

Assesment Of Ground Water Quality With Salinity, Sodium Hazard) And Flourosis Health Impacts In Ganganeru River Basin Kadapa (Andhara Pradesh)

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Abstract: The current research focusing on ground water quality with emphasis on salinity, sodium hazard and fluoride and its health impacts in the objected area. From that study area 24 ground water samples were collected and analyzed physic chemical parameters. In the study area majorly occurred in elevated percentage sodium (12 to 581ppm), fluoride (0.6 to1.9ppm) and specific conductance. Groundwater in the study area has lowest salinity of under 120 mg/l in spring waters from the quartzite terrain, under 760 mg/l in surface water, under 1155 mg/l in alluvial groundwater and highly variable salinity in groundwater from granitic gneiss areas ranging from those shown by surface water and a maximum of as high as 2500 micromhos/cm. groundwater in some granitic rocks continues to have very high chemical quality in several parts of the study area, there has been a progressive increase in salt in soils in a good portion of areas occupied by the same granitic rocks making them more and more alkaline and infertile.

Key words: physic chemical analysis, USSL Graph, piper diagram, sample location map

1.0 DESCRIPTION OF THE STUDY AREA

The Ganganeru River rises in the southwest portion of Kadapa (earlier called Cuddapah and now YSR) District. It lies in between east longitude 78° 35' 22" to 78° 52' 30" and north latitude 14° 04'30" to 14° 18'40" in the Survey of India topographic sheets 57 J/11 and 57 J/16 published in 1979, 57 J/12 published in 1978, and 57 J/15 published in 2002 on a scale of 1:50,000 (Figure 1.0). The catchment area of the basin is 467.9 sq km, which includes 339.3 sq km of village land under the administrative control of the Revenue Department and 128.6 sq km of forestland under the administrative control of the Forest Department. The major problems faced by the study area include erratic rainfall, droughts caused by delayed rainfall, floods caused by excessive rainfall, excessive soil erosion owing to steep slope, unproductive soils of low fertility, siltation of tanks, steep decline of groundwater levels, illegal felling of forest vegetation, and degradation of forestland and land capabilities. The Chittoor-Cuddapah-Kurnool National Highway NH-18 passes through Rayachoti. The Chennai-Kadapa State Highway passing through Rajampet lies towards east of the basin. A network of roads connects all the villages and their hamlets.



Figure 1.0 shows the location map of the study area

2.0 INTRODUCTION

The chemical quality of natural waters should receive as much importance as the quantity of water available in an aquifer. The water quality specifications prescribed depend primarily on its use. The criteria fixed for water used for drinking differ significantly from those fixed for water used for irrigation and industrial use. As the study area is located in a remote area far away from railway stations and airports, the prospects are not bright for the establishment of industries (Murali, M et al., 2019; veeraswamy et al., 2019). It is therefore sufficient to test water for its suitability for drinking and irrigation. The chemical quality of natural waters is dependent upon the soluble salts and gases present in rocks, weathered mantle, soils, and air and, on the duration of contact of water with geological formations contributing dissolved solids. Surface water

contains generally less dissolved solids than groundwater owing to their contact with the geological formations is for a shorter period. In streams having significant base flow, the chemical quality of stream water is almost the same as the chemical quality of groundwater lying beneath the streams. Among the rock types which contribute dissolved solids to groundwater in the study area, quartzite contributes negligible quantities, granitic and dyke rocks contribute small quantities, and dolomitic limestone and shale within Vempalle Dolomite and Bairenkonda Quartzite/Shale contribute moderate quantities rich in calcium and magnesium. Although groundwater with high concentration of calcium and magnesium are not normally desirable for use in industry and need to be removed by some ion-exchange process, such waters are quite safe for use in domestic supplies and irrigation.

3.0 Methods of chemical analysis:

The constituents and properties of water samples analysed in terms of milligrams per liter (mg/l) include silica (SiO₂), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), carbonate (CO₃), bicarbonate (HCO₃), sulphate (SO₄), chloride (Cl), fluoride (F), total dissolved solids (TDS), hardness as CaCO₃, alkalinity as CaCO₃, non-carbonate hardness as CaCO₃. For the purpose of balancing the cations (Ca, Mg, Na and K) with the anions (SO₄, Cl, CO₃ and HCO₃) analysed, their values have to be expressed in terms of milliequivalents per liter (meq/l). Specific conductance Expressed as micromhos/cm at 25°C and hydrogen-ion concentration (pH) is expressed as a number. As silica does not occur in ionic form, it is expressed only as silica in terms of mg/l. Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) values are expressed only in terms of meq/l. Samples of surface water and groundwater were collected in polythene bottles at a depth of one meter below the water level both from surface and wells. When the depth of water column was less than two meters, the sample was collected at the mid-way of the water column. Standard methods for collection, preservation, analysis and interpretation of water samples were followed by following the methods of Rainwater and Thatcher (1960), Brown et al (1970), Hem (1970) and AWWA, 1971). Silica was determined by the molybdate blue method and fluoride by the Zirconium-Eriochrome Cyanine R method by a spectrophotometric method. Hardness and calcium as CaCO₃ were estimated by the complex metric titration methods and chloride by the titration method of Mohr. Sulphate was estimated by a turbidimetric method. Total dissolved solids were estimated both by the calculation and the residue-on-evaporation methods. Noncarbonate hardness was taken as zero, when alkalinity was equal or more than hardness. Otherwise, it was taken as the difference between the two values. Sodium Adsorption Ratio (SAR) is obtained by the equation $SAR = Na / ((Ca+Mg)/2)^{1/2}$ where all the ionic concentrations are expressed in meq/l (Balaji et al.,2018;veeraswamy et all.,2019). When the sum of calcium and magnesium in meq/l is less than the sum of carbonate and bicarbonate in meq/l, twice their difference is taken as the Residual Sodium Carbonate (RSC). Otherwise, it is treated as zero. It has been established conclusively by various workers that specific conductance of natural waters shows a high positive correlation with their

total dissolved solids (or salinity). As it is much easier to determine specific conductance than dissolved solids, the former value is often used to estimate salinity (US Salinity Laboratory, 1954).

4.0 RESULTS OF CHEMICAL ANALYSIS:

Figure 1.0 is a Google Earth satellite image showing the location of 24 sampling points collected over the entire study area. The water samples analysed are grouped into six categories as detailed below. Tanks & Stream Water Samples (Sample Nos. 1 to 4 or T1 to T4) given in Table 1.0. Spring Water from the Quartzite Terrain (Sample Nos. 5 to 8 or S1 to S4) given in Table 2.0. Groundwater with Low Sodium Hazard in the Granitic Terrain (Sample Nos. 9 to 12 or L1 to L4) given in Table 3.0. Groundwater with Medium Sodium Hazard in the Granitic Terrain (Sample Nos. 13 to 16 or M1 to M4) given in Table 4.0. Groundwater with High Sodium Hazard in the Granitic Terrain (Sample Nos. 17 to 20 or H1 to H4) given in Table 5.0. Groundwater in Sandy Alluvium (Sample Nos. 21 to 24 or A1 to A4) given in Table 6.0. The ranges and averages of values determined for the constituents and properties of all the water samples analyzed in the study area are given in Table 3.9. Figures 3.36 and 3.37 show the diagrams describing the water quality of the water samples analysed.

Table 1.0: Chemical Analysis of Tanks & Stream Water Samples in the Ganganeru Basin

Constituent or Property	T1 (1)		T2 (2)		T3 (3)		T4 (4)	
	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l
Silica (SiO ₂)	38		30		32		28	
Caesium (Ca)	26	1.297	32	1.597	20	0.998	24	1.198
Magnesium (Mg)	29	2.385	19	1.563	19	1.563	29	2.385
Sodium (Na)	99	4.304	85	3.696	100	4.348	90	3.913
Potassium (K)	14	0.036	15	0.384	13	0.335	16	0.409
Carbonate (CO ₃)	-		-		-		-	
Bicarbonate (HCO ₃)	224	3.671	231	3.786	204	3.343	250	4.100
Sulphate (SO ₄)	15	0.312	12	0.250	12	0.250	10	0.208
Chloride (Cl)	151	4.258	110	3.102	125	3.525	12	3.440
Fluoride (F)	0.2	0.011	0.4	0.021	0.5	0.026	0.4	0.021
Total Dissolved Solids (TDS)								
Calculated	483		395		422		443	
Residue on Evaporation	491		418		435		451	
Hardness as CaCO ₃	184		158		128		179	
Alkalinity as CaCO ₃	184		183		167		205	
Noncarbonate Hardness as CaCO ₃	0		0		0		0	
Specific Conductance (micromhos/cm at 25°C)	760		627		655		705	
Hydrogen-ion concentration (pH)	7.9		8.0		8.0		8.1	
Sodium Adsorption Ratio (SAR)		3.20		2.90		3.80		2.90
Residual Sodium Carbonate (RSC)		0		1.25		1.56		1.03

Table 2.0: Chemical Analysis of Spring Waters from the Quartzite Terrain In The Ganganeru Basin

Constituent or Property	T1 (1)		T2 (2)		T3 (3)		T4 (4)	
	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l
Silica (SiO ₂)	4		5		7		8	
Caesium (Ca)	5	0.250	4	0.199	4	0.199	5	0.250
Magnesium (Mg)	3	0.247	3	0.247	2	0.164	4	0.329
Sodium (Na)	10	0.434	14	0.609	12	0.522	15	0.652
Potassium (K)	2	0.051	2	0.051			2	0.051
Carbonate (CO ₃)	-		-		-		-	
Bicarbonate (HCO ₃)	26	0.426	30	0.492	28	0.459	31	0.508
Sulphate (SO ₄)	-		-		-		-	
Chloride (Cl)	17	0.480	24	0.677	16	0.451	28	0.790
Fluoride (F)	-		-		-		-	
Total Dissolved Solids (TDS)								
Calculated	54		67		59		77	
Residue on Evaporation	58		72		65		85	
Hardness as CaCO ₃	25		0		18		29	
Alkalinity as CaCO ₃	21		2		23		25	
Noncarbonate Hardness as CaCO ₃	4		0		0		4	
Specific Conductance (micromhos/cm at 25°C)	90		110		96		120	
Hydrogen-ion concentration (pH)	7.6		7.5		7.3		8	
Sodium Adsorption Ratio (SAR)		0.90		1.30		1.20		1.20
Residual Sodium Carbonate (RSC)		0		0.09		0.19		0

Table 3.0: Chemical Analysis of Groundwater's With Low Sodium Hazard In The Granitic Terrain In The Ganganeru Basin

Constituent or Property	T1 (1)		T2 (2)		T3 (3)		T4 (4)	
	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l
Silica (SiO ₂)	25		32		42		35	
Caclium (Ca)	30	1.497	40	1.996	28	1.397	32	1.597
Magnesium (Mg)	17	1.398	24	1.974	28	2.303	41	3.372
Sodium (Na)	13	0.565	62	2.696	111	4.826	136	5.913
Potassium (K)	6	0.153	10	0.256	16	0.409	17	1.435
Carbonate (CO ₃)	-		-		-		-	
Bicarbonate (HCO ₃)	176	2.884	220	3.605	217	3.556	300	4.916
Sulphate (SO ₄)	9	0.187	11	0.229	17	0.354	18	0.375
Chloride (Cl)	15	0.423	105	2.962	175	4.937	209	5.896
Fluoride (F)	0.4	0.021	0.5	0.026	0.4	0.021	0.5	0.026
Total Dissolved Solids (TDS)								
Calculated	202		392		524		636	
Residue on Evaporation	210		400		533		645	
Hardness as CaCO ₃	145		200		185		249	
Alkalinity as CaCO ₃	144		180		178		246	
Noncarbonate Hardness as CaCO ₃	1		20		7		3	
Specific Conductance (micromhos/cm at 25°C)	320		621		822		1,000	
Hydrogen-ion concentration (pH)	7.6		7.5		7.7		7.8	
Sodium Adsorption Ratio (SAR)		0.47		1.90		3.50		3.80
Residual Sodium Carbonate (RSC)		0.47		0		0		0

Table 4.0: Chemical analysis of groundwater's with medium sodium hazard in the granitic terrain in the ganganeru basin

Constituent or Property	T1 (1)		T2 (2)		T3 (3)		T4 (4)	
	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l
Silica (SiO ₂)	32		24		37		35	
Caclium (Ca)	20	0.998	23	1.148	20	0.998	15	0.748
Magnesium (Mg)	15	1.234	11	0.905	11	0.905	9	0.74
Sodium (Na)	192	8.348	24	9.739	230	10.000	242	10.522
Potassium (K)	19	0.486	19	0.486	15	0.384	11	0.281
Carbonate (CO ₃)	-		20	0.667	-		-	
Bicarbonate (HCO ₃)	477	7.817	498	8.161	501	0.250	399	6.539
Sulphate (SO ₄)	15	0.312	19	0.396	12	3.611	14	0.291
Chloride (Cl)	99	2.793	104	2.934	128	0.053	187	5.275
Fluoride (F)	0.5	0.026	0.6	0.032	1.0	0.052	0.9	0.047
Total Dissolved Solids (TDS)								
Calculated	627		690		701		710	
Residue on Evaporation	635		701		714		721	
Hardness as CaCO ₃	112		103		95		74	
Alkalinity as CaCO ₃	391		442		411		327	
Noncarbonated Hardness as CaCO ₃	0		0		0		0	
Specific Conductance (micromhos/cm at 25°C)	990		1085		1105		1000	
Hydrogen-ion concentration (pH)	7.8		8.5		7.9		8	
Sodium Adsorption Ratio (SAR)		7.90		9.60		10.30		12.20
Residual Sodium Carbonate (RSC)		11.2		13.6		12.6		10.1

Table 5.0: Chemical analysis of groundwaters with high sodium hazard in the granitic terrain in the ganganeru basin

Constituent or Property	T1 (1)		T2 (2)		T3 (3)		T4 (4)	
	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l
Silica (SiO ₂)	55		66		24		34	
Caesium (Ca)	20	0.998	14	0.699	10	0.499	31	1.547
Magnesium (Mg)	15	1.234	5	0.411	5	0.411	12	0.987
Sodium (Na)	581	25.261	391	17.000	351	15.261	497	21.609
Potassium (K)	2	0.563	47	1.202	12	0.307	31	0.793
Carbonate (CO ₃)	30	1.000	72	2.400	-		25	0.833
Bicarbonate (HCO ₃)	1050	17.207	522	8.555	605	9.915	541	8.866
Sulphate (SO ₄)	19	0.396	43	0.895	14	0.291	43	0.895
Chloride (Cl)	324	9.140	340	9.591	215	6.065	496	13.992
Fluoride (F)	1.9	0.100	1.4	0.074	0.9	0.047	1.5	0.079
Total Dissolved Solids (TDS)								
Calculated	1585		1236		930		1437	
Residue on Evaporation	1610		1290		944		1470	
Hardness as CaCO ₃	112		56		46		127	
Alkalinity as CaCO ₃	911		548		496		485	
Noncarbonate Hardness as CaCO ₃	0		0		0		0	0
Specific Conductance (micromhos/cm at 25°C)	2500		1950		1480		2310	
Hydrogen-ion concentration (pH)	8.5		8.6		8.0		8.6	
Sodium Adsorption Ratio (SAR)		23.90		22.80		22.60		19.20
Residual Sodium Carbonate (RSC)		32.0		19.7		18.0		14.3

Table 6.0: Chemical Analysis Of Groundwater's In The Sandy Alluvium In The Ganganeru Basin

Constituent or Property	T1 (1)		T2 (2)		T3 (3)		T4 (4)	
	mg/l	meq/l	mg/l	meq/l	mg/l	meq/l	mg/l	meq/l
Silica (SiO ₂)	25		35		30		32	
Caclium (Ca)	32	1.597	24	1.198	31	1.547	27	1.347
Magnesium (Mg)	29	2.385	26	2.138	42	3.454	20	1.645
Sodium (Na)	124	5.391	114	4.957	175	7.609	93	4.043
Potassium (K)	15	0.384	18	0.46	18	0.460	13	0.332
Carbonate (CO ₃)								
Bicarbonate (HCO ₃)	184	3.015	200	3.278	303	4.966	180	2.950
Sulphate (SO ₄)	10	0.208	16	0.333	17	0.354	14	0.291
Chloride (Cl)	120	3.384	184	5.189	272	7.671	142	4.006
Fluoride (F)	0.3	0.016	0.4	0.021	0.5	0.026	0.4	0.021
Total Dissolved Solids (TDS)								
Calculated	426		516		735		430	
Residue on Evaporation	434		525		750		445	
Hardness as CaCO ₃	199		167		250		150	
Alkalinity as CaCO ₃	151		164		248		148	
Noncarbonate Hardness as CaCO ₃	48		3		2		2	
Specific Conductance (micromhos/cm at 25°C)	672		815		1,155		680	
Hydrogen-ion concentration (pH)	7.9		8.0		8.0		8.0	
Sodium Adsorption Ratio (SAR)		3.80		3.80		4.80		3.30
Residual Sodium Carbonate (RSC)		0		0		0		0

Table 7.0: Ranges and averages of values determined for the constituents and properties of water samples analysed in ganganeru river basin

Sl. No.	Constituent or Property	Smallest Value	Largest Value	Average Value
1	Silica (SiO ₂) in mg/l	4	66	30
2	Caesium (Ca) in mg/l	4	40	22
3	Magnesium (Mg) in mg/l	2	42	17
4	Sodium (Na) in mg/l	12	581	157
5	Potassium (K) in mg/l	2	47	6
6	Carbonate (CO ₃) in mg/l	0	72	6
7	Bicarbonate (HCO ₃) in mg/l	26	1050	308
8	Sulphate (SO ₄) in mg/l	0	43	14
9	Chloride (Cl) in mg/l	12	496	150
10	Fluoride (F) in mg/l	0.6	1.9	0.6
11	Total Dissolved Solids in mg/l			
12	Calculated	54	1585	574
13	Residue on Evaporation	58	1610	588
14	Hardness as CaCO ₃ in mg/l	0	250	125
15	Alkalinity as CaCO ₃ in mg/l	2	911	262
16	Noncarbonate Hardness as CaCO ₃ in mg/l	0	48	4
17	Specific Conductance (micromhos/cm at 25oC)	90	2500	902
18	Hydrogen-ion concentration (pH)	7.3	8.6	7.9
19	Sodium Adsorption Ratio (SAR) in me/l	0.47	23.9	7.14
20	Residual Sodium Carbonate (RSC) in me/l	0	32	5.7

Water samples are distinctly alkaline with pH ranging from 7.3 to 8.6. The generally high alkaline nature has led to high concentration of soluble silica of as high as 66 mg/l with a mean of 32 mg/l. Soluble silica is obtained from the decomposition of silicates by hydrolysis, involving removal of hydrogen ions from water and thereby raising water pH (Stevens, 1934). Carbon dioxide in the weathering solutions allows for dissociation of carbonic acid, leading to liberation of hydrogen ions, formation of bicarbonate, and prevention of undue increase in pH. This tendency is prevalent in soils occupying granitic rocks occurring in pediplains in close association with water bodies such as tanks. In such areas, conditions of water logging are noted during monsoon and complete dry conditions of soil during summer. This results in high fluctuations in the water table with migration of soluble salts in deep soil to move in an upward direction for accumulation in top soil (Veeraswamy, G et al., 2018). Formation of clay lenses in the weathered mantle of granitic gneisses prevents effective drainage and results in concentration of harmful salts in the root zone. As a result, there has been a progressive enhancement of salt accumulation in several pediplains under granitic rocks resulting in high concentration of salts in groundwater. While groundwater in some granitic rocks continues to have very high chemical quality in several parts of the study area, there has been a progressive increase in salts in soils in a good portion of areas occupied by the same granitic rocks making them more and more alkaline and infertile. This tendency is almost wholly confined to areas of soils occupied by granitic rocks, while such a tendency is almost absent in the case of soils developed on other geological formations. This prompted the author to demonstrate how there has been progressive deterioration of chemical quality of groundwater in the granitic terrain in Tables 3.5 to 3.7. It is further noted that the areas occupied by poor-quality groundwater are occupied by alkaline soils showing distinct dirty white color without vegetation in the Google Earth satellite images (Figures 2.21). This is also pronounced in areas occupied by water-logged fallow lands (Figures 2.22 and 2.23). The decline in groundwater quality is highly pronounced in areas where there is irrigation with surface water compared to fallow lands with no agriculture at all. Figure 3.38 demonstrates how a land irrigated by a shallow well in the past is now kept fallow owing to the transformation of its soil into alkaline land unfit for any crop production.

5.0 INTERPRETATION OF CHEMICAL ANALYSIS:

According to the US Salinity Laboratory (1954), the suitability of water for irrigation can be known from its salinity hazard (as known from specific conductance having bearing on total dissolved solids) and sodium hazard (as known from sodium adsorption ratio or SAR having bearing on the occurrence of sodium relative to calcium and magnesium) (Figure 3.36). Based on specific conductance expressed in micromhos/cm, the salinity hazard is said to be low (C1) when it is less than 250, moderate (C2) when in between 250 and 750, medium (C3) when in between 750 and 2250, high (C4) when in between 2250 and 4000, and very high (C5) when more than 4000. The highest salinity shown by groundwater in the study area is 2500 micromhos/cm. Based on sodium adsorption ratio (SAR)

expressed in me/l, sodium hazard is said to be low (S1) when SAR is under 10, medium (S2) when between 10 to 17 me/l, high (S3) when between 17 to 25 me/l and very high (S4) when over 25. Water with low salinity and low sodium hazards are highly suitable for irrigation of normal crops. Their suitability for irrigation gets reduced with increase in the salinity and sodium hazards. Prolonged usage of irrigation waters of high salinity and high SAR leads to reduced crop yields and increased land infertility. Groundwater in the study area has lowest salinity of under 120 mg/l in spring waters from the quartzite terrain, under 760 mg/l in surface water, under 1155 mg/l in alluvial groundwater and highly variable salinity in groundwater from granitic gneiss areas ranging from those shown by surface water and a maximum of as high as 2500 micromhos/cm. It is noted that high-SAR water is characterised by high pH, a non-carbonate hardness of zero, and Alkalinity far exceeding total hardness. Prolonged irrigation with such waters may lead to a stage when the land becomes unfit for growing crops at best supporting profuse growth of trees such as *Prosopis juliflora* of low-economic value (Figure 2.0). Such lands require land reclamation at high cost through gypsum treatment to enable growth of crops with good yields. Many such irrigated lands requiring reclamation are found in abundance in parts of the study area close to tanks and other sources of surface water. According to Eaton (1950), water with high RSC has high pH and land irrigated by such water becomes infertile owing to deposition of sodium carbonate. According to US Salinity Laboratory (1954), an RSC under 1.25 meq/l is safe for irrigation, a value of more than 2.5 meq/l is unsuitable for irrigation and a value between 1.25 and 2.5 meq/l is of marginal quality. Surface waters and groundwater in association with quartzite terrain and alluvial aquifers have such low values that they can be safely used for irrigation. But, in the case of groundwater in association with granitic rocks the RSC ranges from very low values suitable for irrigation to very high values of as high as 32 to result in low crop yields. According to Headden (1903), Clarke (1924), Lindgren (1933), Mohr (1944), Feth et al (1965), Garrels (1967) and Hem (1970), carbon dioxide in soil water has an important role in attacking primary silicates and in contributing dissolved solids to groundwater. The anions produced during this attack are bicarbonate and carbonate. As plagioclase is more easily attacked than other minerals, sodium and calcium ions and soluble silica are enriched in groundwater. Much of the calcium reacts with bicarbonate to form insoluble calcium carbonate, while sodium carbonate remains in soluble state. Unlike the highly soluble sodium chloride that gets leached out easily by water, sodium carbonate cannot be leached out from the soil easily. In areas where hard impervious rock or impervious clay occurs at shallow depth, the overlying soil gets oversaturated with water during wet season and becomes nearly dry in summer. This is especially so in the study area where surface water bodies such as tanks carry water for a short period in the year. As excess water in the soil cannot percolate further down due to a bottom impervious formation, there will be cumulative accumulation of sodium carbonate in the soil to make soil more and more infertile with stunted plant growth. It is worthwhile to practice water conservation techniques such as drip irrigation in such

areas to inhibit deposition of excessive salts in the soil. According to Faber (1941) and Kuroda and Sandell (1953), chlorine occurs in hydrous minerals such as biotite, muscovite and hornblende, but also in anhydrous minerals such as quartz, potash feldspar and plagioclase as both solid and liquid inclusions. The average content of chlorine in granitic rocks is estimated at 220 ppm (Kuroda and Sandell, 1953). The work of Chari (1972) on the fluorine-rich granitic rocks of Prakasam district of Andhra Pradesh indicates that their chlorine content ranges from 65 to 1717 ppm with a mean of 553 ppm. Although no information is available, it is possible that the chlorine content of granitic rocks in the study area is high enough to contribute enough chloride to groundwater.

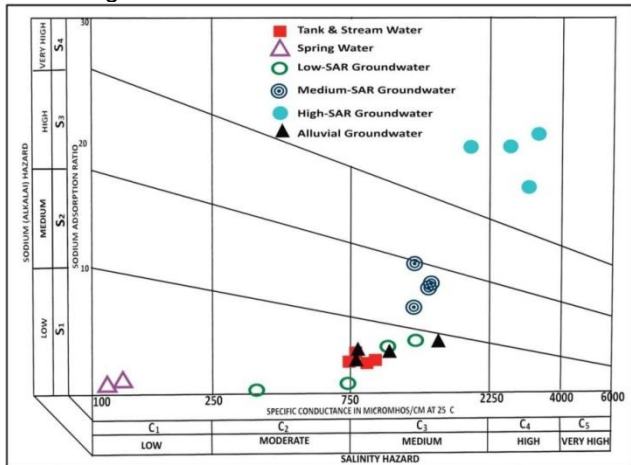


Figure 2.0 rating of water samples analysed for suitability in irrigation as per the diagram of US salinity laboratory (1954) using specific conductance and sodium absorption ratio

6.0 GEOCHEMICAL CLASSIFICATION OF NATURAL WATERS:

This method of graphical representation of chemical analysis was first proposed by Collins (1923) and later modified by Piper (1944) and Davis and Dewiest (1966). This diagram consists of two triangular fields and one rhomb-shaped field (Figure 3.0). The percentages of the three cation groups in me/l (Ca, Mg and Na+K) are plotted as a single point in the left-side triangle and those of the three anion groups in me/l ($\text{HCO}_3 + \text{CO}_3$, Cl+F and SO_4) as a single point on the right-hand triangle. Two straight lines passing through these two points and lying parallel to the outermost sides of the two triangles intersect at one point in the rhomb. The three points so obtained from the analyses of a water sample reflect the chemical character of water in terms of their relative concentrations rather than absolute concentration. Each of the triangles is divided into seven fields, while the rhomb is divided into nine fields as detailed below. Area 1: Alkaline earths exceed alkalis Area 2: Alkalis exceed alkaline earths Area 3: Weak acids exceed strong acids Area 4: Strong acids exceed weak acids Area 5: Carbonate hardness (secondary alkalinity) exceeds 50% Area 6: Noncarbonated alkali (primary salinity) exceeds 50% Area 7: Noncarbonated alkali (primary alkalinity) exceeds 50% Area 8: Carbonate alkali (primary salinity) exceeds 50%, Area 9: Primary or secondary alkalinity or salinity is less than 50%. Based on this classification, it is noted that in majority of cases alkalis exceeds alkaline

earths, weak acids exceed strong acids and primary salinity exceeds 50%.

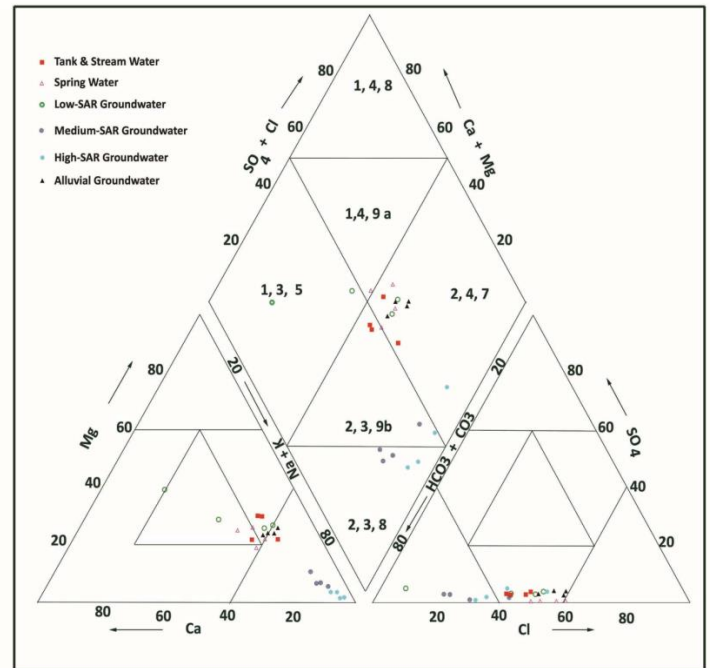


Figure 3.0 piper diagram shows hydro chemical facies of water in the study area

7.0 ENDEMIC FLUOROSIS IN THE STUDY AREA

It is observed that dental mottling or fluorosis with teeth showing symptoms such as lack of luster, chalkiness and development of yellowish, brown or black patches is prevalent in a small section of population in the study area. A study of the chemical analysis of the water samples analysed in the study area revealed that the fluoride content of groundwater in the granitic terrain ranges from zero to 1.9 mg/l with a mean of 0.6 mg/l. The existence of endemic fluorosis, caused by drinking high-fluoride water, was found for the first time from India in and around Podili in Prakasam district of Andhra Pradesh farther north of the study area. (Shortt et al., 1937; World Health Organization, 1958; Chari, 1972; Nagaraju, A et al., 2017). Two types of fluorosis are noted. The one affecting teeth is known as dental fluorosis or mottling, while the other affecting bones and joints is known as skeletal fluorosis or osteofluorosis. In contrast to this, dental caries is found among people drinking water with little or no fluoride. When fluoride content of drinking water is around 1 mg/l, teeth are generally free of both caries and mottling. With increase in fluoride content, teeth show mottling. These symptoms are noted right from childhood during the development of the permanent teeth, with symptoms persisting throughout the life and with severity increasing with the fluoride content of drinking water. Mottling can be mild when fluoride content of drinking water is less than 2.5 mg/l with the affected teeth showing dull luster, chalkiness and development of transverse bands of light yellow to dark brown colour. Except for disfigurement, the affected teeth are generally resistant to caries. Figure 3.39 shows a picture of a boy showing mild dental fluorosis. Even such cases of fluorosis

can be avoided by taking adequate care in providing low-fluoride drinking water to the communities.

CONCLUSION

Groundwater in the study area has lowest salinity of under 120 mg/l in spring waters from the quartzite terrain, under 760 mg/l in surface water, under 1155 mg/l in alluvial groundwater and highly variable salinity in groundwater from granitic gneiss areas ranging from those shown by surface water and a maximum of as high as 2500 micromhos/cm. Groundwater within granitic aquifers is getting progressively mineralised owing to mismanagement of water sources. It is noted that high-SAR water is characterized by high pH, a non-carbonate hardness of zero, and alkalinity far exceeding total hardness. Prolonged irrigation with such waters may lead to a stage when the land becomes unfit for growing crops at best supporting profuse growth of trees such as *Prosopis juliflora* of low-economic value. Such lands require land reclamation at high cost through gypsum treatment to enable growth of crops with good yields. Many such irrigated lands requiring reclamation are found in abundance in parts of the study area close to tanks and other sources of surface water. Because of the occurrence of fluoride in groundwater ranging to a maximum of 1.9 mg/l, a small section of population is afflicted with mild dental fluorosis or mottling. Although mottled teeth show disfiguring, such teeth are quite resistant to caries. Despite that, there is need to eradicate the incidence of fluorosis. This is possible by identifying groundwater carrying fluoride of more than 1 mg/l for avoidance as sources of drinking. Despite making available water for drinking both by public and private sources such as dug wells, hand bores, bore wells, community water supply systems, water shortages are felt in the study area almost every year, necessitating supply of water by private and public tankers. With a view to supply assured sources of drinking water round the year, there are proposals to draw piped water supply from the recently-constructed Veligallu reservoir.

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