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Geochemistry and Assessment of Groundwater Quality for Irrigation Purpose: A Study from Damalcheruvu Area, Pakala Mandal, Chittoor District, Andhra Pradesh, India

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ABSTRACT

The suitability of groundwater quality agricultural purposes was assessed in a predominantly farming and sprawling settlement in the Damalcheruvu area, Pakala mandal of Chittoor district, Andhra Pradesh, India. Various water quality parameters were determined to assess groundwater quality of 15 wells in the study area .Standard methods for physicochemical determinations were employed. Dugwells and boreholes water samples were collected within the locality and analyzed. The quality assessment is made through the estimation of pH, electrical conductivity (EC), Ca, Na, K, Mg, CO_3 and HCO_3. Based on these analyses, parameters like Sodium Adsorption ratio (SAR), Residual sodium carbonate (RSC), Kelly's ratio (KR.), Magnesium Adsorption Ratio (MR), and Sodium percentage (Na%) were calculated. This study indicates that most of the water is suitable for irrigation purposes. On the basis of SAR, RSC, KR, and sodium percentage all the groundwater samples in the study area are good for irrigation. Whereas on the basis of Magnesium Adsorption ratio, 5 water samples are suitable, while 10 water samples are not suitable for irrigation. High values of MAR at some sites restrict the suitability of groundwater for agricultural purposes and demands special management plan for the area. Overall the groundwater quality of the study area is suitable for irrigational purpose.

Keywords: *physicochemical parameter, water quality, agriculture, Damalcheruvu area*

INTRODUCTION

Water is an important and vital component of our life support system. Groundwater is almost globally important for human consumption as well as for the support of habitat. Its quality depends on the recharged water, atmospheric precipitation, inland surface water and subsurface geochemical processes (Twarakavi and Kaluarachchi; 2006). The quality of groundwater depends on various chemical constituents and their concentration which are mostly derived from the geological data of the particular region. Groundwater quality reflects inputs from the atmosphere, soil and water rock reactions as well as pollutant sources such as mining, land clearance, agriculture, acid precipitation, and domestic and industrial wastes (Appelo and Postma, 1993; Zhang et al., 2011). Chemistry of groundwater is an important factor determining its use for domestic and irrigation purposes. Interaction of groundwater with aquifer minerals through which it flows greatly controls the groundwater chemistry. Hydrogeochemistry helps in understanding the suitable water quality needed for cultivation. The chemical composition of groundwater is controlled by any factors that include the composition of precipitation, geological structures and mineralogy and various other factors (Andre et al., 2005). Change in groundwater quality may be caused by variations in climatic conditions, residence time of water, aquifer materials, and inputs from soil during recharge (Giridharan et al; 2008; Krishna et al.,

2009). Several chemical constituents affect the suitability of water for irrigation use (Deshpande and Aher, 2011; Varade et al., 2013). The main objective of study is to know about groundwater quality assessment to estimate its suitability for irrigation purpose in and around Damalacheruvu area, Chittoor district, Andhra Pradesh. Studies of groundwater quality and hydrogeochemically in different part of Andhra Pradesh have been taken up by earlier researchers. (Subba Rao, 2002; Sujatha and Reddy, 2003; Reddy et al., 2012).

STUDY AREA

The study area, Damalcheruvu is a Village in Pakala Mandal in Chittoor District of Andhra Pradesh State, India and lies between latitude 13º 48'15" N and longitude 79º 04' 40" E. It belongs to Rayalaseema region. It is located 36 KM towards North from District head quarters Chittoor. 12 km from Pakala. Damalcheruvu is surrounded by Pakala Mandal towards East, Puthalapattu Mandal towards South, Irala Mandal towards North , and Sodam Mandal towards west . Damalcheruvu is a Famous for mangos which transports all over India. The main resource of the people of this area is mango business and agriculture. Geologically, major part of the area is occupied by granites, basalts shales and sandstones. In this area, ground water occurs under semi-confined conditions. The fractures constitute the porosity and permeability of the rocks. In the study area, temperature varies from 22ºC to 40º C. The average annual rainfall is 500 to 670 mm. Agriculture is the main occupation of the people of the area. The major landuse-landcover patterns are observed in the study area that includes agriculture and wasteland. The main crops of the area are mango gardens, ground nuts, sunflower, leman gardens, and vegetables.

SAMPLING AND ANALYSIS

Water from the wells was pumped out for over 15 minutes, before collecting the samples. 15 ground water samples were collected from dug wells and bore wells in and around Damalcheruvu area, Chittoor district, Andhra Pradesh. Water samples were collected in one liter polyethylene bottles. These sample bottles were washed with dilute hydrochloric acid and then rinsed with distilled water. Chemical analysis of the samples was conducted using standard procedures recommended by APHA 1985, 1992. The water samples were analyzed for various parameters like pH, electrical conductivity (EC), Ca, Na, K, Mg, CO_3 and HCO_3. Analysis of pH, and electrical conductivity were conducted on site with a portable pH and conductivity meter which was calibrated prior to taking of readings. The results of chemical analysis of water samples along with physical parameters are given in Table 1. The obtained results in mg/l were converted in equivalent per million (epm) to determine the groundwater quality for agricultural purpose. The suitability of groundwater from study area was checked for irrigation purpose using Electrical Conductivity (EC), Sodium Adsorption ratio (SAR), Residual sodium carbonate (RSC), Kelly's ratio (KR.), Magnesium Adsorption Ratio (MR), and Sodium percentage (Na%).

RESULTS AND DISCUSSION

The major cations include Ca, Mg, Na, K and anions include CO_3 and HCO_3. The ionic dominance for the major cations and the anions respectively were in these order; Ca>Mg> Na> K and HCO_3> CO_3**.** The summary of hydrochemical analysis data is given in Table 1. In the study area the pH of water varies from 6.9 to 8.4 averaging 7.75 indicating alkaline in nature. The electrical conductivity

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ranging from 370 to 2600 µS/cm and the mean value 2075 µS/cm . TDS varies from 255 to 1050 mg/l and the mean value is 825 mg/l. The calcium values ranges from 35 to 224 mg/l averaging 165.5 mg/l, magnesium ranges from 25 to 198 mg/l averaging 128.8 mg/l, sodium ranges from 30 to 223 mg/l averaging 118.6 mg/l, and potassium ranges from ranges from 0.5 to 14 mg/l averaging 4.95 mg/l, carbonate ranges from 10 to 195 mg/l averaging 40.92 mg/l, and bicarbonate ranges from ranges from 105 to 700 mg/l averaging 284.23mg/l

Table 1. Mean of Physico-chemical data of groundwater samples of Damalcheruvu Area. (All values are in mg/l except pH and Electrical conductivity (EC) in µS/cm)

Hydrochemical parameters	Range of Concentration	Average Concentration of 15 samples
pH	6.9 to 8.4	7.75
TDS	255 to 1050	825
EC	370 to 2600	2075
Ca	35 to 224	165.5
Mg	25 to198	128.8
Na	30 to 223	118.6
K	0.5 to 14	4.95
CO_3	10 to 195	40.92
HCO_3	105 to 700	284.23

QUALITY CRITERIA FOR IRRIGATION

Ground water quality assessment is carried out to determine suitability of water samples in terms of agricultural purposes. Extreme amounts of dissolved ions in irrigation water affect plants and agricultural soil both physically and chemically. The excess salinity reduces the osmotic activity of plants and hence interferes with the absorption of water and nutrient from the soil. EC and Na play a vital role in suitability of water for irrigation. Higher EC in water creates a saline soil. Harmful effects of irrigation water increases with the total salt concentration, irrespective of the ionic composition. Higher salt content in irrigation water causes an increase in soil solution osmotic pressure (Thorne and Peterson, 1954). The salts apart from affecting the growth of plants also affect the soil structure, permeability and aeration which indirectly affect plant growth. The parameters such as Electrical Conductivity (EC), Sodium Adsorption ratio (SAR), Residual sodium carbonate (RSC), Kelly's ratio (KR), Magnesium Adsorption Ratio (MAR), and Sodium percentage (Na %) helps us to identify the quality of water for irrigation (Ayers and Wescot,1985).The computed values of these parameters calculated by the following equations are given in Table 2.

Sodium adsorption ratio (SAR) = $Na^{+}/ (\sqrt{} Ca^{2+}+Mg^{2+})/2)$
Sodium percentage (%Na) = $Na^{++} + {}^{+}K^{+} / (Ca^{2+}+Mg^{2+}+ Na^{+}+ K^{+})$ X100

Residual sodium carbonate (RSC) = $(CO_3^- + HCO_3^-) – (Ca^{2+} + Mg^{2+})$
Kelley Ratio (KR) = $Na^+/ (Ca^{2+}+Mg^{2+})$
Magnesium adsorption ratio (MAR) = Mg^{2+}x 100/ $Ca^{2+}+Mg^{2+}$
(All ionic concentrations used for calculation are expressed in epm)

Table 2: Irrigational water quality parameters from the study area

S.No	SAR	% Na	RSC	KR	MAR
1	2.13	6.02	-12.56	0.36	42.21
2	2.70	7.83	-12.72	0.58	65.07
3	1.16	3.81	-22.75	0.16	48.61
4	3.64	8.26	-8.89	0.85	74.97
5	0.75	2.37	-12.02	0.13	59.18
6	3.17	10.25	-10.97	0.62	55.97
7	3.03	8.36	-13.42	0.53	69.49
8	1.13	3.22	-12.22	0.20	35.84
9	0.69	1.50	-7.68	0.10	53.15
10	1.39	3.70	-7.55	0.23	71.93
11	0.87	1.74	-4.46	0.25	65.61
12	2.13	6.17	-20.31	0.41	46.60
13	0.88	1.92	-6.05	0.15	75.62
14	0.67	2.52	-9.47	0.12	38.56
15	1.10	3.48	-15.24	0.19	77.82
Min	0.67	1.5	-22.75	0.1	35.84
Max	3.64	10.25	-4.46	0.85	77.82
Avg	1.75	4.87	-11.97	0.34	58.48

Sodium Adsorption Ratio (SAR)

Sodium concentration plays an important role in evaluating the groundwater quality for irrigation. Sodium adsorption ratio is a measure of the suitability of water for use in agricultural, as determined by the concentrations of solids dissolved in the water. SAR is a ratio of the concentration of sodium ions to the concentration of calcium plus magnesium ions. The formula for calculating sodium adsorption ratio is: SAR = $Na^+/ (\sqrt{} Ca^{2+}+Mg^{2+})/2$). The groundwater with SAR < 10 is considered as excellent quality, SAR values of the water samples from 10 to 18 is good, 18 to 26 is fair and above 26 is unsuitable for the purpose of irrigation (U.S. Salinity Laboratory Staff, 1954).The SAR values in groundwater of the study area ranges from 0.67 to 3.64 (Avg1.75) which indicates that the water is of excellent quality for irrigation (Table 3).

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Table 3: **classification of groundwater based irrigation suitability and percentage of samples falling in various categories**

Irrigation water quality parameters	Range	Number of samples	Percentage of samples
1.Sodium adsorption ratio (SAR)			
Excellent	0-10	15	100%
Good	10-18	-	-
Fair	18-26	-	-
Unsuitable	>26	-	-
2.Residual Sodium Carbonate (RSC)			
Good/Safe	<1.25	15	100%
Moderate/Marginally suitable	1.25-2.5	-	-
Unsuitable	>2.5	-	-
3.Kelly's Ratio (KR)			
Good	<1	15	100%
Not good	>1	-	-
4.Sodium percentage (%Na)			
Safe	<60	15	100%
Unsafe	>60		
5.Magnesium adsorption ratio (MAR)			
Suitable	<50	05	25%
Unsuitable	>50	10	75%

Residual Sodium Carbonate (RSC)

High RSC value in water leads to an increase in the adsorption of sodium on soil (Eaton, 1950) which damages the soil structure. RSC is mainly due to increasing bicarbonate which precipitates calcium and magnesium as a result increases sodium in the form of sodium carbonate. RSC is calculated using the following equation: (RSC) = $(CO_3^{-} + HCO_3^{-}) – (Ca^{2+} + Mg^{2+})$.RSC values of water <1.25 are to be considered as good and safe, from 1.25 to 2.5 are marginally suitable, while more than 2.5 are unsuitable for the irrigation purpose (Eaton, 1950; Richards, 1954). The RSC values in waters of the study area range from -22.75 to -4.46 (Avg -11.97). All samples are safe for irrigation (Table 3).

Percent Sodium (%Na)

The percent sodium is widely used for evaluating the suitability of water quality for irrigation (Wilcox, 1955).The sodium percentage can be determined using the following equation: (%Na) = $Na^{++} + {}^{+}K^{+} / (Ca^{2+}+Mg^{2+}+ Na^{+}+ K^{+})$ X100. High percent sodium in irrigation water causes exchange of sodium in water, and exchange of calcium and magnesium contents in soil having poor drainage. The % Na in the study area ranges from 1.5 to 10.25 (Avg 4.87).The % Na, <60

represents safe water while it is unsafe if >60 (Eaton, 1950). As per this criterion the water from the study area is safe for irrigation purpose (Table 3).

Kelley's Ratio (KR)

It is the ratio of sodium ions to calcium and magnesium ions. KR is calculated using the following equation: KR = Na^{+}/ (Ca^{2+}+Mg^{2+}).The Kelley's ratio is calculated for groundwater samples (Table 2). It varies from 0.1 to 0.85 (Avg 0.34). KR values of water having <1 are to be considered as good, while the values are >1 are unsuitable for irrigation (Kelley, 1951). Kelly's ratio (KR) of more than one indicates an excess level of sodium in waters. On the basis of Kelley's ratio all water samples in the study area are suitable for irrigational purpose.

Magnesium Adsorption Ratio (MAR)

Magnesium adsorption ratio is calculated by using the equation as MR= Mg^{2+}x 100/ (Ca^{2+}+Mg^{2+}**).** Excess amount of magnesium can affect the quality of soil and reduces the yield of crops. The magnesium ratio of groundwater of study area varies from 35.84 to 77.82 (Avg 58.48). The value of MR < 50 is suitable and > 50 are unsuitable for irrigational purpose (Lloyd and Heathcote, 1985). On the basis of magnesium ratio, 5 groundwater samples in the study area are suitable for irrigation and 10 samples are unsuitable for irrigation (Table 3).

CONCLUSIONS

The suitability of groundwater quality for agricultural purposes was assessed in a predominantly farming and sprawling settlement in the *Damalcheruvu area.* Various water quality parameters were determined to assess groundwater quality of 15 wells in *the study area* .Standard methods for physicochemical determinations were employed. Boreholes water samples were collected within the locality and analyzed. The results revealed that groundwater in the study area indicating mostly alkaline in nature. The major cations include Ca, Mg, Na and K. The cationic chemistry is dominated by calcium and magnesium. Results revealed that the mean concentration of cations is in the order Ca>Mg> Na> K. The anionic chemistry is dominated by bicarbonates. In the study area the quality of groundwater is characterized by alkaline with moderate to high salinity. The suitability of groundwater for irrigation has been evaluated based on various chemical parameters such as sodium adsorption ratio (SAR), sodium percent (Na %), residual sodium carbonate (RSC), Magnesium Adsorption Ratio (MAR), and Kelley's Ratio (KR). This study indicates that most of the water is suitable for irrigation purposes. SAR, RSC, KR, and sodium percentage reveals that all the groundwater samples in the study area are good for irrigation. On the basis of Magnesium Adsorption ratio reveals that five water samples are suitable, while ten water samples are not suitable for irrigation. High values of salinity and Magnesium Adsorption Ratio at some sites restricts the suitability of groundwater for agricultural purposes and demands special management plan for the area. This research may serve as a preliminary study to provide baseline information that may direct future water quality assessment studies in the study area.

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