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RESEARCH ARTICLE

ASSESSMENT OF GROUND WATER FOR IRRIGATION IN NAGULERU SUB BASIN OF GUNTUR DISTRICT, ANDHRA PRADESH, INDIA

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ABSTRACT

The assessment of groundwater quality is made through the estimation of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, EC, TDS,TH and pH in Naguleru Sub-Basin area Guntur District, Andhra Pradesh, India. Based on these analyses, parameters like sodium adsorption ratio, sodium percentage, residual sodium carbonate and magnesium hazard were calculated. Sodium adsorption ratio is shown 62% of groundwater is belongs to C3 S1, indicating high salinity and low alkali water and based on the Na% with 49% for groundwater falls in good to permissible category. Residual sodium carbonate values suggesting safe to marginally suitable category for irrigation purposes. The quality of water in the study area is high for all constituents ruling out pollution from extraneous source.

INTRODUCTION

The quality of a particular water supply must be studied with particular reference to usage as the ground water quality is influenced both by surface physical environment and by the environment where recharge takes place. The chemical quality of ground water depends mostly on the composition of the host rock. The quantity is also subjected to the degree of weathering, movement of ground water, individual ion-contents and ion-exchange, climate and to time variation in the process of recharge and discharge.

The sub-basin is physiographically divided into two parts, i.e., 1) the non-command area (southern part) and 2) the command area (northern part) located between the north latitudes of $16^0 14'29''$ and $16^0 43'05''$ and the east longitudes of $79^0 35'24''$ and $79^0 50'43''$ (Fig.1) and it falls in SOI Toposheet Nos.56 P/10, P/11, P/12, P/14 and P/15 on 1:50,000 scale. Hill ranges surround the southern part from a perfect sub-basin. Within this sub-basin some isolated hills are observed. These hills are having steep to medium slopes. In command area also some isolated hills are observed. On the periphery of Krishna River, steep sided gorges are also observed. Thus the topography is highly undulating having high to moderate slopes in the foothill zones and moderate low to gentle slopes in middle zones of the study area. The area covers 572 sq kms. Covering and adjoining the major areas. The study area receives an annual rainfall of 853 mm and receives maximum rainfall in September and October months.

Geology

The Geology of the area generally comes under Cuddapah Super Group particularly Kurnool group. The northern portion of the study area from centre mainly consists of Nargi lime stones except at northern part where a patch of Banaganapalli conglomerates and quartzites is vividly observed.

The southern portion is mostly occupied by Cumbhum shales and phyllites. The other minor formations include Cumbhum dolomite/limestone, Cumbhum quartzites, Koilakuntla limestones, Banaganapalli conglomerate and quartzite. The Koilakuntla limestone is triangle in shape is underlined as basement is Cumbhum quartzite as the basement.

Drainage

The drainage pattern is dendritic to sub-dendritic. The drainage originates from the divide of the southern semicircular hills and shedding inwards, constitutes stream Naguleru. Naguleru stream flows from south to north and finally merges into the River Krishna.

The elevation of highest peak is about +378 m and elevation of lowest valley point is about +60 m. The master drainage

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direction of study area is from south to north. There are almost 12 tanks of various sizes in the southern as well northern parts. It is the major contributor or water to River Krishna in the study area.

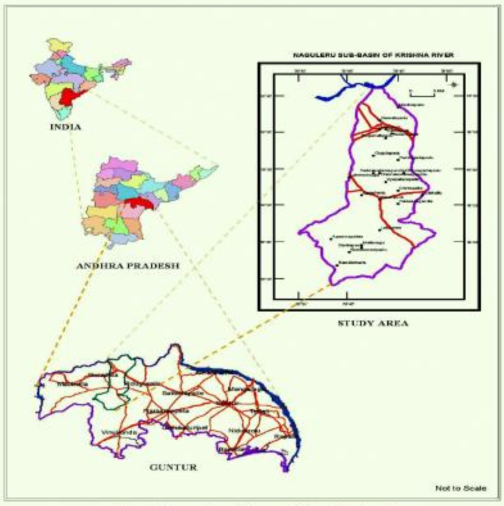

Fig. 1 Location Map of the Study Area

MATERIALS AND METHODS

Forty seven representative ground water samples were collected from the bore wells and analyzed for hydrogen ion concentration (pH), electrical conductivity (EC), total hardness (TH), total dissolved solids (TDS) and important cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}) as well as anions such as carbonates (CO_3^{2-}), bicarbonates (HCO_3^{-}), chlorides (Cl^{-}) and sulphates (SO_4^{2-}). The pH and EC values were measured in the field using a portable conductivity and pH meter. TDS were computed from EC multiplied by a factor (0.55–0.75), depending on relative concentrations of ions. Na+ and K+ were determined by flame photometer, SO42– is analyzed by spectrophotometer. TH as $CaCO_3$, Ca^{2+}, CO_3^{2-}, HCO_3^{-} and Cl^{-} were analyzed by volumetric method. Mg^{2+} was calculated from TH and Ca^{2+} contents. The techniques and methods followed for collection, preparation, analysis, and interpretation are those given by Rain water and Thatcher (1960), Brown *et al* (1970), APHA (1985), ISI (1983) and Hem (1985). The results are presented in Table.

RESULTS AND DISCUSSIONS

Hydrogen-Ion Concentration (pH)

The solvent power of water is indicated by pH value of water. In different chemical reactions, the pH of water changes with the production of hydrogen or hydroxyl ion. With the oxidation reduction potential, temperature and pressure, the pH determines the compounds dissolved, and precipitated in ground water regime. In ground water the oxidation-reduction potential depends on the amount of cations and anions in solution. Thus, the chemical concentration of anion with respect to pH may be inkling to its solubility. The desirable range of pH in drinking water is 6.5 to 8.5 (ISI, 1983). The mean pH value in the area is 7.3 with a minimum of 6.7 and maximum of 8.1. The pH in the water of the study area is within desirable limits.

Electrical Conductivity (EC)

Electrical Conductivity has been universally accepted as a standard measure of water quality, but there is a great degree of variability in choosing the water classes on this basis. The electrical conductivity is an index of degree of mineralization. Electrical conductivity varies with concentration and degree of ionization of the constituents and with temperature. The electrical conductivity of the ground water samples range from 515 to 2900 micro mhos/cm with the mean value of 1292 micro mhos/cm. The lowest value is recorded in sample no. 42 while the highest in No. 32. Electrical conductivity is one of the key physical parameter of water quality.

Table 1 Classification of Water basing of Electrical Conductivity (EC)

Range (Micromhos/cm)	Quality	No. of samples from the study area
< 250	Excellent	--
250 - 750	Good	5
750 - 2250	Medium	42
2250 - 4000	Bad	--
> 4000	Very bad	--

According to the above classification 5 samples (11 %) are good and 42 samples (89%) are medium in quality. Above all, the water fits for practical purposes like drinking, irrigation and agricultural purposes.

Table 2 Statistical summary of the chemical composition of groundwater

	Range	Minimum	Maximum	Mean	Std. Deviation
Ca (mg L-1)	100	20	120	51.57	21.07
Mg (mg L-1)	91.2	4.8	96	43.68	27.82
Na (mg L-1)	363	47	410	176.74	99.10
K (mg L-1)	88	2	90	9.28	13.81
CO3 (mg L-1)	100	20	120	52.13	20.86
HCO3 (mg L-1)	330	70	400	209.60	75.67
SO4 (mg L-1)	610.7	11.3	433	106.73	114.30
Cl (mg L-1)	575	11	586	221.11	139.99
TDS (mg L-1)	1455	321	1776	780.43	346.04
p H	1.4	6.7	8.1	7.3	0.451
EC (µSL-1)	2385	515	2900	1292	564.96

Magnesium (Mg)

Magnesium and calcium are the two elements mainly responsible for hardness of water. Olivine, biotite, hornblende, serpentine, and talc are some major magnesium-bearing minerals. The presence of carbon dioxide influences the solubility of magnesium. The desirable limit of magnesium in natural water is 30 mg/l (ISI, 1983). The concentrations in majority of the samples fall within the desirable limit. The lowest magnesium value is recorded in sample no.18 while the highest is in 29. The concentration of Mg varies between 4.8 mg/l and the 96 mg/l and the average is 43.68 with a range of 91.2.

Total Dissolved Solids (Tds)

The total dissolved solids are important in judging the quality of water as these indicate hardness of water. The TDS ranges between 321 mg/l and 1776 mg/l. The mean 780.43 mg/l. The lowest value is recorded in sample no. 42 and highest in sample 32. TDS is a direct function of electrical conductance.

TDS vs EC

The relationship between TDS and EC parameters of water quality has been shown on X-Y axis. The Figure.2 shows a positive correlation between TDS and EC have show perfect relationship i.e., higher the TDS higher will be EC.

Different limits of TDS are fixed for different purposes by various organizations and individual (Anon, 1946; AWWA, 1950; Robinove *et al*, 1958 and Davis & Dewiest, 1966). They are classified basing on U.S.G.S classification as follows:

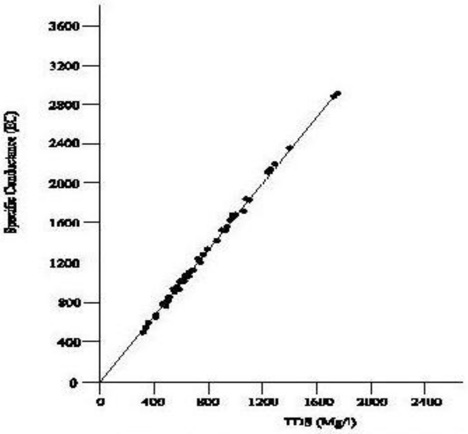

Fig.2. Relation between to EC and TDS

Total Hardness

Hardness, the most important property of water, is mainly due to the presence of carbonate, calcium and magnesium. It is expressed as an equivalent amount of $CaCO_3$. The hardness value is generally termed as hardness as $CaCO_3$ or total hardness. Carbonate hardness includes only that portion of the hardness equal to the HCO_3 + CO_3. If the hardness exceeds alkalinity, the excess is termed as non-carbonate hardness. The hardness of the water samples ranges from 110Mg/l 620 Mg/l with an average of 355 mg/l.

Sodium Adsorption Ratio (SAR)

The U.S. Salinity Laboratory (1954) proposed the use of sodium adsorption ratio (SAR) for adjudging the quality of water for the use of agricultural purposes. This method utilizes SAR and electrical conductivity as a basis for rating irrigation waters. Kelly (1951) pointed out the importance of sodium concentration in assessing the suitability of ground water for irrigation. Excess sodium in irrigation water reacts with soil and results in clogging of particles and reduction of permeability.

In irrigation water, the values of SAR are used as basis for predicting the alkali or sodium hazard that may result from the use of water. High SAR value may cause damage to soil. SAR refers to the predominance of the Na over Ca and Mg ions and is related to the adsorption of Na ions by soil to which water is added. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR) and it can be estimated by the formula

$$SAR = Na^{+} / \sqrt{(Ca^{2+} + Mg^{2+})/2}$$

Table3 Classification of Irrigation water basing on SAR

SAR	Water Class	No. of samples	Percent
< 10	Excellent	46	98
10 - 18	Good	01	02
18 - 26	Fair	--	
> 26	Poor	--	

As per the above classification 98 per cent of waters are excellent and 2 per cent are good.

The groundwater has been classified basing on USSL diagram given by Richard (1947). From the diagram (Fig.3) it can be depicted that 5 samples (11%) fell in C_2-S_1 class, 29 samples (62 %) in C_3-S_1, 9 samples (19 %) in C_3-S_2 , 3 samples (6%) in C_4 - S_2 and only 1 sample (2%) in C_3 - S_3 . The samples indicate low alkali hazard with higher EC. About 13 samples are not good for irrigational purposes. The tolerant crops such as citric etc can be grown.

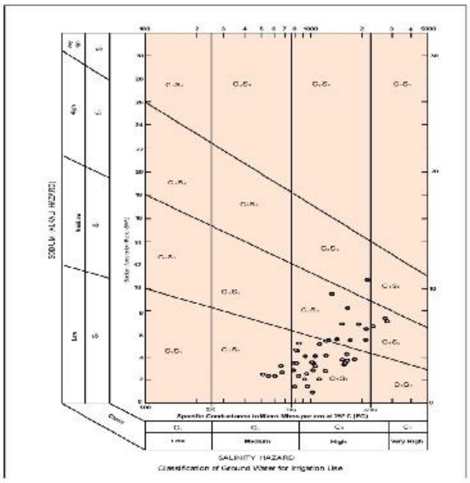

Fig. 3 U.S. Salinity Laboratory Diagram given by Richard (1954)

Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate is used in classifying the quality of water for agriculture. An additional hazard exists when waters are high in bicarbonate and relatively low in calcium. When the total of carbonate and bicarbonate exceeds the sum of calcium and magnesium present, the excess amount gets precipitated as Residual Sodium Carbonate (RSC) that is obtained by the equation.

$RSC = [(HCO_3 - + CO3^{2-}) - (Ca^{2+} + Mg^{2+})]$

RSC defined as twice the amount of carbonate and bicarbonate a water would contain after subtracting an amount equivalent to Ca, Mg in meq/l. Eaton (1950) observed that irrigation waters rich in RSC will have high pH and decrease the fertility of the soil due to the deposition of black alkali. The U.S salinity laboraty (1954) proposed a simple classification of irrigation waters based on RSC. Water contains more than 2.5 meq/l of RSC are not suited for irrigation while those containing between 1.25 and 2.5 meq/l are marginal quality and those containing less than 1.25 meq/l are probably safe Where all the ions are expressed in meq/l. The RSC values of the study area ranges from 0.046 to 6.763 with a mean of 2.94.

Magnesium hazard (MH)

Generally, alkaline earths are in equilibrium state in groundwater. If soils have more alkaline earths, they reduce a crop yield. Szaboles and Darab (1964) have proposed a magnesium hazard in relation to the alkaline earths for irrigation. This hazard is expressed in terms of magnesium hazard (MH), which is computed by using the values of ions in meq/L.

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} x100$$

Table.4 Irrigational quality results of groundwater samples of the study area

S.No	SAR	RSC (MeqL-1)	%Na (MeqL^{-1})	MH (MeqL^{-1})	EC (μSL^{-1})
1	100	---	23.435	28.373	1015
2	3.429	---	43.75	69.776	1560
3	5.145	---	74.78	57.896	1117
4	1.560	---	34.53	54.235	785
5	2.168	0.386	37.973	84.767	915
6	5.633	---	100	86.242	1421
7	3.874	---	47.970	80.270	1525
8	2.130	---	34.576	81.260	1123
9	1.580	---	28.137	62.545	945
10	9.484	6.763	79.63	46.406	1345
11	4.72	1.02	65.29	42.045	820
12	6.93	2.912	68.066	59.002	1512
13	2.893	1.084	45.68	63.204	1040
14	4.182	---	61.978	29.183	935
15	3.603	---	52.025	44.565	1020
16	2.485	---	50.041	43.486	560
17	6.505	---	61.413	51.273	2110
18	5.234	2.521	69.350	14.126	840
19	4.631	2.62	66.255	26.441	822
20	3.334	---	50.017	54.910	1070
21	2.943	0.755	50.470	45.181	785
22	5.504	---	55.154	74.805	2140
23	3.592	0.144	53.836	59.741	1011
24	2.436	---	43.720	30.535	840
25	5.469	0.023	64.265	53.905	1290
26	3.487	0.513	56.451	52.360	790
27	7.108	---	61	54.124	2880
28	5.469	0.382	65.03	47.558	1230
29	3.989	---	46.746	75.278	1844
30	3.771	---	46.82	68.520	1660
31	6.718	---	60.702	55.990	2360
32	7.194	---	59.360	59.420	2900
33	2.840	---	42.487	62.249	1211
34	2.838	---	46.988	57.879	944
35	10.705	---	77.692	41.401	2205
36	4.137	---	57.018	23.794	1070
37	2.455	0.045	54.964	36.126	605
38	4.36	---	53.73	59.745	1668
39	5.515	---	59.368	62.909	1721
40	3.582	0.185	57.217	52.360	820
41	3.315	---	58.349	46.406	664
42	2.527	---	53.567	38.211	515
43	6.938	---	65.075	65.474	1930
44	2.702	0.218	51.466	49.817	672
45	4.147	---	58.08	55.292	1242
46	3.752	---	47.591	76.407	1632
47	8.364	2.696	76.134	44.167	1690

Per Cent Sodium (%Na)

Sodium concentration is important in classifying the irrigation waters as sodium reacts with soil to reduce its permeability. Wilcox (1948) proposed the use of per cent sodium for adjudging the quality of ground water for agricultural purposes. It is calculated as

$$\%Na = \frac{(Na^{+}+K^{+})}{(Ca^{+}+Mg^{+}+Na^{+}+K^{+})} x100$$

Where all ionic concentrations are expressed in meq/l

Wilcox (1955) used this ratio in conjunction with specific conductance for the assessment of the water suitability for irrigation (Fig.4). It is classified into five distinct areas to rate the quality of water in relation to irrigation as 'excellent to good', 'good to permissible', 'permissible to doubtful', doubtful to unsuitable' and 'unsuitable'.

The water of the study area has been classified basing on Wilcox diagram (1955). The diagram depicts that 5 samples come under excellent to good quality (11%), 23 samples under good to permissible (49%), 12 samples under permissible to doubtful(26%) and 6 samples come under doubtful to unsuitable classes (13). Above all, most of the samples have within the permissible limits. Water which comes under permissible to doubtful may be used for alkaline tolerant crops such as citrus etc.

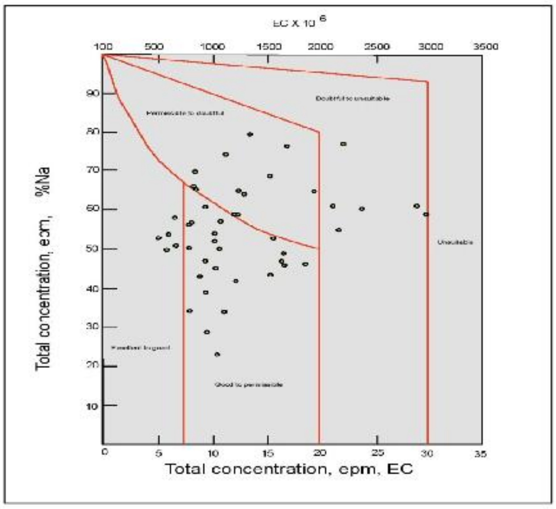

Fig. 4. Diagram for classification of irrigation waters (Wilcox1955)

CONCLUSION

From the diagram it can be depicted that 5 samples (11%) fell in C_2-S_1 class, 29 samples (62 %) in C_3-S_1, 9 samples (19 %) in C_3-S_2, 3 samples (6%) in C_4 - S_2 and only 1 sample (2%) in C_3 - S_3. The samples indicate low alkali hazard with higher EC. About 13 samples are not good for irrigational purposes. The tolerant crops such as citric etc can be grown. According to Wilcox diagram 5 samples come under excellent to good quality (11%), 24 samples under good to permissible (49%), 12 samples under permissible to doubtful(26%) and 6 samples come under doubtful to unsuitable classes (13). Above all, most of the samples have within the permissible limits. The calculated RSC values in the groundwater samples of Naguleru

Sub-basin area are found varies from 0.046 to 6.763. As the value of magnesium hazard in them less than 50 (19 sample locations). The remaining groundwater samples 59% (28 locations) show the value of MH exceeds 50 and hence they are unsafe for irrigation purpose.

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