P, G	HNO_3 - pH < 2	6 months
pH	25	P, G	---	Analyze Immediately
TDS	100	P, G	Cool, 4°C	7 days
Turbidity	500	P, G	Cool, 4°C	48 hours
Metals ions	100	P, G	HNO_3 - pH < 2	6 months
Fluoride	300	P, G	---	28 days
Chloride	50	P, G	---	28 days
Alkalinity	100	P, G	---	14 days
Nitrate	100	P, G	Cool, 4°C	48 hours
Temperature	1000	P, G	---	Analyze Immediately
Sulphate	50	P, G	Cool, 4°C	28 days
Phosphate	50	P, G	Cool, 4°C	24 hours
D.O.	300	G	---	Analyze Immediately

**Note: P - Plastic, G – Glass*

Table 3: Methods used for the determination of the water quality parameters

S. No:	Water quality parameter	Method of determination
1	Hydrogen ion concentration (pH)	pH-metry
2	Electrical Conductivity (EC)	Conductometry
3	Total Dissolved Solids (TDS)	TDS analyzer
4	Total Hardness (TH) as $CaCO_3$	EDTA-Titrimetry
5	Total Alkalinity (TA) as $CaCO_3$	Titrimetry
6	Turbidity (NTU)	Turbidity meter
7	Calcium (Ca^{2+})	EDTA-Titrimetry
8	Magnesium (Mg^{2+})	EDTA-Titrimetry
9	Sodium (Na^{+})	Flame photometry
10	Potassium (K^{+})	Flame photometry
11	Chloride (Cl^{-})	Titrimetry
12	Nitrate (NO_3^-)	Spectrophotometry
13	Bicarbonate (HCO_3^-)	Titrimetry
14	Sulphate (SO_4^{2-})	Spectrophotometry
15	Phosphate (PO_4^{3-})	Spectrophotometry
16	Dissolved Oxygen (DO)	Titrimetry
17	Fluoride (F^{-})	Spectrophotometry

2.5: Water Quality Index (WQI)

Water Quality Index (WQI) is an important technique for evaluating groundwater quality and its suitability for drinking purposes. For the calculation of WQI, the permissible values of various physicochemical parameters for the drinking water used in this study are those recommended by the WHO, BIS and ICMR. The WQI value can be calculated by using the following equation [28]:

$WQI = \sum_{i}^{n}(W_i q_i)$

where, Relative weight, $W_i = \frac{w_i}{\Sigma w_i}$

Quality rating, $q_i = \frac{C_i}{S_i} X100$

where,

n = number of parameters,

w_i = weight of each parameter,

C_i = concentration of each chemical parameter in water sample in mg/lit,

S_i = Indian drinking water standard [19] for each chemical parameter in mg/lit. Computed WQI values are usually classified into five categories [12] as shown in Table 4.

Table 4: Water Quality Index (WQI) and Status of Water Quality

S. No	Water Quality Index	Water Quality Status
1	<50	Excellent Water Quality
2	50-100	Good Water Quality
3	100-200	Poor Water Quality
4	200-300	Very Poor Water Quality
5	> 300	Unfit for drinking

The water is extremely clear at the lower values of WQI i.e., it is free of contamination.

RESULTS AND DISCUSSION

3.1: Physiochemical parameters of Water Quality Index:

Groundwater quality assessment was carried to determine its suitability in terms of drinking purposes. The results of physicochemical analysis of the groundwater from 23 villages of Vinukonda Mandal of Guntur District, composite state of Andhra Pradesh were presented in Table 5. All the groundwater samples collected in the study area were colorless.

Table 5: Physico-chemical characteristics of groundwater of villages of Vinukonda Mandal, Guntur District

Sample Number	pH	EC	TDS	TH	TA	Turbidity	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^-	HCO_3^-	SO_4^{2-}	PO_4^{3-}	DO	F^-
1	8.2	976	815	506	408	1.67	125	66	188	2.34	769	25	365	276	0.26	2.56	3.75
2	7.2	765	620	557	395	1.89	166	74	190	1.58	695	94	272	201	0.45	3.25	3.82
3	7.8	936	745	423	410	1.54	115	56	176	5.65	865	46	405	288	0.25	4.76	3.56
4	8.1	912	715	515	304	2.12	165	69	172	4.21	696	28	296	279	0.20	4.67	3.48
5	8.4	1145	926	620	610	3.34	209	72	221	5.12	986	42	584	301	0.15	5.48	4.27
6	7.9	943	746	414	520	1.34	112	58	191	3.89	642	47	367	221	0.16	4.68	3.88
7	8.2	954	764	603	571	2.45	206	74	184	2.54	814	58	481	245	0.24	2.89	3.69
8	7.8	988	875	496	508	1.42	118	58	196	1.71	774	42	364	218	0.12	4.45	4.09
9	8.1	909	710	475	496	2.23	158	46	161	2.12	809	35	355	245	0.11	3.23	3.37
10	8.2	987	898	595	456	2.45	194	54	157	3.10	799	46	372	226	0.10	4.57	3.28
11	7.4	660	656	542	423	2.38	175	58	181	4.56	717	88	312	241	0.11	3.68	3.68
12	7.8	684	678	456	346	1.76	166	55	174	4.78	658	44	267	239	0.09	2.49	3.52
13	8.2	918	715	477	479	1.58	178	36	193	3.04	565	20	338	248	0.32	3.95	3.95
14	7.9	595	524	424	309	1.98	149	36	180	6.23	515	15	235	217	0.07	3.48	3.62
15	8.5	1218	945	524	587	2.73	184	53	212	7.01	626	31	482	295	0.18	5.12	4.21
16	8.3	950	735	535	532	2.47	189	48	185	3.14	615	47	418	305	0.14	4.32	3.69
17	7.6	1245	1042	586	585	2.83	201	65	166	6.89	789	25	474	330	0.17	7.33	3.45
18	8.1	851	808	359	487	2.21	105	45	178	3.18	674	43	359	249	0.07	4.69	3.59
19	7.8	1034	935	499	496	2.65	178	52	199	4.72	667	76	382	307	0.09	5.01	4.12
20	7.5	975	778	422	342	1.58	148	60	182	2.51	708	31	332	229	0.07	2.78	3.68
21	8.2	1189	997	638	328	1.76	137	84	186	7.24	985	54	295	316	0.20	6.51	3.72
22	7.5	1056	786	512	301	1.39	112	61	163	3.81	728	24	257	212	0.18	4.32	3.43
23	8.4	995	857	492	309	2.28	130	46	173	2.92	674	32	264	304	0.25	6.42	3.49

Units: Except pH, EC (µ S/cm), Turbidity (NTU) all parameters are measured in (mg/lit)

3.2: Calculation of Water Quality Index (WQI):

Water quality index is computed to reduce the large amount of water quality data to a single numerical value [29, 30]. Indices are based on the values of various physicochemical parameters in a water sample. Water quality indices are used for the classification of water [31]. Hence, for calculating the WQI in the present study, 17 parameters have been considered.

There are five steps for computing WQI of a water sample.

1) In the first step, each of the chemical parameters are assigned a weight (w_i) based on their perceived effects on primary health/their relative importance in the overall quality of water for drinking purposes [32] ranging from 1 to 8 depending on the collective expert opinions taken from different previous studies. The mean values for the weights of each parameter along with the references used are shown in Table 6. The maximum weight of 4.6 has been assigned to TDS which has the major importance in water quality assessment and minimum weight of 1.5 has been assigned to Potassium because it plays an insignificant role in the water quality assessment i.e. which is considered as not harmful.

Table 6: Assigned weight (w_i) values adopted from the literature

S. No:	pH	EC	TDS	TH	TA	Turbidity	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^-	HCO_3^-	SO_4^{2-}	PO_4^{3-}	DO	F^-	Ref.
1	4.0	2.0	-	1.0	1.0	2.0	-	-	-	-	-	-	-	-	-	4.0	-	[35]
2	1.0	4.0	-	1.0	-	2.0	-	-	-	-	-	2.0	-	-	-	4.0	-	[36]
3	4.0	2.0	-	1.0	1.0	2.0	-	-	-	-	-	-	-	-	-	4.0	-	[37]
4	1.0	-	-	-	-	-	-	-	-	-	-	3.0	-	-	-	4.0	-	[38]
5	1.0	1.0	-	1.0	-	-	-	-	-	-	-	2.0	-	-	-	4.0	-	[39]
6	1.0	4.0	-	1.0	-	4.0	-	-	1.0	-	-	2.0	-	-	-	4.0	-	[40]
7	4.0	4.0	-	2.0	3.0	-	-	-	-	-	-	-	-	-	-	4.0	-	[41]
8	1.0	2.0	-	1.0	-	2.0	-	-	-	-	-	2.0	-	-	-	4.0	-	[42]
9	3.0	3.0	5.0	3.0	-	-	2.0	2.0	3.0	2.0	5.0	5.0	2.0	3.0	-	-	-	[43]
10	1.0	-	4.0	-	-	2.0	-	-	-	-	-	2.0	-	-	1.0	4.0	-	[44]
11	3.0	-	5.0	-	-	-	2.0	2.0	3.0	1.0	3.0	-	2.0	3.0	-	-	-	[45]
12	4.0	2.0	2.0	4.0	-	4.0	-	-	3.0	-	3.0	5.0	-	4.0	-	-	4.0	[46]
13	7.0	5.0	7.0	5.0	5.0	5.0	2.0	2.0	-	-	7.0	5.0	-	-	3.0	8.0	4.0	[47]
Mean	**2.7**	**2.9**	**4.6**	**2.0**	**2.5**	**2.9**	**2.0**	**2.0**	**2.5**	**1.5**	**4.5**	**3.1**	**2.0**	**3.3**	**2.0**	**4.4**	**4.0**	

2) In the second step, the relative weight (W_i) is calculated by using the following equation [8, 33, 34] and the calculated relative weight (W_i) values for each parameter are presented in Table 7.

Relative weight, $W_i = \frac{w_i}{\Sigma w_i}$

3) In the third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the drinking water guideline recommended by WHO [15] and BIS [19] and then multiplied by 100 using the following equation and the calculated quality rating scale (q_i) values for each parameter are presented in Table 8. The higher the value of q_i is, the more polluted is the water [48].

$q_i = (C_i/S_i) \times 100$

4) In the fourth step, the water quality sub-index (SI) for each chemical parameter is determined using the equation, SI = $W_i q_i$ and values are presented in Table 8.

5) Finally, in the fifth step, the overall Water Quality Index (WQI) is calculated by adding together each sub-index (SI) values of each groundwater samples as per the equation [28] and the calculated values are presented in Table 8.
WQI = $\sum_i^n (W_i q_i)$

Table 7: Relative weight of the water quality parameters

S. No:	Parameters	Assigned Weight (w_i)	Relative Weight (W_i)	S. No:	Parameters	Assigned Weight (w_i)	Relative Weight (W_i)
1	pH	2.7	0.055215	10	K^+	1.5	0.030675
2	EC	2.9	0.059305	11	Cl^-	4.5	0.092025
3	TDS	4.6	0.094069	12	NO_3^-	3.1	0.063395
4	TH	2.0	0.040899	13	HCO_3^-	2.0	0.040899
5	TA	2.5	0.051125	14	SO_4^{2-}	3.3	0.067485
6	Turbidity	2.9	0.059305	15	PO_4^{3-}	2.0	0.040899
7	Ca^{2+}	2.0	0.040899	16	DO	4.4	0.089979
8	Mg^{2+}	2.0	0.040899	17	F^-	4.0	0.081799
9	Na^+	2.5	0.051125		**Total ($\sum w_i$) = 48.9**		

Table 8: Quality rating (q_i), Sub Index of each chemical parameter (SI) and Water Quality Index (WQI) of each groundwater samples of study area

S. No:	pH		EC		TDS		TH		TA		Turbidity		Ca^{2+}		Mg^{2+}		Na^+	
	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$
1	96.5	5.33	325.3	19.3	163.0	15.3	168.7	6.9	204.0	10.4	33.4	1.9	166.7	06.8	220.0	08.9	376	19.2
2	84.7	4.68	255.0	15.1	124.0	11.7	185.7	7.6	197.5	10.1	37.8	2.2	221.3	09.1	246.7	10.1	380	19.4
3	91.8	5.07	312.0	18.5	149.0	14.0	141.0	5.8	205.0	10.5	30.8	1.8	153.3	06.3	186.7	07.6	352	17.9
4	95.3	5.26	304.0	18.0	143.0	13.5	171.7	7.0	101.3	05.2	42.4	2.5	220.0	08.9	230.0	09.4	344	17.5
5	98.8	5.46	381.7	22.6	185.2	17.4	206.7	8.5	305.0	15.6	66.8	3.9	278.7	11.4	240.0	09.8	442	22.6
6	92.9	5.13	314.3	18.6	149.2	14.0	138.0	5.6	260.0	13.3	26.8	1.6	149.3	06.1	193.3	07.9	382	19.5
7	96.5	5.33	318.0	18.9	152.8	14.4	201.0	8.2	285.5	14.6	49.0	2.9	274.7	11.2	246.7	10.1	368	18.8
8	91.8	5.07	329.3	19.5	175.0	16.5	165.3	6.8	254.0	12.9	28.4	1.7	157.3	06.4	193.3	07.9	392	20.0
9	95.3	5.26	303.0	17.9	142.0	13.4	158.3	6.5	248.0	12.7	44.6	2.6	210.7	08.6	153.3	06.3	322	16.5
10	96.5	5.33	329.0	19.5	179.6	16.9	198.3	8.1	228.0	11.7	49.0	2.9	258.7	10.6	180.0	07.4	314	16.1
11	87.1	4.81	220.0	13.0	131.2	12.3	180.7	7.4	211.5	10.8	47.6	2.8	233.3	09.5	193.3	07.9	362	18.5
12	91.8	5.07	228.0	13.5	135.6	12.8	152.0	6.2	173.0	08.8	35.2	2.1	221.3	09.1	183.3	07.5	348	17.8
13	96.5	5.33	306.0	18.1	143.0	13.5	159.0	6.5	239.5	12.2	31.6	1.9	237.3	09.7	120.0	04.9	386	19.7
14	92.9	5.13	198.3	11.8	104.8	09.9	141.3	5.8	154.5	07.9	39.6	2.3	198.7	08.1	120.0	04.9	360	18.4
15	100	5.52	406.0	24.1	189.0	17.8	174.7	7.1	293.5	15.0	54.6	3.2	245.3	10.0	176.7	07.2	424	21.7
16	97.6	5.39	316.7	18.8	147.0	13.8	178.3	7.3	266.0	13.6	49.4	2.9	252.0	10.3	160.0	06.5	370	18.9
17	89.4	4.94	415.0	24.6	208.4	19.6	195.3	7.9	292.5	14.9	56.6	3.4	268.0	10.9	216.7	08.9	332	16.9
18	95.3	5.26	283.7	16.8	161.6	15.2	119.7	4.9	243.5	12.4	44.2	2.6	140.0	05.7	150.0	06.1	356	18.2
19	91.8	5.07	344.7	20.4	187.0	17.6	166.3	6.8	248.0	12.7	53.0	3.1	237.3	09.7	173.3	07.1	398	20.3
20	88.2	4.87	325.0	19.3	155.6	14.6	140.7	5.8	171.0	08.7	31.6	1.9	197.3	08.1	200.0	08.2	364	18.6
21	96.5	5.33	396.3	23.5	199.4	18.8	212.7	8.7	164.0	08.4	35.2	2.1	182.7	07.5	280.0	11.5	372	19.0
22	88.2	4.87	352.0	20.9	157.2	14.8	170.7	6.9	150.5	07.7	27.0	1.6	149.3	06.1	203.3	08.3	326	16.7
23	98.8	5.46	331.7	19.7	171.4	16.1	164.0	6.7	154.5	07.9	45.6	2.7	173.3	07.1	153.3	06.3	346	17.7

Table 8: Continued.

S. No:	K^+		Cl^-		NO_3^-		HCO_3^-		SO_4^{2-}		PO_4^{3-}		DO		F^-		$\sum_i^n (W_i q_i)$
	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	q_i	$W_i q_i$	
1	23.4	0.72	307.6	28.3	55.6	3.5	60.8	2.5	138.0	9.3	2.6	0.11	42.7	3.8	250	20.4	162.66
2	15.8	0.48	278.0	25.6	208.9	13.2	45.3	1.9	100.5	6.8	4.5	0.18	54.2	4.9	254.6	20.8	163.84
3	56.5	1.73	346.0	31.8	102.2	6.5	67.5	2.7	144.0	9.7	2.5	0.10	79.3	7.1	237.3	19.4	166.50
4	42.1	1.29	278.4	25.6	62.2	3.9	49.3	2.0	139.5	9.4	2.0	0.08	77.8	7.0	232.0	18.9	155.43
5	51.2	1.57	394.4	36.3	93.3	5.9	97.3	3.9	150.5	10.2	1.5	0.06	91.3	8.2	284.7	23.2	206.59
6	38.9	1.19	256.8	23.6	104.4	6.6	61.2	2.5	110.5	7.5	1.6	0.07	78.0	7.0	258.7	21.1	161.29
7	25.4	0.78	325.6	29.9	128.9	8.2	80.2	3.3	122.5	8.3	2.4	0.09	48.2	4.3	246.0	20.1	179.40
8	17.1	0.52	309.6	28.5	93.3	5.9	60.7	2.5	109.0	7.4	1.2	0.05	74.2	6.7	272.7	22.3	170.64
9	21.2	0.65	323.6	29.7	77.8	4.9	59.2	2.4	122.5	8.3	1.1	0.04	53.8	4.8	224.7	18.4	158.95
10	31.0	0.95	319.6	29.4	102.2	6.5	62.0	2.5	113.0	7.6	1.0	0.04	76.2	6.9	218.7	17.9	170.32
11	45.6	1.39	286.8	26.4	195.6	12.4	52.0	2.1	120.5	8.1	1.1	0.04	61.3	5.5	245.3	20.0	162.94
12	47.8	1.47	263.2	24.2	97.8	6.2	44.5	1.8	119.5	8.1	0.9	0.04	41.5	3.7	234.7	19.2	147.58
13	30.4	0.93	226.0	20.8	44.4	2.8	56.3	2.3	124.0	8.4	3.2	0.13	65.8	5.9	263.3	21.5	154.59
14	62.3	1.91	206.0	18.9	33.3	2.1	39.1	1.6	108.5	7.3	0.7	0.03	58.0	5.2	241.3	19.7	130.97
15	70.1	2.15	250.4	23.0	68.9	4.4	80.3	3.3	147.5	9.9	1.8	0.07	85.3	7.7	280.7	22.9	185.04
16	31.4	0.96	246.0	22.6	104.4	6.6	69.7	2.8	152.5	10.3	1.4	0.06	72.0	6.5	246.0	20.1	167.41
17	68.9	2.11	315.6	29.0	55.6	3.5	79.0	3.2	165.0	11.1	1.7	0.07	122.2	10.9	230.0	18.8	190.72
18	31.8	0.97	269.6	24.8	95.6	6.1	59.8	2.4	124.5	8.4	0.7	0.03	78.2	7.0	239.3	19.5	156.36
19	47.2	1.44	266.8	24.6	168.9	10.7	63.7	2.6	153.5	10.4	0.9	0.04	83.5	7.5	274.7	22.5	182.55
20	25.1	0.77	283.2	26.0	68.9	4.4	55.3	2.3	114.5	7.7	0.7	0.03	46.3	4.2	245.3	20.0	155.47
21	72.4	2.22	394.0	36.3	120.0	7.6	49.2	2.0	158.0	10.7	2.0	0.08	108.5	9.7	248.0	20.3	193.73
22	38.1	1.17	291.2	26.8	53.3	3.4	42.8	1.7	106.0	7.2	1.8	0.07	72.0	6.5	228.7	18.7	153.41
23	29.2	0.89	269.6	24.8	71.1	4.5	44.0	1.8	152.0	10.3	2.5	0.10	107.0	9.6	232.7	19.0	160.65

It should be noted that interpretation of the calculated WQI values are usually classified into five categories according to drinking purposes as in Table 9 [12, 13, 49].

Table 9: WQI based classification of groundwater in study area

S. No	Water Quality Index	Water Quality Status	No. of water samples
1	<50	Excellent Water Quality	00
2	50-100	Good Water Quality	00
3	100-200	Poor Water Quality	22
4	200-300	Very Poor Water Quality	01
5	> 300	Unfit for drinking	00

Assembling different parameters into one single number leads an easy interpretation of index, thus providing an important tool for management purposes [50]. Table 9 shows the number of groundwater samples that falls under different quality. It is obvious from this classification that on the basis of the WQI, 22 groundwater samples from the study area are of poor quality and one sample is of very poor quality for human consumption indicating the ground waters of this study area are not fit for drinking purposes.

CONCLUSION

The present study shows that the calculation of Water Quality Index is a useful tool in assessing the overall quality of water. Twenty three groundwater samples are collected from 23 villages of Vinukonda Mandal of Guntur District. The 23 groundwater samples are subjected to analyze for various physicochemical parameters like pH, EC, TDS, TA, TH, Turbidity, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, F^{-}, $NO_3^-, HCO_3^-, SO_4^{2-}, PO_4^{3-}$and DO. In this article, Water Quality Index (WQI) for the groundwater samples of study area is calculated to assess the suitability of groundwater quality for drinking purposes. Assembling different parameters in to one single number leads an easy interpretation of water quality. The calculated WQI values ranges from 130.97 to 206.59. The minimum WQI has been recorded from Vinukonda (Sample No. 14), while maximum WQI has been recorded from Brahmanapalli (Sample No. 5). From the WQI values, it is clear that the 22 samples are under the category of poor quality and one more sample is of very poor quality. This suggests that the groundwater from study area is highly polluted due to leaching and anthropogenic activities such as discharge of effluents from industrial, agricultural and domestic uses. The consumption of this poor quality water may pose health hazard on long term and therefore require to be treated before using for drinking purposes. Some techniques like precipitation, ion-exchange, reverse osmosis, electro dialysis, donnan dialysis, nanofiltration, electro coagulation and adsorption are to be used to raise the quality of the water.

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