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Groundwater Geochmistry Study Using GIS in and Around Vallanadu Hills, Tamilnadu, India

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Abstract

Groundwater is an essential part of life. The potential of groundwater is depends upon the subsurface rock and soil conditions. The following study was mainly focused the quality of groundwater in hard rock areas in and around Vallanadu hill using GIS application. The 36 water samples were collected in the study area. The water sample quality parameters such as colour, taste, and odor, turbidity, Ec, P^H, Alkaline, Dissolved constituents of silica, iron, Ca, Mg, K, corbonate, bicarbonate, Cl, No3, TDS was used for the study. The corrosity and rich out technaie is used for further study. The quality of groundwater study is used irrigation purpose determined by the salinity and sodium hazards analysis. The Styfzand's classification is used for brackish and saltwater in the study area. The WHO standards of parameters are a dominant play role for the groundwater quality study.

Key words: Groundwater, GIS, geochemistry, major element, HYCH OUT, Vallanadu.

Introduction

Groundwater is an important source of water supply through out the world. The quantity and the suitability of groundwater for human consumption and for irrigation are determined by its physical, chemical and bacteriological properties. Rain water, which is pure in nature, which falls on the ground, dissolves the soluble minerals, and the quality of water deteriorates depending upon the nature of the formation and the time duration[1-5]. The utility of water for different purpose depends on various physical and chemical parameters. Water samples have been collected and tested in 36 areas located around Vallanadu area used in this study. The available groundwater extensively tapped through open wells and bore wells for drinking and agricultural purpose.

The main objectives of this study are to classify the available ground water of areas around Vallanadu using its physical and chemical parameters and to identify the mechanism which controls the groundwater chemistry. Vallanadu is a major panchayat in the Tuticorin District of Tamilnadu. The study area is comprised of the toposheet no. 58H/13 and 58H/14 of 1: 50,000 scales published by the Survey of India in the year 1969. The size of the area is approximately 400 square Km. the precise location of the study area is between Latitude 8039' – 8051' and Longitude 77045' and 77055' (Figure.1). Vallanadu and the surrounding area are well connected with roads and majority of the roads are metalled and only few are unmetalled. Vallanadu lies about 30Km west of Tuticorin, which has both rail and Airbase connections. The district receives the rain under the influence of both southwest and northeast monsoons. The rainfall was gradually increases towards south, west and north and attains a maximum around Kayattar (722.5 mm) and Kovilpatti (734.8 mm) in the northwestern part. The district enjoys a hot tropical climate. The high relative humidity prevails through out the year between 60 and 75%. The annual mean minimum and maximum temperature are 23°C and 40°C respectively.

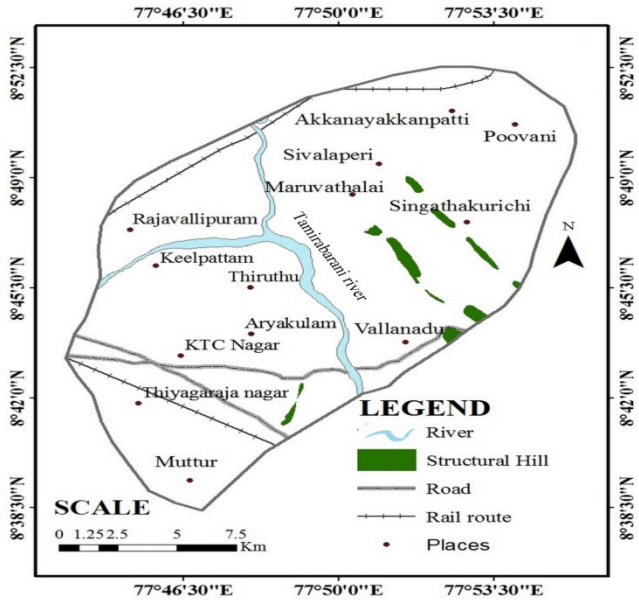

Figure – 1
Location map of the study area

Geology of the study area: Rocks of the Archaean age are extensively exposed in the various parts of the state. The sediments ranging in age from the Gondwanas to recent are

mostly confined to the eastern coast. The crystalline rocks exposed in this part of the peninsular shield include the rocks of the Charnockite group, the Khondalite group and gneisses and schists, traversed by ultramafic, basic, granite and syenite intrusives. About 90% of the district is made up of crystalline rocks of Proterozoic group comprising of Charnockites, Garnetiferous biotite gneiss, Quartzite etc., Karumalai and Vallanadu hillocks are structural features. Few inselbergs are seen in the plain. Pediments, rocky pediments, buried pediments and valley filles are the other landforms in the district. The Vallanadu area is a high grade metamorphic terrain of almandine amphibolite to granulite facies. The area is essentially comprised of different lithotypes i.e., quartzites, calc-silicate rocks, Khondalites, Composite gneisses, Cordierite gneiesses, charnockites, Grey granites and pink granites and veins of pyroxene granulites and amphibolites. Khondalites of vallanadu area of Kerala Khondalite Belt (KKB) are represented by pelitic, Semipelitic, psammitic and calcareous members. The distribution of various lithotypes of the area is shown in figure 2.

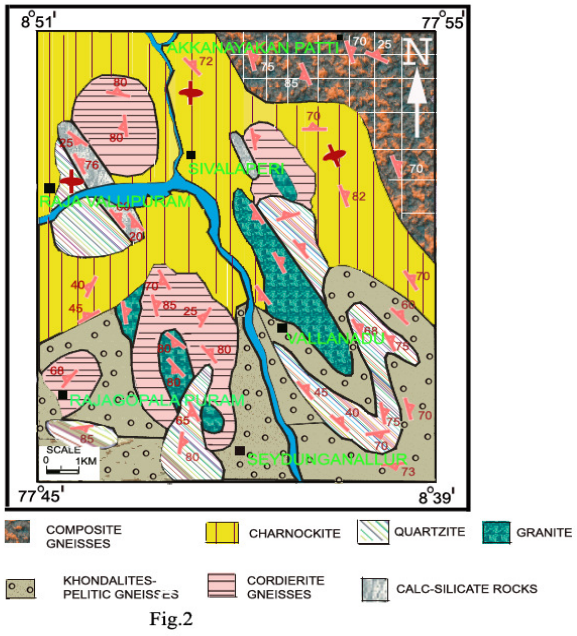

Fig.2

Figure – 2
Geological Map of the study aera

Material and Methods

Groundwater constitutes one portion of the hydrologic cycle as even it is to be regarded as the renewable resources[6-8]. Ground water occurrence in unconsolidated rocks strikingly different from that of in consolidated sediments. The lithology is one of the parameters that control the ground water quality and other factors include evaporation at the surface prior to infiltration, evapotranspiration and nature of aquifer and residence time. Behaviour of ground water in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Broadly two groups of rock formations have been identified, depending on characteristically different hydraulics of ground water viz. porous formations and fissured formations.

Groundwater potential and Scenario of the study area: The geology of the area is mainly composed of hard rocks and the fractured and well jointed nature of the rocks provide good amount of groundwater. Comparatively the gneissic rocks are with high groundwater potential owing to the weathering and fracturing for a considerable depth. Charnockites are low in water potential but well jointed, sheared Charnockites are good for groundwater potential. Quartzites are mostly granular, well jointed, cracked and fissured and these properties are reasons behind Groundwater potential of quartzites[9,10]. The open wells of the area vary in depth from 10 to 40 meters. The district is underlain by both porous and fissured formations. The important aquifer systems in the district are constituted by i) unconsolidated and semi-consolidated formations and ii) weathered and fractured crystalline rocks. The porous formations in the district include sandstones and clays of recent to sub-recent and tertiary age (quaternary). The recent formations comprising mainly sands, clays and gravels are confined to major drainage courses in the district. The maximum thickness of alluvium is 45.0m bgl; whereas the average thickness is about 25.0m. Ground water occurs under water table and confined conditions in these formations and is being developed by means of dug wells and filter points[11,12]. The productive zones are encountered in the depth range of 29.5 to 62m bgl. Alluvium, which forms a good aquifer system along the Tamirabarani, Vaippar and Gundar river bed which is one of the major sources of water supply to the villages. The water-bearing properties of crystalline formations which lack primary porosity depend on the extent of development of secondary intergranular porosity. The occurrence and movement of ground water in these rocks are under unconfined conditions in the joints and fissures and dependent on the nature and extent of pores and interconnection of fractures zones. The yield characteristics of wells vary considerably depending on the topographic set-up, lithology and nature of weathering.

Hydrogeochemistry: Hydrogeochemistry of groundwater is a dynamic process, which undergoes a constant change with reference to time and space. The geochemical quality of groundwater is also related to the nature of host rock as well as the overlying rock types. Geochemical character of groundwater is an essential component of scientific management of existing groundwater resources. In the present day an attempt has been made to identify the suitability of existing groundwater with reference to drinking, domestic, industrial and irrigational needs. The quality of groundwater is an important as its quantity. All groundwater contains dissolved solids in solution that are derived from the location due to movement of the water. In order to carry out the objectives water samples are collected from different locations are

analysed to evaluate groundwater quality. The collection and testing of water samples is a very important operation in any water quality study. To analyse the groundwater quality, the groundwater should be collected in one liter capacity polythene bottles after rinsing the bottle with the water, which is to be sampled and the sample collected and sealed tightly. Sample should be collected from a well, only after it has been pumped for sometimes, otherwise non-representative samples of stagnant or contaminated water may be obtained. Water samples have been collected from the existing bore wells and open well sources in 36 locations of the study area. Water samples have been analysed for major cations such as Ca, Mg, Na, and K and anions – CO_3, HCO_3, S_{O4}, Cl and TDS, pH etc. The statistical report of the analysed results is presented in table no. 2.

Results and Discussion

Numerous computer techniques and programs have been developed for water analysis and for performing geochemical calculations pertaining to groundwater figure 3,4,5,6,7,8,9,10. Balasubrananian and Sastri have developed a computer program for hydrochemical analysis of groundwater in FORTRAN. Later, it was modified in basic language. The analysed results have been processed using HYCH program, which classifies groundwater hydro geochemically and quality assessment can be done at a faster rate without resorting to tedious manual graphical procedure. The analysed results which have classified the study of groundwater and all the results are given in table 3.

Total Dissolved Solids: Total dissolved solids of the ground water[12,13] existing intake following regions above 1000mg/l, namely Vallanadu south (Loc. no.1), Vallanadu north (Loc.no.2), Ariyakulam (Loc.no.3), Thiyagarayanagar (Loc.no.5), Kilpattam (Loc.no.10), Papayapuram (Loc.no.12), Melapalamadai (Loc.no.13), Sivalaperi (Loc.no.15), Maruvathalai (Loc.no.17&18), Savalaperi (Loc.no.19&20), Puliyampatti (Loc.no.21&22), Lakshmipuram (Loc.no.24&25), Akanayakkanpatti (Loc.no.28) and Kilpuvani (Loc.no.32), while in other areas TDS is below 1000 mg/l, such as KTC nagar (Loc.no.4), Rajagopalapuram (Loc.no.6), Muthur (Loc.no.7&), Thiruthu (Loc.no.9), Melpattam (Loc.no.11), Rajavallipuram (Loc.no.14), Sivalaperi (Loc.no.16), Puliyampatti (Loc.no.23), Akanayakkanpatti (Loc.no.26&27), Melpuvani (Loc.no.29,30&31), Kilpuvani (Loc.no.33), Singathakurichi (Loc.no.35) and Kasilingapuram (Loc.no.36), all above water indicate their suitable nature for drinking and domestic purposes.

Groundwater Hardness: If the hardness is too low the water can be quite corrosive leaching copper and lead out of plumbing pipes. With very low hardness there would also be low levels of beneficial ions in the water, especially calcium and magnesium[14-16]. If hardness is too high it can have an unpleasant taste, can dry out skin and cause scaling on fixtures and throughout the water distribution system. This scaling is undesirable because it begins to decrease the efficiency of plumbing systems, which results in greater power consumption and increased costs. With reference to BIS, Indian Standards (IS 10500:1991) desirable limit up to 300 mg/l, permissible limit up to 600 mg/l. (table 1).

Table-1
Groundwater hardness classification of the study area

Hardness (mg/l)	Water Class	Sample location nos
0 – 75	Soft	6,7, 11,27, 30, 34, 35, 36
75 – 150	Moderately hard	8, 14, 16, 31, 33
150 – 300	Hard	9, 23, 29
>300	Very hard	1, 2, 3, 4, 5, 10, 12, 13, 15, 17, 18, 19, 20, 21, 22, 24, 25, 26, 28, 32

Table–2
Chemical analysis of groundwater statistical report- Number of samples 36

Parameter	Unit	Min	Max	Average	St. Dev.	Dev. Coef	Q25	Q50	Q75
Ca	mg/l	43.349	498.362	199.5891	118.9854	59.61521	99.206	178.207	257.895
Mg	mg/l	7.865	356.794	80.67145	66.76775	82.76503	31.99	66.15	106.2
Na	mg/l	0.0	689.387	260.193	216.443	83.18555	64.17	184.762	426.205
K	mg/l	0.0	150.968	36.3724	43.92311	120.7603	6.18	14.369	46.157
Cl	mg/l	28.0	1205.0	313.9722	271.8278	86.57703	85.0	269.0	411.0
HCO3	mg/l	98.0	781.0	357.9445	140.9474	39.37689	268.0	342.0	415.0
CO3	mg/l	0.0	36.0	7.66667	10.79153	140.7591	0.0	0.0	12.0
NO3	mg/l	0.0	11.03	3.1725	2.84132	89.56078	1.17	2.92	4.42
SO4	mg/l	10.5	925.6	248.075	260.7145	105.095	46.3	138.8	373.0
TDS	mg/l	150	4400	1385.556	1060.044	76.50681	580.0	970.0	1650.0
pH		6.7	8.7	7.46348	7.44841	99.79807	0.0	0.0	0.0

Table-3
Results of HYCH out

Loc. No.	Location Name	TDS	CR	Total Hardness	USSL CLSSN.
1	Vallanadu south	1200	2.7887	633.6191	C3S1
2	Vallanadu north	1850	2.2733	318.2712	C4S2
3	Ariyakulam	1040	1.7948	314.5187	C3S1
4	KTC nagar	890	2.2886	424.7125	C3S1
5	Thiyagarayanagar	1080	1.6042	418.6169	C3S1
6	Rajagopalapuram	460	0.4411	39.20665	C3S1
7	Muthur	230	0.2290	31.09589	C2S1
8	Muthur	580	0.5066	122.5094	C3S1
9	Thiruthu	680	1.0182	218.8022	C3S1
10	Kilpattam	4400	2.9770	466.3212	C5S3
11	Melpattam	440	0.8601	32.99741	C2S1
12	Papayapuram	1600	3.1429	682.0701	C4S1
13	Melapalamadai	1070	1.2858	170.933	C3S1
14	Rajavallipuram	390	0.3517	138.1703	C2S1
15	Sivalaperi	3800	2.3786	1343.439	C5S2
16	Sivalaperi	150	0.5193	12.49368	C2S1
17	Maruvathalai	1580	2.6664	804.6872	C4S1
18	Maruvathalai	3100	2.8718	760.7316	C5S2
19	Savalaperi	2900	5.3700	1032.034	C5S2
20	Savalaperi	2900	3.1287	784.1268	C5S2
21	Puliyampatti	1970	2.8704	554.6245	C4S2
22	Puliyampatti	1900	1.3383	421.9371	C4S2
23	Puliyampatti	950	1.6765	178.2572	C3S1
24	Lakshmipuram	1470	4.5356	350.2631	C4S2
25	Lakshmipuram	3400	4.2632	957.0551	C5S2
26	Akanayakkanpatti	970	0.7762	23.0813	C3S1
27	Akanayakkanpatti	950	0.7849	51.52912	C3S1
28	Akanayakkanpatti	1630	4.1300	925.7409	C4S1
29	Melpuvani	780	1.3025	179.0112	C3S1
30	Melpuvani	910	1.2717	34.26414	C3S2
31	Melpuvani	740	0.9803	93.09199	C3S1
32	Kilpuvani	1650	2.7091	587.0051	C4S1
33	Kilpuvani	820	0.9248	67.7968	C3S1
34	Kilpuvani	550	0.4508	38.8835	C3S1
35	Singathakurichi	330	0.4506	20.52805	C2S1
36	Kasilingapuram	520	0.4544	11.49182	C3S1

Stuyfzand's Classification of Groundwater: The following locations of the study areas fall under fresh-brackish water. They are, Rajagopalapuram (Loc.no.6), Muthur (Loc.no.7&8), Melpattam (Loc.no.11), Rajavallipuram (Loc.no.14), Sivalaperi (Loc.no.16), Akanayakkanpatti (Loc.no.26&27), Melpuvani (Loc.no.31), Kilpuvani (Loc.no.33&34) Singathakurichi (Loc.no.35), Kasilingapuram (Loc.no.36). The brackish water samples are Thiruthu (Loc.no.9), Savalaperi (Loc.no.19), Puliyampatti (Loc.no.23), Lakshmipuram (Loc.no.24), Melpuvani (Loc.no.29&30). Vallanadu south (Loc.no.1), Vallanadu north (Loc.no.2), Ariyakulam (Loc.no.3), KTC nagar (Loc.no.4), Thiyagarayanagar (Loc.no.5), Papayapuram (Loc.no.12), Melapalamadai (Loc.no.13), Maruvathalai (Loc.no.17&18), Savalaperi (Loc.no.20), Puliyampatti (Loc.no.21&22), Lakshmipuram (Loc.no.25), Akanayakkanpatti (Loc.no.28), Kilpuvani (Loc.no.32) are undr brackish –salt water. Kilpattam (Loc.no.10), Sivalaperi (Loc.no.15&16) are the salt water (figure 7).

Salinity and Sodium Hazard: For diagnosis and classification, the total concentration of soluble salts (salinity hazard) in the irrigation water could be expressed in terms of specific conductance[17,18]. In terms of salinity hazards as low (C1), medium (C2), high (C3) and very high (C4) and also sodium hazards as low (S1), medium (S2), high (S3) and very high (S4). Most of the samples occur within C3-S1 (good water) category and it is suitable for irrigation purposes. USSL groundwater classification of the study area is given in the table no.8 and (figure 8 and table 4).

Table-4
Groundwater classification based on USSL

Category	Sample location no.
C2S1	7, 11, 14, 16, 35
C3S1	1, 3, 4, 5, 6, 8, 9, 13, 29, 30, 31, 33, 34, 36
C4S1	12, 28
C3S2	23, 26, 27
C4S2	2, 17, 22, 24, 32
C4S3	21

Corrosivity Ratio: If the CR is less than 1, then the water is non-corrosive and if the CR is greater than 1, then the water is corrosive[18,19] Rengarajan et al, used this methodology to identify the corrosive groundwater in Ramanathapuram district and Kodavanar basin respectively. The following locations of groundwater are fall under non-corrosive type of water, which can be easily transported through metal pipes. They are, Rajagopalapuram (Loc.no.6), Muthur (Loc.no.7&8), Melpattam (Loc.no.11), Rajavallipuram (Loc.no.14), Sivalaperi (Loc.no.16), Akanayakkanpatti (Loc.no.26&27), Melpuvani (Loc.no.31), Kilpuvani (Loc.no.33&34), Singathakurichi (Loc.no.35) and Kasilingapuram (Loc.no.36). The other locations of the study area are found to be corrosive water, it can only be transported through PVC pipes (figure 5).

Conclusion

The thematic map for TDS, TH, pH, Corrosivity ratio, Stuyfzand's, Wilcox are prepared and shown. The following conclusions are derived after the evaluation of hydrogeochemical investigation of groundwater in and around Vallanadu area. The TDS value is below the desirable limit occur in some pockets of area and it can be used for drinking and domestic purposes, most of the areas fall under above desirable limits. With reference to total hardness of the groundwater, hard and very hard water exist in this study area. Based on corrosivity ratio, the area is mostly occupying corrosive water, which can be transported through PVC pipes. With reference to salinity and sodium hazard most of the groundwater is suitable for irrigation. Based on Stuyfzand's classification most of the area Brackish and brackish salt water occur. Based on BIS and WHO[20,5] standards of TDS, TH, CR, USSL, EC and NO3 the study areas Rajagopalapuram (Loc.no.6), Muthur (Loc.no.7), Melpattam (Loc.no.11), Rajavallipuram (Loc.no.14), Sivalaperi (Loc.no.16), Singathakurichi (Loc.no.35) and Kasilingapuram (Loc.no.36) are good water for drinking, domestic and irrigation purposes. As per Gibbs value calculated by HYCH Out, most of the samples are rock interaction, indicating a longer residence time.

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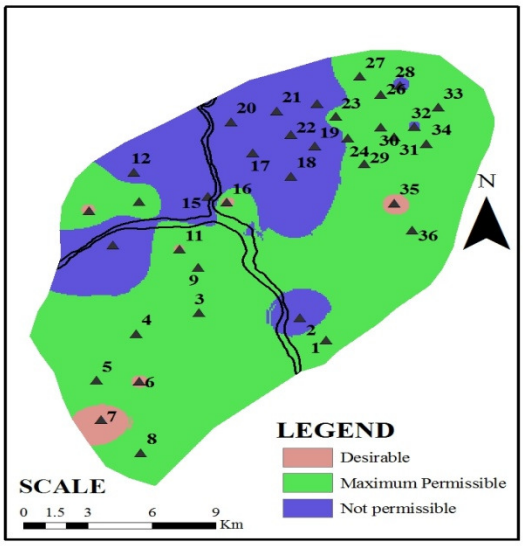

Figure - 3
Total dissolved solids of groundwater

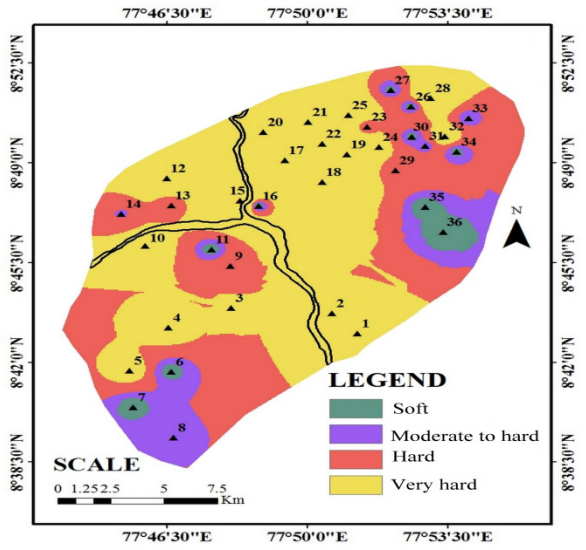

Figure - 4
Total hardness of groundwater

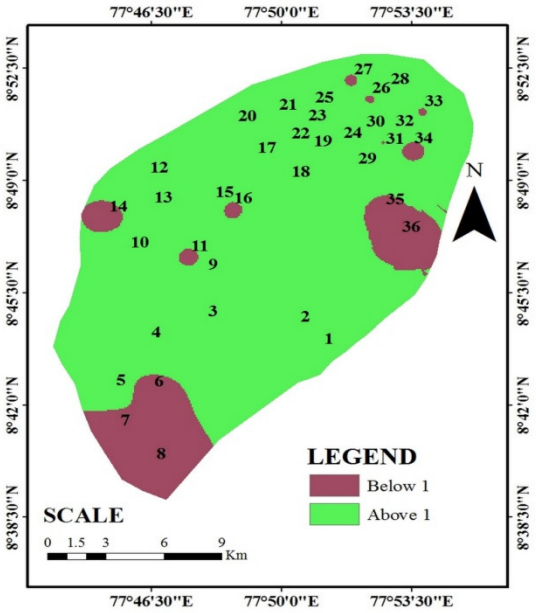

Figure - 5
Corrisivity ratio of groundwater

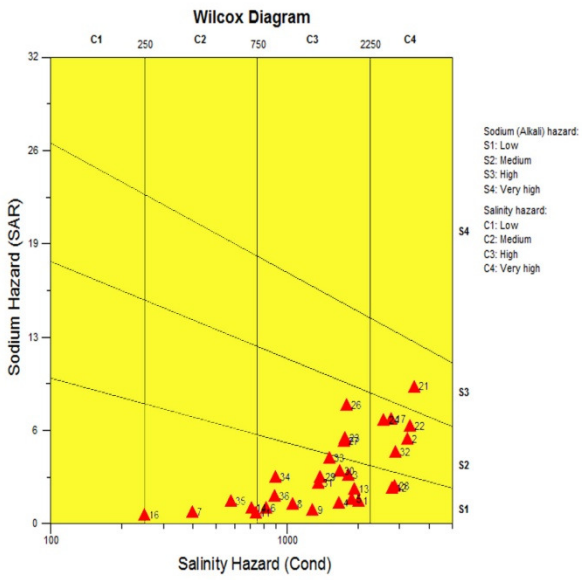

Figure - 6
Classification of irrigation waters

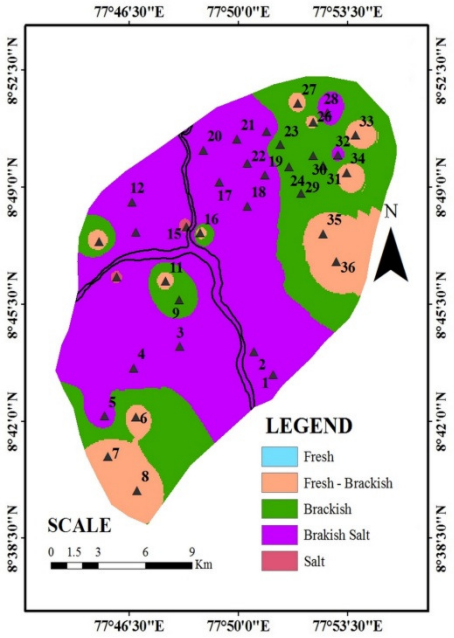

Figure - 7
Stuyfzand's classification of groundwater

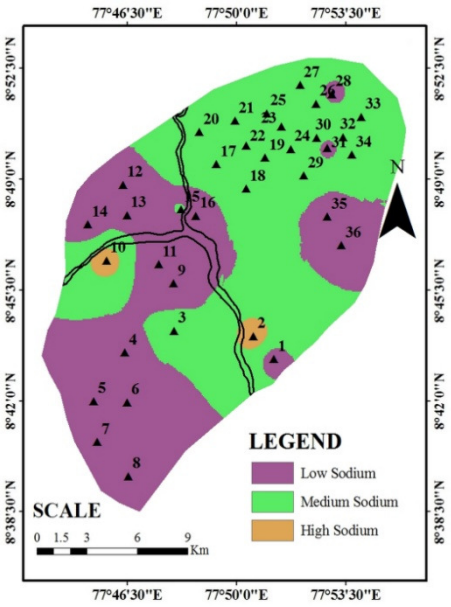

Figure - 8
Sodium Absorption Ratio(SAR)

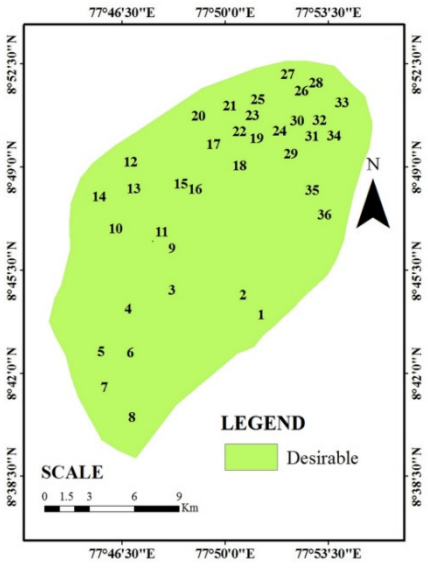

Figure - 9
pH of Groundwater

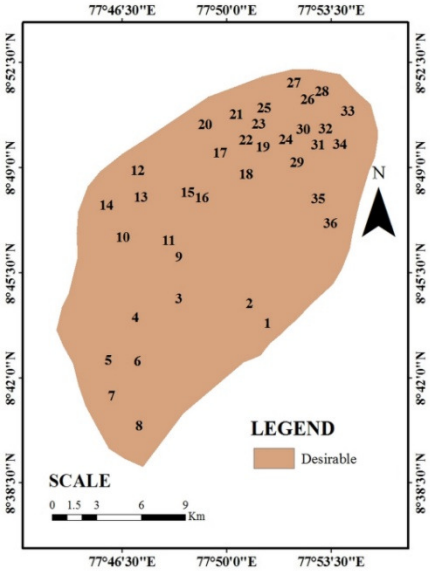

Figure - 10
NO_3 of the study area groundwater

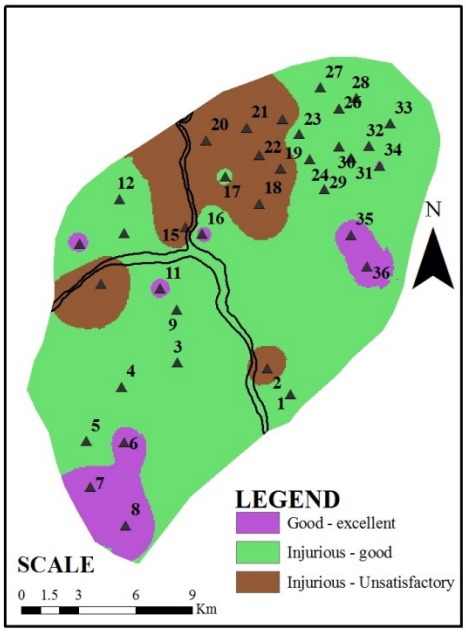

Figure -11
Electrical conductance of groundwater