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Groundwater Quality Assessment of Nandyal district using Geographical Information System

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***Abstract*:** Nandyal district was situated on west side of Nallamala of Eastern ghats range in Andhra Pradesh. The physiography of the district acts as catchment and basin for Kundu river drain a rivulet to Penna river of Andhra Pradesh. Groundwater samples of Nandyal district were analyzed for various properties *viz.,* pH, EC, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+}; CO_3^{-2}, HCO_3^{-}, Cl^{-} and SO_4^{-2}. The pH, EC, SAR, RSC, Kelly's ratio (KR), soluble sodium percentage (SSP) and permeability index (PI) in groundwater ranged from 6.5 to 8.4, 0.2 to 22.0 (dSm^{-1}), 0.18 to 34.1 ($mmol\ l^{-1})^{1/2}$, -91.2 to 7.6 ($me\ l^{-1}$), 0.07 to 10.9, 6.99 to 88.45 and 32.79 to 110 respectively. The relative abundance of ions for most of the water samples were Na^{+}> Ca^{+2}> Mg^{+2}> K^{+} for cations and HCO_3^{-}> Cl^{-}> SO_4^{-2}> CO_3^{-} for anions. The irrigation water quality of groundwater classified as good (66.67%), marginally saline (19.75%), saline (3.29%), high SAR saline (7.41%), marginally alkali (1.65%), alkali (0.41%) and high SAR alkali (0.82%). Based on thematic maps developed using inverse distance weightage method in geographical information system, the poor quality groundwater was observed in Midtur, Nandyal, Gadivemula, Gospadu, Koilakuntla, Dornipadu, Uyyalawada, Chagalamarri, Allagadda mandals of Nandyal district.

***Keywords*:** Nandyal ground water quality, EC, RSC, SAR, Spatial variability

Assessment of spatial variability in groundwater quality for irrigation is key for sustainable groundwater use. The quality of groundwater is dynamic and it changes with the rainfall distribution and climate change activities. Demand for groundwater has increased tremendously in recent years due to increase in population and intense agricultural activities. Good quality irrigation water helps the farmer in achieving the targeted production and with optimum input management. Spatial variability information of groundwater quality helps the farmers and other stakeholders for effective management of inputs in crop production (Vinoth Kanna et al 2020). It is essential to understand the spatial distribution of groundwater quality in order to determine its suitability for irrigation purposes. Such an assessment is helpful to understand the influence of irrigation water quality on crop productivity and to suggest agronomic practices for better crop yields by reducing the adverse effects of saline/alkaline water irrigation (Subbaiah et al 2022). Keeping this in view a study was conducted to assess the groundwater quality of Nandyal district of Andhra Pradesh state, India using Geographical information system.

MATERIAL AND METHODS

Study area: Nandyal district was situated on west side of Nallamala of Eastern ghats range in Andhra Pradesh lies in between 14°53' 18.68 " and 16° 9' 18.938" of Northern latitudes and 77° 39' 12.261" and 78° 55' 1.722" Eastern longitudes occupies central part of Andhra Pradesh. Nandyal has a total geographical area of 9681 km^2. The district is bordered by Nagarkurnool district of Telanagana state in North, east by Prakasam and on the South by Kadapa, Anantapur and west by Kurnool and district.

Methodology: Two hundred and forty three (243) ground water samples were randomly collected along with GPS coordinates from each mandal of Nandyal district (Fig. 1). Standard procedures were followed to analyze the quality of water. pH in water samples was determined by potentiometrically using pH meter. Electrical conductivity was determined by using Conductivity Bridge. 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). Sodium Adsorption Ratio (SAR), RSC were calculated by using the formulas given by Richards (1954) such as SAR = Na/ $((Ca^{2+}+Mg^{2+})/2)^{0.5}$ and 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 RSC, SAR, KR, SSP, PI was computed for irrigation water quality.

Kelley's ratio: Kelley's ratio was used to classify the

irrigation water quality (Kelley 1940), which is the level of Na^+ measured against calcium and magnesium.

$$KR = \frac{Na^+}{(Ca^{+2} + Mg^{+2})}$$

Where the concentration of ions are in mg/L

Soluble sodium percentage (SSP): Sodium concentration in groundwater is a very important parameter in determining the irrigation quality. The formula used for calculating the sodium percentage (Wilcox,1955)

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

where all ionic concentrations are in meq/L.

Permeability index: Long-term use of irrigation contains Na^+, Ca^{+2}, Mg^{+2} and HCO_3^- ions greatly influence the soil permeability . Doneen 1964 expressed the degree of soil permeability in terms of permeability index (PI).

$$PI = \frac{(Na^+ + \sqrt{HCO_3^-})}{(Ca^{+2} + Mg^{+2} + Na^+)} \times 100$$

where all ionic concentrations are in meq/L.

Statistical analysis and mapping: Research data were analyzed in SPSS 20.0 using Pearson correlation coefficient matrix to know significant variations between the physicochemical properties. Descriptive statistics were calculated using Microsoft Excel (Microsoft, WA, USA) spread sheet. Spatial distribution of groundwater quality was depicted in figures using Q-GIS 3.16.10.

RESULTS AND DISCUSSION

Groundwater Quality Determination

Spatial variability in water reaction (pH): The pH of water samples of Nandyal district varied from 6.5 to 8.4 with a mean of 7.26. (Table 1, Fig. 2). The highest pH (>7.6) in groundwater was in parts of Kothapalle, Gadivemula, Banaganapalle, Gospadu, Koilakuntla, Dornipadu mandals of Nandyal district.

Spatial variability in EC: The electrical conductivity of groundwater of Nandyal district ranged from 0.4 to 22.3 dS m^{-1} . Based on electrical conductivity groundwater is grouped into different classes (Table 2) *viz.,* Groundwater with <2 dSm^{-1} (72.84%), 2-4 dSm^{-1} (16.87%), 4-6 dSm^{-1} (4.94%), 6-8 dSm^{-1} (2.06%), 8-10 dSm^{-1} (1.23%) and >10 dSm^{-1} (2.06%). Highest EC (22.3 dSm^{-1}) was reported with Nandyal mandal and lowest EC (0.4 dS m^{-1}) was reported with Owk mandal. The variation in EC may be due to variation in geological conditions, soil type, drainage and climate. Groundwater salinity is observed mostly with cuddapah and Nandyal formations and in black cotton soils of eastern part of the district. Gneissic and sedimentary terrain of the district maybe the reason for the good (low saline) quality water of the district. The correlation matrix of the groundwater samples exhibits highly significant positive correlation (>0.6) between EC and Ca^{+2}, Mg^{+2} (0.867**), Na^+ (0.972**), Cl^- (0.952**) and SO_4^{-2}. The higher EC of groundwater is due to the presence of alluvial and black cotton soils might decreased the infiltration of rainwater at flood plains of Kundu river and in parts Gadivemula, Nandyal, Gospadu, Koilakuntla, Dornipadu, Uyyalawada mandals of Nandyal district (Fig. 3). The concentration and composition of ions of groundwater significantly influenced the electrical conductivity of water (Subbaiah et al 2023)

Variability in ionic concentration: The concentration of cations viz., calcium, magnesium, sodium and potassium in water samples varied from 1.2-39.6, 0-56.0, 0.26-131 and 0.005-78.5 meq L^{-1} with mean values of 6.03, 4.51, 11.49 and 0.32 meq L^{-1} respectively. The relative abundance of ions for most of the water samples are $Na^+ > Ca^{+2} > Mg^{+2} > K^+$. The concentration of anions viz., carbonate, bicarbonate, chloride and sulphate varied from 0-0.8, 0.8-12.2, 0.8-197

Table 1. Descriptive statistics for water quality parameters in Nandyal district

Parameter	Range	Mean
pH	6.5-8.4	7.26
EC(dSm^{-1})	0.4-22.3	2.07
CO_3^{2-}(me L^{-1})	0.0-0.8	0.01
HCO_3^-(me L^{-1})	0.8-12.2	6.22
Cl^-(me L^{-1})	0.8-197	9.87
SO_4^{2-}(me L^{-1})	0.02-8.84	1.73
Ca^{2+}(me L^{-1})	1.2-39.6	6.03
Mg^{2+}(me L^{-1})	0.0-56.0	4.51
Na^+(me L^{-1})	0.26-131	11.49
K^+(me L^{-1})	0.005-78.5	0.32
RSC(me L^{-1})	-91.2 to 7.6	-4.32
SAR	0.18-34.1	4.46
KR	0.07-10.9	1.35
SSP	6.99-88.45	43.61
PI	32.79-110	59.0

Table 2. Grouping of groundwater based on EC (dSm^{-1})

EC (dSm^{-1})	No. of samples	Per cent of samples
0-2	177	72.84
2-4	41	16.87
4-6	12	4.94
6-8	5	2.06
8-10	3	1.23
>10	5	2.06

and 0.02-8.84 meq L^{-1}. The relative abundance of ions for most of the water samples are HCO_3^-> Cl^-> SO_4^{-2}> CO_3^{-2}.The chloride and bicarbonate ions are dominant among all the anions then followed by sulphates and carbonates.

Spatial variability in SAR : The SAR of groundwater of Nandyal district ranged from 0.18Owk mandal - 34.1 (m mol $l^{-1})^{1/2}$ in Banaganapalle. The lowest SAR of 0.18 (m mol $l^{-1})^{1/2}$ in water samples was observed in . The highest SAR(>10) in groundwater was observed in parts of Gadivemula, Nandyal, Banaganapalle, Gospadu, Koilakuntla, Dornipadu, Uyyalawada. Based on SAR of groundwater most (91.77%) of the samples are <10 (m mol $l^{-1})^{1/2}$ in Nandyal district (Table 3, Fig. 4).

Spatial variability in RSC: The residual sodium carbonate (RSC) of groundwater in Nandyal district varied from –91.2 to 7.6 meq L^{-1} with a mean of -4.32 meq L^{-1} . The highest RSC of 7.6 meq L^{-1} in water samples was observed in parts of Kothapalle mandal. highest RSC (>2.5 me/L) in groundwater was observed with parts of Kothapalle mandal of Nandyal district (Fig. 5).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 235 samples were of safe category, 4 samples each were moderately suitable and unsuitable for irrigation purposes (Table 4). Naidu et al (2020) and Subbaiah et al (2022) also reported similar results with Nellore and Kadapa districts.

Grouping of Groundwater Quality for Irrigation

Minhas and Gupta classification: The groundwater of Nandyal district was classified into 7 classes for irrigation purpose (Minhas and Gupta, 1992) (Table 5). The irrigation water quality of groundwater classified as good (66.67%), marginally saline (19.75%), saline (3.29%), high SAR saline (7.41%), marginally alkali (1.65%), alkali (0.41%) and high SAR alkali (0.82%)**(Fig. 6).**

Wilcox classification: Based on soluble sodium per cent values (Wilcox 1955), the quality of groundwater was classified as excellent (11.11%), good (28.4%), permissible (44.44%), doubtful (14.40%) and unsuitable (1.46%). Overall majority of the samples are with less sodium hazard (Table 6).

Kelley's ratio: Kelley's ratio lies between 0.07-10.9 mg/L. Kelley's ratio value less than one is suitable for irrigation(108 samples) and more than one is unsuitable(135 samples).

Permeability index: The permeability index (of groundwater of Nandyal district varied from 32.79 to 110 (Table 7). Based on the permeability index classification given by Doneen (1964) 9.47 per cent samples of Nandyal district were suitable for irrigation, 90.53 per cent are marginal. Unsuitable quality was not reported. Permeability of soil was reduced due to the activity of high bicarbonate ions in irrigation water (Kumar and Kumar 2021)

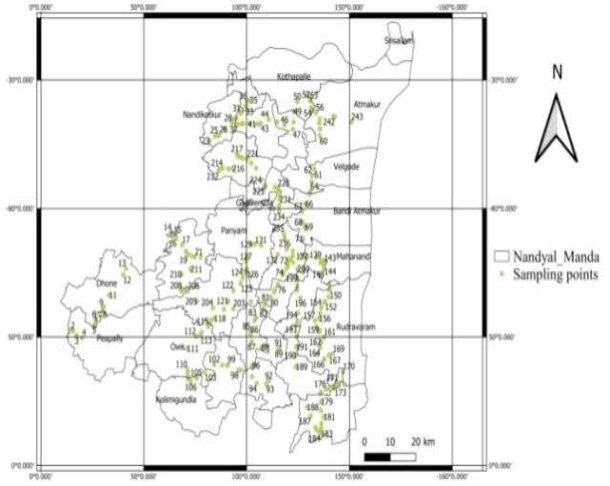

Fig 1 .Groundwater sampling points

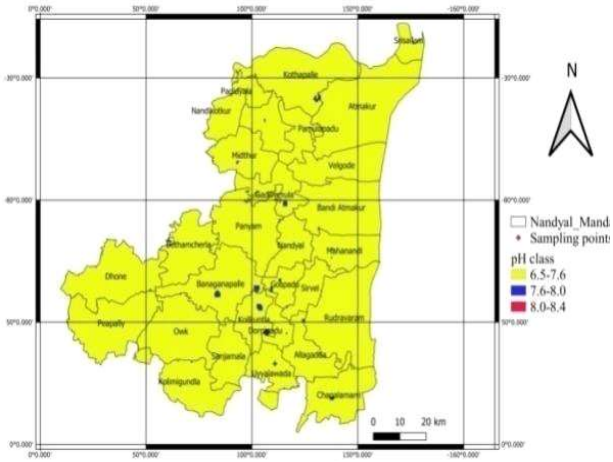

Fig 2. Spatial variability in pH of groundwater

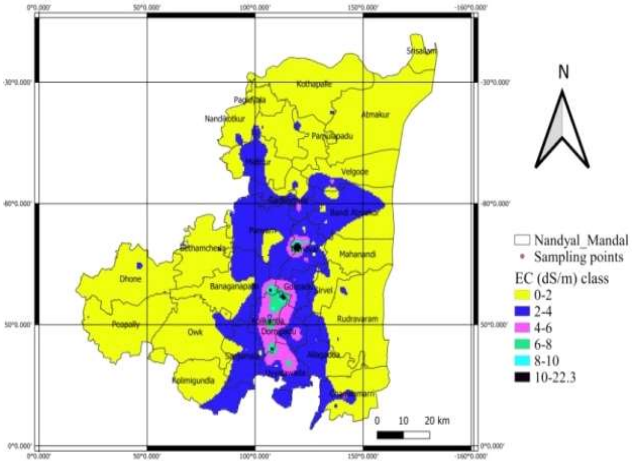

Fig 3. Spatial distribution of EC (dS/m) in groundwater

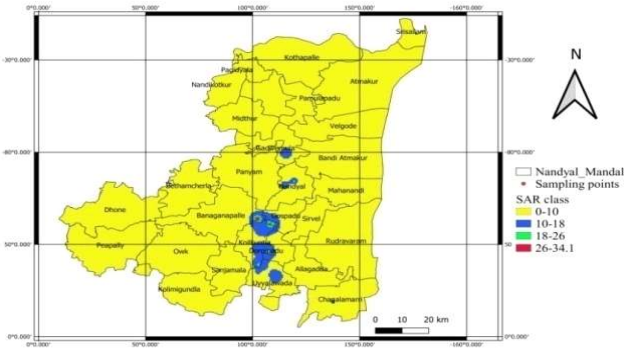

Fig 4. Spatial variability in SAR of groundwater

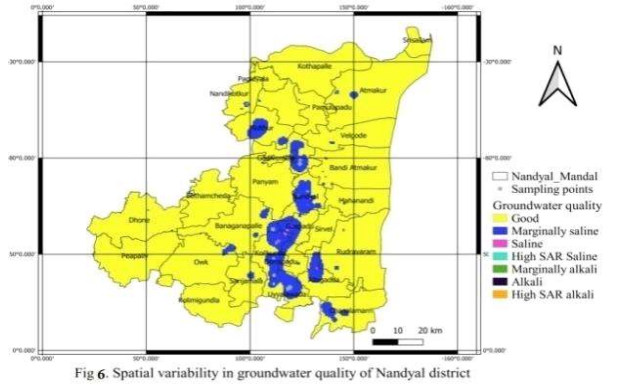

Fig 6. Spatial variability in groundwater quality of Nandyal district

Table 3. Grouping of groundwater based on SAR

SAR	No. of samples	Per cent of samples
<10	223	91.77
10-18	13	5.35
18-26	5	2.06
>26	2	0.82

Table 4. Grouping of groundwater based on RSC (mel^{-1})

RSC (mel^{-1})		No. of samples	Per cent of samples
Class	Value		
None	<2.5	235	96.71
Slight to moderate	2.5-4	4	1.65
Severe	>4	4	1.65

Effect geological conditions and soil type on ionic composition: The dominance of major ions was in the order of $Na^+ > Ca^{+2} > Mg^{+2} > K^+$ for cations and $HCO_3^- > Cl^- > SO_4^{-2} > CO_3^-$ for anions (Table 8) Therefore, the chemical composition of the groundwater was characterized by Na^+- HCO_3^- type due

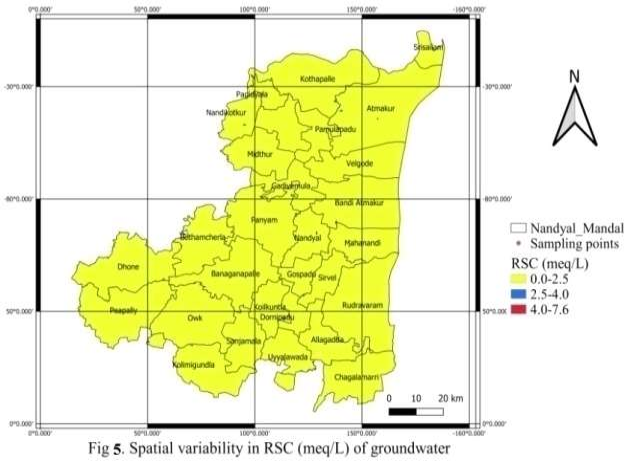

Fig 5. Spatial variability in RSC (meq/L) of groundwater

Table 6. Grouping of groundwater based on % Na values (Wilcox 1955)

Percent Na (After Wilcox 1955)	Classification	Total no. of samples	Percentage
<20	Excellent	27	11.11
20-40	Good	69	28.40
40-60	Permissible	108	44.44
60-80	Doubtful	35	14.40
>80	Unsuitable	4	1.65

Table 7. Grouping of groundwater based on permeability index (PI) for irrigation (Doneen 1964)

Classification of PI	Permeability	Suitability	Sample	
			Number	Per cent
I	>75	Suitable	23.00	9.47
II	25-75	Marginal	220.00	90.53
III	<25	Unsuitable	0.00	0.00

Table 5. Grouping of groundwater of Nandyal district 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	162	66.67
B. Saline						
Marginally saline	B1	2-4	<10	<2.5	48	19.75
Saline	B2	>4	<10	<2.5	8	3.29
High SAR Saline	B3	>4	>10	<2.5	18	7.41
C. Alkali water						
Marginally alkali	C1	<4	<10	2.5-4.0	4	1.65
Alkali	C2	<4	<10	>4.0	1	0.41
High SAR alkali	C3	Variable	>10	>4.0	2	0.82

Table 8. Dominance of ions in groundwater of various mandals in Nandyala district

Name of the mandal	Type of rocks and minerals	Soil type	Groundwater type	GPS Co-ordinates
Nandyal	Shale, limestone	Loam	Na-Cl	15.476,78.435;15.473,78.489;15.458,78.475;15.487,78.489; 15.472,78.518;15.435,78.506;15.453,78.491;15.537,78.458; 15.524,78.459;15.521,78.46;15.492,78.467; 15.463,78.477; 15.462,78.482; 15.443,78.471;15.437,78.467;15.424,78.455;15.419,78.453
Nandikotkur	Lime stones	Red, black (loam)	Na-Cl	15.806,78.188;15.819,78.207;15.821,78.219;15.823,78.224; 15.841,78.243;15.856,78.269;15.869,78.276
Midtur	Limestone, shale	Red , black (loam)	Na-Ca -HCO_3-Cl	15.718,78.22;15.725,78.223;15.726,78.236;15.724,78.256; 15.725,78.271;15.767,78.287;15.760,78.291;15.758,78.301; 15.755,78.308;15.753,78.324;15.741,78.338;15.726,78.356; 15.692,78.376;15.675,78.387
Gadivemula	Shale	Red, black (loam)	Na-Cl-HCO_3	15.675,78.391;15.672,78.425;15.668,78.435;15.660,78.44; 15.656,78.442;15.652,78.441;15.638,78.441;15.618,78.44; 15.601,78.439
Pagidyala	Limes tone	Red	Ca-HCO_3	15.906,78.319;15.907,78.319;15.924,78.334;15.920,78.323
Jupadu bunglow	Shale, lime stone	Red	Na-Ca-Mg-Cl- HCO_3	15.871,78.285;15.885,78.30;15.889,78.304;15.854,78.289; 15.855,78.305;15.856,78.31;15.855,78.334;15.854,78.356; 15.854,78.368;15.857,78.374;15.867,78.402
Pamulapadu	Shale	Red	Na-Ca-Cl-HCO_3	15.860,78.434;15.851,78.459;15.839,78.49;15.860,78.492; 15.891,78.493
Kothapalle	Shale	Red	Na-Ca-HCO_3	15.919,78.506;15.939,78.541;15.924,78.552;15.922,78.552; 15.902,78.557;15.893,78.559
Atmakur	Quartzite	Red	Na-Ca-HCO_3	15.887,78.573;15.869,78.587;15.857,78.586;15.840,78.588; 15.821,78.587;15.876,78.637;15.876,78.642;15.860,78.701
Velugod	Quartzite	Red	Na-Ca-HCO_3	15.723,78.567;15.706,78.559;15.687,78.557;15.658,78.553
B.Atmakur	Quartzite	Red	Na-Cl	15.652,78.551;15.623,78.534;15.601,78.524;15.570,78.524; 15.557,78.534;15.551,78.534;15.522,78.526
Mahanandi	Quartzite	Red	Na-Ca-HCO_3	15.471,78.543;15.468,78.576;15.460,78.592;15.460,78.606; 15.456,78.609;15.453,78.605;15.451,78.603;15.443,78.603; 15.452,78.602;15.452,78.6;15.452,78.59;15.434,78.602
Rudravaram	Quartzite	Red	Na-Ca-HCO_3	15.374,78.623;15.354,78.619;15.340,78.606;15.338,78.603; 15.322,78.593;15.306,78.588;15.291,78.584,15.285,78.57; 15.267,78.575;15.258,78.584;15.252,78.588;15.237,78.602; 15.223,78.592;15.221,78.59;15.207,78.588;15.187,78.577; 15.174,78.604;15.185,78.62;15.186,78.622;15.188,78.634
Allagadda	Barites	Red, black (loam)	Ca-HCO_3	15.137,78.671;15.104,78.653;15.100,78.65;15.092,78.64; 15.090,78.638;15.088,78.619;15.086,78.609;15.077,78.591; 15.074,78.589;15.151,78.50;15.184,78.501;15.209,78.502; 15.240,78.503
Chagalamarri	Limestone, shale, quartzite	Red	Na-Ca -HCO_3-Cl	15.050,78.591;15.024,78.591;15.006,78.60;14.987,78.593; 14.973,78.591;14.959,78.589;14.968,78.576;14.976,78.57; 15.009,78.554;15.034,78.541
Sirivella	Limestone, shale, quartzite	Black (loam)	Na-Ca -HCO_3-Cl	15.275,78.504;15.285,78.506;15.307,78.508;15.351,78.517; 15.374,78.505;15.390,78.621
Gospadu	Limestone, shale, quartzite	Black (loam)	Na-Cl	15.390,78.436;15.386,78.434;15.373,78.424;15.367,78.421; 15.353,78.408;15.337,78.391;15.385,78.505;15.407,78.506
Koilakuntla	Limestone with shale	Black (loam)	Na-Cl	15.293,78.358;15.285,78.351;15.253,78.336;15.243,78.337; 15.224,78.34;15.208,78.376;15.155,78.343
Uyyalawada	Limestone with shale	Black (loam)	Na-Cl	15.110,78.402;15.102,78.393;15.103,78.359;15.123,78.342
Kolimigundla	Limestone with shale	Red	Ca-HCO_3	15.119,78.142;15.119,78.14;15.108,78.12;15.118,78.11
Owk	Shale, Limestone	Red	Ca-Na-HCO_3	15.121,78.11;15.135,78.109;15.143,78.108;15.204,78.106; 15.239,78.138;15.243,78.154;15.251,78.16;15.268,78.184; 15.273,78.188;15.136,78.17
Peapully	Shale	Red	Ca-HCO_3	15.258,77.687;15.255,77.693;15.242,77.707;15.235,77.726; 15.273,77.77;15.288,77.777;15.304,77.791
Dornipadu	Shale	Black (loam)	Na-Cl	15.204,78.439;15.205,78.441;15.205,78.438;15.320,78.384
Sanjamala	Shale	Black (loam)	Na-Cl	15.142,78.301;15.142,78.293;15.157,78.253;15.155,78.252; 15.156,78.234;15.158,78.205

Cont...

Table 8. Dominance of ions in groundwater of various mandals in Nandyala district

Name of the mandal	Type of rocks and minerals	Soil type	Groundwater type	GPS Co-ordinates
Banaganapalli	Sandstone, Lime stone	Red	Na-Ca-Cl-HCO_3	15.286,78.192;15.291,78.204;15.318,78.24;15.340,78.254; 15.342,78.256;15.372,78.275;15.393,78.301;15.409,78.308; 15.422,78.318;15.341,78.338;15.320,78.274;15.322,78.201; 15.341,78.143; 15.370,78.109
Bethamcherla	Limestone, dolomite	Red	Ca-Mg-HCO_3	15.540.78.05;15.533,78.057;15.524,78.068;15.504,78.088; 15.486,78.103;15.476,78.107;15.473,78.122;15.469,78.135; 15.468,78.157; 15.376,78.088;15.371,78.088;15.373,78.084;15.419,78.087; 15.434,78.119
Dhone	Limestone, Dolomite	Red	Ca-Mg-HCO_3	15.318,77.801;15.322,77.803;15.326,77.805;15.359,77.824; 15.418,77.875;15.436,77.885
Panyam	Quartzite, limestone, Shale	Red, black (loam)	Na-Ca-Cl-HCO_3	15.435,78.322;15.455,78.319;15.471,78.323;15.506,78.341; 15.507,78.352;15.503,78.374

Table 9. 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	KR	PI	SSP
pH	1														
EC	0.127	1.000													
CO_3^{-2}	0.042	-0.034	1.000												
HCO_3^-	0.009	0.190	0.063	1.000											
Cl^-	0.070	0.952**	-0.028	0.122	1.000										
SO_4^{-2}	0.189	0.845**	-0.062	0.177	0.722**	1.000									
Ca^{+2}	-0.062	0.818**	-0.058	0.057	0.828**	0.719**	1.000								
Mg^{+2}	0.007	0.867**	0.016	0.195	0.922**	0.614**	0.773**	1.000							
Na^+	0.202	0.972**	-0.035	0.208	0.881**	0.857**	0.696**	0.762**	1.000						
K^+	-0.105	0.148	0.030	0.278	0.113	0.187	0.130	0.124	0.086	1.000					
RSC	0.030	-0.859**	0.043	0.086	-0.910**	-0.670**	-0.928**	-0.910**	-0.734**	-0.073	1.000				
SAR	0.329	0.811**	-0.036	0.304	0.667**	0.829**	0.456	0.505	0.909**	0.079	-0.447	1.000			
KR	0.431	0.479	-0.024	0.329	0.356	0.554	0.106	0.189	0.614**	0.031	-0.087	0.864**	1.000		
PI	0.398	0.238	-0.022	0.314	0.157	0.347	-0.089	-0.013	0.377	-0.092	0.122	0.614**	0.766**	1.00	
SSP	0.352	0.487	-0.012	0.365	0.387	0.635**	0.216	0.232	0.579	0.187	-0.158	0.774**	0.804**	0.863**	1.000

**Significant >0.6

to the presence of shale, limestone, quartzite and dolomite minerals and loam and red sandy loam soils. Significant positive correlation (Table 9) was observed between EC and Cl^-, SO_4^{-2}, Ca^{+2}, Mg^{+2}, Na^+, RSC and SAR.

CONCLUSIONS

The groundwater quality of Nandyal district varied from place to place due to different geological and soil type, drainage and climate of the district. The groundwater type is Na-HCO_3^- type. High EC and SAR of groundwater was observed in parts Gadivemula, Nandyal, Gospadu, Koilakuntla, Dornipadu, Uyyalawada mandals of Nandyal district and high RSC in parts of Kothapalle mandal of Nandyal district. Farmers were advised to take up suitable reclamation measures against RSC and SAR and conjunctive use with good quality groundwater is recommended for high EC water.

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