Application of Water Quality Index (WQI) for Assessment of Groundwater Quality in Narasaraopet Mandal of Guntur District, Andhra Pradesh, India

Babu Rao Gudipudi
Associate Professor,
Department of Civil Engineering,
Narasaraopeta Engineering College
(Autonomous), Kotappakonda, Narasaraopet,
Guntur, Andhra Pradesh, India

K. Dinesh Kumar
Assistant Professor,
Department of Civil Engineering,
Narasaraopeta Engineering College
(Autonomous), Kotappakonda, Narasaraopet,
Guntur, Andhra Pradesh, India

M. Srinivasa Rao
Assistant Professor, Department of Civil Engineering,
Narasaraopeta Engineering College (Autonomous),
Kotappakonda, Narasaraopet, Guntur,
Andhra Pradesh, India

***Abstract*— Twenty two groundwater samples were collected from pre-determined locations in Narasaraopet mandal of Guntur District. The samples were analysed for pH, EC, TDS, Ca^{2+}, Mg^{2+}, K^+ Na^+, Cl^-, HCO_3^-, SO_4^{2-}, NO_3^- and F^-. According to Freeze and Cherry, 36% of the total samples fall in brackish type (1000-10000 mg/L) and 64% of the samples fall in very hard categories (< 1000 mg/L) respectively. According to sawyer and Mc Carty (1967) 36 % of the samples fall under hard type (150- 300 mg/L) and 64 % of samples fall under very hard category (>300 mg/L). The concentration of calcium, magnesium, sodium and potassium in the water samples collected varies from 16.0 to 112 mg/L, 15 to 112 mg/L, 60 to 444 mg/L and 3.00 to 89mg/L respectively with an average of 50.64 mg/L, 53.91 mg/L, 173.82 mg/L and 38.23 mg/L respectively. The concentration of chloride, Bi-carbonate, nitrates and fluoride in the study area varies from 78.00 to 421.00 mg/L, 143 to 412 mg/L, 22.00 to 95.00 mg/L and 0.22 to 4.0 mg/L with an average of 177.36 mg/L, 257.27 mg/L, 56.86 mg/L and 1.87 mg/L respectively. The overall water quality index of the study area indicates, about 13.63 % of samples fall in good category and rest of the samples fall in poor category (86.37 %) which indicates groundwater in many locations of the study area is not suitable for drinking and irrigation.**

Keywords*— Water Quality Index, groundwater, Narasaraopet mandal

INTRODUCTION

Groundwater is considered as one of the most vital resource for drinking and irrigation purposes for millions of people in many parts of the world. It is used predominantly because it is believed to be comparatively clean and free from pollution than surface water. Even at conservative estimates, 85% of rural drinking water in India is derived from wells (World Bank, 2010). In India, about 50% of the total irrigated area is dependent on groundwater irrigation and according to FAO groundwater constitutes about 53% of the total irrigation potential of the country and sixty percent of irrigated food production is from Groundwater (FAO, 2017). In addition, an imprudent extraction of the groundwater resources and consecutive droughts in recent years have also led to expedited descend of the groundwater level and deterioration of water quality which has become a strategic issue for a number of countries including India. Most of the aspects of water quantity and quality are closely interlinked. Water quality can vary in importance depending on the actual water quantity and the dilution rate. The quantity and the suitability of groundwater for human consumption and for irrigation are determined by its physical, chemical and bacteriological properties. Suitability of groundwater for drinking, irrigation and other purposes depends upon purely its quality. But degraded ground water cannot be used for bathing, recreation and as a source of raw water supply. The major problem with the ground water is that once contaminated, it is difficult to restore its quality. Water quality monitoring and assessment is the foundation of water quality management; thus, there has been an increasing demand for monitoring water quality of many rivers and ground water by regular measurements of various water quality variables. Hence there is a need and concern for the protection and management of ground water quality. In view of the present context the groundwater quality assessment has been carried out with the help of Water Quality Index (WQI) for Narasaraopet mandal of Guntur District.

STUDY AREA

The study area lies in north eastern part of Guntur district of Andhra Pradesh State. It lies between East latitude and north longitudes: $80^0\ 04^1\ 92.70^{11}$ and $16^0\ 23^1\ 48.80^{11}$ to $80^o\ 02^1\ 57.4^{11}$ and $16^o\ 14^1\ 05.6^{11}$ (Fig.1). The total geographical extent of the study area is 52.80 Sq. km. The population of the study area is 2, 12,000 according to 2011 census. The average annual rainfall is 761mm. The main source of water for irrigation in the study area comes from Nagarjuna Sagar Right Canal. The land use pattern of the study area is agriculture. So there is a chance for application of pesticides and fertilizers to lawns and crops which can have influence on water quality timely. The study area experiences semi-arid climatic conditions. The maximum, minimum and mean temperatures are 45°C, 27°C and 36°C. The highest temperatures are recorded in summer season at Rentachintala were IMR station is present. The relative humidity is with an average of 80%. The prominent wind direction is towards the east, during the south west monsoon and towards west during North West monsoon. The mean wind velocity ranges from 5.7 to 12.9 Km/h with an average of 9.3 Km/h. The wind velocity is maximum during south west monsoon, and minimum in the remaining period. The Average annual rainfall is 761 mm respectively.

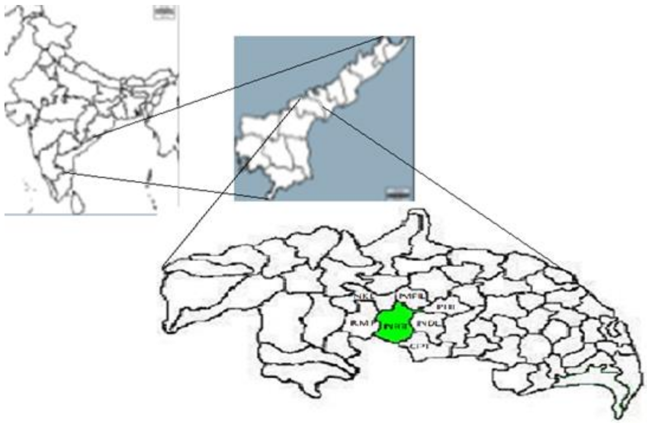

Fig 1 Location map of Narasaraopet Mandal (Shaded part) of Guntur District

METHODOLOGY

Twenty two groundwater samples were collected from bore wells during December, 2018. Each sample was collected in acid-washed polyethylene 500 ml bottle. Before collection of water in a particular bottle, the bottle was rinsed thoroughly with the respective samples of the groundwater. Sample location was written on the bottle and suitable preservatives were added for storage till completion of quantitative chemical analysis. The bottle was filled to the brim with water taking care that no air bubble was trapped within the water sample. In order to prevent evaporation, the bottles were sealed with double plastic caps and precaution was also taken to avoid sample agitation during transfer to the laboratory. Immediately after collection, samples were transferred to the laboratory. pH and electrical conductivity (EC) were measured in situ using portable instruments. Water analyses were carried out by using standard procedures (APHA 2003). Bicarbonate (HCO3-), calcium (Ca^{2+}), magnesium (Mg^{2+}), and chloride (Cl^-) were analysed by titration method. Sulphate (SO_4^{2-}) nitrate (NO_3^-) were determined by using Digital Spectrophotometer (model GS5 700A). Sodium (Na^+) and potassium (K^+) are by flame photometer. The charge balance between cations and anions varies by about 5–10%. Total dissolved solids are calculated by multiplying a ratio between 0.9 and 1.6. The nitrates, sulphates, fluoride can be determined by using spectrophotometer.

RESULTS AND DISCUSSION

The pH in the study area varies from 7.5 to 8.73 with an average of 8.21, indicating an alkaline nature. The EC value ranges from 958 to 2516 µS/cm with an average of 1478.13 µS/cm indicating about 91% of the total samples is within the permissible limit (750-2000) and 9% samples fall in doubtful (2000-3000) categories respectively. TDS value is dependant up on climate, the host rock, and the residence time of the groundwater in the geological matrix. It is higher in arid/desert areas compared to tropical areas. The TDS values are getting enhanced in agricultural arid areas due to cyclic salting process, in which salts are concentrated and precipitated in the soil zone from irrigated water due to high evaporation rates, and then leached from the soil zone by either irrigation or rainwater and percolated, hence reaching the groundwater. In the present study area the TDS varies from 102 to 521 mg/L with an average 348.44 mg/L. According to Freeze and Cherry(1979), 64% of the total samples fall in fresh water category (< 1000 mg/L) and 36% of the samples fall in brackish water categories respectively (1000- 10000 mg/L; Table 1).

TABLE 1Classification of groundwater based on TDS values.

TDS (mg/L)	Nature of sample	Sample number	% of samples
<1000	Fresh water	1,2,3,7,8,11,12,13,14,16,17,18,19,20	64
1000-10,000	Brackish water	4,5,6,9,10,15,21,22	36
10,000-100,000	Saline water	Nil	Nil
>100,000	Brine water	Nil	Nil

Total Hardness is the combination of both calcium and magnesium present in the water. The total hardness of water is not a specific constituent but is a variable and complex mixture of cations and anions. According to Sawyer and Mc Carty (1967) 36 % of the samples fall under hard type (150-300 mg/L) and 64 % of samples fall under very hard category (>300 mg/L: Table 2). This may be due to of agricultural areas where lime and fertilizers are applied to the land; excessive hardness may indicate the presence of other chemicals such as nitrate.

Table 2 Classification of groundwater based on TH (mg/L)

Total Hardness as $CaCo_3$ (mg/L)	Water class	Sample numbers exceeding BIS limits	% of the samples exceeding BIS limits
< 75	Soft	Nil	Nil
75-150	Moderately hard	Nil	Nil
150-300	Hard	1,3,6,8,9,11,12,22	36
>300	Very hard	2,4,5,7,10,13,14,15,16,17, 18,19,20,21	64

Calcium is essential for many body functions and it helps to regulate the heartbeat, sends nerve impulses, helps clot blood, and stimulates hormone secretions. The calcium content in the water samples of the study area varies from 16.0 to 112 mg/L with an average of 50.64 mg/L. Only 13.6% of the samples exceeded the permissible category (75

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mg/L). Magnesium is a mineral that is important for normal bone structure in the body. Low magnesium levels in the body have been linked to diseases such as osteoporosis, high blood pressure, clogged arteries, hereditary heart disease, diabetes, and stroke. The concentration of magnesium in the water samples varies from 15 to 112 mg/L with an average of 53.91 mg/L. About 95 % of the total water samples have exceeded the permissible limit (30 mg/L) prescribed by BIS. Bicarbonate is usually thought to enter the groundwater system as a result of the uptake of CO_2 either from soil zone gases or direct atmospheric inputs (Langmuir, 1971). Additional sources can come from carbonate dissolution. In the present study area its concentration varies from 143 to 412 mg/L with an average of 257.27 mg/L. About 95.5% of the samples exceeded the permissible limit (150 mg/L). Chloride is found naturally in ground water through the weathering and leaching of sedimentary rocks and soils end the dissolution of salt deposits. Chloride is often attached to sodium, in the form of sodium chloride (NaCl). The concentration of chloride in the study area varies from 78.00 to 421.00 mg/L with an average of 177.36 mg/L. Only 9% of the samples exceeded the permissible limit (250 mg/L) prescribed by WHO. Higher concentrations of fluoride in drinking water may cause dental and skeletal fluorosis. The concentration of fluoride in the study area varies from 0.22 to 4 mg/L with an average of 1.87 mg/L. About 63.6% of samples are exceeding the permissible limit prescribed by WHO (1.5 mg/L). 72.7% of samples have exceeded the permissible limit prescribed by BIS (1.0 mg/L). Sulphate ions are essential nutrients for plants, if present in excess may increase the salinity and hardness of water. In the present study, the sulphate concentration ranges from 44 to 367 mg/L with an average of 136.04 mg/L. Only 18 % of samples fall above permissible limit (200 mg/L). Nitrate mostly comes from industrial, agricultural chemicals and fertilizer application. The nitrate concentration in the study area ranges between 22 and 95 mg/L, and average value is 56.86 mg/L. About 59.09% of total samples have exceeded the permissible limit (45 mg/L) suggested by WHO.

WATER QUALITY INDEX (WQI)

A Water quality index (WQI) basically consists of a simpler expression of more or less complex parameters, which serve as water quality measurements. A number, a range, a verbal description, a symbol or a color could be used to represent the index. WQI provides information about water quality in single value. It is commonly used for the detection and evaluation of water pollution and may be defined as a reflection of composite influence of different quality parameters on the overall quality of water (Horton, 1965). Several researchers carried out groundwater quality assessment using WQI in different parts of the world. Rupal et al. 2012 in India; Sarker and Hassan, 2016 in Bangladesh; Brhane, 2016 in Ethiopia and Moghini,2016 in Iran.

CALCULATION OF WATER QUALITY INDEX

The Indian standard specified for drinking water (BIS, 1991) was used for the calculation of WQI. After the analysis of the samples, the WQI was computed through three steps. First, each of the 13 parameters (pH, TDS, Total Hardness, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, F^-, Mg^{2+}, K^+, Na^+) was assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight 5 was assigned to nitrate because of its major importance in water quality assessment; minimum weight 1 was assigned to HCO_3^- because of its insignificant role. Other parameters such as pH, TDS, Total Hardness Cl^-, $SO4^{2-}$, F^-, Ca^{2+}, Mg^{2+}, K^+, and Na^+ were assigned weights between 1and 5 based on their relative significance in water quality evaluation. Second, the relative weight (Wi) of the chemical parameter was computed using the following equation.

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

Where Wi is the relative weight, wi is the weight of the each parameter, and n is the no of parameters.

Table 3 Relative Weight of chemical parameters

Chemical parameter	Indian standards	Weight(wi)	Relative weight(Wi)
pH	6.5-8.5	4	0.117
TDS	500-2000	4	0.117
Total hardness	300-600	2	0.058
Calcium	75-200	2	0.058
magnesium	30-100	2	0.058
Chloride	250-1000	4	0.117
Fluoride	1-1.5	4	0.117
Manganese	0.1-0.3	4	0.117
Nitrate	45-100	5	0.176
Sulphate	200-400	4	0.117
		∑Wi =34	

Calculated relative weight (Wi) values of each parameters are given in the Table 3. In the third step, a quality rating scale (qi) 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:

$$Qi = (Ci / Si) \times 100$$

Where, Qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/L, Si is the Indian drinking water standard for each chemical parameter in mg/L. For computing WQI, sub index (SI) is first determined for each chemical parameter by using the following formulae.

$$SIi = Wi * qi; \; WQI = \sum SI \; i\text{-}n$$

Where, SIi is the sub index of ith parameter, Wi is the relative weight of ith parameter, Qi is the rating based on concentration of ith parameter and n is the number of chemical parameters.

The weighed arithmetic index (WAI) method has been used for the calculation of WQI of the water body. Further, quality rating or sub index (qn) was calculated using the following expression.

$q = 100 [V_n – V_{io}]/[S_n – V_{io}]$

Where, Q_n = quality rating for the nth water quality parameter, V_n = estimated value of nth parameter, S_n = standard permissible value of nth parameter, V_{io} = ideal value of nth parameter in pure water. Unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter.

$W_n = k/S_n$

Where W_n = unit weight for nth parameter, S_n = standard value for nth parameter, K = constant for proportionality. The overall Water Quality Index was calculated by aggregating the quality rating with unit weight linearly (Table 4).

$WQI = \sum q_n W_n / \sum W_n$

Table 4 Classification of Water Quality Index

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

The calculated WQI values ranges from 95.87 to 198.92 with a mean of 130.65. The overall water quality index of the study area indicates, about 13.63 % of samples fall in good category and rest of 86.37 % of samples fall in poor category which indicates water in the study area is not suitable for drinking and irrigation in many locations.

Table 5 WQI values of the samples

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
WQI value	128	123	104	118	164	117	133	99	100	127	96	125	157	122	199	148	126	148	122	128	127	165

CONCLUSIONS

The concentration of calcium, magnesium, sodium and potassium in the water samples collected varies from 16.0 to 112 mg/L, 15 to 112 mg/L, 60 to 444 mg/L and 3.00 to 89mg/L respectively with an average of 50.64 mg/L, 53.91 mg/L, 173.82 mg/L and 38.23 mg/L. The concentration of chloride, Bi-carbonate, nitrates and fluoride in the study area varies from 78.00 to 421.00 mg/L, 143 to 412 mg/L, 22.00 to 95.00 mg/L and 0.22 to 4.0 mg/L with an average of 177.36 mg/L, 257.27 mg/L, 56.86 mg/L and 1.87 mg/L respectively. The overall water quality index of the study area indicates that majority of the samples fall in poor category (86.37 %) and only few samples (13.63 %) fall in good category which indicates groundwater in many locations of the study area is not suitable for drinking and irrigation.

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