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Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India

C. R. RAMAKRISHNAIAH[*], C. SADASHIVAIAH[#] and G. RANGANNA[§]

[*]Research Scholar, Department of Civil Engineering, S.I.T, Tumkur-572103.
[#]Karavali Institute of Technology, Neerumarga, Mangalore-575023, India.
[§]Department of Mathematics, UGC-CSA,
Central College Campus, Bangalore University, Bangalore-560 001, India.
rama_bmsce@yahoo.com

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Abstract: The present work is aimed at assessing the water quality index (WQI) for the groundwater of Tumkur taluk. This has been determined by collecting groundwater samples and subjecting the samples to a comprehensive physicochemical analysis. For calculating the WQI, the following 12 parameters have been considered: pH, total hardness, calcium, magnesium, bicarbonate, chloride, nitrate, sulphate, total dissolved solids, iron, manganese and fluorides. The WQI for these samples ranges from 89.21 to 660.56. The high value of WQI has been found to be mainly from the higher values of iron, nitrate, total dissolved solids, hardness, fluorides, bicarbonate and manganese in the groundwater. The results of analyses have been used to suggest models for predicting water quality. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination

Keywords: Groundwater, Water quality standards, Water quality index, India

Introduction

Groundwater is used for domestic and industrial water supply and irrigation all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions. Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas. According to WHO organization, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source. It therefore becomes imperative to regularly monitor the quality of groundwater and to device ways and means to protect it. Water quality index is one of the most effective tools[1-4] to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of groundwater. WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption.

The objective of the present work is to discuss the suitability of groundwater for human consumption based on computed water quality index values.

Study area

Tumkur taluk is located in the southeastern corner of Karnataka state between 13° 06'30" to 13° 31' North latitude and 76° 59' to 77° 19' East longitude and (Figure 1) covers an area of 1043 sq.km with a population[5] of 5,16,661. The major sources of employment are agriculture, horticulture and animal husbandry, which engage almost 80% of the workforce. The major industries are that of chemicals, oil, cotton, soap, tools, food processing, rice mills, stone crushing and mining. Occurrence, movement and storage of groundwater are influenced by lithology, thickness and structure of rock formations. Weathered and fractured granites, granitic gneiss and shale form the main aquifer of Tumkur taluk (Figure 2).

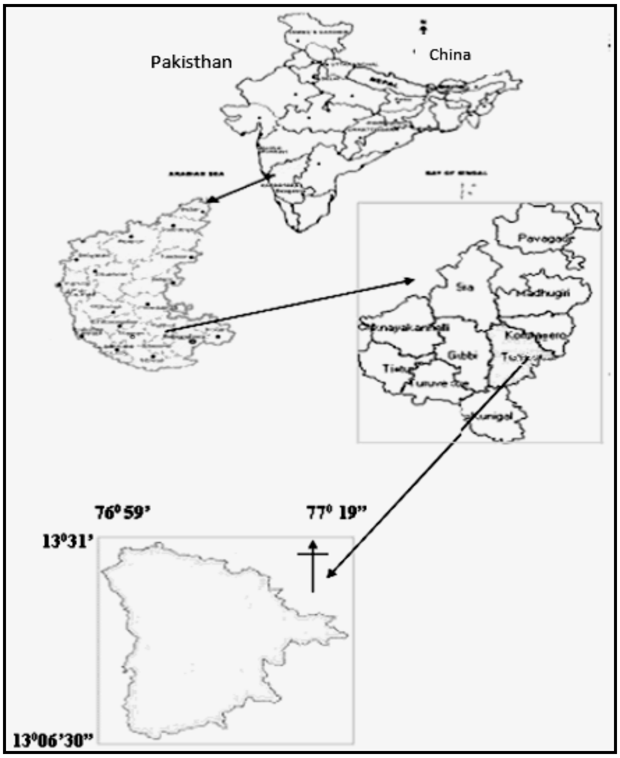

Figure 1. Location map of the study area.

Groundwater in the study area occurs under water table conditions in the weathered and fractured granite, Gneisses. There is no perennial river in the study area. The major ion chemistry of groundwater of Tumkur taluk has not been studied earlier.

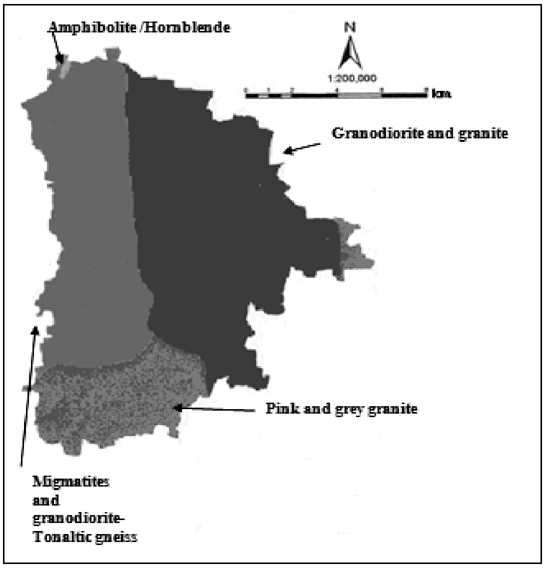

Figure 2. Geological map of study area.

Methodology

Groundwater samples were collected from 269 locations during pre-monsoon period (February 2006) (Figure 3). Each of the groundwater samples was analyzed for 17 parameters such as pH, electrical conductivity, TDS, total hardness, bicarbonate, carbonate, chloride, sulphate, phosphate, nitrate, fluoride, calcium, magnesium, sodium, potassium, iron and manganese using standard procedures recommended by APHA[6].

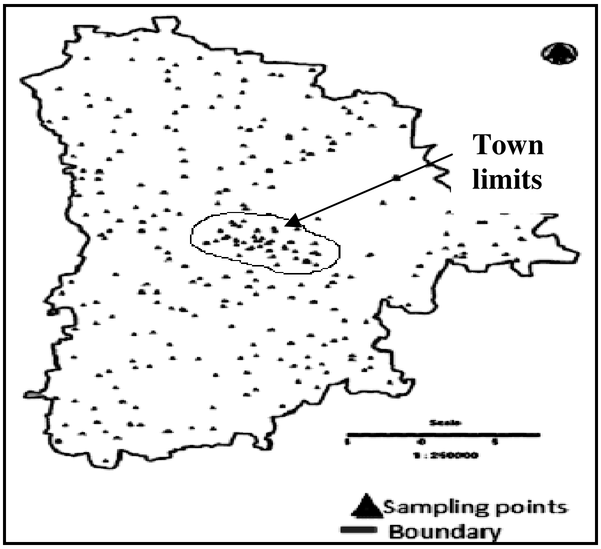

Figure 3. Groundwater sampling locations.

The chemical parameters obtained were used for regression analysis. The regression analysis is carried out by taking TDS as dependent variable and Ca, Mg, Cl, SO_4, NO_3, Na and (HCO_3+CO_3) as independent variables. Trend analysis represents the process of using the analysed data for predictions. This may be used to predict or forecast values of the dependent variable. The regression models can be used to find out the ionic concentration of the groundwater samples, if the dependent variable TDS is measured for different locations, by inverse calculations. Water quality index is calculated from the point of view of suitability of groundwater for human consumption.

Results and Discussion

The chemical analyses of the groundwater and the percent compliance with the Indian Standards[7] and WHO[8] are summarized in Table 1. Normal statistics of water quality parameters of 269 groundwater samples are presented in Table 2.

Table 1. Comparison of groundwater quality with drinking water standards, Indian and WHO.

Parameters	Indian Standard	Percent compliance	WHO Standard	Percent compliance
pH	6.5-8.5	98.5	7.0-8.0	91
Electrical conductivity	-	-	-	-
Total dissolved solids	500	70	1,000	96.5
Total hardness as $CaCO_3$, mg/L	300	70	100	0.5
Carbonate, mg/L	-	-	-	-
Bicarbonate, mg/L	-	-	-	-
Chloride, mg/L	250	97	250	97
Sulphate, mg/L	200	100	250	100
Phosphate, mg/L	-	-	-	-
Nitrate, mg/L	45	51.5	50	56.5
Fluoride, mg/L	1	30	1	30
Calcium, mg/L	75	96	75	96
Magnesium, mg/L	30	26	30	26
Sodium, mg/L	-	-	200	-
Potassium, mg/L	-	-	-	-
Iron, mg/L	0.3	0.5	0.1	0.5
Manganese, mg/L	0.1	17	0.05	17

The following regression models have been obtained from the results of analysis of water samples. Considering a known value of TDS, the percentage contribution of each ion can be obtained by substituting an average ionic value for the entire study area for pre-monsoon season.

$$Ca^{++} = 0.0368\ TDS + 15.435$$
$$Mg^{++} = 0.0594\ TDS + 19.311$$
$$HCO_3^{-}+CO_3^{--} = 0.1063\ TDS + 157.26$$
$$Cl^{-} = 0.1914\ TDS + 8.6634$$
$$SO_4^{--} = 0.0383\ TDS + 12.902$$

$NO_3^- = 0.0528$ TDS + 32.852
$Na^+ = 0.0378$ TDS + 23.685
Total hardness = 0.9937 (Ca+Mg) Hardness + 1.7501
Conductivity, µmohs/cm = 1.9151 TDS - 2.6814

Table 2. Normal statistics of water quality parameters of groundwater samples.

Parameters	Pre-monsoon samples (2006)							
	Min	Max	AM	SD	CV	Q1	Med	Q3
pH	6.61	8.90	7.5	0.416	5.548	7.42	7.46	7.48
Electrical conductivity µmohs/cm	130	3000	874.3	85.48	81.23	530	760	560
Total dissolved solids	70	1500	453.3	479.5	54.84	280	400	560
Total hardness as $CaCO_3$	70	1060	271.4	129.1	47.55	224	248	272
Bicarbonate	45	550	199.4	47.86	27.77	155	196	226
Chloride	4.9	662.3	105.2	12.68	55.96	49.98	79.98	141.5
Sulphate	1.5	174	29.93	29.65	32.92	12	22.5	35
Phosphate	0.05	5.6	1.49	1.266	85.15	0.6	1.1	1.9
Nitrate	261	0.44	54.3	48.58	144.2	17.72	42.09	69.5
Fluoride	0.02	3.2	1.43	23.26	65.33	1.0	1.5	1.8
Calcium	1.60	174.7	31.21	21.3	68.22	17.64	27.25	38.48
Magnesium	0.24	229.4	47.06	29.2	62.06	29.4	41.8	57.83
Sodium	4	140	29.65	19.95	99.05	27	35	48
Potassium	1	27	3.79	3.229	49.47	2	3	5
Iron	0.1	4.72	1.95	48.58	89.46	1.56	1.9	2.2
Manganese	0.05	5.5	0.76	0.624	43.55	0.2	0.3	0.85

All units except pH and Electrical conductivity are in mg/l, Min-Minimum, Max-Maximum, AM-Arithmetic mean, SD-Standard deviation, CV-Coefficient variation, Q1-Median of the lower half, Q3-Median of the upper half, Med-Median

For computing WQI three steps are followed. In the first step, each of the 19 parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 3). The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment. Magnesium which is given the minimum weight of 1 as magnesium by itself may not be harmful. Other

In the second step, the relative weight (W_i) is computed from t he following equation:

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

Where, W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters. Calculated relative weight (W_i) values of each parameter are also given in Table 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 guidelines laid down in the BIS and the result multiplied by 100:

$$q_i = (C_i / S_i) \times 100 \qquad (2)$$

Table 3. Relative weight of chemical parameters.

Chemical parameters	Indian Standards	Weight (w_i)	Relative weight (W_i)
pH	6.5-8.5	4	0.09756
Total hardness (TH)	300-600	2	0.04878
Calcium	75-200	2	0.04878
Magnesium	30-100	2	0.02439
Bicarbonate	244-732	3	0.07317
Chloride	250-1,000	3	0.07317
Total dissolved solids (TDS)	500-2,000	4	0.09756
Fluoride	1-1.5	4	0.09756
Manganese	0.1-0.3	4	0.09756
Nitrate	45-100	5	0.12195
Iron	0.3-1.0	4	0.09756
Sulphate	200-400	4	0.09756
		$\sum w_i = 41$	$\sum W_i = 1.000$

Groundwater Quality Variation

where q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample in mg/L, and S_i is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the BIS[7] 10500, 1991.

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation

$$SI_i = W_i \cdot q_i \quad (3)$$

$$WQI = \sum SI_i \quad (4)$$

SI_i is the subindex of ith parameter; q_i is the rating based on concentration of ith parameter and n is the number of parameters. The computed WQI values are classified into five types, "excellent water" to "water, unsuitable for drinking".

Electrical conductivity of water is a direct function of its total dissolved salts[9]. Hence it is an index to represent the total concentration of soluble salts in water[10]. In our study area, the electrical conductivity of the groundwater samples varied between 130- 3000 µS/cm during pre-monsoon.

The permissible total dissolved salts for drinking water is 500 mg/L. In the absence of potable water source the permissible limit is upto 2000 mg/L**.** It is found from the analysis, all the well water samples TDS is within the maximum limit of 2000 mg/L in pre-monsoon period. The range of TDS levels in the study area is 70-1500 mg/L. Total 84 samples in pre-monsoon period show TDS value beyond the desirable limit of 500 mg/L**.** The highest concentration of total dissolved solids was found to be 1500mg/L at Devalapura (N 13.4878^0 E 77.10525^0) due to dense residential area and due to intensive irrigation in that area. High values of TDS in groundwater are generally not harmful to human beings but high concentration of these may affect persons, who are suffering from kidney and heart diseases[11]. Water containing high solids may cause laxative or constipation effects[12]**.**

During pre-monsoon season of the year 2006, based on the comparisons of chemical constituents with WHO (1994) standards, it is found that, for 269 water samples, eleven samples have total hardness value above maximum permissible limit of 500 mg/L. Total hardness varies from 70 to 1060 mg/L**.** The hardness values for the study area are found to be high for almost all locations for pre-monsoon and determined to fall above the desirable limit of WHO specification. According to Sawyer and McCarty's classification[13] for hardness, 26 samples fall under the moderately hard class and 242 samples fall under the hard class to very hard class for pre-monsoon water samples.

Chloride is a widely distributed element in all types of rocks in one or the other form. Its affinity towards sodium is high. Therefore, its concentration is high in ground waters, where the temperature is high and rainfall is less. Soil porosity and permeability also has a key role in building up the chlorides concentration[14]. The chloride content in rural part of Tumkur taluk was found to be well within the permissible levels. The chloride content ranges from 5 to 662 mg/L.

In Tumkur taluk, the nitrate value varies from 0.4 to 261 ppm for the pre-monsoon period. For the post-monsoon period, the value varies from 0.39 to 149 ppm. The nitrate value for the study area is found to be more than 45 ppm as per WHO (1994) in 131 locations. More nitrate value is found in the rural part of the study area due to over-application of fertilizer, improper manure management practices, and improper operation and maintenance of septic systems.

In this study, the computed WQI values ranges from 89.21 to 660.56 and therefore, can be categorized into five types "excellent water" to "water unsuitable for drinking". Table 4 shows the percentage of water samples that falls under different quality. The high value of WQI at these stations has been found to be mainly from the higher values of iron, nitrate, total dissolved solids, hardness, fluorides, bicarbonate and manganese in the groundwater.

Table 4. Water quality classification based on WQI value

WQI value	Water quality	Percentage of water samples (Pre-monsoon)
<50	excellent	00
50-100	good water	1.5
100-200	poor water	63.5
200-300	very poor water	22
>300	Water unsuitable for drinking	13.0

The degree of a linear association between any two of the water quality parameters, as measured by the simple correlation coefficient (r), is presented in Table 5. Magnesium and chloride are highly interrelated among themselves. This interrelationship indicates that the hardness of the water is permanent in nature.

Table 5. Correlation coefficient matrix of water quality parameters.

Para-meter	pH	TH	Ca	Mg	HCO_3	Cl	TDS	FL	Mn	NO_3	Fe	SO_4
pH	1											
TH	-0.28	1										
Ca	-0.22	0.356	1									
Mg	-0.21	0.912	-0.06	1								
HCO_3	-0.14	0.479	0.104	0.469	1							
Cl	-0.21	0.767	0.287	0.698	0.015	1						
TDS	-0.23	0.709	0.342	0.61	0.208	0.746	1					
FL	0.111	-0.04	-0.14	0.015	0.085	-0.14	-0.16	1				
Mn	-0.03	-0.08	-0.12	-0.04	0.097	-0.16	-0.07	0.057	1			
NO_3	-0.24	0.181	0.329	0.047	0.096	-0.12	0.144	0.007	0.113	1		
Fe	-0	0.009	-0	0.007	0.043	0.024	-0.01	0.048	0.087	-0.13	1	
SO_4	-0.24	0.364	0.249	0.282	0.269	0.014	0.225	0.059	0.038	0.417	-0.1	1

Conclusions

The WQI for 269 samples ranges from 89.21 to 660.56. Almost ninety nine percent of the samples exceeded 100, the upper limit for drinking water. The high value of WQI at these stations has been found to be mainly from the higher values of iron, nitrate, total dissolved solids, hardness, fluorides, bicarbonate, chloride and manganese in the groundwater. About 63.5% of water samples are poor in quality. In this part, the groundwater quality may improve due to inflow of freshwater of good quality during rainy season. Magnesium and chloride are significantly interrelated and indicates that the hardness of the water is permanent in nature. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination

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