Hydro Geochemical Processes in the Groundwater Environment of Vemula area, Kadapa District, South India

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Research Article

Abstract: Groundwater is the most precious gift of nature to living beings, particularly to the mankind and is essential for life. In recent years, rapid development has created an increased demand for drinking water, which is increasingly being fulfilled by groundwater abstraction. Groundwater constitutes one of the principal sources of fresh water. Hence it assumes enormous importance in domestic as well as Industrial activities. In view of the groundwater being used for potable purpose, its quality remains one of the issues of concern. The present study was undertaken to assess major ion chemistry of ground water to understand geochemical evolution of groundwater and water quality for promoting sustainable development and effective management of groundwater resources. Sampling procedures and chemical analysis were carried out as per the standard methods. A total of 19 water samples were collected and the water chemistry of various parameters viz. pH, EC, Total Hardness (TH), Total Dissolved Solids (TDS), calcium (Ca^{++}), sodium (Na^{+}), potassium (K^{+}), carbonate (CO_3^{-}), bicarbonate (HCO_3^{-}), chloride (Cl^{-}), nitrate (NO_3^{-}), and fluoride (F^{-}) are carried out. A comparison of groundwater quality in relation to drinking water quality standards revealed that most of the samples are suitable for drinking purpose.

***Key Words*:** Hydrochemistry, groundwater quality, Vemula area, A.P. India

Introduction:

Quality drinking water is essential for life. Groundwater is almost globally important for human consumption as well as for the support of habitat and for maintaining the quality of base flow to rivers, while its quality assessment is essential to ensure sustainable safe use of the resources for drinking, agricultural, and industrial purposes. The drastic increase in population, urbanization and modern land use applications and demands for water supply has limited the globally essential groundwater resources in terms of both its quality and quantity. Because, quality is a function of the physical, chemical and biological parameters, and can be subjective, since it depends on a specific intended use (Tatawat and Chandel, 2008, Ravikumar P. and R. K. Somashekar, 2011) and is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices. The chemical character of any groundwater determines its quality and utilization.

Naturally, ground water contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer; they are referred to as dissolved solids. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer. The quality of ground water depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region (Aher K.R.,2012). Water quality may be related to the suitability of water for a particular use or purpose. The quality of water is characterized by a range of physical, chemical and biological parameters, which arise from a variety of natural and human influences. Considering this aspect the present study assesses the quality of groundwater, which is the main source of drinking water.

Location of the Study area

Vemula area of Kadapa district is one of the chronically drought affected mandal of Rayalseema region of Andhra Pradesh and lies between Lat, 14^{o} 19' 00''-14^{o} 21' 00'' N; Long. 78^{o} 22' 30'' E, and is covered in part of the Survey of India Toposheet No.57J/7. The study area is about 65 Kms away from the district headquarter Kadapa and 15 Kms from Pulivendla.

Geology and Hydrogeology

The study area forms part of the Lower Cuddapah super group comprising Papaghni and Chitravati groups (Nagaraja Rao *et al.,* 1987). The study area mostly consists of conglomerates, shales, basalts, dolomites, limestones and dolomitic limestones, the basaltic hills generally flat-topped and are bald at some places. The soil types of study area are black cotton, alluvial, brown and mixed soils. Groundwater occurs in the weathered residuum under unconfined conditions as well as in the fractured rocks under semi confined conditions. Drainage pattern of study is dendritic to sub-dendritic. The region falls under semi-arid or even arid belt with associated high temperatures and hence is classified as drought prone area. The average annual rainfall is 600- 650 mm and the average temperature varies from 20.4^{o}C in the month of December to 43.2 ^{o}C in the month of April. The area also experiences the effect of S-W and N-E monsoons. In study area, rainfall is the main source of groundwater recharge and this water is the only source for drinking and irrigation purpose. The main crops of the area are ground nuts, sunflower, leman gardens, jowar, and vegetables.

Materials and Methods:

In order to assess the physico-chemical parameters, a total of 19 ground water samples from borewells were collected in good quality polyethylene bottles of one-liter capacity and prior to sampling all the sampling containers were washed and rinsed with the groundwater. The chemical parameters viz. pH and electrical conductivity (EC) were measured, using digital instruments immediately after sampling. The groundwater sampled bottles were labeled, tightly packed, transported immediately to the laboratory for further analysis.

The collected groundwater samples were analyzed for total hardness (TH), calcium (Ca^{++}), sodium (Na^{+}), potassium (K^{+}), carbonate (CO_3^{-}), bicarbonate (HCO_3^{-}), chloride (Cl^{-}), nitrate (NO_3^{-}), and fluoride (F^{-}) following the standard water quality methods (Table 3). The evaluation of chemical characteristics of groundwater and suitability of groundwater quality was for drinking purposes. Total dissolved solids (TDS) and magnesium (Mg^{++}) were calculated, using the values of EC, TH, and Ca^{++} respectively. The chemical characteristics were determined immediately in the lab as per the standard methods for examination of water and wastewater (APHA, 1992) and all results are compared with standard limit recommended by the Indian Standard Specification for drinking water (ISI,1983) and world health organization (WHO,1984).

Results and Discussions:

Hydrogeochemistry of Groundwater

Understanding the quality of groundwater is important as its quality because it is the main factor determining its suitability for domestic, drinking, agricultural and industrial purposes. The results of the physicochemical analysis are presented in table 1 and table 2 shows the comparison of the quality parameters of groundwater with WHO and ISI for drinking purpose.

pH

The pH indicates the strength of the water to react with the acidic or alkaline material present in the water. It controls by carbon dioxide, carbonate and bicarbonate equilibrium. The combination of CO_2 with water forms carbonic acid, which affects the pH of the water. The pH values of the groundwater vary between 6.3 and 8.6, indicating slightly alkaline to alkaline nature (Table,1).

Electrical Conductivity (EC)

The EC is a measure of a material's ability to conduct an electric current so that the higher EC indicates the enrichment of salts in the groundwater. Electrical conductivity in groundwater varies from 495 to 1384 uS/cm (Table 1) where as permissible limit is <1500 uS/cm for domestic use indicating that the all the values are within permissible limit. Conductivity values are divided in to the three groups from general experience (Plummer *et al*, 2003) (Table,4).

Total Dissolved Solids (TDS)

The total dissolved solids (TDS) are the concentrations of all dissolved minerals in water indicate the general nature of salinity of water. The total dissolved solids in all the study area varies from 310 mg/L to 725 mg/L (Table,1).

Table 3 Instrumental and volumetric methods used for chemical analysis

Parameter	Units	Methods, Instrument	Reference
pH	-	pH meter	APHA (1992)
EC	uS/cm	EC meter	APHA (1992)
TDS	mg/L	EC x conversion factor	Hem (1991)
TH	mg/L	Volumetric	APHA (1992)
Ca^{++}	mg/L	Volumetric	APHA (1992)
Mg^{++}	mg/L	Calculation (TH-Ca)	APHA (1992)
Na^{+}	mg/L	Flame Photometer	APHA (1992)
K^{+}	mg/L	Flame Photometer	APHA (1992)
HCO_3^-	mg/L	Volumetric	APHA (1992)
CO_3^-	mg/L	Volumetric	APHA (1992)
Cl^-	mg/L	Argentometric	APHA (1992)
NO_3^-	mg/L	Spectrophotometer	APHA (1992)
F^-	mg/L	Spectrophotometer	APHA (1992)

Table.4 Classification of groundwater from conductivity values.

Conductivity range uS/cm	Classification	No. of sample	Percentage of samples
< 1500	Permissible	All	100
1500-3000	Not permissible	-	-
> 3000	Hazardous	-	-

Degree of groundwater quality can be classified as fresh, if the TDS is less than 1,000 mg/L; brackish, if the TDS is between 1,000 and 10,000 mg/L; saline; if the TDS is varied from 10,000 to 1,000,000 mg/L; and brine, if the TDS is more than 1,000,000 mg/L (Todd,1980). Accordingly, the quality of groundwater in the present study area is classified as fresh (Table 1). Generally, the higher TDS decreases palatability, and causes gastrointestinal irritation in the consumers. It has also laxative effect, especially upon transits. But, the prolonged intake of water with the higher TDS can cause kidney stones, which are widely reported from different parts of the country (Garg *et al*, 2009, Subba Rao *et al*, 2011).

Total Hardness (TH)

Hardness is an important criterion for determining the usability of water for drinking as well as for other domestic supplies, as it causes unpleasant taste and reduces ability of soap to produce lather. The concentration of Total Hardness varies from 190 to 569 mg/L. The TH can be classified as soft, if the TH is less than 75 mg/L; moderately hard, if the TH is varied from 75 to 150 mg/L; hard, if the TH is between 150 and 300 mg/L; and very hard, if the TH is more than 300 mg/L (Davis and Dewiest, 1966). According to the classification of TH, approximately 32% of the groundwater samples (5, 7, 8, 11, 13 and 14) falls under the hard category and the remaining 68% of the groundwater samples (1, 2, 3, 4, 6, 9, 10, 12, 15, 16, 17, 18 and 19) falls in the very hard category (Table,5).

Sodium (Na^+)

Sodium is the sixth most abundant element in The Earth's crust and sodium stems from rocks and soils. Not only seas, but also rivers and lakes contain significant amounts of sodium. Concentrations however are much lower, depending on geological conditions and waste water contamination sodium compounds serve many different industrial purposes, and may also end up in water from industries. The concentration of sodium is varied from 8 to 124 mg/L (Table,1). All samples are within the maximum permissible limit. (Table,2) prescribed by WHO (1984) and ISI (1983).

Potassium (K^+)

The concentration of potassium is varied from 1 to 22 mg/L (Table,1). Potassium is an essential element for humans, plants and animals, and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The European Economic Community (EEC,1980) has prescribed the guideline level of potassium at 10 mg/l in drinking water. As per European Economic Community (EEC,1980) criteria, 10.52 % samples exceeding maximum permissible limit while 89.47 % samples of the study area fall within the guideline level of 10 mg/l.

Table 5 Classification of groundwater on the basis of Total Hardness

Hardness mg/L	Water class	No. of sample	Percentage
0 – 75	Soft	-	-
75– 150	Moderately hard	-	-
150– 300	Hard	6	32
> 300	Very hard	13	68

Table 1. Analytical results of groundwater samples in Vemula area

Sample No	pH	EC (uS/cm)	TH mg/L	TDS mg/L	Na^+ mg/L	K^+ mg/L	Ca^{++} mg/L	Mg^{++} mg/L	CO_3^- mg/L	HCO_3^- mg/L	Cl^- mg/L	NO_3^- mg/L	F^- mg/L
1	7.9	1168	554	710	32	3.4	125	67	5	419	98	20	0.49
2	6.9	610	371	725	74	2	62	19	8	369	19	25	0.75
3	8.0	610	362	505	8	1	84	15	2	264	25	15	0.30
4	7.5	847	410	694	41	4.8	150	35	10	311	39	35	0.70
5	6.3	713	298	333	22	2	90	19	5	173	30	45	0.89
6	8.2	810	320	539	32	4	148	21	3	400	22	22	0.52
7	6.4	750	278	400	42	2.4	85	10	4	225	21	35	0.95
8	6.8	495	225	310	16	2	54	8	8	102	18	10	0.75
9	7.2	790	328	498	20	4	112	22	3	248	15	65	0.87
10	7.8	1123	505	619	69	22	125	39	5	423	88	17	0.49
11	7.1	732	286	410	30	3.8	79	34	4	320	50	19	0.50
12	7.7	1067	395	600	100	3	80	56	6	233	200	100	0.46
13	8.2	750	300	405	40	1.9	74	21	3	289	79	60	0.36
14	7.9	696	190	500	110	12	55	10	6	174	35	29	2.00
15	7.6	885	530	622	20	7	69	64	3	420	123	26	1.20
16	7.9	916	376	565	35	4	138	20	7	342	66	26	0.32
17	7.8	709	312	465	20	4	61	32	6	250	16	12	2.20
18	7.1	782	448	510	17	1	82	75	2	361	158	20	0.43
19	8.6	1384	569	724	124	8	98	29	12	333	159	29	0.40

Table 2. Comparison of the quality parameters of groundwater with WHO and ISI for drinking purpose.

Sr.No.	Water Quality parameters	WHO(1984) Highest Desirable	Maximum Permissible	ISI (1983) Highest Desirable	Maximum Permissible	Concentration in the Study area
1	pH	7.0 to 8.5	6.5 to 9.2	6.5 to 8.5	No relaxation	6.3 to 8.6
2	TDS	500	1500	500	2000	310 to 725
3	TH	100	500	300	600	190 to 569
4	Na^+	-	200	-	200	8 to 124
5	Ca^{++}	75	200	75	200	54 to 150
6	Mg^{++}	30	150	30	100	8 to 75
7	Cl^-	200	600	250	1000	15 to 200
8	F^-	0.6 to 0.9	0.8 to1.7	1.0	1.5	0.30 to 2.20
9	NO_3^-	45	45	45	100	10 to 100

Calcium (Ca^{++})

The calcium is an important element to develop proper bone growth. The concentration of calcium observed from the study area is varied from 54 to 150 mg/L, which is below the standard limit of 75 mg/L indicating that all samples are within the maximum permissible limit. (Table,2) prescribed by WHO (1984) and ISI (1983).

Magnesium (Mg^{++})

The concentration of Mg^{++}, ranging from 8 to 75 mg/L, and all samples are within the maximum permissible limit (Table,2) prescribed by WHO (1984) and ISI (1983). Although, Mg^{++} is an essential ion for functioning of cells in enzyme activation, but at higher concentration, it is considered as laxative agent (Garg *et al,* 2009).

Chloride (Cl^-)

The concentration of Chloride in the study area varies from 15 to 200 mg/L and all samples are within the permissible limit given by WHO (1984) and ISI (1983). Generally, chloride is considered as the important inorganic ions, which deteriorate the quality of drinking water at larger extent. For example, the Cl^- plays an important role in balancing level of electrolytes in blood plasma, but higher concentration can develop hypertension, risk of stroke, left ventricular hypertrophy, osteoporosis, rental stones, and asthma (McCarthy, 2004).

Carbonate (CO_3^-) and Bicarbonate alkalinity (HCO_3^-)

Alkalinity is the measure of the capacity of the water to neutralize a strong acid. The Alkalinity in the water is generally imparted by the salts of carbonates, silicates, etc. together with the hydroxyl ions in free State. The carbonate alkalinity varies from 2 to 12 mg/L and the bicarbonate alkalinity varies from 102 to 423 mg/L (Table, 1) indicating that all the samples are within the maximum permissible limit of WHO (1984). Bicarbonate is a major element in human body, which is necessary for digestion. When ingested, for example, with mineral water, it helps buffer lactic acid generated during exercise and also reduces acidity of dietary components. It has a prevention effect on dental cavities (Subba Rao *et al*, 2011).

Fluoride (F^-)

The concentration of F^- in study area ranges from 0.30 to 2.20 mg/L and only two samples (10.52 %) exceeds the maximum permissible limit prescribed by WHO (1984) (Table,1). This may be attributed to the presence of either fluorine bearing minerals or may be due to leaching of F^- from weathered material like soil alluvium. The F^- concentration in groundwater depends upon the degree of weathering and leaching of fluoride from rocks and soils (Ramesam and Rajagopalan, 1985; Shivanna and Mohokar, 2003; Madhnure *et al*., 2007). Raja Reddy (1979) has stated that the higher intake of F^- may change the metabolic activities of soft tissues (thyroid, reproductive organs, brain, liver, and kidney). Chlubek *et al*. (1998) have reported that the F^- concentration in marginal part of placenta in women has high plasma F^- concentration.

Nitrate (NO_3^-)

Nitrogen is an essential input for the sustainability of agriculture (Lake *et al*, 2003, Schroder *et al*, 2004). However, nitrate contamination of groundwater is a worldwide problem (Saadi and Maslouhi, 2003; Liu *et al*, 2005). Nitrate is soluble and negatively charged and thus has a high mobility and potential for loss from the unsaturated zone by leaching (DeSimone and Howes, 1998; Chowdary *et al,* 2005). Higher concentration of NO_3^- in groundwater is an anthropogenic pollutant contributed by nitrogenous fertilizers, human and animal wastes through biochemical activity of nitrifying bacteria. Nitrate has been linked to agricultural activities due to excessive use of nitrate fertilizers (Harter *et al*, 2002**;** Shrestha and Ladha, 2002; Jordan and Smith, 2005; Dunn et al., 2005; Liu *et al,* 2005, Janardhana *et al*, 2009., Chandra Sekhar and Ramana Reddy, 2011). The NO_3^- is a non-lithological source. In natural conditions, the concentration of NO_3^- does not exceed 10 mg/L in the water (Cushing *et al*, 1973) so that the higher concentration of NO_3^-, beyond the 10 mg/L, is an indication of anthropogenic pollution. The nitrate in the study area varies from 10 mg/L to 100 mg/L (Table,1) and three samples (15.78%) exceeded the permissible limit (>45) prescribed by WHO (1984). It is mainly due to influences of poor sanitary conditions (Subba Rao *et al*, 2011) and indiscriminate use of higher fertilizers for higher crop yields in the study area. Nitrogen in groundwater is mainly derived from organic industrial effluents, fertilizer or nitrogen fixing bacteria, leaching of animal dung, sewage and septic tanks through soil and water matrix to groundwater (Richard, 1954). It causes blue baby syndrome called methemoglobinemia, which is an often fatal disease in infants of less than 4 months old (Bouwer,1978).

Conclusions:

The groundwater sources in the Vemula area of Kadapa district have been evaluated for their chemical composition and suitability for drinking purpose. Hydro chemical parameters of the study area are compared with WHO and ISI standard reveals that groundwater of study area is suitable for drinking purposes. The high values of NO_3^- in three water sample are might be excessive use of nitrate fertilizers in agriculture. These three waters are unsuitable for drinking purpose. With regard to the nitrate problem in ground waters the best suggestion to avoid health risks is to have wells checked frequently and to reduce the fertilization of fields. In the areas where the nitrate concentration is known to be high the public should be educated about the potential danger of using the water for feeding/drinking. The high F^- concentration in two groundwater samples may be attributed to the presence of either fluorine bearing minerals or may be due to leaching of F^- from weathered material like soil alluvium and overall the most of the samples are suitable for drinking purpose.

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