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Research Paper

Assessing Groundwater Quality and its Suitability for Drinking and Irrigation Purposes in Kalwakurthy Area, Mahabubnagar District, Andhra Pradesh, India

Chemistry

KEYWORDS : Groundwater Quality, Drinking, Irrigation, Water type

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ABSTRACT

In order to assess the groundwater suitability for drinking and irrigation purposes in parts of Kalwakurthy area Mahabubnagar district, Andhra Pradesh. 56 groundwater samples were collected and analyzed for various parameters. The various parameters were evaluated such as Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Na+, K+, Ca2+, Mg2+, Cl-, HCO3-, CO3-, SO4-, NO3- and Chemical index like Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index (PI) were calculated based on the analytical results. Based on US salinity diagram, 80% of the groundwater samples fall in the C2-S1 water class, indicating medium salinity and low sodium waters. The abundance of the major ions is as follows: CO3 > NO3 > Cl and K > Mg > Ca. These parameters were compared with standard limits and were found to be in limits and suitable for drinking purpose and irrigation purpose.

Introduction

Water quality analysis is one of the most important aspects in groundwater studies. The hydrochemical study reveals quality of water that is suitable for drinking, agriculture and industrial purposes. Further, it is possible to understand the change in (Kelley, 1940; Wilcox, 1948) quality due to rock water interaction or any type of anthropogenic influence. Groundwater is a significant water resource in India for domestic, irrigation, and industrial needs. More than 85% of rural and 50% of urban domestic water requirements are being met from groundwater resources, while irrigation accounts for around 92% of groundwater extraction (Jha, 2007).

Groundwater is a vital natural resource. Depending on its usage and consumption it can be a renewable or a non renewable resource. It is estimated that approximately one third of the world's population use groundwater for drinking purpose (Nickson,; McArthur,; Shrestha,; Kyaw-Nyint,; Lowry, 2005.). In recent times, there has been a tremendous increase in demand for fresh water due to population growth and intense agricultural activities. The hydrogeological factors controlling recharge and hydrogeochemical reactions are so important for the chemical constituents to reach the groundwater uses.

Hydrochemical evaluation of groundwater systems is usually based on the availability of a large amount of information concerning groundwater chemistry (Aghazadeh,; Mogadam,; Hossien, 2004). Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes (Schiavo, Havser, Gusimano, Gatto, 2006; Subramani, Elango, Damodarasamy, 2005). The water resources management has become very important to meet the increased demand for water due to agriculture expansion, growing population and urbanization. The interaction of natural and anthropogenic factors leads to various water types. According to Hamzaoui-Azaza (Hamzaoui-Azaza, Ketata, Bouhlila, Gueddari, Riberio, 2011) the increased knowledge of geochemical evolution of water quality could lead to effective management of water resources.

Location of the Study Area

The study area covering about 60 sq. km falls in Mahabubnagar district of Andhra Pradesh. It is located 80 km from Hyderabad, India on Srisailam highway. It is around 56 km from the District head quarter Mahabubnagar. Kalwakurthy lies in between North Latitudes 16° 34′ 30″ to 16° 42′ 00″ and East longitudes 78° 24′ 00″ to 78° 28′ 48″ (figure 1) and falls in the Toposheet No. 56 L/6 and 56 L/10. Grey granites occupy dominant portion of the study area. These rocks are composed of quartz, feldspar, biotite and hornblende. The climate of the study area is generally hot. Average Temperature in summer is 40.9^{0}C, in winter is 25^{0}C and rainfall is 604 mm.

Geology

Grey granite occupies dominant portion of the area (Fig.2) these rocks are composed of quartz, feldspars, and biotite. These are medium to course grained and equigranular in texture. The typical grey colour is due to the presence of the plagioclase feldspars and quartz. The potash feldspars that are present in the rock are orthoclase and microcline but in less abundance. Biotite is the most predominant mineral in these rocks

Materials and Methods

In order to assess the groundwater quality, 56 groundwater samples have been collected. The water samples collected in the field were analyzed for electrical conductivity (EC), pH, total dissolved solids (TDS), Total Hardness (TH), major cations like calcium, magnesium, sodium, potassium and anions like bicarbonate, carbonate, chloride, nitrate and sulphate, trace element like fluoride in the laboratory using the standard methods given by the American Public Health Association (APPHA, 1995). Sampling was carried out using pre-cleaned polyethylene containers. The results were evaluated in accordance with the drinking water quality standards given by the World Health Organization (WHO, 2004) and Bureau of Indian Standard (BIS, 2009)

The pH was measured with Digital pH Meter (Model 802 Systronics) and Ec was measured with Conductivity Meter (Model

304 Systronics), Sodium and Potassium was measured with Flame photometer (Model Systronics 130). Sulphates and Nitrates were measured with Spectronics 21 (Model BAUSCH & LOMB), Carbonate, Bicarbonate, Calcium, Magnesium, Total Dissolved Solids, Total Hardness, and Chloride by titrimetric methods, Fluoride concentration was measured with Orion ion analyzer with fluoride ion selective electrode. Nitrate was determined by spectrophotometer. The concentration of EC is expressed in microsiemens/cm at 25ºC and TDS, TH, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, $C1^{-}$, SO_4^{-}, NO_3^{-}, CO_3^{-}, HCO_3^{-} and F^{-} are expressed in mg /l. Location map of the water sample is shown in the (Fig. 1).

Results and discussion

Groundwater chemistry

Understanding the groundwater quality is important as it is the main factor determining its suitability for drinking, domestic, agricultural and industrial purposes**.** The chemical composition of groundwater results from the geochemical processes occurring as water reacts with the geologic materials which it flows (Appelo, Postma, 1996)**.** Physical and chemical parameters including statistical measures such as minimum, maximum, mean, Median, Std.Dev are summarized in Table 1. Classification of groundwater on the basis of TDS, TH, EC, SAR, RSC, is shown in Table 2. The water quality analyses included all major anions, cations. The allover groundwater pH and electrical conductivity (EC) values of the study area are range from 7.42 to 8.8 and 78.44 to 1568.8 μS cm, respectively. In the study area, the Na and K concentrations in groundwater range from 17 to 182 and 10 to 47 mg/L, respectively. The concentrations of calcium range from 16.03 to 154.03 mg/L, which is derived from calcium rich minerals like feldspars, pyroxenes and amphiboles. The major source of magnesium (Mg) in the groundwater is due to ion exchange of minerals in rocks and soils by water (Appelo, Postma, 1996). The concentrations of Mg and HCO_3^{-} ions found in the groundwater samples of study area are ranged from 2.91 to 83.83 and 48.8 to 219.6 mg/L respectively.

The concentration of chloride range from 21.3 to 678.05 mg/L. Sulfate range from 4 to 180 mg/L. The nitrate concentration in groundwater samples range from 1.1 mg/L to 112.5 mg/L with an average value of 40.2 mg/L. The source of nitrate in area is N fertilizers (commonly urea, nitrate or ammonium compounds) that are used for agricultural practices. Fluoride is one of main trace elements in groundwater, which generally occurs as a natural constituent. Bedrock containing fluoride minerals is generally responsible for high concentration of this ion in groundwater (Bardsen, 1996; Wenzel, Blum, 1992). The concentration of fluoride in groundwater of the study area varies between 0.17 to 2.57 mg/L. According to BIS (2009) and WHO (2004) standards Total Dissolved Solids (TDS) by 7%, Total Hardness (TH) by 38%, Calcium (Ca) by 7%, Carbonate (CO3) by 89%, Chloride (Cl) by 7%, Magnesium (Mg) by 29%, Potassium (K) by 89%, Nitrate (NO_3) by 38%, Fluoride (F) by 44% exceed the permissible limit.

Gibbs Diagram

For determining hydrochemical constituents and their relationship to respective aquifers such as chemistry of the rock types, chemistry of precipitated water, and rate of evaporation, Gibbs (Gibbs, 1970) has suggested a diagram in which ratio of dominant anions and cations are plotted against the value of TDS. Gibbs diagrams, representing the ratio 1 for cations $[(Na^+ + K^+)/(Na^+ + K^+ + Ca^{2+})]$ and ratio 2 for anions $[Cl^-/ Cl^- + HCO_3^-]$ as a function of TDS are widely employed to assess the functional sources of dissolved chemical constituents, such as precipitation, rock, and evaporation dominance. The chemical data of groundwater samples are plotted in the Gibbs diagram (see Fig. 3a and b). The Gibbs plot of data from study area indicates that rock is the dominant processes controlling the major ion composition of groundwater.

Drinking and Irrigation Water Quality

Total Dissolved Solids (TDS) and Total Hardness (TH)

In natural water, dissolved solids consists mainly of inorganic salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter and dissolved gases. To ascertain the suitability of groundwater of domestic and irrigation purposes, it is essential to classify the groundwater depending upon their hydrochemical properties based on their TDS values (Davis, De Wiest, Wiley 1966) which are presented in Tables 3. The TDS of the water samples ranges from 50.2 to 1004 mg/L. According to the WHO and BIS specification, TDS up to 500 mg/L is desirable for drinking water. The study shows that 85% of the sample is below desirable limit of TDS which can be used for drinking without any risk, 7% of the samples belong to maximum permissible category and remaining 9% of samples are useful for irrigation and unfit for drinking, which is shown in Table 3.

According to BIS specification TH up to 200 mg/L. The hardness values range from 75 to 560 mg/L during June 2011. The classification of groundwater based on total hardness (Sawyer, McCarty, 1967) shows that 20% of the groundwater samples fall in the very hard water category, 48% hard category and remaining samples fall in moderately hard category (Table 2).

Electrical Conductivity (EC)

Electrical Conductivity is a good measure of salinity hazard to crops as it reflects the TDS in groundwater. The US Salinity Laboratory classified Groundwaters on the basis of electrical conductivity (Table 2). Based on this classification, 42% samples are belonging to the excellent category, 51% good category, 7% permissible category. Salinity and indices such as, sodium absorption ratio (SAR), sodium percentage (Na %), residual sodium carbonate (RSC), and permeability index (PI), Chloro Alkaline Indices (CAI), Kelly's Ratio (KR) are important parameters for determining the suitability of groundwater for agricultural uses (Srinivasa Gowd, 2005)

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio (SAR) is an important parameter for determining the suitability of groundwater for irrigation because it is a measure of alkali/sodium hazard to crops, SAR is defined by Karanth (Karanth, 1987) as Equation (1)

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}} \text{ -------- } (1)$$

Where all ionic concentrations are expressed in meq/l. The SAR values range from 0.63 to 3.6 and according to the Richards (Richards, 1954) classification based on SAR values (Table 2), all of samples are belong to the excellent category. SAR can indicate the degree to which irrigation water tends to enter into cation-exchange reactions in soil. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure and becomes compact and impervious (Raju, 2006). The analytical data plotted on the US salinity diagram (Figure 4) (USDA, 1954) illustrates that 80% of the groundwater samples fall in the field of C2-S1, indicating medium salinity and low sodium water, which can be used for irrigation on all types of soil without danger of exchangeable sodium.

Residual Sodium Carbonate (RSC)

If water contains carbonate and bicarbonate in excess of calcium and magnesium, then it is likely to perceptible calcium displayed by exchange reactions. The result is an increase in sodium hazard of water. This excess quantity of carbonate and bicarbonate is denoted by Residual Sodium Carbonate and is determined by the formula (3) as below (Eaton, 1950)

$$RSC = (CO_3 + HCO_3 - (Ca + Mg)) \text{ ------ } (3)$$

Where all ionic concentrations are expressed in meq/L. The classification of irrigation water according to the RSC values (Table 2) is waters containing more than 2.5 meq/L of RSC are not suitable for irrigation. Groundwater of the study area is classified on the basis of RSC and is presented in Table 3. The RSC values varied from -6.91 to 0.19 meq/L. it is observed that 100 % of groundwater of the area values less than 1.25 meq/L, considered safe for irrigation.

Permeability Index (PI)

The Permeability Index (PI) values also depicts suitability of groundwater for irrigation purposes, since long-term use of irrigation water can affect the soil permeability, influenced by the Na^+, Ca^{2+}, Mg^{2+} and HCO_3^- contents of the soil. The PI can be expressed as

$$PI = \frac{(Na+K)+\sqrt{HCO_3}}{Ca+Mg+Na+K} x100 \text{ ----- } (4)$$

The concentrations are reported in meq/l. (Doneen, 1964) developed a criterion for assessing the suitability of water for irrigation based on PI, where waters can be classified as classes I, II, and III. The PI of the area varied from 28.01 to 86.81 and the average value is 60.22. According to PI values, 7% groundwater samples had fallen in class I, 82% in class II and 11% in class III of the Doneen's chart [35] which is shown in (Figure 5).

Conclusions

Hydrochemical study reveals that the groundwater in the study area is fresh, hard to very hard. The suitability of water for irrigation was assessed on the basis of SAR and shows that all of the groundwater in Kalwakurthy area is classified as excellent for irrigation. The analytical data plotted on the US salinity diagram illustrates that 80% of the groundwater samples fall in the field of C2-S1, indicating medium salinity and low sodium water. Based on the classification of irrigation water according to the RSC values, all of groundwater samples belongs to the good category. According to PI values the groundwater in study area is suitable for irrigation purposes. Assessment of water samples from various methods indicated that groundwater in study area is chemically suitable for drinking and agricultural uses.

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Table 1 Statistical Summary of the Chemical Composition of Groundwater

Parameter	Minimum	Maximum	Mean	Median	Std.Dev	Acceptable Limit(WHO,2004) (BIS, 2009)	% of samples exceeding the limit
pH	7.42	8.8	8.04	8.1	0.29	6.5-8.5	5
EC	78.44	1569	387.88	314	272.86	1500	4
TDS	50.2	1004.03	248.2	201	174.57	500	5
CO_3^-	0	15	7.411	6	3.46	10	89
HCO_3^-	48.8	219.6	122.35	122	38.81	500	Nil
Cl^-	21.3	678.05	123.75	56.85	135.62	250	7
TH	75	560	206	172	104.28	200	39
Ca^{++}	16.03	154.03	41.232	32.000	26.535	75	5
Mg^{++}	2.91	83.83	26.326	23.000	17.107	30	29
Na^+	17	182	55.589	44.500	35.608	250	Nil
K^+	10	47	15.161	14.000	6.771	10	89
SO_4^-	4	180	29.705	20.000	33.83	200	Nil
NO_3^-	1.1	112	39.63	28	31.84	45	43
F^-	0.17	2.57	1.13	0.94	0.66	1	46

Table 2 Classification of Groundwater for Drinking, Irrigation Suitability and % of Samples Falling in Various Categories.

Category	Ranges	Percent of the samples
Based on TDS(mg/L)		
Desirable for drinking	<500	85
Permissible for Drinking	500–1,000	07
Useful for irrigation	1,000–3,000	08
Unfit for drinking and irrigation	>3,000	00
Based on Total Hardness (mg/L)		
Soft	<75	00
Moderately Hard	75-150	00
Hard	150-300	48
Very Hard	>300	20
Based on EC (µS/cm)		
Excellent	<250	41
Good	250-750	51
Permissible	750-2250	7
Doubtful	2,000–3,000	00
Unsuitable	>3,000	00
Based on Alkalinity Hazard(SAR) (Richards 1954)		
Excellent	<10	100
Good	10-18	00
Doubtful	18-26	00
Unsuitable	>26	00
Residual Sodium Carbonates (Richards 1954)		
Safe for irrigation	<1.25	100
Moderate for irrigation	1.25-2.5	00
Unsuitable for irrigation	>2.5	00

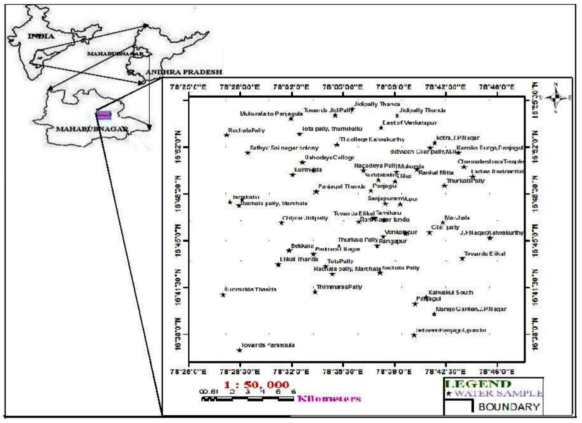

Fig. 1 Location Map of the Study Area with Water Samples

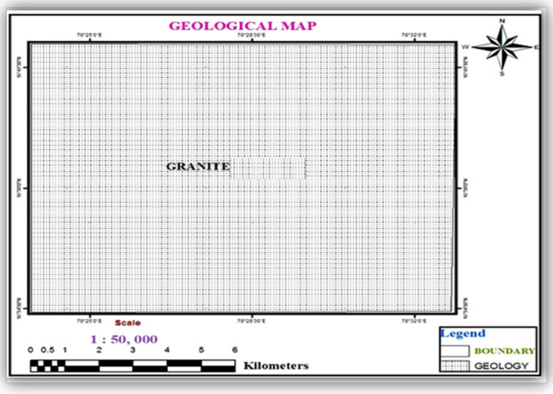

Figure. 2 Geological Map of the study

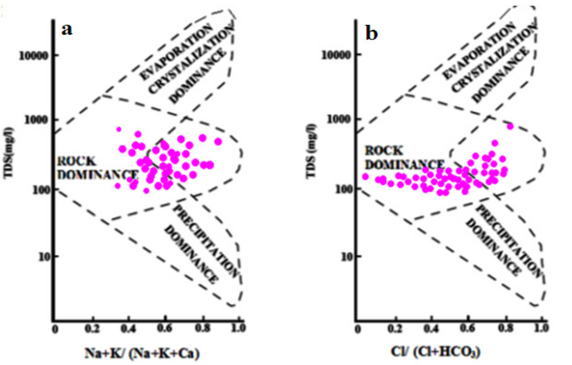

Fig. 3 Gibbs Diagram Showing TDS vs. (a) [($Na^+ + K^+$)/ ($Na^+ + K^+ + Ca^{2+}$)], and (b) [Cl^-/ (Cl^-+ HCO_3)]

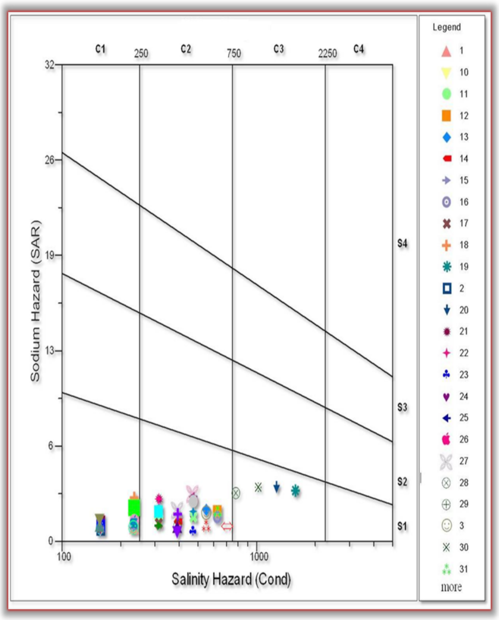

Fig. 4 Rating of Groundwater Samples in Relation To Salinity and Sodium Hazard

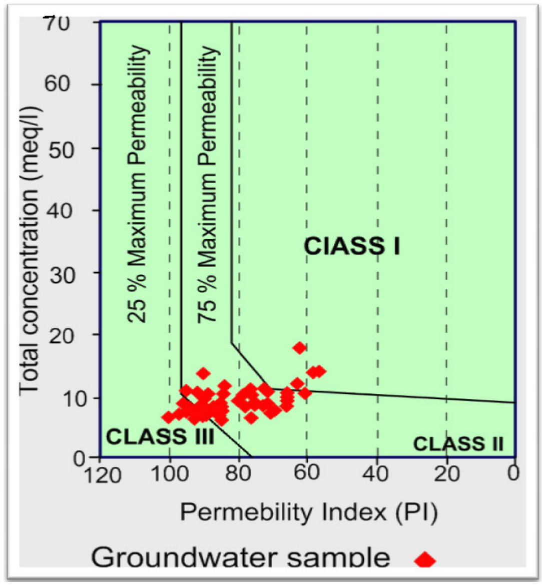

Fig. 5 Doneen Classification (1964) of Irrigation Water Based on The Permeability Index of Study Area.

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