*The Andhra Agric. J* 67 (2): 46-55, 2020

# Assessment of Groundwater Quality for Irrigation in Chittoor District of Andhra Pradesh

**P Venkata Subbaiah, M V S Naidu Y Radha Krishna and M J Kaledhonkar**
AICRP on Management of salt affected soils and use of saline water in Agriculture
ANGRAU, Bapatla, A.P.

**ABSTRACT**

A survey was undertaken during the year 2019 to assess the quality of groundwater for irrigation in various mandals of Chittoor district, Andhra Pradesh. A total of 358 water samples were collected from 66 mandals of Chittoor district and GPS location of sampling points were recorded. The water samples were analyzed for various chemical properties *viz.,* pH, EC, $Ca^{+2}$, $Mg^{+2}$, $Na^{+}$ and $K^{+}$; $CO_3^{-2}$, $HCO_3^{-}$, $Cl^{-}$ & $SO_4^{-2}$. Accordingly the groundwater was classified into various classes based on the guidelines given by United States Salinity Laboratory (USSL) by computing ion composition into EC, RSC and SAR. The irrigation water samples of Chittoor district was classified into 7 classes *viz.,* C1S2, C2S1, C3S1, C3S2, C4S1, C4S2 and C4S3. Out of 358 water samples 2 (0.55%) are under C1S2 class, 18 (5.02%) under C2S1 class, 271 (75.69%) under C3S1, 2 (0.55%) under C3S2, 62 (17.31%) is under C4S1, 2 (0.55%) under C4S2 and 1 (0.27%) under C4S3 class. Among the 66 mandals of Chittoor district highest mean pH (7.78) of groundwater was recorded in Pulicherla mandal with a range varied 7.2-8.8 and lowest was with Satyavedu (pH 6.18) with varied pH 5.5-6.4. Highest mean EC (4.26 $dSm^{-1}$) from 1.9-13.5 $dSm^{-1}$ was reported in KVB Puram mandal and lowest was recorded with Satyavedu mandal (EC : 0.4 $dSm^{-1}$) with a range from 0.3-0.5 $dSm^{-1}$. The mean Residual Sodium Carbonate (RSC) was high (2.72 me $L^{-1}$) in Ramachandrapuram mandal and lowest (-9.84 me $L^{-1}$) was recorded in Nindra mandal. The highest mean Sodium Adsorption Ratio (SAR) of groundwater was reported with KVB Puram mandal (8.37) and lowest noticed in Satyavedu mandal (0.49). The ground water quality of mandals *viz.*, Vadamalapeta, Tirupati urban, vedurukuppam, Satyavedu, Yerravaripalem, Kalakada, Madhanapalli, Nimmanapalli, Thambalapalli, Chandragiri, Kuppam, Ramakuppam, V.Kothakota, S.R. Puram, Irala, Pakala,Gangavaram, Ramasamudram and Peddapanjari of Chittoor were in good quality and can be used safely for irrigation.

**Keywords:** *EC, Groundwater quality, RSC and SAR.*

The growing ground water usage and pollution generation has got over the threshold limits in various parts, owing to fast shifting land use pattern (Raju *et al.,* 2011; Singh *et al.,* 2015). During the past few decades, the competition for economic development associated with the population growth and urbanization has led to the significant changes in land use thereby resulting in more demand of water for agriculture, household and industrial activities (Nag and Das, 2014). Groundwater is an essential natural resource particularly for drinking and irrigation uses. The quality of groundwater used for domestic and irrigation purposes varies greatly in quality depending upon type and amount of dissolved salts. Groundwater contains a number of dissolved inorganic chemical elements in various concentrations, ensuing from chemical and biochemical interactions between water and the geologic materials (Bazakiyaei *et al.,* 2013).

The chemical composition of water is controlled by various factors which include the precipitation, composition, the underlying geological structure, the mineralogy of the watersheds and the geochemical processes involved, in addition to residence time and the reactions that take place within the system (Hamzaoui-Azaza *et al*., 2011; TliliZrelli *et al*., 2013; Etteieb *et al*., 2017). Groundwater contains both spatial and temporal variations in quality while, the spatial variations occurs due to its natural hydrological setting, the temporal variability in a particular area is often assigned to anthropogenic reasons (Adhikari *et al*., 2012; Bhat *et al*., 2016).Groundwater is the chief source of irrigation in arid and semi-arid regions of the globe, hence, agriculture is restricted owing to scarcity of quality irrigation water. The quality of irrigation water has an overwhelming influence on crop production and strongly affects physical and chemical properties (Jalali, 2010).

The irrigation water quality is defined by the type and the concentrations of dissolved salts and substances (Etteieb *et al*., 2017). Groundwater is precious only when its quality is suitable for a variety of purposes. Water for irrigation should satisfy the needs of soil and the crop as the liquid phase in soil water for plant growth and crop production (Manjusree *et al*., 2009). The water– soil–rock interactions and source of various pollutants are responsible for the

variation of groundwater quality in addition to excess withdrawal of groundwater which also can change the natural quality of groundwater. Therefore, the safety management measures are necessary for improving the groundwater quality. For the sustainable development of society, the groundwater is indispensable, hence, the assessment of groundwater quality in every corner of the country is prerequisite for its better supervision (Rao, 2018). Keeping in view the afore mentioned facts, the present study was undertaken to assess the quality of groundwater for irrigation purposes in various mandals of Chittoor district of Andhra Pradesh.

## MATERIAL AND METHODS

The Chittoor district lies in between 12° 37' and 14° 18' of Northern latitudes and 78 °03' and 79° 55' Eastern longitudes (Fig. 1). Chittoor has a total geographical area of 15,152 km$^2$ and bordered by the SPSR Nellore to the East, North Arcot and Dharmapuri districts of Tamilnadu to the south and in the north by YSR Kadapa and Anantapuram districts. The annual rainfall of the district ranged from 719 to 908 mm through South-West and North-East monsoons. The maximum temperature varied 36 to 46°C during summer and the minimum temperature of 23 to 24 $^0$C during winter.

Three hundred and fifty eight (358) ground water samples were collected from different sources like bore wells, open wells and hand pumps by selecting 5-6 villages at random in each mandal and in each village one sample was collected. Sampling was carried out using preconditioned clean high density polythene bottles, which were rinsed three times with sample water prior to sample collection. The pumps were run for 5-6 minutes prior to collection of water samples. Immediately after collection of water samples toulene was added to avoid microbiological deterioration

pH in water samples was determined potentiometrically by pH meter. Electrical conductivity was determined by 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), other ionic composition of water estimated by using standard procedures(Table 1.). SAR and RSC were as calculated by using the formulas given by Richards (1954), which are as follows

Sodium Adsorption Ratio (SAR) =

$$\frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Wherein,

$Na^+$, $Ca^{2+}$ and $Mg^{2+}$ are in m e $L^{-1}$

Residual Sodium Carbonate (RSC) =

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

Wherein,

RSC, $CO_3^{2-}$, $H\,CO_3^-$, $Ca^{2+}$ and $Mg^{2+}$ are in m e $L^{-1}$

## RESULTS AND DISCUSSION

The ground water samples were analyzed for various chemical parameters like pH, EC, Cations ($Ca^{+2}$, $Mg^{+2}$, $Na^+$ and $K^+$) and anions ($CO_3^{-2}$, $HCO_3^-$, $Cl^-$ and $SO_4^{-2}$) . subsequently SAR and RSC were calculated for these samples. The mandal wise quality of irrigated ground water is presented in Table 2.

### *pH of water samples*

The mean pH of irrigated groundwater varied among the various mandals of Chittoor district. Highest pH of 7.76 (Table 2), was reported with Pulicherla mandal with a pH range from 7.2-8.8. Lowest pH was recorded with Satyavedu mandal (pH 6.18) with a range from 5.5-6.4. Higher pH of ground water may be due to dominance of $Na^+$, $Ca^{+2}$, $Mg^{+2}$ and $CO_3^-$ and $HCO_3^-$ ions (Al-tabbal and Al-Zboon,2012).

### *Electrical conductivity (EC)*

Water salinity is determined in terms of EC. The EC values in water samples of various mandals of Chittoor district were classified with the rating chart provided by USSL and presented in Table 3. About 5.02 per cent of water samples were classified under medium salinity (C2) class , 76.53 per cent were classified under high salinity (C3) class and 17.87 per cent samples were classified under very high salinity (C4) class (Fig. 2). EC of less than 0.25 dSm$^{-1}$ (0.55%) was considered as good quality water whereas EC of > 2.25 dSm$^{-1}$ was considered to reduce the productivity to a large extent (Wescott and Ayers 1984). About 17.87 per cent of water samples in Chittoor district exhibited high salinity hazard and hence not suitable for irrigating the crops. Among the various mandals of Chittoor district, highest mean salinity of irrigated groundwater was recorded with KVB Puram mandal ( 4.26 dSm$^{-1}$) with a range from 1.9-13.5 dSm$^{-1}$ and lowest was recorded with Satyavedu (0.4 dSm$^{-1}$) mandal with a range from 0.3-0.5 dSm$^{-1}$. The higher electrical conductivity might be due to the presence of higher ionic composition in groundwater due to weathering or leaching (Sanjeev Kumar Pal *et al.,* 2018).

***Chlorides concentration***

Among anions, the chlorides were the second dominant ions after bicorbonates. Further, 44.97 per cent of groundwater samples were classified under excellent (A1) class, 24.02 per cent of samples were categorized under moderately good (A2) class, 24.02 per cent of water samples were classified under slightly unsuitable (A3) class and 6.98 per cent samples were classified under not suitable (A4) for irrigation purpose (Table 6 and Fig. 3). The chloride content in the groundwater may be due to natural process like weathering, dissolution of salt deposits and irrigation drainage return flow (Kumar *et al*., 2009).

***Residual Sodium Carbonate (m e $L^{-1}$)***

About 91.60 per cent samples were classified under good quality class (B1) which can be used safely whereas 6.14 per cent of water samples were classified under marginally good class (B2) which can be used with certain management. However, 2.23 per cent of water samples were classified under unsuitable (B3) for irrigation, which can be used with gypsum (Table 4 & Fig. 4). RSC values were calculated to determine the hazardous effect of carbonates and bicarbonates in the water quality for agricultural purpose (Eaton 1950; Richards 1954). According USSL diagram, RSC value of < 1.25 m $eL^{-1}$ is safe for irrigation. If it is > 2.5 me $L^{-1}$, it is not suitable for irrigation. Majority of the samples have RSC < 1.25 me $L^{-1}$ . Hence, the quality of irrigation water is safe for irrigation in the study area. Similar findings were previously reported by Jafer (2013). Among the various mandals of Chittoor district the mean RSC was higher in Ramachandrapuram mandal (2.72 me $L^{-1}$) with a range from 0.6-5.2 me $L^{-1}$ and lowest was with Nagiri mandal (-9.84 me $L^{-1}$) with a range from -11.8 me $L^{-1}$ to -5.8 me $L^{-1}$. Naseem *et al.* (2010) reported that pH, EC and SAR of irrigation water are significantly influenced by RSC

***Sodium Adsorption Ratio (SAR)***

About 98.60 percent of samples were classified under low sodium water class (S1) which can be used on all types of soils with little or no danger of development of sodium hazard and 1.11 per cent of samples were classified under medium sodium water (S2) class, which when used produce sodium hazard in fine textured soils with high CEC especially with low leaching. However, 0.27 per cent samples were under high sodium (S3) class which, produce harmful level of exchangeable sodium in most of the soils (Table 5 & Fig. 5). Among the various mandals of Chittoor district highest mean SAR was recorded with KVB Puram mandal (8.37) with a range from 2.79-20.14 and lowest was with Satyavedu mandal (0.48) with a range from 0.41-0.56. With increase in SAR of irrigation water the SAR of soil solution increases which ultimately results in the increase of exchangeable sodium of the soil ( Isaac *et al*., 2009).

***Groundwater Quality***

Among the 358 water samples 0.55 per cent samples (Table 7) were recorded C1-S2 class, 5.02 per cent samples with C2-S1 class, 75.69 per cent samples with C3-S1, 0.55 per cent samples recorded C4-S1 class, 17.31 per cent samples were with C4-S1 class, 0.55 per cent samples with C4-S2 samples and 0.27 per cent samples recorded C4-S3 class(Fig.6). The ground water quality of mandals *viz.*, Vadamalapeta, Tirupati urban, Vedurukuppam, Satyavedu, Yerravaripalem, Kalakada, Madhanapalli, Nimmanapalli, Thambalapalli, Chandragiri, Kuppam, Ramakuppam, V.Kothakota, S.R. Puram, Irala, Pakala,Gangavaram, Ramasamudram and Peddapanjari were in good quality (Table 8) and can be used safely. Other mandals like Varadayapalem, Nagiri, Kalikiri, Peddamandyam, Gurramkonda, Kurabalakota, Santhepuram, Palamaneru, Gudipalli, Penumuru, G. D. Nellore recorded moderate quality (80%) and the remaining were marginally saline (<20%) . Mandals like Puthur, Narayana Vanam, Ramachandrapuram, Renigunta, Thottembedu, Nagalapuram, Pichatur, Rompicherla, B. Kothakota, Byrediipalli, Chittoor, Punganur recorded good quality (>60%). and rest were marginally saline. In Karvetinagram, 28.6 per cent samples were good in quality, 14.3 per cent samples were marginally saline and 57.14 per cent samples were marginally alkali. In Yerpedu, the groundwater quality is good (60%), marginally saline (20%) & Alkali (20%). Srikalahasti recorded good quality (33.3%) and marginally saline (66.7%). KVB Puram recorded good(40%), margianlly saline (20%), high SAR saline (20%) and high alkali (20%). In BN Kandriga, 50 per cent samples were good, 16.7 per cent samples were marginally saline, 16.7 per cent were marginally alkali and 16.7 per cent are alkali in quality. In Vijayapuram, 60 per cent samples are marginally saline. In Chinnagottigallu, water samples are good (50%), marginally saline (33.3%) and marginally alkali(16.7%). Sadum 66.7 % samples were good, 16.7% were marginally saline and 16.7% were marginally alkali. In KV Palli mandal, 16.7% were marginally alkali and the rest were (83.3%) good in quality. In Vayalpadu, Peddatippasamudram, 60 per cent were good in quality and the rest were marginally saline and marginally in nature. Mandals like Pulicherla (60%), Gudiapala (100%), Thavanampalli(100%), Yadamarri (80%), Mulakal acheruvu (80%) ,Tirupati rural (80%) Puthalapattu (60%), Palasamudram (60%), Bangarupalem(80%), Somala (60%) and

**Table 1. Methods used for estimation of different chemical 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) |

**Table 2. Quality of irrigation water in different mandals of Chittoor District**

| S.No. | Name of the Mandal | pH | | EC ($dSm^{-1}$) | | RSC (me $L^{-1}$) | | SAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| 1 | Puthur | 7.36 | 7.1-7.6 | 1.74 | 0.9-2.7 | -0.52 | -2.6 to 0.8 | 4.25 | 1.72-6.92 |
| 2 | Karvetinagaram | 7.40 | 7.3-7.6 | 1.98 | 1.2-2.8 | 1.8 | -1.0 to 3.6 | 7.12 | 3.13-12.3 |
| 3 | Narayanavanam | 7.28 | 6.9-7.5 | 2.07 | 1.3-3.5 | -5.8 | -11.2 to -1.2 | 2.64 | 0.76-6.27 |
| 4 | Vadamalpeta | 7.60 | 7.4-8 | 1.62 | 1.5-1.8 | -2.8 | -4.6 to -2.0 | 2.51 | 1.47-3.71 |
| 5 | Tirupati Urban | 6.94 | 6.6-7.3 | 1.14 | 0.7-1.9 | -1.53 | -4.0 to 0.8 | 1.46 | 0.96-2.06 |
| 6 | Ramachandrapuram | 7.36 | 7.1-7.7 | 1.70 | 1.3-2.4 | 2.72 | 0.6 to 5.2 | 3.60 | 2.14-6.69 |
| 7 | Vedurukuppam | 7.22 | 6.8-7.8 | 1.30 | 0.9-1.5 | -1.28 | -2.4 to 1.2 | 2.42 | 1.11-2.9 |
| 8 | Yerpedu | 7.46 | 7.2-8.0 | 2.00 | 1.3-3.0 | -4.2 | -15.6 to 5.8 | 3.47 | 1-9.69 |
| 9 | Srikalahasti | 7.38 | 7.3-7.6 | 2.25 | 1.8-2.9 | -2.27 | -4.8 to 1.2 | 4.55 | 2.45-7.0 |
| 10 | Renigunta | 7.39 | 6.9-8.2 | 1.51 | 0.4-2.4 | 1.12 | -1 to 0.6 | 3.60 | 0.64-3.96 |
| 11 | KVB Puram | 7.36 | 7.0-8.0 | 4.26 | 1.9-13.5 | -6.08 | -37.6 to 2.0 | 8.37 | 2.79-20.14 |
| 12 | Thottembedu | 7.24 | 6.7-7.6 | 1.38 | 0.2-2.2 | -3.2 | -5.6 to 0.2 | 1.54 | 0.4-2.29 |
| 13 | B.N. Kandriga | 7.33 | 7.0-7.5 | 1.50 | 1.1-2.6 | -0.93 | -9.4 to 5.4 | 4.31 | 0.85-8.51 |
| 14 | Nagalapuram | 7.49 | 7.2-7.6 | 1.44 | 0.7-2.1 | -1.66 | -6.4 to 1.4 | 1.73 | 0.69-3.13 |
| 15 | Satyavedu | 6.18 | 5.5-6.4 | 0.40 | 0.3-0.5 | -0.8 | -1.4 to -0.2 | 0.49 | 0.41-0.56 |
| 16 | Varadayapalem | 7.36 | 7.3-7.5 | 1.80 | 1.3-2.0 | -2.88 | -5.4 to 0.8 | 2.89 | 2.3-4.66 |
| 17 | Pichatur | 7.42 | 7.1-7.5 | 2.24 | 1.4-2.7 | -3.84 | -4.6 to -2 | 3.36 | 1.66-4.73 |
| 18 | Nagiri | 7.06 | 6.7-7.1 | 1.30 | 0.6-3.5 | -0.88 | -6.6 to 2.2 | 1.6 | 0.72-3.31 |
| 19 | Nindra | 7.32 | 7.2-7.5 | 3.36 | 2.5-3.8 | -9.84 | -11.8 to -5.8 | 4.43 | 3.52-4.84 |
| 20 | Vijayapuram | 7.26 | 7.1-7.4 | 2.16 | 1.8-2.6 | -1 | -3.4 to 0.2 | 4.54 | 3.99-5.35 |
| 21 | Kalikiri | 7.29 | 7.0-7.5 | 1.56 | 1.0-2.1 | -0.89 | -2.6 to 2.2 | 2.41 | 1.69-3.18 |
| 22 | Chinnagottigallu | 7.38 | 7.2-7.6 | 1.85 | 1.4-2.4 | -0.4 | -2.6 to 2.6 | 3.18 | 1.67-5.04 |
| 23 | Sadum | 7.38 | 7.2-7.6 | 1.60 | 13.-2.1 | -0.67 | -3.6 to 2.6 | 3.17 | 2.68-4.32 |
| 24 | Rompicherla | 7.57 | 7.4-8.0 | 1.83 | 1.6-2.2 | -1 | -2.8 to 0.4 | 3.13 | 2.69-3.68 |
| 25 | Yerravaripalem | 7.47 | 7.3-7.6 | 1.22 | 0.9-1.9 | 0.6 | 0.2 to 1.0 | 1.86 | 1.26-3.59 |
| 26 | Piler | 7.13 | 7.0-7.2 | 2.12 | 1.9-2.3 | -3.4 | -3.6 to -2.4 | 3.86 | 3.6-3.9 |
| 27 | K.V.Palli | 7.48 | 7.4-7.7 | 1.55 | 1.1-1.8 | 1.83 | -0.2 to 4.6 | 3.22 | 1.43-5.8 |
| 28 | Peddamandyam | 7.34 | 7.1-7.5 | 1.90 | 1.0-3.5 | -0.96 | -2.8 to 0.8 | 3.41 | 1.92-7.47 |
| 29 | Vayalpadu | 7.42 | 7.3-7.6 | 1.78 | 1.3-2.2 | -1.76 | -4.2 to 3.2 | 3.23 | 2.68-5.22 |
| 30 | Kalakada | 7.26 | 6.8-7.5 | 1.60 | 1.5-1.8 | -5.96 | -7.2 to -2.8 | 2.43 | 1.95-4.18 |
| 31 | Gurramkonda | 7.36 | 7.2-7.9 | 1.02 | 0.9-1.1 | 1.48 | 0.8 to 2.6 | 2.62 | 2.2-3.32 |
| 32 | B.Kothakota | 7.54 | 7.3-7.5 | 1.78 | 1.3-2.3 | -2.52 | -5.2 to 0.8 | 3.39 | 3.07-3.89 |
| 33 | Madhanapalli | 7.64 | 7.4-8.1 | 1.54 | 1.4-1.9 | -1.28 | -2.2 to -0.2 | 2.28 | 2.19-2.37 |

Table 2. cont...

| S.No. | Name of the Mandal | pH | | EC ($dSm^{-1}$) | | RSC (me $L^{-1}$) | | SAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| 34 | Nimmanapalli | 7.44 | 7.3-7.6 | 1.16 | 0.5-1.8 | -0.28 | -2.8 to1.0 | 2.41 | 1.8-3.32 |
| 35 | Peddathippasamudram | 7.56 | 7.5-7.7 | 1.54 | 0.9-1.9 | 1.76 | -0.6 to 3.4 | 3.36 | 1.77-4.37 |
| 36 | Kurabalakota | 7.34 | 7.2-7.6 | 1.48 | 1.1-1.8 | 0.4 | -1.8 to 2.4 | 2.76 | 2.18-3.67 |
| 37 | Thambalapalli | 7.66 | 7.4-7.8 | 1.58 | 1.2-1.8 | -2.28 | -8.6 to 0.2 | 3.08 | 0.76-4.1 |
| 38 | MulakalaChruvu | 7.64 | 7.2-8.0 | 2.06 | 1.6-2.4 | -2.36 | -4.0 to 2.4 | 4.17 | 3.07-4.91 |
| 39 | Tirupati Rural | 7.60 | 7.4-7.7 | 2.05 | 1.4-2.4 | -0.17 | -1.6 to 3.8 | 3.82 | 2.83-4.72 |
| 40 | Chandragiri | 7.38 | 7.0-7.6 | 0.97 | 07-1.3 | 0 | -0.6 to 0.6 | 1.03 | 0.81-1.29 |
| 41 | Pulciherla | 7.76 | 7.2-8.8 | 1.28 | 0.5-2.0 | 2.52 | 0.2 to 3.6 | 2.48 | 0.27-4.63 |
| 42 | Byreddipalli | 7.40 | 7.0-7.9 | 1.70 | 1.1-1.2 | -3.44 | -9.0 to 0.6 | 1.56 | 1.0-2.28 |
| 43 | Santhepuram | 7.40 | 7.0-7.8 | 1.84 | 1.3-2.3 | -3.48 | -6.6 to 0.0 | 1.57 | 1.25-2.19 |
| 44 | Kuppam | 7.16 | 7.0-7.4 | 1.40 | 1.1-1.8 | 0.12 | -2.6 to 1.6 | 2.76 | 2.42-3.28 |
| 45 | Ramakuppam | 7.27 | 6.7-7.7 | 1.05 | 0.9-1.2 | -1 | -3.4 to 0.8 | 1.22 | 1.12-1.36 |
| 46 | Palamaner | 7.38 | 7.1-7.5 | 2.00 | 0.7-4.5 | -4.96 | -2.0 to 1.0 | 2.68 | 2.62-3.21 |
| 47 | V Kothakota | 7.17 | 6.9-7.3 | 1.46 | 0.7-1.9 | -3.63 | -6.2 to -1.2 | 1.23 | 0.5-2.0 |
| 48 | Gudipalli | 7.24 | 7.0-7.4 | 1.62 | 1.2-1.8 | -2.48 | -5.0 to 2.6 | 1.91 | 1.59-2.65 |
| 49 | Gudipala | 7.54 | 7.4-7.7 | 2.26 | 2.1-2.4 | -1.24 | -2.0 to 0.0 | 3.72 | 3.1-4.05 |
| 50 | Yadamarri | 7.44 | 7.2-8.0 | 2.02 | 1.3-2.4 | 0.6 | -3.0 to 4.2 | 4.50 | 2.74-6.47 |
| 51 | Puthalapattu | 7.32 | 7.0-7.8 | 2.26 | 1.1-3.2 | -0.64 | -3.0 to 0.8 | 4.80 | 1.51-7.33 |
| 52 | Penumuru | 7.34 | 7.1-7.5 | 1.70 | 1.5-2.3 | 0.4 | -0.8 to 1.8 | 3.57 | 2.12-5.16 |
| 53 | Palasamudram | 7.50 | 7.3-7.7 | 1.82 | 1.1-2.8 | 1.68 | 0.2 to 2.8 | 3.89 | 1.7-6.53 |
| 54 | G.D.Nellore | 7.32 | 7.1-7.5 | 1.32 | 1.0-2.3 | -0.68 | -2.0 to 1.4 | 2.27 | 1.88-3.75 |
| 55 | S.R. Puram | 7.40 | 7.2-7.9 | 2.28 | 2.1-2.6 | -0.04 | -1.6 to 1.4 | 4.55 | 2.78-5.46 |
| 56 | Bangarupalem | 7.38 | 7.3-7.5 | 1.92 | 1.2-3.1 | 0.24 | -6.8 to 3.8 | 4.01 | 1.77-4.98 |
| 57 | Irala | 7.36 | 6.9-7.6 | 1.72 | 1.5-1.9 | 0.76 | -1.2 to 2.4 | 2.97 | 2.52-3.27 |
| 58 | Thavanampalli | 7.44 | 7.3-7.5 | 2.16 | 2.1-2.2 | -1.6 | -2 to -0.4 | 4.84 | 4.59-5.06 |
| 59 | Chittoor | 7.22 | 7.1-7.4 | 1.98 | 1.6-2.8 | -2.32 | -4.8 to 2.4 | 2.68 | 1.18-7.3 |
| 60 | Pakala | 6.98 | 6.9-7.1 | 1.08 | 0.9-1.2 | -1.2 | -4.8 to 2.4 | 1.57 | 1.16-2.3 |
| 61 | Gangavaram | 7.38 | 7.1-7.7 | 1.30 | 1.0-1.6 | -1.24 | -3.4 to 0.2 | 2.11 | 1.78-2.43 |
| 62 | Ramasamudram | 7.46 | 7.3-7.6 | 1.76 | 1.7-1.8 | -2.72 | -3.6 to -2.4 | 2.94 | 2.83-3.15 |
| 63 | Somala | 7.36 | 7.3-7.4 | 2.14 | 0.3-3.7 | -3.88 | -7.4 to 0.2 | 3.29 | 1.15-5.14 |
| 64 | Chowdepalli | 7.46 | 7.2-7.6 | 2.42 | 1.4-3.6 | -6.8 | -12.8 to -0.4 | 2.66 | 0.72-4.76 |
| 65 | Peddapanjari | 7.36 | 7.3-7.5 | 1.44 | 0.8-2.0 | -0.68 | -4.0 to 2.0 | 2.47 | 2.27-2.72 |
| 66 | Punganur | 7.42 | 7.3-7.5 | 2.24 | 1.3-3.9 | -2.76 | -10.4 to 1.4 | 4.27 | 3.0-7.24 |

**Table 3. Classification of ground water samples based on EC ($dSm^{-1}$)**

| S.No. | EC($dSm^{-1}$) | | No.of samples | Per cent of samples |
|---|---|---|---|---|
| | Class | Value | | |
| 1 | C1 | <0.25 | 2 | 0.55 |
| 2 | C2 | 0.25-0.75 | 18 | 5.02 |
| 3 | C3 | 0.75-2.25 | 274 | 76.53 |
| 4 | C4 | >2.25 | 64 | 17.87 |

**Table 4. Classification of ground water samples based on RSC (me $L^{-1}$)**

| S.No. | RSC ($mel^{-1}$) | | No.of samples | Per cent of samples |
|---|---|---|---|---|
| | Class | Value | | |
| 1 | B1 | <1.25 | 328 | 91.6 |
| 2 | B2 | 1.2-2.5 | 22 | 6.14 |
| 3 | B3 | >2.5 | 8 | 2.23 |

**Table 5. Classification of ground water samples based on SAR**

| S.No. | SAR | | No.of samples | Per cent of samples |
|---|---|---|---|---|
| | Class | Value | | |
| 1 | S1 | <10 | 353 | 98.6 |
| 2 | S2 | 18-Oct | 4 | 1.11 |
| 3 | S3 | 18-26 | 1 | 0.27 |
| 4 | S4 | >26 | 0 | 0 |

**Table 6. Classification of ground water samples based on $Cl^-$ (me $L^{-1}$)**

| S.No. | $Cl^-$ (me $L^{-1}$) | | No.of samples | Per cent of samples |
|---|---|---|---|---|
| | Class | Value | | |
| 1 | A1 | <4 | 161 | 44.97 |
| 2 | A2 | 7-Apr | 86 | 24.02 |
| 3 | A3 | 12-Jul | 86 | 24.02 |
| 4 | A4 | >12 | 25 | 6.98 |

**Table 7. Classification of Ground water samples based on USSL diagram**

| S.No. | Class | No.of samples | Per cent samples |
|---|---|---|---|
| 1 | C1-S2 | 2 | 0.55 |
| 2 | C2-S1 | 18 | 5.02 |
| 3 | C3-S1 | 271 | 75.69 |
| 4 | C3-S2 | 2 | 0.55 |
| 5 | C4-S1 | 62 | 17.31 |
| 6 | C4-S2 | 2 | 0.55 |
| 7 | C4-S3 | 1 | 0.27 |

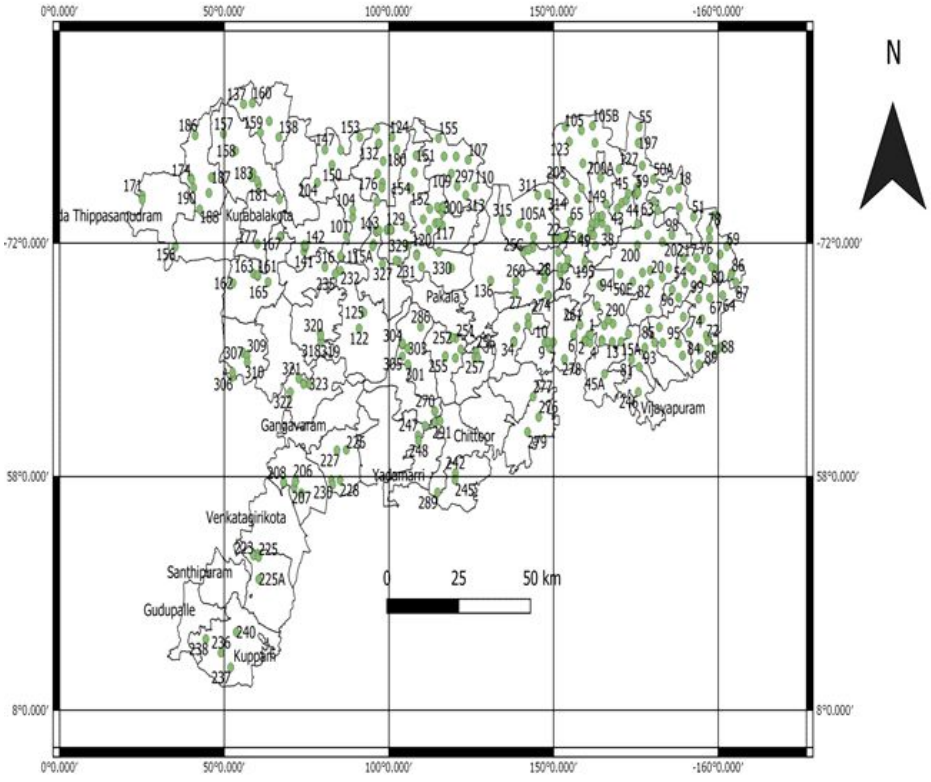


Fig 1. Groundwater Sampling sites of Chittoor District

**Table 8. Percentage distribution of ground water samples under different quality classes for different mandals of Chittoor district**

| S.No. | Name of the Mandal | No.of Samples | Good | Marginally saline | Saline | High SAR Saline | Marginally alkali | Alkali | High alkali |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Puthur | 5 | 60 | 40 | -- | -- | -- | -- | -- |
| 2 | Karvetinagaram | 7 | 28.6 | 14.3 | -- | -- | 57.14 | -- | -- |
| 3 | Narayanavanam | 6 | 66.7 | 33.33 | -- | -- | -- | -- | -- |
| 4 | Vadamalpeta | 5 | 100 | -- | -- | -- | -- | -- | -- |
| 5 | Tirupati Urban | 8 | 100 | -- | -- | -- | -- | -- | -- |
| 6 | Ramachandrapuram | 5 | 60 | 40 | -- | -- | -- | -- | -- |
| 7 | Vedurukuppam | 5 | 100 | -- | -- | -- | -- | -- | -- |
| 8 | Yerpedu | 5 | 60 | 20 | - | - | - | 20 | - |
| 9 | Srikalahasti | 6 | 33.3 | 66.7 | - | - | - | - | - |
| 10 | Renigunta | 10 | 70 | 10 | - |  | 10 | - | 10 |
| 11 | KVB Puram | 5 | 40 | 20 | - | 20 | - | - | 20 |
| 12 | Thottembedu | 5 | 60 | 40 | - |  | - | - | - |
| 13 | B.N. Kandriga | 6 | 50 | 16.7 | - | - | 16.7 | 16.7 | - |
| 14 | Nagalapuram | 7 | 71.4 | 28.57 | - | - | - | - | - |
| 15 | Satyavedu | 5 | 100 |  | - | - | - | - | - |
| 16 | Varadayapalem | 5 | 80 | 20 | - | - | - | - | - |
| 17 | Pichatur | 5 | 60 | 40 | - | - | - | - | - |
| 18 | Nagiri | 5 | 80 | 20 | - | - | - | - | - |
| 19 | Nindra | 5 | - | 100 | - | - | - | - | - |
| 20 | Vijayapuram | 5 | 40 | 60 | - | - | - | - | - |
| 21 | Kalikiri | 7 | 85.7 | 14.3 |  | - | - | - | - |
| 22 | Chinnagottigallu | 6 | 50 | 33.3 | - | - | 16.7 | - | - |
| 23 | Sadum | 6 | 66.7 | 16.7 | - | - | 16.7 | - | - |
| 24 | Rompicherla | 6 | 66.7 | 33.3 | - | - | - | - | - |
| 25 | Yerravaripalem | 6 | 100 | - | - | - | - | - | - |
| 26 | Piler | 6 | 33.3 | 66.7 | - | - | - | - | - |
| 27 | K.V.Palli | 6 | 83.3 | - | - | - | 16.7 | - | - |
| 28 | Peddamandyam | 5 | 80 | 20 | - | - | - | - | - |
| 29 | Vayalpadu | 5 | 60 | 20 | - | - | 20 | - | - |
| 30 | Kalakada | 5 | 100 | - | - | - | - | - | - |
| 31 | Gurramkonda | 5 | 80 | - | - | - | 20 | - | - |
| 32 | B.Kothakota | 5 | 60 | 40 | - | - | - | - | - |
| 33 | Madhanapalli | 5 | 100 | - | - | - | - | - | - |
| 34 | Nimmanapalli | 5 | 100 | - | - | - | - | - | - |
| 35 | Peddathippasamudram | 5 | 60 | - | - | - | 40 | - | - |
| 36 | Kurabalakota | 5 | 80 | - | - | - | 20 | - | - |
| 37 | Thambalapalli | 5 | 100 | - | - | - | - | - | - |
| 38 | MulakalaChruvu | 5 | 20 | 60 | - | - | 20 | - | - |
| 39 | Tirupati Rural | 6 | 16.7 | 66.7 | - | - | 16.7 | - | - |
| 40 | Chandragiri | 6 | 100 | - | - | - | - | - |  |
| 41 | Pulciherla | 5 | 40 | - | - | - | 40 | 20 | - |
| 42 | Byreddipalli | 5 | 60 | 40 | - | - | - | - | - |
| 43 | Santhepuram | 5 | 80 | 20 | - | - | - | - | - |
| 44 | Kuppam | 5 | 100 | - | - | - | - | - | - |
| 45 | Ramakuppam | 6 | 100 | - | - | - | - | - | - |
| 46 | Palamaner | 5 | 80 | 20 | - | - | - | - | - |
| 47 | V Kothakota | 7 | 100 | - | - | - | - | - | - |
| 48 | Gudipalli | 5 | 80 | - | - | - | 20 | - | - |
| 49 | Gudipala | 5 | - | 100 | - | - | - | - | - |
| 50 | Yadamarri | 5 | 20 | 40 | - | - | 20 | 20 | - |
| 51 | Puthalapattu | 5 | 40 | 60 | - | - | - | - | - |
| 52 | Penumuru | 5 | 80 | 20 | - | - | - | - | - |

Table 8. Cont...

| S.No. | Name of the Mandal | No.of Samples | Good | Marginally saline | Saline | High SAR Saline | Marginally alkali | Alkali | High alkali |
|---|---|---|---|---|---|---|---|---|---|
| 53 | Palasamudram | 5 | 40 | 40 | - | - | 20 | - | - |
| 54 | G.D.Nellore | 5 | 80 | 20 | - | - | - | - | - |
| 55 | S.R. Puram | 5 | 100 | - | - | - | - | - | - |
| 56 | Bangarupalem | 5 | 20 | 40 | - | - | 40 | - | - |
| 57 | Irala | 5 | 100 | - | - | - | - | - | - |
| 58 | Thavanampalli | 5 | - | 100 | - | - | - | - | - |
| 59 | Chittoor | 5 | 60 | 40 | - | - | - | - | - |
| 60 | Pakala | 5 | 100 | - | - | - | - | - | - |
| 61 | Gangavaram | 5 | 100 | - | - | - | - | - | - |
| 62 | Ramasamudram | 5 | 100 | - | - | - | - | - | - |
| 63 | Somala | 5 | 40 | 60 | - | - | - | - | - |
| 64 | Chowdepalli | 5 | 20 | 80 | - | - | - | - | - |
| 65 | Peddapanjari | 5 | 100 | - | - | - | - | - | - |
| 66 | Punganur | 5 | 60 | 40 | - | - | - | - | - |

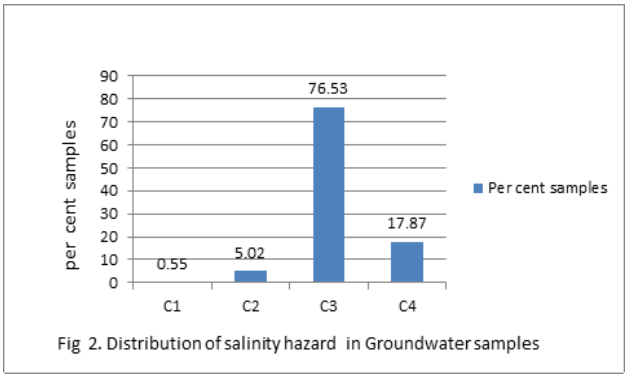

Fig 2. Distribution of salinity hazard in Groundwater samples

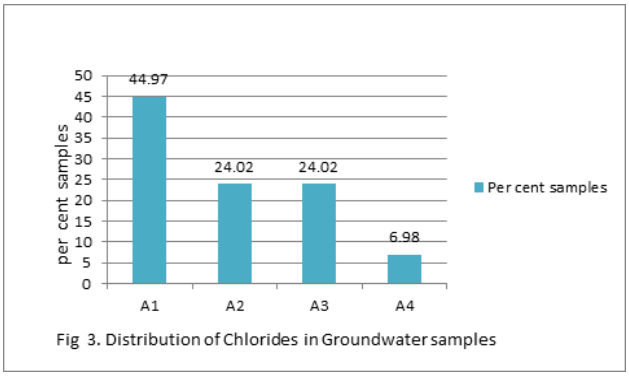

Fig 3. Distribution of Chlorides in Groundwater samples

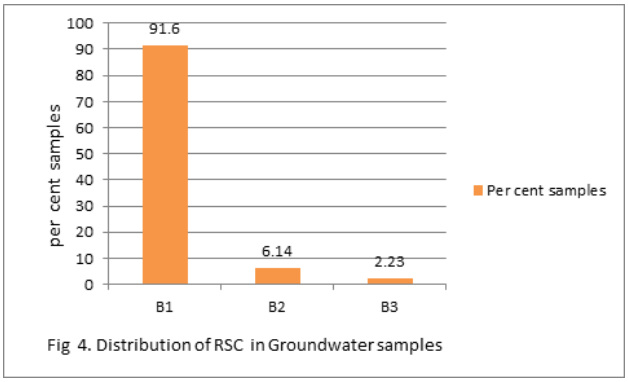

Fig 4. Distribution of RSC in Groundwater samples

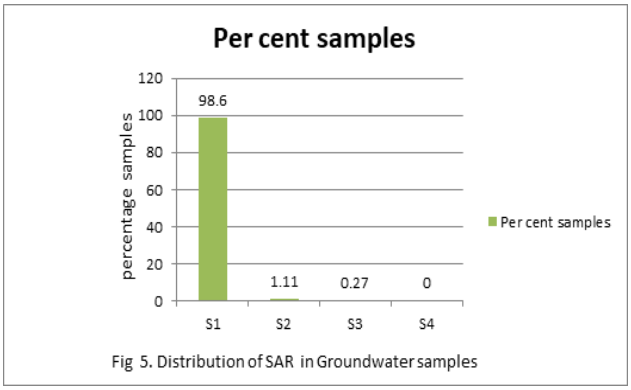

Fig 5. Distribution of SAR in Groundwater samples

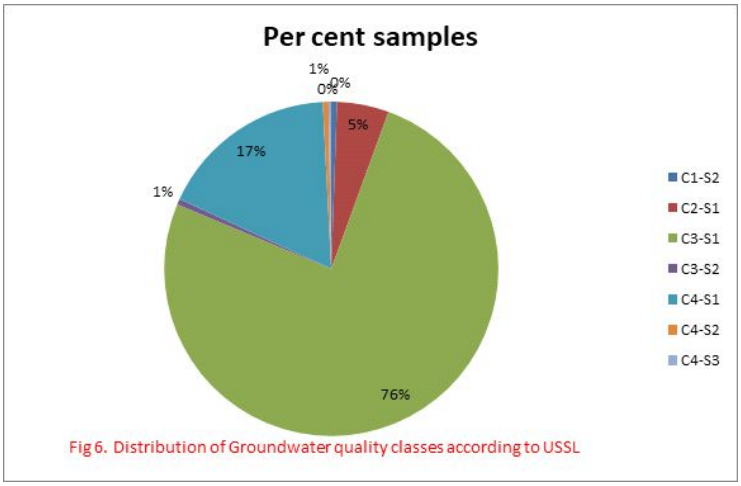

Fig 6. Distribution of Groundwater quality classes according to USSL

Chowdepalli( 80%) recorded and posed more problematic groundwater in Chittoor district of Andhra Pradesh. The problematic nature of water might be due to leaching of salts to the undergroundwater, weathering salt containing minerals and other anthropogenic activities (Nag and Das, 2014).

## CONCLUSION

The ground water quality varied among various mandals of Chittoor district. The analysis of water samples revealed that, based on EC most of water samples were under C3 class indicting high salinity and were not suitable for irrigation under restricted drainage conditions. Higher salt content in irrigation water causes an increase in osmotic pressure causing ex-osmosis, finally leading to the wilting of the plant. Based on USSL about 75.69 per cent samples were categorized under C3-S1 class and exhibited high salinity hazard with low sodium hazard, hence they can be used in well drained soils without any sodium hazard. Mandals like Pulicherla (60%), Gudiapala (100%), Thavanampalli(100%), Yadamarri (80%), Mulakal acheruvu (80%) ,Tirupati rural (80%) Puthalapattu (60%), Palasamudram (60%), Bangarupalem(80%), Somala (60%) and Chowdepalli( 80%) recorded and posed more problematic groundwater in Chittoor district of Andhra Pradesh. Hence, good management practices coupled with conjunctive use better available water may help in crop production.

**Acknowledgements**

The research was carried out by AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture, Bapatla. The financial support of the Indian Council of Agricultural Research to the centre is thankfully acknowledged.

## LITERATURE CITED

**Adhikari K B, Chakraborthy and Gangopadhyay A 2012** Assessment of irrigation potential of Groundwater using water quality index tool. *Environmental Research Journal* 6(3):763-771.

**Al-Tabbal J A and Al-Zboon K K 2012** Suitabilityassessment of groundwater for irrigation and drinking purpose in the Northern Region of Jordan. *Journal of Environmental Science and Technology* 5(5): 274-290.

**Bazakiyaei Zb, Shriati F, Oshaksaraei L and Amiri E 2013** Evaluation of Groundwater quality and its suitability for drinking and agriculture use (Case Study: *Astaneh Ashrafiyeh*). International Journal of Agriculture and Crop Sciences 5(1) : 50-53.

**Bhat M A, Grewal M S, Ramprakash, Rajpaul Wani S A and Dar EA 2016** Assessment of Groundwater quality for irrigation purposes using chemical inidices. *Indian Journal of Ecology* 43(2): 574- 579.

**Chesnin L and CH Yien 1950** Turbidimetric determination of available sulphates. *Proceedings of Soil Science Society of America* 14: 149-151.

**Eaton F M 1950** Significance of carbonate in irrigation water. *Soil Science* 69: 123-133.

**Etteieb S, Cherif S and Tarhouni J 2017** Hydrochemical assessment of Water quality for irrigation ; a case study of the Medjerda River in Tunisia. *Applied Water Science* 7: 469-480.

**Hamzaoui-Azaza F, Ketata M and Bouhlila R 2011** Hydrogeochemical characteristics and assessment of drinking water quality in Zeuss-Koutine aquifer Southeastern Tunisia. *Environmental monitoring and Assessment* 174 (1-4) : 283-298.

**Isaac R K, Khura T K and Wurmbrand J R 2009** Surface and subsurface water quality appraisal for irrigation. *Environmental Monitoring and Assessment* 159: 465-473.

**Jalali M 2010** Groundwater geochemistry in the Alisadr, Hamadan, western Iran. *Environmental Monitoring and Assessment* **166:** 359-369.

**Jafer A, Ananthakrishnan A, Loganathan K and Manikanndan K 2013** Assessment of groundwater quality for irrigation in Perambadur district, Tamil nadu. *Journal of Applied Water Sciecne* 3: 763-771

**Kumar S K, Rammohan V, Sahayam J D and Jeevanandam M 2009** Assessment of groundwater quality and hydrogeochemistry of Manimuktha River basin, tamil Nadu, India. *Environmental Monitoring and Assessment* 159: 341-351

**Manjusree T M, Joseph S and Thomas J 2009** Hydrogeochemistry and groundwater quality in the Coastal sandy clay aquifers of Alappuzha District, Kerala. *Journal of Geological Society of India* 74 : 459-468

**Nag S K and Das S 2014** Quality assessment of groundwater with special emphasis on irrigation and domestic suitability in Suri I & II blocks, Birbhum District, West Bengal, India, *American Journal of water Resources* 2(4) : 81-98.

**Naseem S, Hazma S, Bashir E 2010** Groundwater geochemistry of Winder agricultural Farms, Balochistan, Pakistan and assessment for

irrigation water quality. *European Water* 31: 21-32

**Osborn G H and Johns H 1951** The rapid determination of sodium and potassium in rocks and minerals by flame photometry, *Analyst* 76: 410-415.

**Raju N J, Shukla U K and Ram P 2011** Hydrogeochemistry for the assessment of groundwater quality in Varanasi: A fast-urbanizing center in Uttarpradesh, India. *Environemntal monitoring and Assessment* 173: 279-300.

**Rao N S 2018** Groundwater quality from a part of Prakasam district, Andhra Pradesh, India. Applied Water Science 8.30.https://doi.org/10.1007/s13201-018-0665-2.

**Richards L A 1954** Diagnosis and improvement of saline and alkali soils. *Agricultural Hand Book* No.60, USDA, Washington DC, 160.

**Sanjeev Kumar Pal, Rajpaul, Ramprakash, Mohammad Amin Bhat and Yadav S S 2018** Assessment of Groundwater quality for irrigation use in Firozpur-Jhirka Block in Mewat district of Haryana, North India. *Journal of Soil Salinity and water Quality* 10(2) : 157-167.

**Singh S N, Raju J and Ramakrishna C 2015** Evaluation of groundwater quality and its suitability for domestic and irrigation use in parts of the Chandauli-Varanasi Region, Uttar Pradesh, India. *Journal of Water Resource and Protection* 7: 572-587.

**Tlilli-Zrelli B, hamzaoui-Azaza F, Gueddari M and Bouhlila R (2013)** Geochemistry and quality assessment of groundwater using and multivariate statistical methods. A Case study : Grombalia Preatic aquifer (Northeastern Tunisia). *Arab Journal of Geosciences* 6: 3545-3561.

**Wescott D W and Ayers RC 1984** Water quality criteria in irrigation with reclaim municipal wastewater. *State Water resources Control Board S Aramento*, California

Received on 05.06.2020 and revised on 26.06.2020