Suitability of groundwater for irrigation purpose in the Ipur and Rompicherla mandals of the Guntur District, Andhra Pradesh.

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Abstract: An attempt has been made to analyze the groundwater suitability for drinking and irrigation purpose of the rural areas of Ipur and Rompicherla mandals of Guntur District, Andhra Pradesh, India. Twenty five groundwater were collected from pre-determined locations. The collected samples were analyzed for major cations and anions. The results were compared with WHO and BIS Standards for assessing the drinking purpose utility. Irrigation suitability parameters like Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP), Magnesium Adsorption Ratio (MAR) and Kelly's Ratio (KR) were calculated. The results indicate that groundwater is categorized by fresh and brackish, hard and very hard type of water based on TDS and TH. Most of the samples are unsuitable for irrigation based on MH and KR.

***Index Terms* – Groundwater, suitability for irrigation, RSC, SSP, PI, MH.**

I. INTRODUCTION

Groundwater Quality is the function of its physical and chemical parameters which in turn depend upon the soluble products of weathering, decomposition, and the related changes that occur with respect to time and space (K.Srinivasamoorthy 2009; Bhargava and Killender 1988; Prasad 1984). The chemical composition of groundwater plays a significant role in determining the water quality for various utility purposes like domestic, agricultural, and industrial purposes. Criteria used for classification of water for particular purpose is not suitable for other standards; better results can be obtained by combining chemistry of all the ions than the individual or paired ionic character (Hem 1985).There are various physico-chemical parameters which play a vital role regarding the quality of groundwater for consumption and irrigation purposes. If the concentration of any parameter is above the prescribed limit there can be serious health issues. The hydrochemistry and groundwater suitability for irrigation and drinking purposes in different parts of the world have also been evaluated which is used in Groundwater quality and its suitability for irrigation and domestic Purposes: which may vary with temporally and spatially. Several workers have assessed the groundwater quality and its suitability for drinking and irrigation purposes which include Nag et al. 1997; Hossien, 2004; Nag et al. 2016; Pichaiah et al. 2013 and srinivasamoorthy et al. 2010.

The present work aims at finding the suitability of groundwater's of Ipur and Rompicherla mandal of Guntur district, Andhra Pradesh and hence determining its suitability for drinking and irrigation purposes. In view of this, an attempt has been made to analyze the groundwater quality of the study area to determine the exact level of physico-chemical parameters giving emphasis on its irrigation and domestic suitability. Since there has been no previous study on groundwater quality of these mandals, this study will serve as guideline at exhaustively discussing the groundwater quality of Ipur and Rompicherla mandal in future.

II. STUDY AREA

The study area lies in northeastern part of Guntur district, of Andhrapradesh State between east latitudes 16° 13' 50.52" and 16° 22' 23.42" and North longitudes 79° 49' 00.00" and 79° 46' 54.54". The total geographical extent of the study area is 52.80 sq.kms. The population of these mandals are 1, 07,320 according to 2011 census. The study area experiences semi-arid climatic conditions. The maximum, minimum and mean temperatures are 47 °C, 24°C and 31.5 °C. The highest temperatures are recorded in summer season at Rentichentala were IMR station is present. Average annual rainfall varies from 710 to 830 mm. respectively.

III. MATERIALS AND METHODS

Twenty five groundwater samples each were collected from bore wells of pre-monsoon period during March 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 (HCO_3^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), and chloride (Cl^-) were analyzed by titration method. Sulfate (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 is calculated by multiplying a ratio between 0.9 and 1.7

The concentration of various ions as obtained from chemical analysis of ground water samples were converted to milli equivalent/liter (meq/L) and used to derive certain parameters. They are Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), and Magnesium Adsorption Ratio (MAR), Residual Sodium Carbonate (RSC), Permeability Index (PI), Kelly's ratio (KR) and Total Hardness (TH). These parameters help to evaluate the irrigational as well as domestic suitability of ground water in the study area.

IV. RESULTS AND DISCUSSION

pH is the measure of acidicity or basicity of an aqueous solution. If pH in water is less than 6.6 it is said to be acidic and if it is greater than 7.3 it is basic or alkaline. In the study area the pH varies from 7.82 to 8.7 with an average of 8.28, indicating an alkaline nature. Electrical Conductivity (EC) is the measure of its ability to conduct electrical current through ionic charge carriers. In the study area EC ranges from 703 to 3896 µS/cm with an average of 185.36 µS/cm. The EC Classification in the study area indicates about 64% of the total samples are within the permissible limit (750-2000) and 12% and 16% samples fall in doubtful (2000-3000) and unsafe (> 3000) categories respectively and doubtful and unsafe categories indicate that water has high concentration of dissolved ions (Table 1).

Table 1 Irrigation Suitability parameters of the study area

Parameters	Range	Class	Sample number	Percentage of samples
SAR	<20	Excellent	1-25	100
	20-40	Good	0	0
	40-60	Permissible	0	0
	60-80	Doubtful	0	0
	>80	Unsafe	0	0
EC	<250	Excellent	Nil	Nil
	250-750	Good	25,16	8
	750-2000	Permissible	1,2,4,5,6,7,9,10,11,12,14,15,17 18,21,22	64
	2000-3000	Doubtful	20,23,24	12
	>3000	Un safe	3,8,13,19	16
TH	<75	Soft	Nil	Nil
	75-150	Moderate	Nil	Nil
	150-300	Hard	1,2,4,6,7,10,15,16,22,24,25	44
	>300	Very hard	3,5,8,9,11,12,13,14,17,18,19,20,21,23	56
RSC	1.25	Safe	3,9,10-14,16-23,25	64
	1.25-2.50	Marginally suitable	4,5,7	12
	>2.50	Un suitable	1,2,6,8,15,24	24

MAR	<50	Suitable	12,15,22,23,24,25	24
	>50	Un suitable	1,2,3,4,5,6,7,8,13,15,17,19,20,22,23,24	76
SSP	<200	Suitable		
	>200	Un suitable		
KR	<1.0	Suitable	9,10,11,12,14,16,18,21,25	36
	>1.0	Un suitable	1,2,3,4,5,6,7,8,13,15,17,19,20,22,23,24	64
PI	<80	Good	3,5,8,9,10,11,12,14,16,17, 18,20,21,22,23,25	64
	80-100	Moderate	1,2,4,6,7,13,15,19,24	36
	100-120	Poor	Nil	Nil

Total Dissolved Solids (TDS) is the sum of all inorganic salts and small amounts of organic matter present in solution in water. The presence of excess dissolved solids in water affects its permeability. A high level of TDS is objectionable because it imparts bad taste and causes excessive scaling in water pipes, boilers and household appliances. The TDS in the study area varies from 450 to 2493 mg/L with a mean of 1206.64 mg/L. According to Freeze and Cherry, (1979), majority (60%) of the samples come under the brackish water (1000-10000mg/L). Thirty six percent and four percent samples come under fresh water (< 1000 mg/L) and saline water (10,000- 1, 00,000) respectively (Table 2).

Table 2 Freeze and Cherry classification of groundwater based on TDS values

TDS (mg/l)	Nature of sample	Sample number	Percentage of samples
<1000	Fresh water	1,4,9,10,12,14,16,22,25	36
1000-10,000	Brackish water	2,5,6,7,8,11,13,15,17,18,19,20,21,23,24	60
10,000-100,000	Saline water	3	4
>100,000	Brine water	Nil	Nil

It indicates that majority of the study area is having higher TDS which cannot be used for safe drinking purpose. Total Hardness is the combination of both calcium and magnesium present in the water. It varies from 180 to 860 with an average 352.80 mg/L. According to Sawyer and Mc Carty (1967), 44% of the total samples fall in hard type (150-300 mg/L) and 56% of the samples fall in very hard category (>300 mg/L; Table 3).

Table 3 Classification of groundwater based on TH (mg/l)

Total hardness as $caco_3$ (mg/l)	Water class (Sawyer et al.2003)	Sample number exceeding BIS limits	Percentage of the samples exceeding BIS limits
<75	Soft	Nil	Nil
75-150	Moderately hard	Nil	Nil
150-300	Hard	1,2,4,6,7,10,15,16,22,24,25	44
>300	Very hard	3,5,8,9,11,12,13,14,17,18,19,20,21,23	56

Higher concentrations of TH are observed in agricultural areas where lime and fertilizers are applied to the land for higher productivity indicated by the presence of other chemicals such as nitrate. Calcium and Magnesium in groundwater are due to weathering of primary minerals present in the rocks. These constituents in small quantities are essential for strengthening of teeth and bones in humans. If these are present in excess leads to hardness of water. The concentration of calcium in the water samples collected varies from 8.0 to 96 mg/L with an average of 47.68 mg/L. The concentration of magnesium in the water samples collected varies from 19 to 165 mg/L with an average of 56.68 mg/L. Sodium is a highly soluble chemical element which often occurs naturally in groundwater. The permissible limit of sodium in water is 200 mg/L. Excess consumption may lead to hypertension, heart disease or kidney problems (Nag et al. 2016). The concentration of sodium in the study area varies from 48 to 590 mg/L with an average of 239.96 mg/L. Potassium controls body balance and maintains normal growth of the human body. Its deficiency may lead to weakness of muscles and rise in blood pressure. The concentration of potassium in the study area varies from 7.00 to 300 mg/L with an average of 68.04 mg/L. Chloride is found naturally in groundwater through the weathering and leaching of sedimentary rocks and soils and the dissolution of salt deposits. Its deficiency in plants may lead to leaf mottling and chlorosis. The concentration of chloride in the study area varies from 59.00 to 843.00 mg/L with an average of 257.56 mg/L. The concentration of Bi-carbonate in the study area varies from 70 to 630 mg/L with an average of 313.60 mg/L.Sulphate is essential nutrient for plants. Excess sulphate concentration increases salinity and hardness of water. At levels above 1000 mg/L, sulphate in drinking water can have a laxative effect. Its concentration varies from 35 to 335 mg/L with an average of 153.72 mg/L. The concentration of nitrates in the study area varies from 6.00 to 122.00 mg/L with an average of 36.64 mg/L. Higher concentrations of nitrates (> 45 mg/L) is harmful to humans, which may cause blue baby disease. Higher concentrations indicate a man made pollution particularly due to poor drainage conditions. Fluoride in groundwater has dual effects. Higher concentrations (> 1.5 mg/L) may lead to different stages of fluorosis, while lower concentrations (< 0.6 mg/L) may lead to decay of teeth, bones etc. The concentration of fluoride in the study area varies from 0.8 to 4.0 mg/L with an average of 1.99 mg/L.

V. **IRRIGATION WATER QUALITY**

The overall irrigational water quality of the samples in the study area is obtained by calculating (i) Sodium Adsorption Ratio (SAR), (ii) Soluble Sodium Percentage (SSP), (iii)Permeability Index (PI), (iv) Residual Sodium Carbonate (RSC), (v) Magnesium Adsorption Ratio (MAR) and (vi) Kelly's Ratio (KR)

Sodium Adsorption Ratio (SAR): The sodium adsorption ratio (SAR) was calculated by the Richards (1954) using the following equation:

$$\mathbf{SAR = (Na^+)/ \{[(Ca_2^+) + (Mg_2^+)]/2\}1/2}$$

Concentrations of all ions have been expressed in meq/L.

High sodium concentration leads to development of alkaline soil. Alkaline soils are difficult to take into agricultural production. Due to the low infiltration capacity, rain water stagnates on the soil easily and, in dry periods, cultivation is hardly possible without copious irrigated water and good drainage. All the samples of the study area fall in excellent category based on SAR value (< 20 mg/L; Table 1).

Soluble Sodium Percentage (SSP): It is calculated by the following equation by taking all concentrations are in meq/L.

$$\mathbf{SSP= [(Na^+ + K^+)*100] / [Ca_2^+ + Mg_2^+ + Na^+ + K^+]}$$

High SSP values make the water not suitable for irrigation because sodium absorbed by clay particles, dispersing magnesium and calcium ions. This exchange process of sodium in water for Ca^{2+} and Mg^{2+} in soil reduces the permeability and eventually results in soil with poor internal draining. The SSP values range from 28.92 –82.73 with an average value of 56.13. According to Todd, 1980 classification of SSP about 46% and 54% of the total samples fall in suitable (< 50 mg/L) and unsuitable (> 50 mg/L) categories respectively (Table 1).

Permeability index (PI): The permeability of soil is affected by sodium, calcium, magnesium and bicarbonate contents of irrigation water. Doneen, 1964 calculated the permeability index by taking all the concentrations in meq/L based on the formula

$$\mathbf{PI= \{[Na + (HCO_3^-) 1/2)]*100\}/ (Ca+ Mg+ Na)}$$

PI value varies from 46.29 to 93.65 with an average value of 73.21. According to Doneen, 1964 classification of PI about 64% and 36% of the total samples fall in good (<80 mg/L) and moderate (80-100 mg/L) categories respectively. (Table 1).

Residual Sodium Carbonate (RSC): The Residual Sodium carbonate (RSC) is calculated according to formula proposed by Raghunath (1987) taking all concentrations in meq/L.

$$\mathbf{RSC = (CO_3 + HCO_3) – (Ca + Mg)}$$

The sum of concentration of the carbonates and bi-carbonates is in excess to that of calcium and magnesium, there may be a possibility of complete precipitation of calcium carbonate and magnesium carbonate. If the concentration of Ca and Mg are low compared to sodium, then SAR index will be higher which will lead to alkalizing effect resulting in increase of the pH. RSC In the present study the RSC varies from -11.76 to 8.86 with an average of -0.22. According to the RSC classification proposed by Raghunath (1987) about 64%, 12%, 24% of the total samples fall in safe (<1.25); marginally suitable (1.25-2.5); un-suitable (>2.5; Table 1).

Magnesium Adsorption Ratio (MAR): Magnesium is essential for plant growth, but excess magnesium can have severe toxicity effect on plants. MAR is used for calculating the magnesium hazard caused when it is in equilibrium in groundwater. Magnesium Adsorption Ratio (MAR) is calculated by taking all the concentrations in meq/L and by using the following equation. MAR is broadly classified into two groups which are suitable (< 50) and unsuitable (> 50) based on suitability for irrigation.

$$\mathbf{MAR = (Mg*100)/ (Ca + Mg)}$$

Based on MAR, about 24% and 76% of the total samples fall in suitable (< 50) and unsuitable (> 50) respectively in the study area (Table 1).

Kelly's Ratio (KR): It is as the ratio between sodium measured against Ca^{2+} and Mg^{2+} in meq/L . The following formula is used for calculation.

$$\mathbf{KR= Na^{+}/ (Ca2^{+} + Mg^{2+})}$$

Based on KR classification of the samples in the study area, about 36% and 64% of the total samples fall in suitable (<1.0) and unsuitable (>1.0) categories respectively (Table 1).

VI. Conclusions:

The overall water quality for irrigation in the groundwater of the study area indicates that majority of the locations are not suitable based on TDS, majority (60%) , TH, (44% -hard type and 56%-very hard) and SSP(54%), MH (76%) and KI (64%).

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