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Groundwater Quality Assessment for Anantapur District of Andhra Pradesh for Irrigation Purpose

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ABSTRACT

Background: Assessment and mapping of quality of irrigated groundwater may help the farmers in selection of suitable crops and other agronomic management practices for getting profitable yields without affecting the soil health. The spatial maps of different parameters, prepared using GIS could be valuable for policy makers.

Methods: A survey was undertaken during the year 2021 to assess the quality of groundwater for irrigation in various mandals of Anantapur district, Andhra Pradesh. A total of 492 samples were collected and GPS locations of sampling points were recorded. The water samples were analyzed for various chemical properties *viz.,* pH, EC, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+}; CO_3^{-2}, HCO_3^{-}, Cl^{-} and SO_4^{-2}.

Result: The pH, EC, SAR and RSC in groundwater ranged from 6.7-8.4, 0.4-10.7 (dSm^{-1}), 0.43-36.4 (mmol $l^{-1})^{1/2}$, -66.8-15.4 (me l^{-1}). The concentration of cations *viz.,* Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} varied from 0.8-28.4, 0-43.2, 0.73-70.1 and 0.001-51.76 me l^{-1} with mean values of 4.23, 3.86, 5.29 and 0.22 me l^{-1} respectively. Concentration of anions *viz*., CO_3^{-2}, HCO_3^{-}, Cl^{-} and SO_4^{-2} varied from 0-1.8, 0.88-15.4, 0.4-59.6 and 0.21-17.08 me l^{-1} with an average values of 0.22, 6.42, 5.33 and 2.29 me l^{-1} respectively.

Key words: Anantapur ground water quality, EC, RSC, SAR, Spatial variability.

INTRODUCTION

Water is an essential input not only for the human existence, but also for all developments. Demand for ground water has increased tremendously in recent years due to the industrialization, urbanization, population increase and intense agricultural activities. The degree and kind of mineralization of the groundwater are governed by the diverse hydrometeorology, topographical, drainage, geo-hydrology conditions as well as from activities like surface water irrigation and overexploitation of coastal aquifers. Thus groundwater quality, influenced by so many factors, varies spatially. In general, over exploitation of ground water might lead to quality and quantity deterioration. The temporal aspect of groundwater quality variations has become important nowadays. In several parts of the world lots of studies have been carried out to assess the geochemistry of groundwater. Quality of irrigation water is an important consideration in any appraisal of salinity or alkali conditions in an irrigated areas and it depends on primarily on the total amount of salt present and proportion of sodium to other cations and certain other parameters (Singh *et al.*, 2019). In the areas where surface water availability is limited throughout the year, farmers are compelled to use poor quality ground water for agricultural purposes. Poor quality irrigation water may decrease the yield of crops (Rahul *et al.,* 2021). The Anantapur district is not coastal district of Andhra Pradesh (Fig 1) and mean sea level elevation of Anantapur is 610 m. Farmers of the district using ground water as major source for irrigation. Anantapur district has of 34525 tube wells and filter points and 52937 dug wells covering nearly 90.8 per cent irrigated area of the district (CGWB, 2019). However, farmers in the district report ground water quality issues in certain pockets. It means that groundwater problems are due to hydro-geological reasons and not due to sea water intrusion. Such assessment might be helpful to understand the effect of irrigation water quality on crop productivity and to suggest the soil and crop management practices for better crop yields by reducing adverse effects of saline, alkali water irrigation.

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MATERIALS AND METHODS

Four hundred and ninety two (492) ground water samples were collected during 2021 from different sources like bore wells, open wells and hand pumps. Around 5 to 6 samples along with GPS coordinates were randomly collected from each mandal of Anantapur district (Fig 2) in all the mandals of Anantapur district. Sampling was carried out using preconditioned clean high density polythene bottles, which were rinsed three times with sample water prior to sample collection. The dug wells waters were lifted to the ground surface by rope and bucket while tube well waters were pumped to the surface by using hand pump. The pumps

were run for 5-6 minutes prior to collection of water samples. Samples were collected in polyethylene bottles and immediately after collection of water samples toluene was added to avoid microbiological deterioration. Standard procedures were (Table 1) followed to analyze the quality of water. pH in water samples was determined by potentiometrically using pH meter (Jackson 1973). Electrical conductivity was determined by using Conductivity Bridge (Willard *et al*. 1974). Chlorides (Mohr's method), carbonates and bicarbonates (double indicator method) and calcium and magnesium (versenate method) were determined by adopting the procedures given by Richards (1954). Similarly the sodium and potassium in ground water samples were determined by using flame photometer (Richards 1954) at AICRP on management of salt affected soils and use of saline water in agriculture. The sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were as calculated by using the formulas given by Richards (1954) such as.

$$SAR = Na/ [(Ca^{2+}+Mg^{2+})/2]^{0.5}$$

$$RSC = (CO_3^{2-} + H\,CO_3^{-}) - (Ca^{2+} + Mg^{2+}).$$

The Na^{+}, Ca^{2+} and $Mg2^{+}$ are in m e L^{-1}. RSC, CO_3^{2-} , H CO_3^{-}, Ca^{2+} and Mg^{2+} are in meq L^{-1}.

The ground water samples were classified under different classes as per the limits of EC, SAR and RSC given by Gupta *et al.* (1994). Correlation coefficient of water properties were obtained as per the standard methodology given by Panse and Sukhatme (1961). Soil samples were also collected and analyzed for soil salinity and sodicity. Spatial distribution of groundwater quality was depicted in figures using Q-GIS 3.16.10.

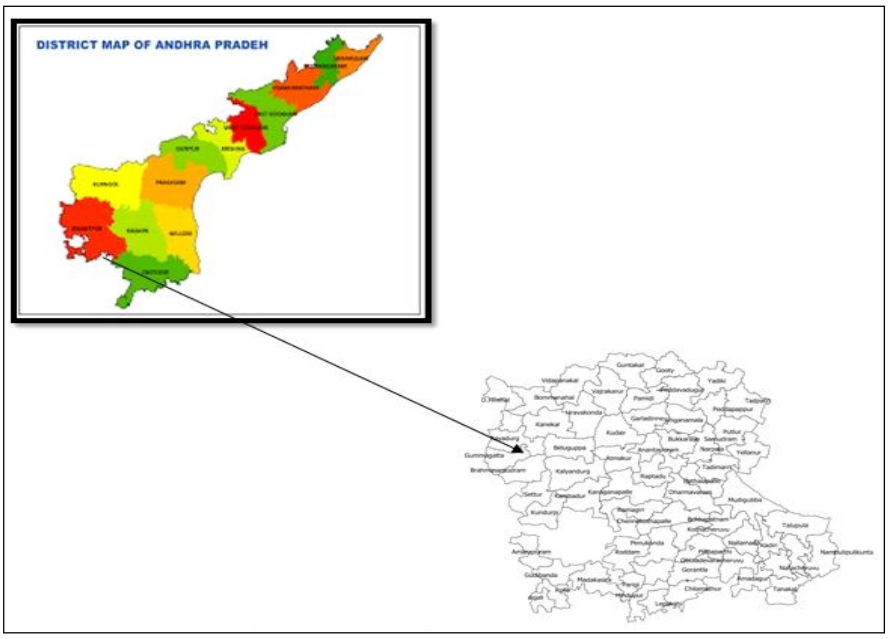

Fig 1: District location map of Anantapur.

Table 1: Methods used for estimation of different hydrochemical parameters of groundwater.

Parameters	Method used
pH	Glass electrode (Richards,1954)
EC (Electrical conductivity)	Conductivity Bridge method (Richards,1954)
Na^{+} (Sodium)	Flame Photometric method (Osborn and Johns, 1951)
K^{+} (Potassium)	Flame Photometric method (Osborn and Johns, 1951)
Ca^{+2} (Calcium)	EDTA titration method (Richards, 1954)
Mg^{+2} (Magnesium)	EDTA titration method (Richards, 1954)
CO_3^{-2} (Carbonate)	Acid titration method (Richards,1954)
HCO_3^{-} (Bicarbonate)	Acid titration method (Richards,1954)
Cl^{-} (Chloride)	Mohr's titration method (Richards,1954)
SO_4^{-2} (Sulphate)	Turbidity method using $CaCl_2$ (Chesnin and Yien, 1950)

RESULTS AND DISCUSSION

Groundwater quality determination

The analytical data of ground water samples collected from various mandals of Anantapur district in Andhra Pradesh during 2021 are presented in meq L^{-1} and given in the Table 2.

Spatial variability in pH

The pH of ground water is important parameter for determining its reaction in determining its acidity, neutrality or alkalinity. The pH of water samples varied from 6.7 to 8.4 (Table 2) with a mean of 7.41. The low pH may be due to presence of forest areas in certain pockets and dominance of chloride ions in groundwater. Higher pH of ground water may be due to dominance of Na^+, Ca^{+2}, Mg^{+2} and CO_3^- and HCO_3^- ions (Gupta *et al*., 2019). The spatial variability of pH of groundwater in Anantapur is depicted in Fig 3. Indicates that the highest pH (>7.6) in groundwater was in parts of Agali, Rolla, Madakasira, Roddam, Kundurpi, Sttur, Kambadur, Ramagiri, C.K. Palli, Bommanhal, Narpala, Bathalapalli, Puttaparthy mandals of Anantapur district.

Spatial variability in electrical conductivity (EC)

Water salinity determined in terms of EC. The EC values in water samples of various mandals of Anantapur district was ranged from 0.4 to 10.7 dS m^{-1} with a mean of 1.57 dS m^{-1} (Table 2). Electrical conductivity is customarily used for indicating the total concentration of the ionized constituents of natural water. Electrical conductivity is related to the conduction of electricity and is correlated to the saturation of water with regard to the dissolved solids (Pal *et al*., 2018). The spatial variability of EC of Ground water in Anantapur district is depicted in Fig 4. The electrical conductivity classes (Table 3) were grouped into different classes with an interval of two units upto 12 dSm^{-1}. Out of 492 samples collected 80.69 per cent samples had <2 dSm^{-1} followed by 17.07 per cent in range of 2-4 dSm^{-1} followed by 1.42 per cent in 4-6

Table 2: Range and average of different water quality parameters in Anantapur district.

Parameter	Range	Mean	Standard deviation	Standard error
pH	6.7-8.4	7.41	0.29	0.01
EC (dSm^{-1})	0.4-10.7	1.57	1.05	0.05
CO_3^{2-} (me L^{-1})	0-1.8	0.22	0.30	0.01
HCO_3^- (me L^{-1})	0.88-15.4	6.42	2.16	0.10
Cl^- (me L^{-1})	0.4-59.6	5.33	5.80	0.26
SO_4^{2-} (me L^{-1})	0.21-17.08	2.29	2.23	0.10
Ca^{2+} (me L^{-1})	0.8-28.4	4.23	2.91	0.13
Mg^{2+} (me L^{-1})	0-43.2	3.86	3.36	0.15
Na^+ (me L^{-1})	0.73-70.1	5.29	6.04	0.27
K^+ (me L^{-1})	0.001-51.76	0.22	2.36	0.11
RSC (me L^{-1})	-66.8-15.4	-1.44	6.06	0.27
SAR	0.43-36.4	7.40	2.95	0.13

EC: Electrical conductivity; RSC: Residual sodium carbonate; SAR: Sodium adsorption ratio.

Table 3: Ground water samples based on EC (dSm^{-1}).

EC (dSm^{-1})	No. of samples	Per cent of samples
0-2	397	80.69
2-4	84	17.07
4-6	7	1.42
6-8	2	0.41
8-10	1	0.20
10-12	1	0.20

Table 4: Classification of ground water samples based on SAR.

SAR	No. of samples	Per cent of samples
<10	482	97.97
10-18	7	1.42
18-26	1	0.20
>26	2	0.41

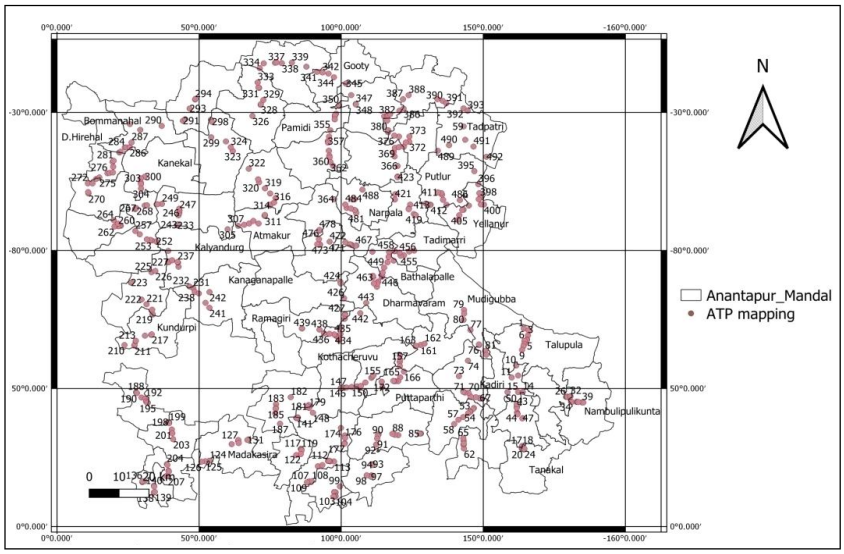

Fig 2: Groundwater sampling sites of Anantapur district.

dSm^{-1}, 0.41 per cent in 6-8 dSm^{-1} range, 0.20 per cent in 8-10 dSm^{-1} and 0.20 per cent in 10-12 dSm^{-1} range. The groundwater samples having higher electrical conductivity were less in number. The variation in EC may be due to variation in hydro-geological conditions and the anthropogenic activities in the region.

The concentration of cations *viz*., calcium, magnesium, sodium and potassium in water samples varied from 0.8-28.4, 0-43.2, 0.73-70.1 and 0.001-51.76 meq l^{-1} with mean values of 4.23, 3.86, 5.29 and 0.22 meq L^{-1} respectively. The cationic concentration followed the order sodium, calcium, magnesium and potassium.

The concentration of anions *viz*., carbonate, bicarbonates, chloride and sulphate varied from 0-1.8, 0.88-15.4, 0.4-59.6 and 0.21-17.08 meq L^{-1} with an average values of 0.22, 6.42, 5.33 and 2.29 meq L^{-1} respectively. The relative abundance of ions for most of the water samples are Cl^{-}> HCO_3^{-}> SO_4^{-2}> CO_3^{-}.

Spatial variability in sodium adsorption ratio (SAR)

The SAR of groundwater of Anantapur district ranged from 0.43- 36.4 (m mol $l^{-1})^{1/2}$ with a mean of 7.40 (m mol $l^{-1})^{1/2}$. The lowest SAR of 0.43 (m mol $l^{-1})^{1/2}$ in water samples was observed in Kudair village and mandal and the maximum

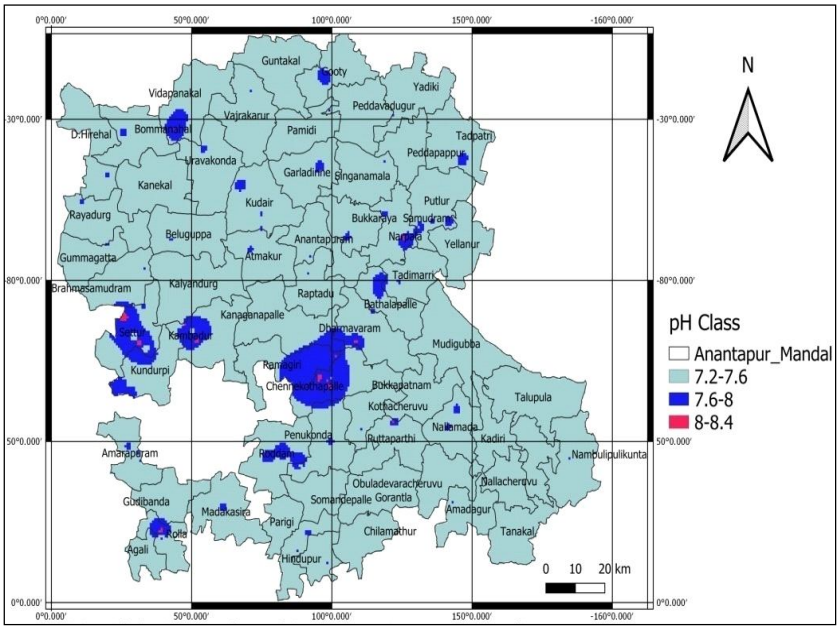

Fig 3: Spatial distribution of pH of ground water in Anantapuram district.

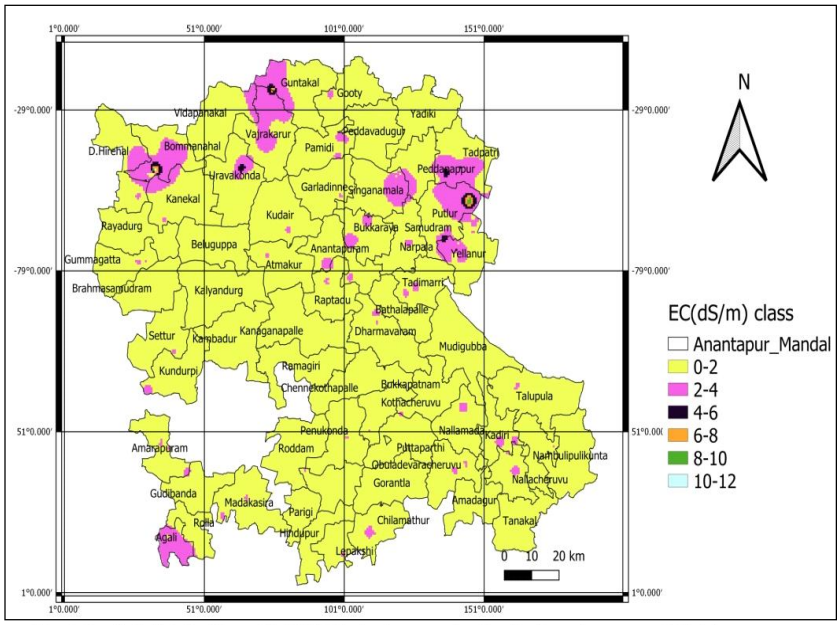

Fig 4: Spatial distribution of EC (dS/m) of ground water in Anantapuram district.

value of SAR was found as 36.4 (m mol $l^{-1})^{1/2}$ in village Hussainapuram of Tadipatri mandal. The spatial variability of SAR of groundwater in Anantapur district is depicted in Fig 5 indicated that highest SAR (>10) in groundwater was observed in parts of Rolla, Tadipatri, Putlur, Singanamala, Vajrakarur, Guntakal, Pamidi mandals. It was observed that with increase in SAR of irrigation water, the SAR of soil solution increases which ultimately increases the exchangeable sodium of the soil (Bhat *et al*., 2018). sodium in soils. According to Ayers and Westcot (1976) classification 97.97, 1.42 and 0.20 per cent samples (Table 4) belonged to excellent, good and doubtful, respectively.

Spatial variability in residual sodium carbonate (RSC)

Residual sodium carbonate is an important parameter that has extraordinary influence on the suitability of irrigation water (Pal *et al*., 2018). The residual sodium carbonate

Table 5: Classification of ground water samples based on RSC (mel^{-1}).

RSC (mel^{-1})		No. of	Per cent of
Class	Value	samples	samples
None	<2.5	417	84.76
Slight to moderate	2.5-4	33	6.71
Severe	>4	42	8.54

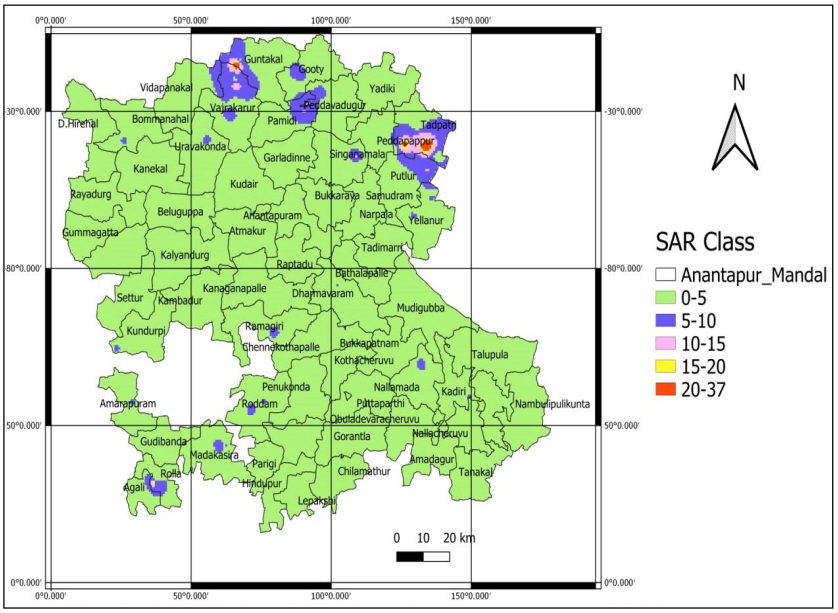

Fig 5: Spatial distribution of SAR of ground water in Anantapuram district.

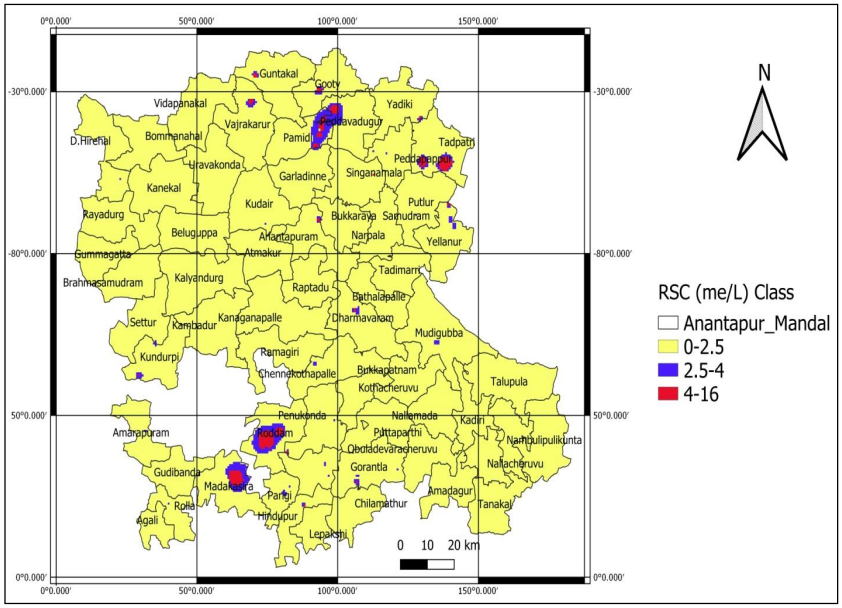

Fig 6: Spatial distribution of RSC (me/L) of ground water in Anantapuram district.

Table 6: Correlation matrix among the chemical constituents of the groundwater.

	pH	EC	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+	RSC	SAR
pH	1											
EC	-0.21	1.00										
CO_3^{-2}	0.15**	0.10	1.00									
HCO_3^-	-0.19	0.34**	0.14	1.00								
Cl^-	-0.21	0.94**	0.07	0.20	1.00							
SO_4^{-2}	-0.21	0.76**	0.01	0.24	0.68	1.00						
Ca^{+2}	-0.39	0.69**	-0.15	-0.02	0.74	0.61	1.00					
Mg^{+2}	-0.18	0.83**	0.04	0.12	0.86	0.62	0.68	1.00				
Na^+	-0.07	0.81**	0.21	0.46**	0.70	0.71	0.32	0.53	1.00			
K^+	-0.02	0.25**	-0.04	0.05	0.06	-0.02	0.07	0.07	0.00	1.00		
RSC	0.22**	-0.66**	0.15	0.31**	-0.75	-0.55	-0.87**	-0.84**	-0.27	-0.06	1.00	
SAR	0.05	0.50**	0.26**	0.57**	0.37	0.45	-0.02	0.13	0.82**	-0.02	0.15	1

Significant at 0.05 probability level*.

*Significant at 0.01 probability.

Table 7: Classification of ground water for irrigation (Minhas and Gupta, 1992).

Rating	Class	EC (dSm^{-1})	SAR	RSC (me L^{-1})	number of samples	Per cent samples
A. Good	A	<2	<10	<2.5	326	66.26
B. Saline						
Marginally saline	B1	2-4	<10	<2.5	87	17.68
Saline	B2	>4	<10	<2.5	7	1.42
High SAR Saline	B3	>4	>10	<2.5	3	0.61
C. Alkali water						
Marginally alkaline	C1	<4	<10	2.5-4.0	28	5.69
Alkali	C2	<4	<10	>4.0	34	6.91
Highly alkaline	C3	variable	>10	>4.0	7	1.42

(RSC) of groundwater in Anantapur district varied from -66.8-15.4 meq L^{-1} with a mean of -1.44 meq L^{-1}. The highest RSC of 15.4 meq L^{-1} in water samples was observed in parts of Hussainapuram village of Tadipatri mandal. The spatial distribution of residual sodium carbonate was depicted in Fig 6. Indicates that highest RSC (>2.5 me/L) in groundwater was observed with parts of Madakasira, Roddam, Dharmavaram, Gorantla, Hindupur, Vajrakarur, Guntakal, Pamidi, Paddavaduguru, Tadipatri, Yellanur and Singanamala mandals of Anantapur district. The pH, EC and SAR of the irrigation water were significantly influenced by RSC. Based on RSC water can be categorized into three categories such as safe (<2.5 meq L^{-1}), moderately suitable (2.5-4.0 meq L^{-1}) and unsuitable (>4 meq L^{-1}). In the present study, it was found that 417 samples (Table 5) were of safe category, 33samples were moderately suitable and 42 samples were unsuitable for irrigation purposes.

Ionic correlation studies

The dominance of major ions was in the order of $Na^+ > Ca^{+2} > Mg^{+2} > K^+$ for cations and $Cl^- > HCO_3^- > SO_4^{-2} > CO_3^-$ for anions (Table 6). Therefore, the chemical composition of the groundwater was characterized by Na^+-Cl^- water type. Significant positive correlation was observed between pH and CO_3^{-2} (r=0.15**) and RSC (0.22**), between EC and Ca^{+2}(0.69**), Mg^{+2}(0.83**), Na^+(0.81**), K^+, Cl^-(0.94**), SO_4^{-2} (0.76**) and HCO_3^-, between major cations, Na^+ - Ca^{+2} (r=0.32**) and Na^+ - Mg^{+2} (r=0.53**), between Na^+ - Cl^- (r=0.70**), Na^+ - HCO_3^- (r=0.46**) and Na^+ - SO_4^{-2} (r=0.71**). The positive correlation indicated that dissolution of sodium from respective e ion containing minerals. The correlation between SO_4^{-2} and Mg^{+2} (r=0.62**) implied that a part of the SO_4^{-2} and Mg^{+2} may also be derived by the weathering of magnesium sulphate mineral (Subbaiah *et al*., 2020 and Naidu *et al.,* 2020). The correlation between Mg^{+2} and HCO_3^- (r=0.12**) between Mg^{+2} and Cl^- (r=0.86**) and between Ca^{+2}

Table 8: Classification of ground water based on % Na values (Wilcox 1955).

% Na (after Wilcox 1955)	Classification	Total no. of samples	Percentage
<20	Excellent	39	7.93
20-40	Good	271	55.08
40-60	Permissible	134	27.24
60-80	Doubtful	39	7.93
80	Unsuitable	9	1.83

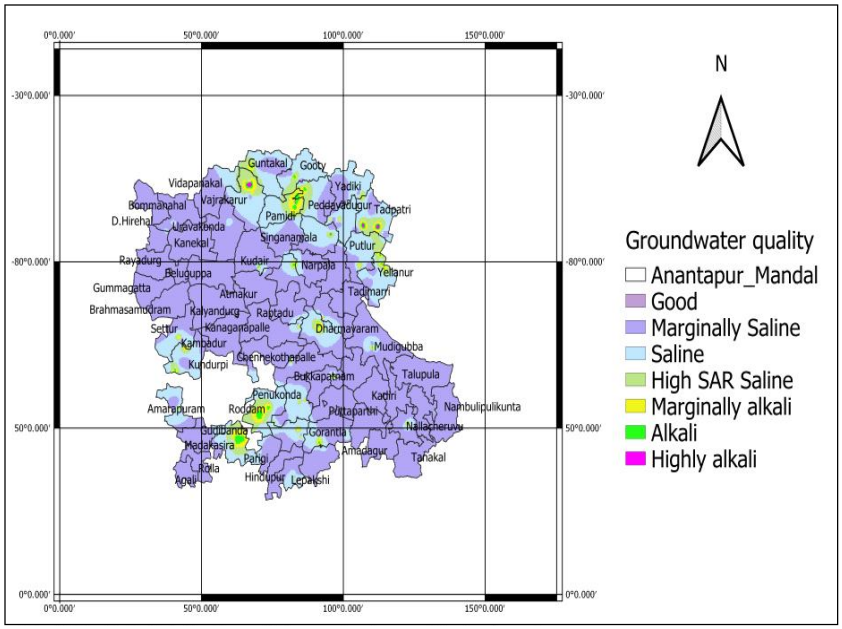

Fig 7: Spatial distribution of ground water quality in Anantapuram.

and Cl^- (r=0.74**) indicates that they most likely derive from the same source of water (Pal *et al*., 2018).

Ground water quality classification for irrigation purpose

The groundwater of Anantapur district was classified into 7 classes for irrigation purpose (Minhas and Gupta, 1992) and details are presented in Table 7. The 66.26% samples were of good quality, 17.68% were of marginally saline, 1.42% of saline, 0.61% high SAR saline, 5.69% of marginally alkali, 6.91% of alkali and 1.42% of highly alkali (Fig 7).

Sodium (%)

Sodium concentration in groundwater is a very important parameter in determining the irrigation quality. The formula used for calculating the sodium percentage was

$$Na\ \% = \frac{(Na^+ + K^+)}{(Ca^{+2} + Mg^{+2} + K^+ + Na^+)} \times 100$$

Where

All ionic concentrations are in meq/L.

The determined value of sodium percentage lies between 11.58 and 96.64 (Table 8). The maximum allowable limit of sodium percentage in groundwater is 60% (Ramakrishna 1998).

CONCLUSION

The ground water quality in Anantapur district varied from place to place. The dominance of major ion was in the order of $Na^+ > Ca^{+2} > Mg^{+2} > K^+$ for cations and $Cl^- > HCO_3^- > SO_4^{-2} > CO_3^-$ for anions, which indicated the quality of groundwater used for irrigation is Na^+-Cl^- type. Less than 66 per cent of the ground water samples were good in quality for irrigation. However, adoption of proper management practices is needed in case of poor quality ground water. The spatial maps of different parameters, prepared using GIS could be valuable for policy makers for initiating groundwater quality monitoring the area as well as for suggesting management plans.

Conflict of Interest: None.

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