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Assessment of Groundwater Quality in Parts of Kadapa and Anantapur Districts, Andhra Pradesh, India

V. Sunitha[1]*, J. Abdullah Khan[1], B. Muralidhara Reddy[1], M. Prasad[2], M. Ramakrishna Reddy[2]

[1]Department of Geology, Yogi Vemana University, Kadapa, Andhra Pradesh, India. [2]Department of Earth Sciences, Yogi Vemana University, Kadapa, Andhra Pradesh, India.

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ABSTRACT

Groundwater is a significant water resource in India for domestic, irrigation, and industrial needs. The use of groundwater has increased significantly in the last decades due to its widespread occurrence and overall good quality. The contribution from groundwater is vital; because about two billion people depend directly upon aquifers for drinking water, and 40% of the world's food is produced by irrigated agriculture that relies largely on groundwater. Despite its importance, contamination from natural, human activities, steady increase in demand for water due to rising population and per capita use, increasing need for irrigation, changes in climates and overexploitation has affected the use of groundwater as source of drinking water. The main objective of this study is to assess the groundwater quality in parts of Kadapa and Anantapur districts. The study area is located in the Survey of India toposheets Number 57 J/3 lying between East 78°00'0" and 78°15'0" longitudes and 14°15'0" to 14°30'0" North latitudes covering an area of 720 km^2. Geologically, it is underlain mainly by Peninsular gneisses of Archean age, followed by Gulcheru and Vemapalli formations comprising quartzites, conglomerates, dolomites and shales. Major geomorphic units are denudational hills, residual hills, pediments, pediplains, structural hills and valleys. 20 drinking water samples collected from parts of Kadapa, Anantapur district, Andhra Pradesh, India were analyzed for fluoride contamination, besides water quality parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium, chloride. The groundwater of the study area is mainly alkaline in nature. The EC of the samples ranged from 320 to 660 mg/L. TDS range from 205 to 402 mg/L. The TH values range from 60 to 180 mg/L. Calcium (Ca^{2+}) in the groundwater varies 28-144 mg/L. Chloride values range from 18 to 168 mg/L. The chlorides of the samples were well with-in the prescribed standards for drinking water. The fluoride concentration was ranged from 0.1 to 6.7 mg/L with highest fluoride level at Kotareddipalli (3.8 mg/L) and lowest at Kottala (0.2 mg/L). Most of the parameters analyzed were within the permissible limits of both standards except fluoride. Due to the higher fluoride level in drinking water several cases of dental fluorosis were appearing at alarming rate in this region. It is inferred from the study that these water sources can be used for potable purpose only after prior treatment.

Key words: *Groundwater quality, Groundwater, Kadapa, Anantapur, Dental fluorosis, Andhra Pradesh, India.*

1. INTRODUCTION

Accessibility to a safe and reliable source of water is essential for sustainable development. The reliability of the water for various purposes depends on the chemical and physical quality of water. Groundwater chemistry is mainly controlled by natural as well as anthropogenic factors. Chemical composition of geologic formations affects the hydrochemical characteristics of groundwater during their circulation in the subsurface [1]. This underground passage through the pore spaces and weathered zones may alter the natural composition of the groundwater by the action of various hydrochemical processes [2]. Groundwater chemistry can be modified by a variety of anthropogenic sources [3]. These include point sources, such as waste disposal facilities, industrial pollution, wastewater treatment works, on-site sanitation, cemeteries, and many others [4]. Systematic assessment of the physicochemical parameters, their sources, and controlling hydrochemical processes are essential in maintaining the sustainable ecosystem. Water is the most valuable and vital resource for sustenance of life and also for any developmental activity. With the surface water sources dwindling to meet the various demands, groundwater has become the only reliable resource. The indiscriminate

*Corresponding Author:
E-mail: vangala_sunitha@yahoo.com,
Tel.: 08562-225444, Phone: +91-9441117475,
Fax: 08562 225499

use of this vital natural resource is creating groundwater - mining problem in various parts of the world [5]. The chemical composition of groundwater is one of the prime factors on which the suitability of water for domestic, industrial or agricultural purpose is determined. However, in the era of economic growth, groundwater is getting polluted due to urbanization and industrialization. Hence, the groundwater resource should be evaluated thoroughly, carefully and reliably on a real time basis to meet the ever growing needs. Groundwater is a natural resource for the economic and secure provision of drinking water, which plays a fundamental role in human well-being. However, the pressure on groundwater, in terms of both quantity and quality, has increased to an extent whereby not only drinking water sources but also sensitive ecosystems are threatened by contamination through human exploitation. It is a well-known fact that a polluted environment has a detrimental effect on health of people, animal life, and vegetation. Groundwater is extensively used for domestic, industrial and irrigation purposes. Water quality analysis is one of the most important issues in groundwater studies. Its monitoring and assessment is imperative for devising preventive measures against health hazards [6]. Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes. Variation of groundwater quality in the area is a function of physical and chemical parameters that are generally influenced by geological formations and anthropogenic activities [7]. The hydrogeochemical study reveals the zones and quality of water that is suitable for drinking, agricultural and industrial purposes [8]. The chemical quality of groundwater is related to the lithology of the area and the residence time of the water in contact with rock material. Weathered mantle, soils, and atmosphere are the important factors responsible for contribution of dissolved solids to water. It is impossible to control the dissolution of undesirable constituents in the waters after they enter the ground. The main objective of this study is to assess the groundwater quality in parts of Kadapa and Anantapur districts.

2. STUDY AREA

The study area lies between Pulivendula and Sanivaripalli situated between parallels of 78°00’0” to 78°15’0” E longitude and 14°15’0” to 14°30’0” N latitude with intended boundary falling in Survey of India (SOI) topographic sheet #57J/03 on 1:50,000 scale covering an area of 720 km^2. Study area location map is shown in Figure 1. The study area includes five revenue mandals namely, Pulivendula, Lingala, Udumakurti, Krishnamgaripalli, and Sanivaripalli and is shown in Figure 1. The central and southern part of study area is occupied by high hills, ridges, and valleys. The value of contours in the study area ranges from 200 to 600 m. The slope category is within 1-15°. The Maddaleru is the only seasonal river fed by monsoon, which is flowing in the NW direction in the southernal part of the study area. The climate is dry with mean annual rainfall of 100-150 cm and mean annual temperature of 32°C. The month of May is considered to be the hottest (45°C) while December is considered to be the coldest (25°C).

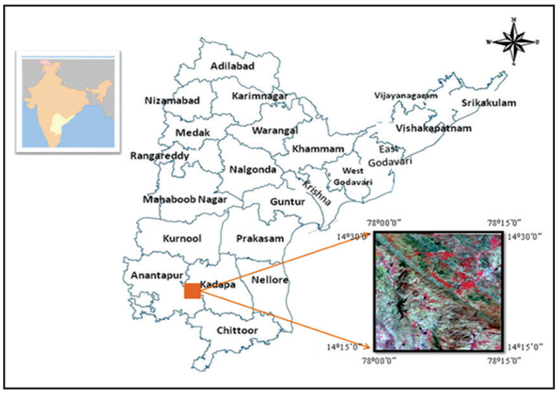

Figure 1: Study area location map.

3. MATERIALS AND METHODS

In the present study, water samples were collected from 20 tube wells in the study area. The field work included water level measurements, well inventory and collection of water samples from tube wells and the study of geological and geomorphological features of the area in general. The groundwater samples collected during June 2013 were analyzed, as per the procedure of APHA (1995), and suggested precautions were taken to avoid contamination. The various parameters determined were: pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), chloride (Cl^-), calcium (Ca^{+2}) and fluoride (F^-). pH was determined by pH meter; TH, Cl^-, Ca^{+2} by titrimetry; EC was determined by conductivity meter, TDS by TDS meter, F^- was determined by using ion selective electrode (Orion 4 star ion meter, Model: pH/ISE). The method of collection and analysis of water samples followed are essentially the same as given by APHA [9].

4. RESULTS AND DISCUSSION

The results of chemical and statistical parameters analyzed are given in Table 1. Understanding the quality of groundwater is as important because it is the main factor determining its suitability for drinking, domestic, agricultural, and industrial purposes. A comparison of water quality parameters (drinking) of the study area with WHO and Indian Standards is given in Table 2.

4.1. pH

The pH of water is very important of its quality and provides an important piece of information in many types of geochemical equilibrium or solubility calculations [10]. The limit of pH value for drinking

Table 1: Result of chemical analysis and statistical parameters of groundwater samples collected from the study area.

Village name	pH	EC µS/cm	TDS mg/L	TH mg/L	Ca^{+2} mg/L	Cl^{-} mg/L	F^{-} mg/L
Kottala	7.9	460	295	100	104	32	0.2
Gajjalapalli - 1	7.8	430	275	140	88	128	1.5
Gajjalapalli - 2	7.4	480	308	160	16	110	6.7
Gajjalapalli - 3	7.6	560	359	100	8	92	4.0
Malakavemula	8.2	580	371	80	32	57	1.9
Sanevaripalli	8.0	520	333	140	48	131	1.7
Kotareddypalli	7.9	660	422	100	16	67	3.8
Vaddekindi tanda	8.2	560	358	100	240	64	2.7
Mallepalli	7.1	430	275	180	64	120	2.9
Yogi vemana reservoir	8.0	420	269	120	992	75	2.4
Dorigallu	7.2	460	294	100	32	90	2.1
Eguvapalli	6.9	380	243	140	256	43	0.1
Diguvapalli	7.2	340	218	60	32	18	0.4
Ambakapalli	6.1	390	250	120	64	28	0.6
Nalagondavaripalli - 1	7.9	410	262	80	104	64	0.7
Nalagondavaripalli - 2	7.8	320	205	120	88	78	0.2
Mallikarjunapuram	8.0	360	230	100	80	28	0.7
Ippatla	7.8	510	326	180	32	160	0.5
Chinnakuddala	7.6	430	275	180	40	168	0.5
Lingala	8.0	400	256	180	56	103	0.3

EC: Electrical conductivity, TDS: Total dissolved solids, TH: Total hardness

Table 2: A comparison of water quality parameters (drinking) of the study area with WHO and Indian Standards.

Parameters	WHO International Standard (1983)	Indian Standards for drinking water specification	Mean value of parameters under analysis
pH	7-8.5	6.5-8.5	7.63
TDS (mg/L)	500		
TH (mg/L)	100	300	124
Ca^{+2} (mg/L)	200	75	119.6
Cl^{-} (mg/L)	200	250	82.69
F^{-} (mg/L)	1.5	1.5	1.695

TDS: Total dissolved solids, TH: Total hardness

water is specified as 6.5-8.5 [11]. In most natural waters, the pH value is dependent on the carbon dioxide-carbonate-bicarbonate equilibrium. As the equilibrium is markedly affected by temperature and pressure, it is obvious that changes in pH may occur when these are altered. Most ground waters have a pH range of 6-8.5 [12]. The pH of groundwater in the study area is ranging from 6.1 to 8.2. pH values for all the samples are within the desirable limits. It is observed that most of the groundwater is alkaline in nature. Though pH has no direct effect on the human health, all biochemical reactions are sensitive to variation of the pH [13]. The pH of the samples was well with-in the prescribed standards for drinking water.

4.2. EC

The conductivity measurement provides an indication of ionic concentrations. It depends upon temperature, concentration and types of ions present [10]. The maximum limit of EC in drinking water is prescribed as 1500 µSiemens/cm [14]. The EC of the samples ranged from 320 to 660 (µSiemens/cm). Elevated concentration of EC may possibly be credited to high salinity and high mineral content.

4.3. TDS

The mineral constituents dissolved in water constitute dissolved solids. The concentration of dissolved solids in natural water is usually <500 mg/L while water with more than 500 mg/L is undesirable for drinking and many industrial uses. The total concentration of dissolved minerals in water is a general indication of the over-all suitability of water for many types of uses. Water with high dissolved solid content would, therefore, be expected to pose problems such as taste, laxative and other associated problems with the individual minerals. Such waters are usually corrosive to well screens and other parts of the well structure. If the water contains <500 mg/L of dissolved solids, it is generally satisfactory for domestic use and for many industrial purposes. Water with more than 1000 mg/L of dissolved solids usually gives disagreeable taste or makes the water unsuitable in other respects. TDS can be removed by reverse osmosis, electrodialysis, exchange and solar distillation process. It was reported that TDS value of 500 mg/L is the desirable limit and 2000 mg/L is the maximum permissible limit and that water containing more than 500 mg/L of TDS causes gastrointestinal irritation [15]. High value of TDS influences the taste, hardness, and corrosive property of the water [16,17]. TDS of the groundwater of the study area is ranging from 205 to 422 mg/L.

4.4. TH

Calcium and magnesium mostly cause the hardness of water. The TH of water may be divided into two types, carbonate or temporary and bi-carbonate or permanent hardness. The hardness produced by the bi-carbonates of calcium and magnesium can be virtually removed by boiling the water and is called temporary hardness. The hardness caused mainly by the sulfates and chlorates of calcium and magnesium cannot be removed by boiling and is called permanent hardness. TH is the sum of the temporary and permanent hardness. Water that has a hardness of <75 mg/L is considered soft. A hardness of 75-150 mg/L is not objectionable for most purposes. Water having more than 150 mg/L hardness, is unsafe. The removal of temporary hardness by heat causes the deposition of calcium and magnesium carbonates as a hard scale in kettles, cooking utensils, heating coils, and boiler tubes resulting in a waste of fuel. The maximum allowable limit of TH for drinking purpose is 500 mg/L, and the most desirable limit is 100 mg/L as per the WHO international standard. For TH, the most desirable limit is 80-100 mg/L [18]. Groundwater exceeding the limit of 300 mg/L is considered to be very hard [19]. TH of the study area is ranging from 60 to 180 mg/L. Most of the groundwater of the study area is within the permissible limit.

4.5. Calcium

The range of calcium content in groundwater is largely dependent on the solubility of calcium carbonate, sulfate and rarely chloride. The solubility of calcium carbonate varies widely with the partial pressure of CO_2 in the air in contact with the water [12]. The salts of calcium and magnesium are responsible for the hardness of water. The permissible limit of calcium in drinking water is 75 mg/L [11]. The calcium of the groundwater is ranging from 28 to 144 mg/L.

4.6. Chloride

Chloride is minor constituent of the earth's crust. Rain water contains <1 ppm chloride. Chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt, and saline intrusion [14]. Its concentration in natural water is commonly <100 mg/L unless the water is brackish or saline [20]. High concentration of chloride gives a salty taste to water and beverages and may cause physiological damages. Water with high chloride content usually has an unpleasant taste and may be objectionable for some agricultural purposes. The level of chloride taste perception is variable from person to person, but is generally of the order of 250 mg/L. Animals usually can drink water with much more concentration than humans can tolerate (300-400 mg/L). Chloride is also relatively free from effects of exchange adsorption and biological activity. Once taken into solution it is difficult to remove it through natural process [21] reported that the higher concentration of Chloride is considered to be an indicator of pollution due to higher animal waste. According to [22,16] concentration up to 250 mg/L are not harmful, but is an indication of organic pollution. Chloride values range from 18 to 168 mg/L. The chlorides of the samples were well with-in the prescribed standards for drinking water.

4.7. Fluoride

Among the various elements, fluoride is thirteenth in the order of abundance in the earth's crust. Fluorine is the most electronegative of all known elements (electronegativity 4.0); [23] and the most reactive. Its abundance in the continental crust is about 626 µg/g [24,25]. It rarely occurs free in nature, therefore in minerals, fluorine is generally found as the fluoride ion (F^-). Occurrence of fluorine in groundwater has drawn worldwide attention due to its considerable impact on human physiology [26]. Fluoride in small amounts is an essential component for normal mineralization of bones and formation of dental enamel [27]. The main source of fluoride for the human body is usually drinking water, covering about 75-90% of daily intake [28]. Fluoride is a common geogenic contaminant of drinking water, and its effects on human beings have been recognized in both the industrialized and developing countries of the world. Contamination of water resources with fluoride beyond acceptable limits is a health-associated problem in many areas of South Asia and other regions of the world. In some regions of India, water contains fluoride up to 38 mg/L, which is exceedingly high compared to the maximum permissible limit of 1 mg/L set for India [29]. The dietary source of fluoride is drinking water. The major source of fluoride in the groundwater is fluoride bearing rocks from which it get weathered and/or leached out and contaminates the water. The fluoride concentration in the study area is ranging from 0.2 to 3.2 mg/L with highest fluoride level at Kotareddipalli (3.2 mg/L) and lowest at kottala (0.2 mg/L). Few cases of dental fluorosis were observed in the village Kotareddipalli.

Fluorides occur in three forms, namely, fluorospar or calcium fluoride (CaF_2), apatite or rock phosphate Ca_3F (PO_4)3 and cryolite (Na_3AlF_6). Concentration of fluorides is 5 times higher in granite than in basalt rock areas. Similarly, shale has a higher concentration than sandstone and limestone [30]. The geological SOI has brought out considerable data which reveal that fluorite, topaz, apatite, rock phosphate, phosphatic nodules and phosphorites are widespread in India and contain high percentage of fluorides. Elevated levels of fluoride are most often associated with groundwater due to accumulation of fluoride during weathering and circulation of water in rocks, soils, and geothermal sources containing fluoride bearing minerals. Fluoride at varying levels is present in several hundred minerals, from as high as 73% in the rare mineral griceite (LiF) to many others with <0.2% [31]. Igneous rocks (such as granites, gneisses, and basalts) and sedimentary rocks (such as shales, limestone and sandstone) contain fluoride in the range of 300-1200 ppm and 50-800 ppm, respectively [32].

5. CONCLUSION

The purpose of the present study area was to understand the groundwater quality in parts of Kadapa, Anantapur districts, Andhra Pradesh. The pH values of groundwater range from 6.1 to 8.2. This shows that the groundwater of the study area is mainly alkaline in nature. The EC of the samples ranged from 320 to 660 mg/L. TDS range from 205 to 402 mg/L. The TH values range from 60 to 180 mg/L. Calcium (Ca^{2+}) in the groundwater varies 28-144 mg/L. Chloride values range from 18 to 168 mg/L. The chlorides of the samples were well with-in the prescribed standards for drinking water. The fluoride concentration was ranged from 0.2 to 3.8 mg/L with highest fluoride level at Kotareddipalli (3.8 mg/L) and lowest at Kottala (0.2 mg/L). Most of the parameters analyzed were within the permissible limits of both standards except fluoride. Few cases of dental fluorosis were observed in the village Kotareddipalli. Chronic exposure to high fluoride in this population represents a concern due to possible health effects from their long-term exposure. For developing countries like India, the most effective and a simple approach to the fluoride trouble would be low-cost defluoridation techniques, which should be planned for smaller rural communities. In addition, such information should be made available to health professionals in order to avoid feasible overmedication and treat through use of children's vitamins and other dental caries prevention programs. Hence, proper attention should be given to water quality monitoring besides groundwater resource development.

6. ACKNOWLEDGMENTS

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***Bibliographical Sketch**

Dr.V. Sunitha, did B.Sc from Govt Arts College, Anantapur District, Andhra Pradesh. She did M.Sc Geology from S.V University, Tirupati in 1997 and M.Sc Tech Environmental Geochemistry from Osmania University, Hyderabad in 2000. She Completed her Ph.D in Applied Geochemistry from Osmania University Hyderabad in 2004. She did her post Doctoral Research at Osmania University and National Geophysical Research Institute, Hyderabad. She has been awarded with Young Scientist Award in 2008, from DST (Govt. of India), New Delhi, India. She published forty National and International research papers. Her major research fields are Hydrogeochemistry, Remote Sensing and GIS. At present she is working as Assistant Professor, Department of Geology, Yogi Vemana University, Kadapa, Andhra Pradesh, India.