International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.7, pp 218-227, 2017

Groundwater Quality Assessment using Correlation and Regression Model in Tirupathi, India

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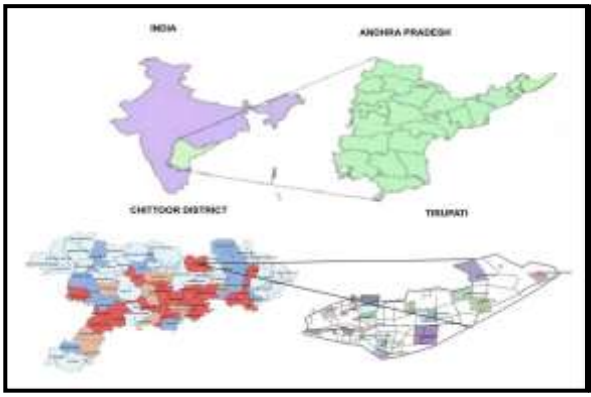
Abstract : The groundwater is the major source of water for drinking, agricultural and industrial requirements. Groundwater is the most important natural source required for drinking to the public's around the world, particularly in rural areas. An attempt has been made in order to determine the spatial distribution of groundwater quality parameters and to study the correlation and regression method. The physical and chemical analysis results were compared to the standard guideline values as recommended by the Bureau of Indian standards for drinking and public health in order to have an indication of the present groundwater quality. According to the overall assessment of the basin, almost all the parameters analysed are above the desirable limits of standards. Using Geographic Information System, spatial distribution maps of various parameters, correlation and regression method. The spatial analysis of ground water quality patterns of the study area shows that the Total Dissolved Solids values are similar throughout the sample station. The spatial distribution map of Total hardness shows that a majority of the groundwater samples are in the permissible limit only. The correlation analysis provides an excellent device for the calculation of parameter values within realistic degree of accuracy. The subsistence of strong correlation between calcium and Magnesium, electrical conductivity and chloride is determined.
Key Words: Groundwater, physical and chemical analysis, Geographic Information System, Spatial Distribution, correlation and regression analysis.

Introduction and Experimental

Generally, the accessibility of a groundwater supply sufficient in terms of both quality and quantity and is essential to human existence. Water demand has increased over the years and this has led to scarcity of water in many parts of the world (1). The fresh water is a limited and inadequate resource. The situation is infuriated by the crisis of water pollution. India towards a freshwater calamity is mainly due to inappropriate executive of water resources and environmental squalor (10, 13). This leads to require of access to protected potable water supply to millions of people. According to WHO organization, about 80% of water borne diseases in human beings occurs. Further the groundwater and the pollutants, it may take move with such a less velocity that it may take substantial time for the pollutants to pass away from the pollution source and also squalor in the quality of groundwater may stay concealed for period of years (2, 4). Once the groundwater is polluted, its quality cannot be restored by arresting the pollutants from the source. Therefore it becomes very important to regularly check the groundwater quality and to device ways and means to protect it (3, 8). The main important objective in the present study is to estimate the groundwater quality in the Tirupati and preparation of thematic maps using Geographic Information System (GIS) and Analysis of correlation and regression method. Using GIS software can be used as a effective tool for early solutions for water resources problems for calculating

water quality, determining water availability in the study area, understanding the natural environment, preventing flooding and managing water resources on a local or district area.

Tirupati is situated on the Chittoor district of Andhra Pradesh, India and located at 13º 39'N & 79º 25'E (Fig 1). The average elevation is 162 meters. Tirupati is famous for the richest temple Venkateswara Swami temple dedicated to Lord Venkateswara, located about 20 kilometres (12 mi) northwest of Tirupati in the Tirumala hills at an elevation of 853 metres (2,799 ft.). It has a population of about 4,59,985 as per 2011 census, India. This growth is because of recent inclusion of various villages into the municipal corporation area. Tirupati total geographical area is nearly 201 Sq.km and average rainfall is 1086 mm. One of the most important pilgrimage centres in the World, the temple draws millions of pilgrims and is the busiest pilgrimage centre in the world. Tirupati has several temples and famous for its copper, red wooden toys and brass idols. People in this area majorly depend upon ground water for drinking and other purposes. For the past few years, Tirupati is facing a severe water scarcity due to rapid growth of population.



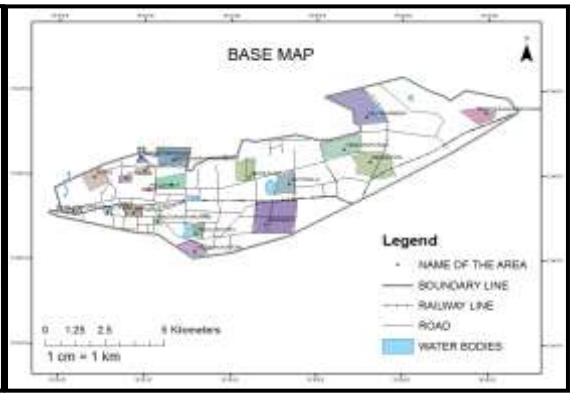


Figure 1. Location of the Study area (Tirupathi) Figure 2. Base Map of the Study area

The ground water samples are collected manually from 20 bore wells which were approximately equally distributed all over Tirupati (Fig 2). The samples were analysed using standard procedures in the laboratory. The list of samples collected was given in Table 1. The Parameters, which are analysed during water analysis, P_H, Temperature, Total alkalinity, TDS, EC, Total hardness ,Calcium, Magnesium, Chloride, Iron, Fluoride, Nitrate, Sodium, Potassium, Sulphate, Phosphate. The study is carried out with the help of two major components: toposheet and field data. The toposheet collected from the SOI demarcating all areas were scanned and digitized to generate a digital output forming a spatial database. Field work was conducted and groundwater samples were collected with the help of the map. These samples were tested using standard procedures in the laboratory and the results were tabulated in an excel worksheet. The correlation and regression analysis for each sample was calculated. The spatial and attribute database generated were integrated for the generation of the spatial distribution maps of all water quality parameters. The water quality data (attribute) is linked to the sampling location (spatial) i.e. Tirupati maps showing spatial distribution were prepared using Arc Map 10.1software.

Table 1. Well Location name of sampling point with various sources

Station no	Well Location name	Source	Station no	Well Location name	Source
S1	Bhavani Nagar	BW	**S11**	Tiruchanuru	HP
S2	T.K Street	BW	**S12**	Padmavathipuram	BW
S3	K.T. Road	BW	**S13**	Korlagunta	BW
S4	Sri Padmavathi Mahila University	BW	**S14**	S.I.V.M.S	BW
S5	Setti Palli	BW	**S15**	Karakambadi	HP
S6	D.R Mahal	BW	**S16**	Satyanarayanapuram	**BW**
S7	P.K. Layout	BW	**S17**	Mangalam	**BW**
S8	R.C. Road	BW	**S18**	Venkatapuram	DW
S9	Yogimallavaram	BW	**S19**	Srinivasapuram	**BW**
S10	Damenidu	HP	**S20**	Renigunta	**BW**

Correlation Coefficient (r):

Let x and y be any two variables and (Xi, Yi) be n pairs of observed values of these variables (I =1, 2, 3……n). The correlation coefficient r between the variables x and y is given by equation 1. (13)

$$r = \frac{n \Sigma x y - \Sigma x \Sigma y}{\sqrt{[n \Sigma x^2 - (\Sigma x)^2][n \Sigma y^2 - (\Sigma y)^2]}} \quad \text{---- (1)}$$

Where, the summations are taken above 1 to n (n=number of observations). The values of observed parameters a and b were considered with the help of equations 2 and 3.

$$a = \frac{n \Sigma x y - \Sigma x \Sigma y}{n \Sigma x^2 - (\Sigma x)^2} \quad \text{------- (2)}$$

Regression equation

$$y = a x + b \quad \text{---------- (3)}$$

The correlation study between various water quality parameters, the regression analysis was taken out using software SPSS 18 (9).

Results and Discussion

Groundwater Quality Variation

The variations of the physical and chemical characteristics of the ground water in the different parts of Tirupati were given in table 2. The quality of ground water varies from place to place. It depends upon both the surface and subsurface characteristics. Presence of landfills, open dump, usage of fertilizers, disposal of industrial wastes, etc., changes the quality of ground water. Even at the same location, from seasons to seasons the quality of ground water varies. The variations of water quality were discussed below.

Table 2. Physico-chemical parameters of various sampling station points

Station NO./ Parameters	pH	TDS	TA	TH	Ca	Mg	Cl	EC	SO_4	P	K	Na	NO_3	F	Fe
S1	7.6	180	180	210	260	133.65	309.75	1540	250	189.78	1.56	6.44	45	1.8	0.02
S2	7.5	189	200	215	224	111.78	177	1850	250	99.88	3.9	2.76	50	2	0.02
S3	7.77	199	240	200	150	66.82	132.75	1720	200	199.77	2.34	5.75	35	1.9	0.01
S4	7.95	123	150	200	360	194.4	309.75	2350	300	159.81	2.73	5.29	50	0.9	0.01
S5	7.85	145	210	190	140	85.05	309.75	2650	370	99.88	12.87	23	30	1.5	0.01
S6	7.86	178	210	180	400	218.7	354	3660	280	99.88	23.79	8.04	45	2	0.03
S7	7.29	198	180	200	90	30.37	177	1760	450	119.86	8.58	5.06	20	0.7	0.01
S8	7.7	178	140	190	330	176.17	354	2360	270	199.77	7.02	3.68	25	0.9	0.01
S9	7.9	197	220	210	340	85.05	265.5	2600	250	119.86	11.3	32.2	40	1.8	0.01
S10	8.08	145	150	198	40	24.3	398.25	2650	320	149.82	3.9	0	30	0.9	0.03
S11	7.5	178	160	190	210	103.27	354	2900	250	99.88	3.12	13.6	20	0.6	0.01
S12	8.12	145	180	200	46	24.3	88.5	1910	260	129.85	22.22	22.1	45	1.5	0.02
S13	7.76	134	160	215	340	182.25	486.75	3160	300	169.8	12.48	11.5	30	1.8	0.03
S14	7.1	187	170	210	204	99.63	177	1270	400	199.77	4.29	1.84	35	0.8	0.02
S15	7.68	198	200	170	140	60.75	177	3130	400	139.84	5.46	17	45	1	0.03
S16	7.7	156	160	215	240	121.5	177	1580	200	179.79	10.53	3.68	25	0.8	0.02
S17	7.1	187	150	180	300	157.95	265.5	3040	250	99.88	0.97	6.44	10	0.8	0.01
S18	8.04	189	190	190	180	85.05	177	1700	270	149.82	21.45	5.52	20	0.9	0.03

S19	7.6	156	200	180	200	97.2	265.5	2440	300	149.82	14.43	16.1	15	0.7	0.02
S20	7.95	189	170	180	80	24.3	531	4190	350	159.81	3.12	0	40	0.9	0.02

The permissible limit of pH in drinking water is within 6.5-8.5 according to bureau of Indian standards (BIS). The value of pH in all categories of water is within the permissible range. The value of PH in groundwater samples of the study area ranges between 7.1-8.12. Measurement of pH in one of the most important and frequently used tests, as every phase of water and wastewater treatment and waste quality management is pH dependent (12), whereas the maximum at S12 and minimum at S14 and S17 in the well points (Fig 3).

Electrical conductivity is the ability of water to allow electric current Through it and is expressed in micro mhos per centimeter (µ mhos/cm). Conductivity value of fresh waters is in the range of 5 to 500 µmhos/cm. Maximum value of 4190µ mhos/cm was observed at S20 while minimum value was 1270µ mhos/cm at S14 (Fig 4).

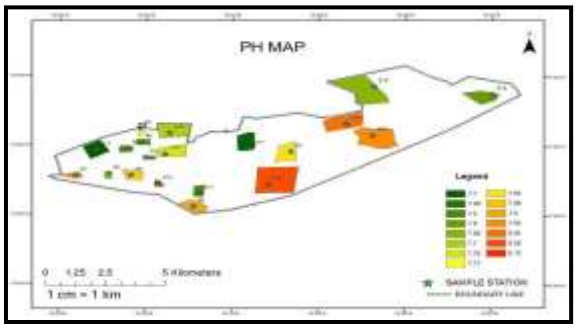


Figure 3. pH map

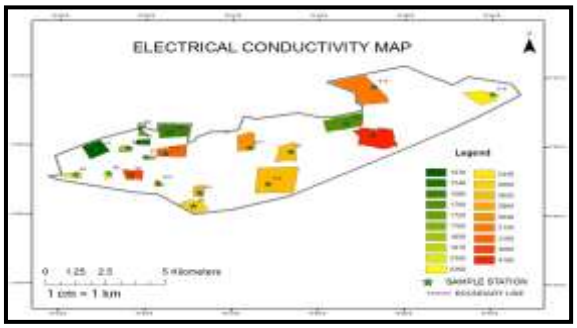


Figure 4. Electrical Conductivity map

The values of alkalinity at stations were found in the range of 140-240mg/l. The alkalinity values for all seasons fluctuate from 30-40mg/l. The value shows that there is very little fluctuation in alkalinity in the area whereas the Maximum at S32 40 mg/l and minimum at S8 140 mg/l as shown (Fig 5).

Hardness is frequently used as an assessment of the quality of water supplies. The hardness of a water is governed by the content of calcium and magnesium salts (temporary hardness), largely combined with bicarbonate and carbonate and with sulphates, chlorides, and other an ions of mineral acids (permanent hardness) maximum at S13, S2 215mg/l and minimum at S6, S19, and S20 180 mg/l (Fig 6).

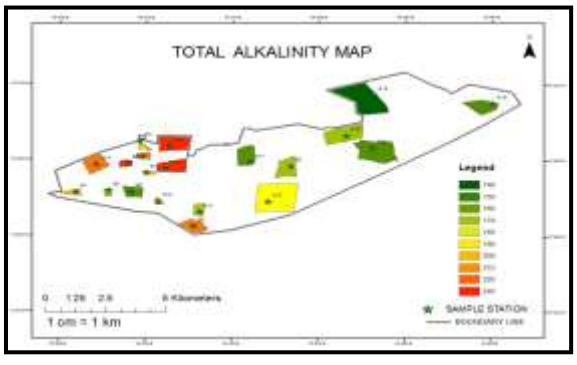


Figure 5. Total alkalinity map

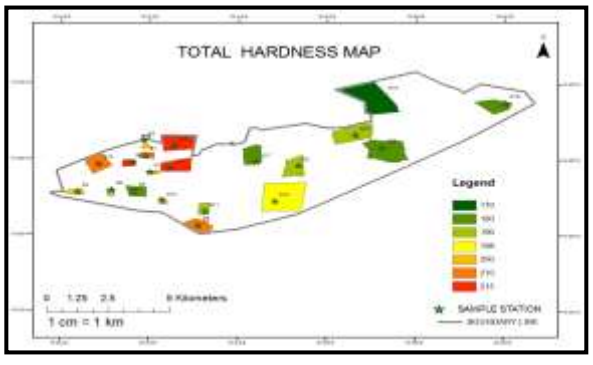


Figure 6. Hardness map

High levels of iron are attributed to the dominating literatic soil. Iron is present in drinking water due to domestic discharges, geological sources and industrial wastes and also from mining products. Excess amount of iron i.e., more than 10mg/l causes rapid increase in respiration, pulse rate and coagulation of blood vessels. The concentration of iron in all water samples of the study area ranges from 0.01-0.03 mg/l. Maximum at S6,S10,S13 and S18 0.03 mg/l and minimum at S3,S4,S5,S7,S8,S9,S11 and S17 0.01 mg/l (Fig 7).

The fluoride concentrations were found to be in the range of 0.6-2.0 mg/l in ground water, fluoride concentrations vary with the type of rock that the water flows through but do not usually exceed 10mg/l (11). Presence of large quantities fluoride is associated with dental and skeletal fluorosis and inadequate amounts with dental caries. Maximum at S6 2 mg/l and minimum at S11 0.6 mg/l (Fig 8).

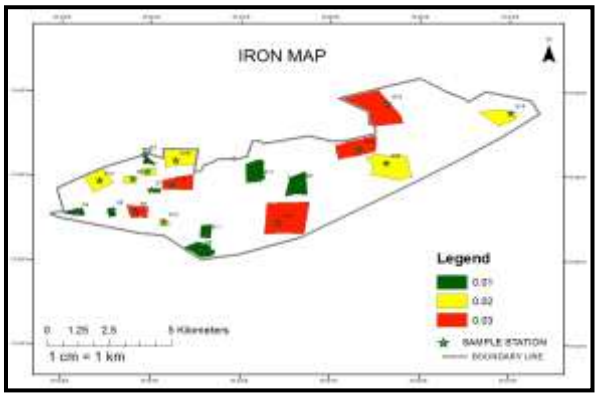


Figure7. Iron map

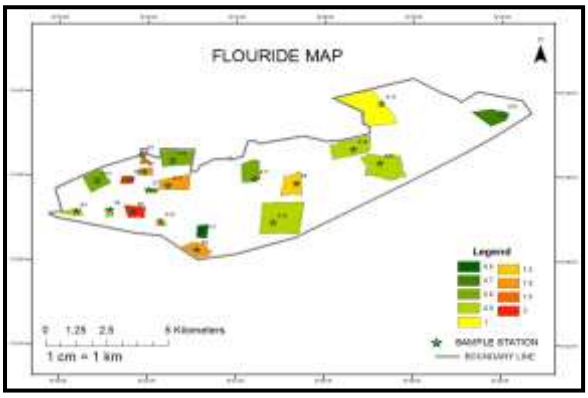


Figure 8. Fluoride map

The nitrite concentration in the study area ranges from 10-50 mg/l. The permissible limit of nitrate is 45mg/l. Nitrates generally occur in trace quantities in surface waters but may attain high levels in ground waters. It can be toxic to certain aquatic organisms even at concentrations of 100mg/l (15). In excessive limits, it contributes to the illness known as methenogobinemia in infants whereas the maximum at S2 and S4 50 mg/l and minimum at S17 10 mg/l (Fig 9).

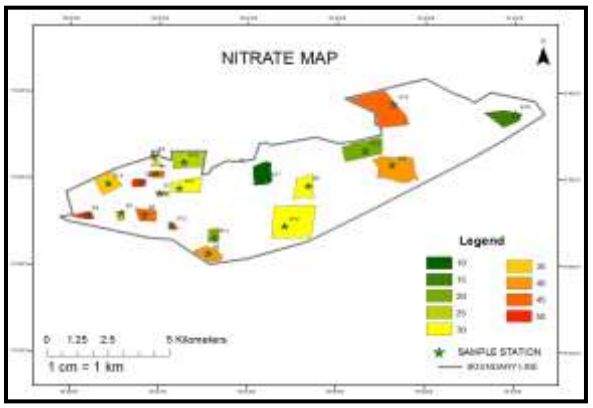


Figure 9. Nitrate map

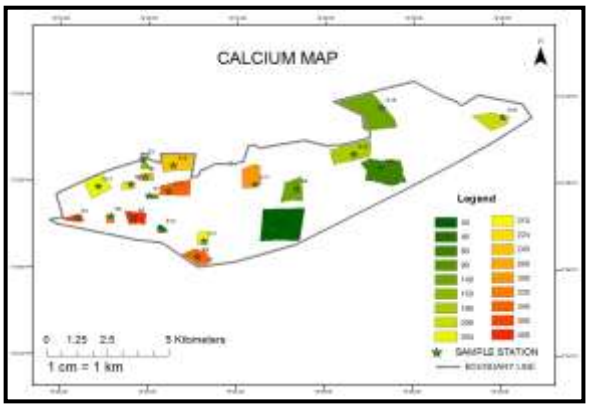


Figure 10. Calcium map

The maximum permissible and allowable concentration of calcium in drinking water in study area ranges between 2-20 mg/l. Calcium is a major constituent of various types of rocks. Calcium is present in water due to incrustation in boilers and caused by hardness. Calcium is an essential constituent of human being. The low content of calcium in drinking water may cause rickets and defective teeth. It is very important for cardiac function, coagulation of blood and nervous system whereas the maximum at S6 400 mg/l and minimum at S10 mg/l.

The chloride concentration in the study area ranges from 2.5-15 mg/l. The permissible limit of chlorides is 250mg/l. High chloride content may harm metallic pipes and structures as well as growing plants. Chlorides takes place in excess the salty taste to water and people are not used to high chloride which are subjected to laxative result (7). The chloride values for all the seasons fluctuate from 481-507mg/l. Maximum at S20 531 mg/l and minimum at S2, S7, S14, S15, S16 and S18 177 mg/l.

The maximum permissible limit of calcium hardness is 30mg/l. The concentration of magnesium in the study area 2-14.5 mg/l. The various process involved chemical softening, reverse osmosis, electro dialysis, or ion exchange reduces the magnesium and associated hardness to acceptable levels. The maximum at S6 218.7 mg/l and minimum at S10 and S20 24.3 mg/l are presented in Table 2.

The concentrations of sodium in the study area ranges between 0.08-1.4 mg/l in all samples person afflicted with certain diseases require low sodium concentration. The maximum at S9 32.19 mg/l and minimum at S10 and S20 0 mg/l are shown in Fig 11.

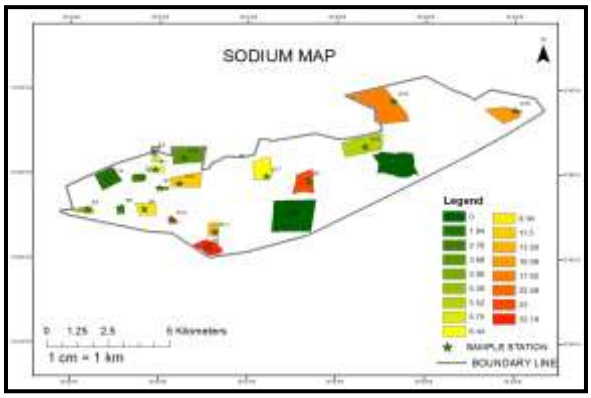


Figure 11. Sodium map

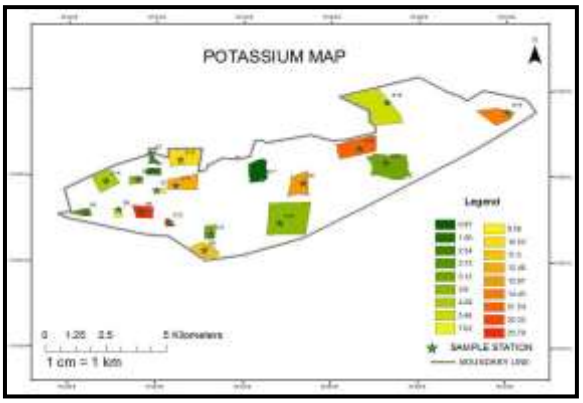


Figure 12. Potassium map

It ranks seventh among the elements in order of abundance yet its concentration in most drinking waters seldom reaches 20mg/l. However, the concentrations of potassium were analysed from 0.01-0.61 mg/l. for the entire sample whereas the maximum at S6 23.79 mg/l and minimum at S1 1.56 mg/l.

The major physiological effects resulting from the ingestion of large quantities of sulphate are catharsis, dehydration, gastrointestinal irritation and corrosion of distribution systems (14). The sulphate concentrations were found to be in the range of 200-450 mg/l. Maximum at S7 450 mg/l and minimum at S3 200 mg/l (Fig. 13).

The levels of phosphate in ground water from all parts of sample stations are found to be in the range of 100-200 mg/l. High concentration of phosphate might be due to use of detergents for washing of clothes and utensil activities by the villagers around most or the dug wells(2). The maximum S3 199.77 mg/l at and minimum at S2, S5, S6, S11 and S17 99.88 mg/l are presented in (Fig. 14).

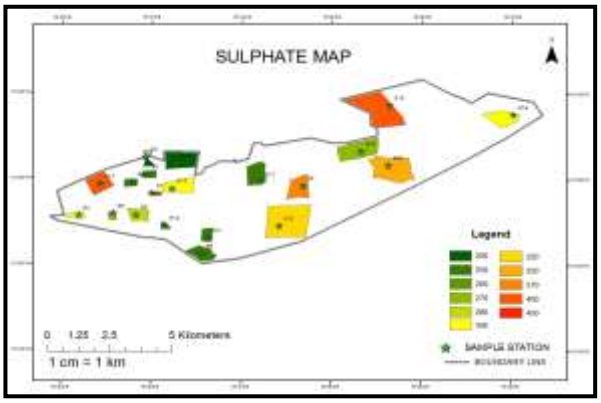


Figure 13. Sulphate map

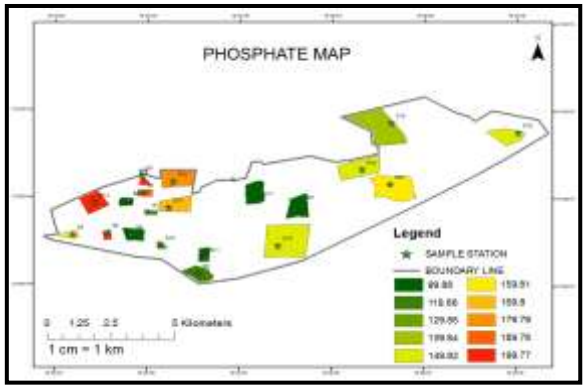


Figure 14. Phosphate map

Concentration of dissolved solids in groundwater decides its applicability for drinking, irrigation or industrial purposes. Concentration of dissolved matter in water is given by the weight of the material on evaporation of water to dryness up to a temperature of 180ºC(5). The values are expressed in mg/l. Major constituents of TDS include Bicarbonates (HCO^{3}-), Sulphates (SO_4^{2-}) and Chlorides (Cl^-) of Calcium,

Magnesium, Sodium and Silica. Groundwater containing more than 1000 mg/l of total dissolved solids is generally referred as brackish water. In the study area, TDS in groundwater ranges from 199 to 123 mg/l. Maximum at S3 199 mg/l and minimum at S4 123 mg/l as shown in Fig 15.

The temperature of the sample is taken when the sample is collected using the standard thermometer. The average temperature of the ground water in Tirupati is around 30ºc. The temperature at the sampling stations S2, S3, S9, S10, S12, S13, S15, S16, S18, and S20 is 29ºc and at S5 and S19 is 31ºc and remaining stations it is 30ºc as shown in Fig 16.

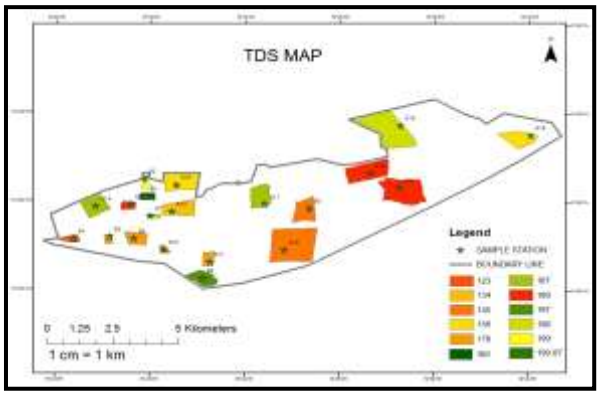


Figure 15. TDS map

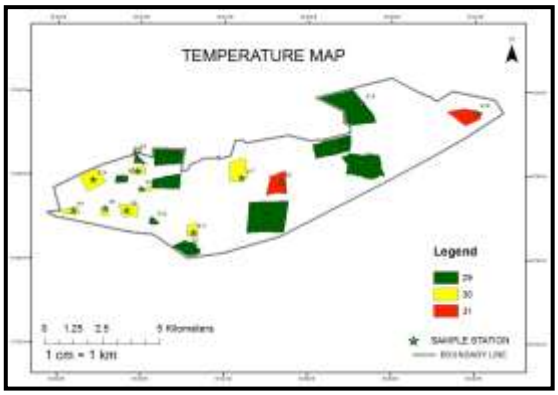


Figure 16. Temperature map

Table 3. Correlation values for Water Quality Parameters

Parameters	pH	TDS	TA	TH	Ca	Mg	Cl	EC	SO4	P	K	Na	NO3	F	Fe
pH	1	-.416	.157	-.054	-.160	-.171	.205	.231	-.225	.042	.455	.235	.382	.275	.323
TDS		1	.402	-.197	-.083	-.253	-.290	-.058	.068	-.055	-.206	-.085	-.063	.041	-.118
TA			1	-.065	-.094	-.232	-.391	-.074	-.061	-.199	.298	.461	.280	.594	.007
TH				1	.145	.072	-.167	-.608	-.273	.305	-.112	-.077	.234	.359	-.087
Ca					1	**.930**	.239	.136	-.372	.016	.052	.061	.078	.278	-.108
Mg						1	.273	.131	-.332	.047	.060	-.124	.044	.218	-.017
Cl							1	**.726**	.093	.014	-.171	-.167	-.035	-.025	.137
EC								1	.150	-.387	.036	.128	.037	.011	.184
SO4									1	-.097	-.049	-.029	.001	-.346	.113
P										1	-.254	-.410	.062	-.095	.086
K											1	.400	-.021	.225	.403
Na												1	.077	.278	-.183
NO3													1	.598	.205
F														1	.145
Fe															1

From the correlation analysis, Calcium has positive and signification correlation with Magnesium and weak correlation with Electrical conductivity, Chloride, Phosphorus, Potassium, Sodium, Nitrate and Fluoride and then negative correlated with Sulphate and Iron. Electrical conductivity has positive and signification

correlation with Chloride, weak correlation with Sulphate, Potassium and Iron and negative correlated with Phosphorus, Sodium, Nitrate and Fluoride. The remaining parameters are weak and negative correlation with some other parameters as presented in the table 3. The regression equation for dependent and independent variables and R^2 values are shown in the table 4.

Table 4. Regression equation for given parameters

Y (dependent)	X (Independent)	correlation	b	a	Regression Equation	R^2
Ca2+	Mg2+	0.930	136.567	1.701	Ca2+=1.701 Mg2+ +136.567	0.865
EC	Cl-	0.726	1110.480	4.784	EC = 4.784 Cl- +1110.480	0.528

Conclusion

The completion of the study area revealed that water is suitable or unfit for domestic purposes. Totally 20 well points are analysed by the physical and chemical parameters and compared with standards. The experimental results that the areas such as S1 to S6, S7, S9, S11, S13, S 14, S16, S15,S16, S17, S18, S19 and S20 has been water quality poor for drinking. The study area observed that the fluoride concentration is high in the area of S6, S1, S2, S3, S5, S9, S12 and S13. The remaining areas are within the permissible limits. The sampling points such as S20, S19, S17, S13, S11, S10, S9, S8, S6, S5, S4 and S1 were affected by the high chloride concentration whereas the other areas within the permissible limits. Alkalinity is present highly in the areas such as S3, S5, S6 and S9. Total hardness was found to be high in S1, S2, S9, S16, S13 and S14, the other areas are within permissible limits. Total dissolved salts were within the permissible limit for all areas pH was within the permissible limit in all the areas, highly pH values caused the area like S12 which is 8.12. Iron also within the permissible limit in all the areas. Potassium was highly in the areas like S5, S6, S12, S13, S18 and S19, remaining areas was within the permissible limit. Sodium is within in the permissible limit for all areas. Calcium is high in all areas except two areas only within the limits like S10and S12. Nitrate is highly in the areas like S2 and S4, remaining areas are within the permissible limit. Electrical conductivity is highly in the areas of S4, S5, S6, S8, S9, S10, S11, S13, S15, S17, S19 and S20 are greater than the limits. Sulphur is high except in S3 and S1. Magnesium was shown to be high except in S20, S12 and S10. S1, S2, The final output has been given in the thematic representation of ground water quality and therefore, the sampling points such as S3,S4, S5,S6, S8,S9,S11, S13, S14, S15, S16, S17, S18, S19, S20 are unfit for drinking purposes. The result of the correlation and regression analysis that calcium has strong positive correlated with magnesium and electrical conductivity has strong positive correlated with chloride. The others parameters are weak correlated and negative correlation with some others parameters. The final result of the study area suggests that well location point needs some degree of water treatment before consumption. The study helps us to understand the quality of the water as well as to develop suitable management practices to protect the ground water resources.

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