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GIS Based Evaluation on Geochemical Studies of Groundwater in and around Pandalgudi region of Viruthunagar District, Tamilnadu, India

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Abstract

The GIS based evaluations of geochemical studies of groundwater were carried out in the metamorphic terrain area of Pandalgudi region of Viruthunagar District, Tamilnadu, India. The stratigraphic succession of the study area is given. In order to cover the entire study area, 20 groundwater samples, from bore wells as well as from open wells for the both post-monsoon and pre-monsoon periods were collected. These samples were analyzed for various physico-chemical parameters such as pH, EC, TDS, Cations Na^+, Ca^{2+}, Mg^{2+}, K^+, Anions CO_3^-, HCO_3^-, NO_3^-, SO_4^{2-} and Cl^-. The results of the analysis were interpreted for different water qualities by Correlation, Gibbs mechanism and Piper method. The correlation study parameters of all water samples show positive correlations. The gibbs mechanism illustrates the evaporation dominance and rock dominance character which are controlling water chemistry. According to piper analysis, the geochemistry of ground water samples of the study area shows CaCl and NaCl rich facies. The Arc GIS 10.1 software was used for the generation of various thematic maps. An interpolation technique such as Inverse Distance Weighting (IDW) method was used to obtain the spatial distribution of groundwater quality parameters. Further, the water qualities are compared with BIS and WHO standards of drinking water and other standards such as livestock use and irrigation purposes.

Key words: GIS, Interpolation, Groundwater quality, IDW, Hydrogeochemistry, BIS, WHO.

Introduction

Ground water is more precious and widely distributed resources of the earth. The necessity in groundwater development and utilization, particularly in developing countries for agriculture, industries and domestic purposes are being increased. At present, one-fifth of all the water used in the world is obtained from groundwater resources. Due to overgrowth of population, economical development, rapid urbanization and environmental concern, water stress has been emerged as a real threat for human lives. Many of our country have already been under severe water stress; Numerous researchers have concentrated their research on hydrogeochemical studies of groundwater, not only in India but also in various part of the world[1-4]. The quality of groundwater is highly affected spatially and temporally by various factors such as lithology, chemical composition of the aquifer, rock-water interaction and its circulation, microbial action, pollution and sea water ingress[5]. These complex processes are making different hydrogeochemical conditions occurring in the wide range of rock types from the ages of Archean crystalline rock to Recent Alluvium. The hydrogeochemistry of groundwater can be varied in large way especially in India due to lithological variations[6]. There are many villages located near Pandalgudi region of Viruthunagar district, which are utilizing groundwater long time for domestic and irrigation purposes. But no much research work has been concentrated in the Pandalgudi region pertaining to geochemistry of groundwater. Keeping with this aim in mind, for the welfare of the people of the study area, an attempt has been made in this paper, to evaluate the geochemical studies of groundwater, utilizing GIS based techniques. The study area is situated above the Vaippar basin and extends over a distance of 90sq.km located around Pandalgudi region of Viruthunagar district, Tamilnadu, India. Pandalgudi is located at the distance of 15 km from Aruppukottai town, 85 km from Tuticorin town and 40 km from Madurai town. The area is generally well connected with good road networks. It falls in the survey of india toposheet no 58/K3, prepared in the scale of 1:63 360. It encompasses within the Latitude 9°30’00’’N - 9°15’0’’N and Longitude of 78°0’00’’E - 78°15’0’’E (Figure-1).

Geomorphology and Geology: The area under investigation lies at a distance of approximately 60km away from the coast line of Gulf of Mannar and its topography rises towards the height of about maximum 82 m from the M.S.L. It is generally flat and plain with top covered soil outcrops. The overall drainage density is medium and drainage texture is also dense which shows the general water resource potential of this area. Most of the drainage patterns are dendritic type and in some places, especially in the north-eastern side, shows radial pattern. The ephemeral river vaippar is running in the south which is located away from the study area. The drainage slope direction is generally towards south and southeast direction. The study area generally experiences the semiarid to arid climate with maximum temperature of 38°C to minimum 24°C, whereas the average relative humidity of the study area is 63%. The average rainfall of the study area is 700mm, which receives rainfall under the influence of both southwest and northeast monsoons. Rain fed tank irrigation is generally practiced in most part the study area. The study area is mainly a hard rock terrain. Proterozoic formation is basement rocks which consist of quartzite, metasediments of crystalline limestone, calc granulite, hornblende-biotite gneiss, charnockite or pyroxene granulite and the later intrusion of pink granite, white granite and pegmatitic veins. The weathered, fissured cracks, shear zones and joints, in the basement rock act as a good groundwater potential zone in the study area. Proterozoic formation is overlain by a thick calcrete profile with a thickness of the 1.20m, which is believed to be the age of Holocene to Pleistocene deposits. The calcrete deposit is generally overlain by black soil and detached batches of red sandy loamy soil. The general stratigraphic succession of the study area is shown in Table-1.

Materials and Methods

In order to cover the entire area, ground water sampling from both open wells and dug wells were collected from 20 locations around Pandalgudi for both pre monsoon and post monsoon periods. The Garmin Handheld 72 GPS was used to locate the exact coordinates of the sample collection for continuous monitoring purposes. Methods of collection and analysis of water samples were adopted by the standard procedures[7]. Samples were collected in double Stoppard one liter capacity polyethylene cans. Prior to the collection, cans were thoroughly washed with diluted HNO_3 acid and then rinsed with distilled water in the laboratory before filling cans with water samples. In case of bore wells, sampling was done, after pumping the water from bore wells for about ten minutes to ensure representative sampling. Moreover, well inventory details such as location, geology, well shape and dimensions and depth of water table were also noted while collecting the samples. Physical parameters pH, TDS and EC, Cations Ca^{2+}, Mg^{2+}, Na^+, K^+ and Anions HCO_3^-, SO_4^{2-}, Cl^-, NO_3^- and F^- of the water samples were analyzed. Calcium and Magnesium were determined by titration method using standard EDTA. Sodium (Na^+) and Potassium (K^+) were determined by flame photometry (ELCO CL361). Sulphate content was analyzed through spectrophotometer. Chloride by standard $AgNO_3$ titration method and Bicarbonate concentration were determined by acid titration of 0.02N H_2SO_4. Nitrate is determined by Brucine method using spectrophotometer. Fluoride is determined by spectrophotometrically using Eriochrome Cyanine – R method. The analytical data of 12 major parameters of 20 samples of pre monsoon and post monsoon are given in Table-2. The estimated eight parameters of water quality studies such as Total Hardness (TH), Non Carbonate Hardness (NCH), Sodium Percentage (Na %), Electrical Conductivity (EC), Sodium Absorption Ratio (SAR), Permeability Index (PI) and Total Dissolved Solids (TDS), are compared with the experimental results of 12 parameters[8]. The parameters of the experimental results of the study area are given in the form GIS based spatial contour maps. The Inverse Distance Weighted (IDW) interpolation technique has been followed to know the spatial extent of parameters. In IDW interpolation, the values of parameter at different sample locations have been categorized as drinking water standard in 3 classes, i.e. desirable, permissible and non potable (Table-2)[9,10]. A computer software program Aquachem 4.0 was used for calculation and graphical representation of Gibbs and USDA diagram. Multiple Correlations of parameters were determined through the geo software 'PAST'.

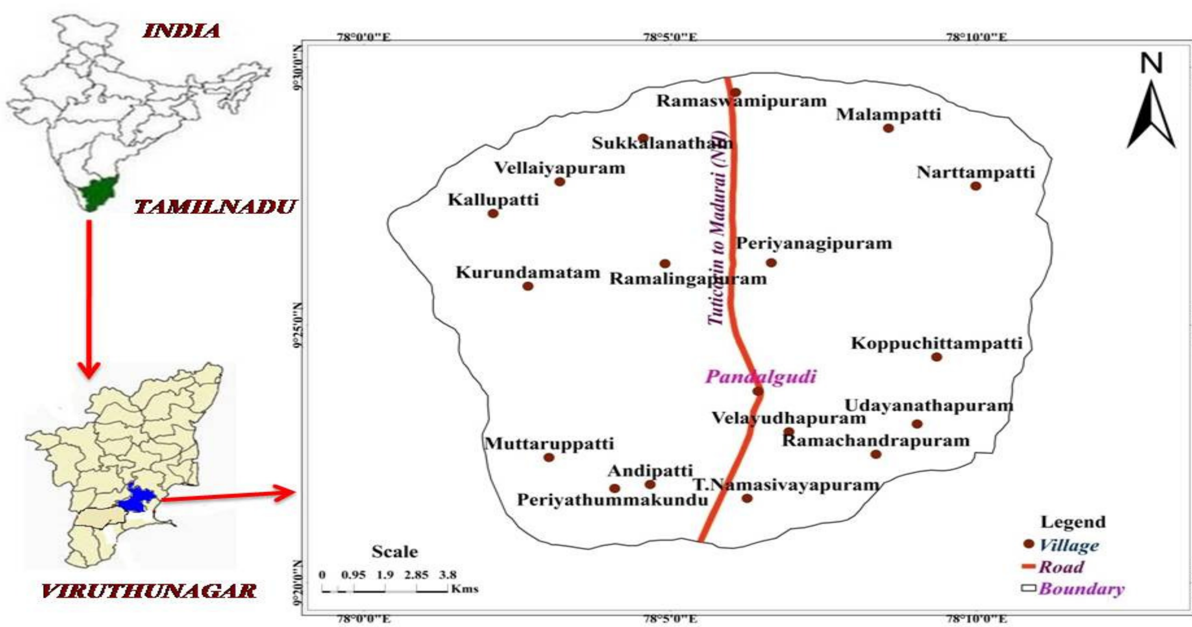

Figure-1
Location map of the study area

Table-1
Stratigraphical succession in and around Pandalgudi area

Age		**Stratigraphy**
Recent (1500 year)		Black cotton soil, Red soil, Sandy loamy soil and Calcrete, as Cap rocks
Proterozoic	520 Ma	Pink granites, White granites and Pegmatites
	550 Ma	Charnockite (With bands of Pyroxene granulites and intrusive of Pink granite veins)
	>2000Ma	Hornblande Biotite gneisses with enclaves of calc-silicate rocks, veins of crystalline limestone band.

Table-2
Water quality parameters of all values in mg/L except EC in µS/Cm

Parameters	**Pre Monsoon**			**Post Monsoon**			**Drinking Water Standards**	
	Min	**Max**	**Avge**	**Min**	**Max**	**Avge**	**WHO 2011 mg/l**	**BIS 2012 mg/l**
pH	7	8.1	7.55	8	8.3	8.15	6.5-8.5	6.5-8.5
EC	586	14865	7725.5	444	12551	6497.5	1,400	-
TDS	394	10771	5582.5	384	8632	4508	500	500-2,000
Ca	13	1192	602.5	8	940	474	75	75-200
Mg	4	477	240.5	4	457	230.5	50	30-100
Na	32	930	481	22	830	426	200	200-400
K	5	130	67.5	3	120	61.5	-	-
HCO_3	98	830	464	98	45134	22616	300	200-600
Cl	43	5247	2645	28	4013	2020.5	500	250
SO_4	51	1183	617	34	1173	603.5	400	200-400

Results and Discussion

Distribution: The average values of the analytical data of thirteen major parameters of twenty water samples for both premonsoon and postmonsoon seasons are given in Table-2. The spatial distribution maps prepared through Arc GIS, software 10.1 of each parameter are given Figure-2a-k.

GIS Based Evaluation: The pH value of the groundwater samples less than 7 and above 7 are measured as acidic and alkalic nature respectively. The value of 7 is treated as neutral. The GIS based spatial distribution map of pH of the area illustrate the places of > 8 ranges and the places within the ranges of from 7-8 (Figure-2a). In general, the sample of the area is slightly alkalic in nature of pH. However, all the samples are suitable for drinking purpose as recommended by WHO[10]. Electrical Conductivity is a parameter related to TDS. These two parameters make effects on the corrosivity of water samples and their effect on the solubility of $CaCO_3$[11]. The importance of electrical conductivity is an indirect measure of salinity[11]. Water quality classification based on electrical conductivity, is classified as 0 – 333 µS/cm – excellent; 333 – 500 µS/cm – good; 500 – 1, 100 µS/cm – permissible; 1, 100 µS/cm – brackish; 1, 500 – 10, 000 µS/cm saline. The average spatial distribution maps of EC of the study area for two seasons are shown in the Figure-2b. This map illustrates Pandalgudi, Ramlingapuram, Ramaswamipuram, Periyanayagipuram and Andipatti village samples are showing high EC content (> 4000). Total Dissolved Solids (TDS) means the total concentration of all constituents dissolved in water. Then new classification of drinking water and irrigation water standard based on TDS was proposed as 0 – 500 mg/L; desirable for drinking; 500 – 1000 mg/L; permissible for drinking; upto 3000 mg/L; – useful for irrigation; Above 3000 mg/L; – unfit for drinking[12,13]. The average spatial map of TDS of the study area for two seasons is shown in the Figure-2c. Based on above classification for two seasons, about 12.5% of the sample of the area falls in desirable category; 32.5% of the sample in permissible category; 42.5% in useful for irrigation and 12.5% are in unfit categories. The Ramalingapuram and other places Periyanakipuram, Ramaswamypuram and Andipatti village samples are showing high concentration of TDS. The places Sukalanattam and Vellayapuram water are showing desirable for drinking. The TDS concentration of the following villages such as Malampatti, Koppuchittampatti, Udayanathapuram, Ramachandrapuram, T.Namasivayapuram, Periyathumagundu, Mutharupatti are showing the level of permissible for drinking. The TDS concentration of the villages viz., Malaipatti, Kuthipparai, Kallupatti, Kurunthamadam, Ramaswamypuram, Narthampatti, Periyanayakipuram, Vellayuthapuram, Pandalgudi are showing the level of useful for irrigation. The TDS concentration of the villages such as Ramalingapuram and Andipatti are showing the level of unfit for drinking. The reason for increasing level of TDS is not only saline water ingress into coastal aquifer, but also sometime in deep water condition, dissolution of ionic particle from rocks mixed with fresh water, increase the total dissolved solid in groundwater[14]. Since the study area is for away from coastal region, there is no such possibility of sea water intrusion activity supporting the increasing TDS content. The increasing TDS content reflects the change in water level, differential weathering of rocks and leaching of mineral content from soil[15]. Since study area is a hard metamorphic terrain covered by black soil outcrop, differential weathering from the rocks of Hornblende-Biotite gneiss, Charnockite, Pink granite and Crystalline limestone and leaching of mineral content from black soli causes for increasing TDS content in the study area.

Calcium is a major constituent of igneous rocks. The range of calcium content in groundwater is largely dependent on the solubility of calcium carbonate, sulphide and rarely chloride. Calcium and Magnesium are known to occur naturally through mineral deposits and rock strata and contribute to its total hardness[11]. The spatial distribution of Ca^{2+} and Mg^{2+} content maps (Figure-2d-e) indicates that Ramalingapuram and Ramasamypuram wells are showing higher concentration of Ca^{2+} and Mg^{2+} than the other wells of the study area. The abundance of Ca^{2+}, Na^+ and Mg^{2+} is associated with minerals such as montmorillonite, Illite and chlorite[16]. The carbonate weathering and silicate weathering are the main source for Ca^{2+} and Mg^{2+} ions in the groundwater[16]. So, the presence of dissolution of Ca^{2+} and Mg^{2+} from crystalline limestone and calcrete, weathering of silicate minerals from hornblende-biotite gneiss, charnockite, granite and black soil, may be the prime contributors of Ca^{2+} and Mg^{2+} in the study area. The following reaction explain the dissolution and weathering process of the minerals:

$$CaCO_3 + H_2CO_3 \xrightarrow{\text{dissolution}} Ca^{2+} + 2HCO^-_3 \quad (1)$$
(Calcite)

$$\text{(Dolomite) } Ca\,Mg\,(CO_3)_2 + 2H_2CO_3 \;\downarrow^{\text{dissolution}}\; Ca^{2+} + Mg^{2+} + 4HCO^-_3 \quad (2)$$

$$\text{(Anorthite) } Ca\,Al_2\,Si_2\,O_8 + 2CO_2 + 3H_2O \;\downarrow^{\text{weathering}}\; 2Ca^{2+} + Al_2\,Si_2\,O_5\,(OH)_4 + 2HCO^-_3 \quad (3)$$

$$\text{(Montmorillonite) } Ca_{0.5}\,Mg_{0.5}\,Fe_3 + Al_3Si_8\,OH_2\,nH_2O \;\downarrow^{\text{leaching}}\; Ca^+ + Mg^+ + Fe^+ + (Al_3\,Si_8\,OH_2) \quad (4)$$

$$\text{(Hypersthene) } Ca\,Mg\,(Si_2\,O_6) + 4CO_2 + 6H_2O \;\downarrow^{\text{weathering}}\; Ca^{2+} + Mg^{2+} + 4HCO^-_3 + 2Si\,(OH)_4 \quad (5)$$

$$\text{(Hornblende) } Ca_2Mg_5Si_8O_{22}(OH)_2 + 14CO_2 + 22H_2O \;\downarrow^{\text{weathering}}\; 2Ca^{2+} + 5Mg^{2+} + 14HCO^-_3 + 8Si(OH)_4 \quad (6)$$

$$\text{(Biotite) } K\,(Mg\,Fe)_3\,(Al\,Si_3\,O_{10})\,(OH\,F)_2 \;\downarrow^{\text{weathering}}\; K^+ + Na^+ + Ca^+ + (Mg\,Fe) + (Al\,Si_3\,O_{10})OH_2 \quad (7)$$

Sodium is the dominant cation next to calcium in the groundwater of the study area. In groundwater, the sources of Na^+ content are greatly dependent on the rock type of aquifer and generally result from natural ion exchange. Sources of Na^+ are generally from halite, sea spray, hot spring, brines and some silicates or rare minerals such as Nahcolite ($NaHCO_3$)[4]. But the Na^+ and K^+ sources in the study area are due to from weathering of Na^+ rich silicate minerals from source rock and clay minerals from black soil. The following reaction explains the sources of Na^+ and K^+;

$$\text{(Albite) } NaAlSi_3O_8 + 2H^+\,2H^+ + 9H_2O \;\downarrow^{\text{weathering}}\; Al_2Si_2O_5\,(OH)_4 + 2Na^+ + H_4SiO_4 \quad (8)$$

$$\text{(Orthoclase or Microcline) } 4KAlSi_3O_8 + 22\,H_2O \;\downarrow^{\text{weathering}}\; 40H^- + Al_4Si_4O_{10}\,(OH)_8 + 8\,H_4SiO_4 + 4K^+ \quad (9)$$

The average spatial distribution map of Na^+ and K^+ for two seasons is given Figure-2f-g. These maps illustrates that Ramalingapuram, Andipatti and Ramasamypuram wells are showing high concentration of Na^+ and K^+ than the other area wells of the study area.

The average spatial distribution map for two seasons of Cl^-, HCO_3^- and SO_4^{2-} are given in Figure-2h-j. The iso-chloride spatial map indicates that Ramalingapuram, Pandalgudi, Andipatti, Ramaswamypuram and velayuthapuram village wells are showing more concentration Cl^- content. The higher Cl^- content in groundwater may be attributed to the presence of soluble chloride form rock and sea water ingress[17]. The black soil may be the prime contributor of chloride to groundwater and recharge of river water which may increase concentration of Cl^{-16}. In naturals waters, the probable sources of Cl^- comprise the leaching of Cl^- containing minerals (like apatite) and rocks with which the water comes in contact, inland salinity and the discharge of agricultural, industrial and domestic waste waters.

The Cl^- content in the study area is mainly obtained from sources black soil and source rocks. The iso-bicarbonate spatial map indicates that Kurunthamadam, Kallupattui, Velayuthapuram, Koppuchittampatti and Udayanathapuram village wells are showing higher concentration HCO_3^- ions. These wells are located in the calcrete terrain. The calcrete rock is formed by evapo-transpiration of groundwater and pedogenic leaching of meteoric water under arid and semi arid climatic condition[18]. The dissolving Calcium and bicarbonate ion from groundwater derived from the sources rocks of calc – alkaline nature forms calcrete[18]. The HCO_3^- source of groundwater is obtained from the minerals calcite, dolomite and aragonite bearing rocks of crystalline limestone, calc granulite and calcrete. The iso-sulphate spatial map of the study area indicates that Andipatti, Velayuthapuram, Periyathummakundu and T.Namasivayapuram village are having more concentration of sulphate from groundwater. The sources of SO_4^- are obtained from the sulphur, sulphides and sulphate of heavy metal, gypsum and anhydrite from the rocks and hydrolysis of pyrite, and also from excessive use of fertilizers in agriculture field. The following reactions explain the SO_4^- sources;

(Pyrite) $2FeS_2 + 7H_2O + 15\,(O) \rightarrow 2Fe\,(OH)_3 + 4H_2SO_4$ (10)

$FeS + 7\,(O) + H_2O \rightarrow Fe_2\,(SO_4^{2-}) + H_2SO_4$ (11)

$2FeSO_4 + H_2SO_4 + (O) \rightarrow Fe_2\,(SO_4^{2-})_3 + H_2O$ (12)

Where sulphuric acid react with $CaCO_3$, it produce calcium sulphate

$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$ (13)

Gypsum also produces sulphate in groundwater[16]

(Gypsum) $H_2O + CaSO_4.2H_2O \rightarrow Ca^{2+} + SO_4^{2-} + 3H_2O$ (14)

The nitrate sources in groundwater are generally obtained from anthropogenic sources, such as nitrogen fertilizer used agricultural practice, sewage effluents, animal excreta and manure and municipal waste[4,19]. The average spatial data map of nitrate is not able to provide due to the absence of data values in many samples. In general, the nitrate concentration is negligible in the study area. Fluoride in groundwater is mainly derived from the weathering of fluoride bearing minerals such as apatite, hornblende, muscovite and biotite. Fluoride is also obtained from industrial and agricultural sources[20]. The alkaline nature of groundwater suggests favorable environmental conditions for fluoride dissolution[20]. Despite the rock and water interaction providing more fluoride content to groundwater, the secondary contribution of fluoride is obtained from leaching of phosphatic fertilizers or off from fly ash produced by thermal power plants in many areas[20]. The natural concentration of fluoride in drinking water is normally 0.1 to 1.0 mg/L[20]. The fluoride level in the study area for two seasons which is less than the permissible limit defined by WHO (Table-2). The average spatial map of fluoride content for both seasons is given in Figure-3k. The villages Ramaswamipuram, Kurundhamadam, Pandalgudi, Mutharupatti, Udayanadhapuram and Ramachandrapuram show little higher concentration of fluoride than the other area (0.23 – 0.24) mg/L.

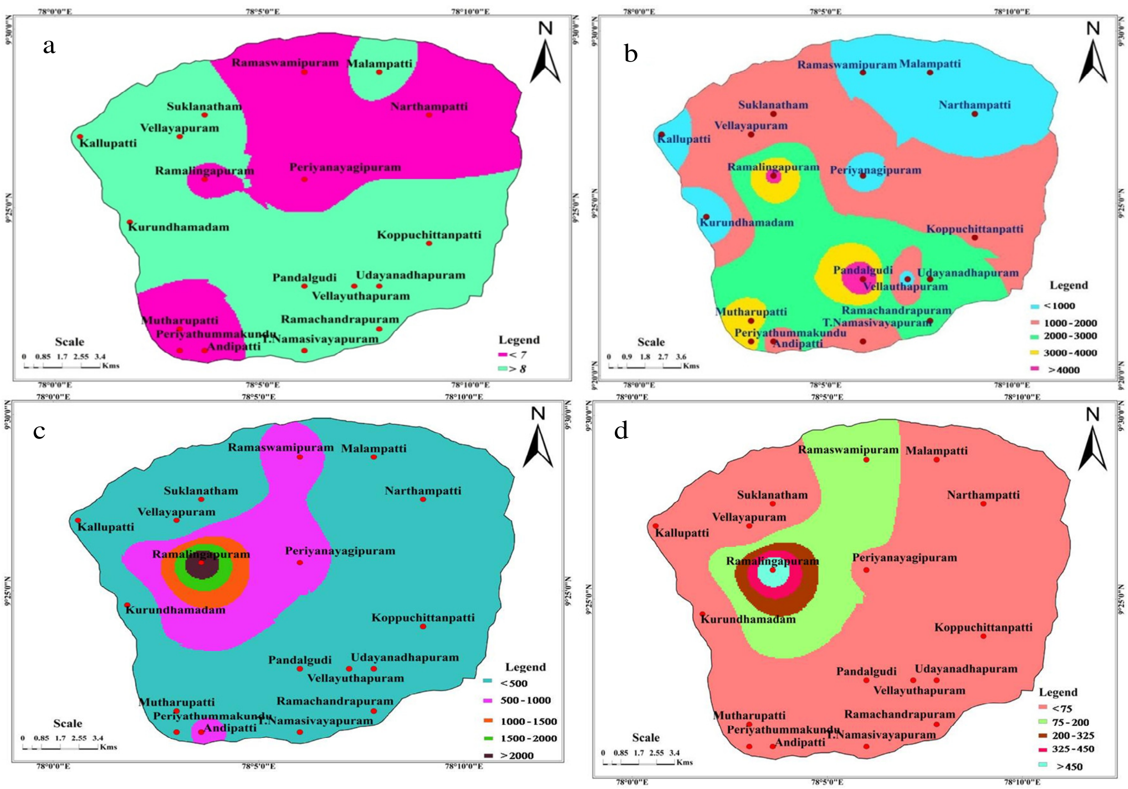

Figure-2 (a-d)
Spatial distribution map of the (a) pH, (b) EC, (c) TDS and (d) Calcium

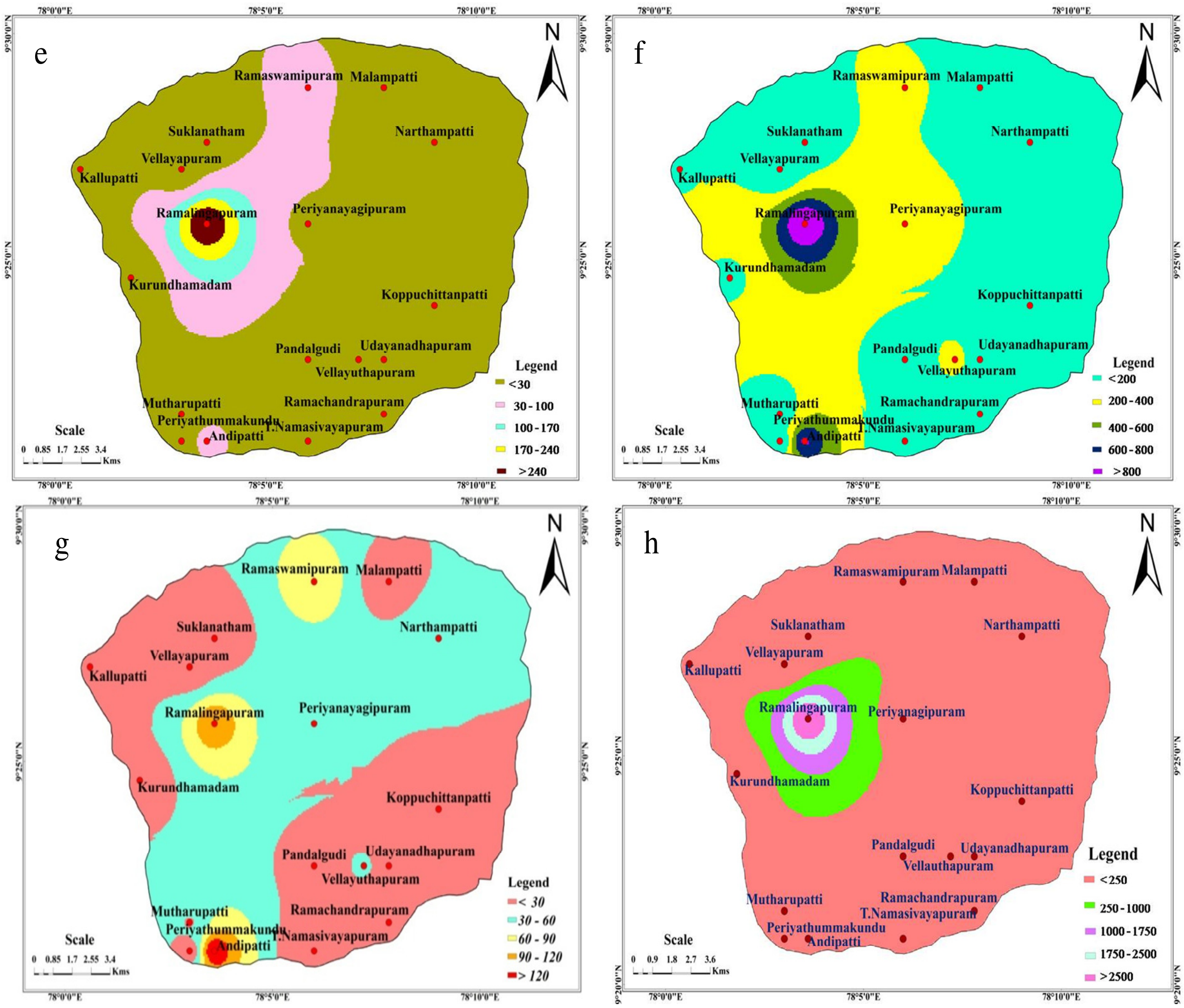

Figure-2 (e-h)
Spatial distribution map of the (e) Magnesium, (f) Sodium, (g) Potassium and (h) Chloride

Multiple Correlations: Multiple Correlations coefficient is a basic statistical tool to show the degree of dependency of variables with one another. The average correlation matrix of thirteen groundwater parameter variables of two seasons from different areas is discussed[5,18,21,22]. The bivariate relation between the variables such as (Ca^{2+} + Mg^{2+}) Vs EC, (Na^{+} + K^{+}) Vs EC, Cl^{-} Vs EC, HCO_3^{-} Vs EC, Cl^{-} Vs Na^{+} (Ca^{2+} / Mg^{2+}) Vs Na^{+} + K^{+} shows positive correlations[5]. The relationship of above variables in the study area also shows existing same positive correlation except Ca^{2+}/Mg^{2+} Vs Na^{+} + K^{+}, due to the influence of carbonate lithology on water chemistry. The sodium and potassium are mainly obtained from the calc-alkaline group rocks such as hornblende – biotite gneiss, charnockite, granite, whereas the carbonate source are mainly obtained from the peralkaline group of rocks such as calc – granulite, calcrete and crystalline limestone. The correlation study between TDS Vs Na^{+} + (Ca^{2+} / Mg^{2+}) shows the positive correlation which indicates that the combined operation of chemical weathering, groundwater movement and river basin recharge controlled the chemistry of groundwater.

Mechanism controlling groundwater quality: The close relationship between water bearing formation and water composition has established with Gibbs standard diagram of cations and anions[23]. This will help in describing the factors that control the chemistry of groundwater on Cl^{-}/(Cl^{-} + HCO^{-}_{3}) Vs TDS and Na^{+} + K^{+}/(Na^{+} +K^{+} + Ca^{+}) Vs TDS. The cation and anion Gibb's diagrams (Figure-3a-b) for the average value indicate that the evaporation and crystallization dominance and rock dominance mechanism characters are controlling the ground water chemistry. Numerous researchers have illustrated such similar gibb's mechanism from various areas[5,14,15,18,24]. The high TDS indicates that there is a limited dilution process by pedogenic leaching by surface water or rain water. The presence of more calcrete profile deposit within the regolith part indicates that evaporation of groundwater is the active process in the study area under arid and semiarid climatic condition.

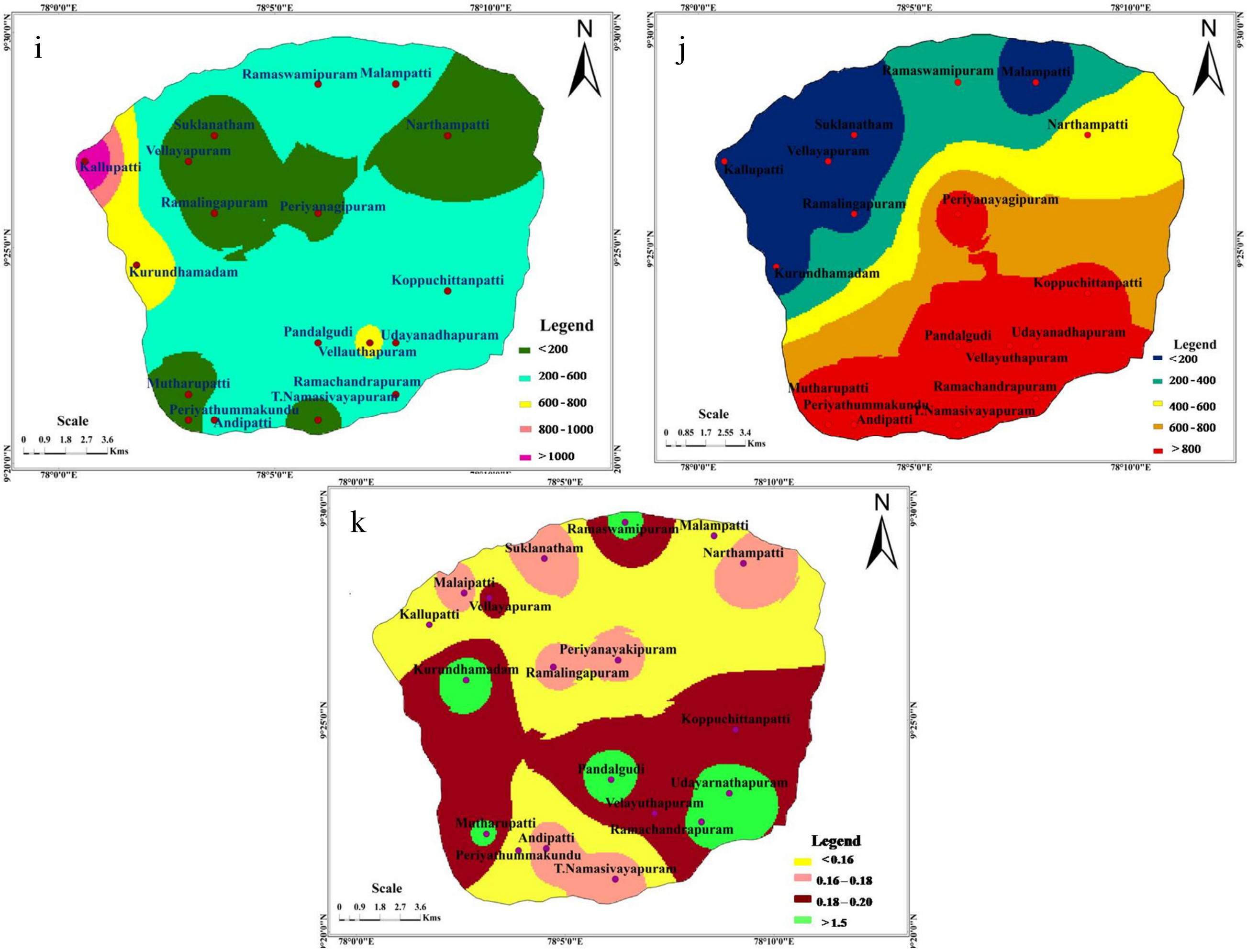

Figure-2
Spatial distribution map of the (i) Bicarbonate, (j) Sulphate and (k) Fluoride

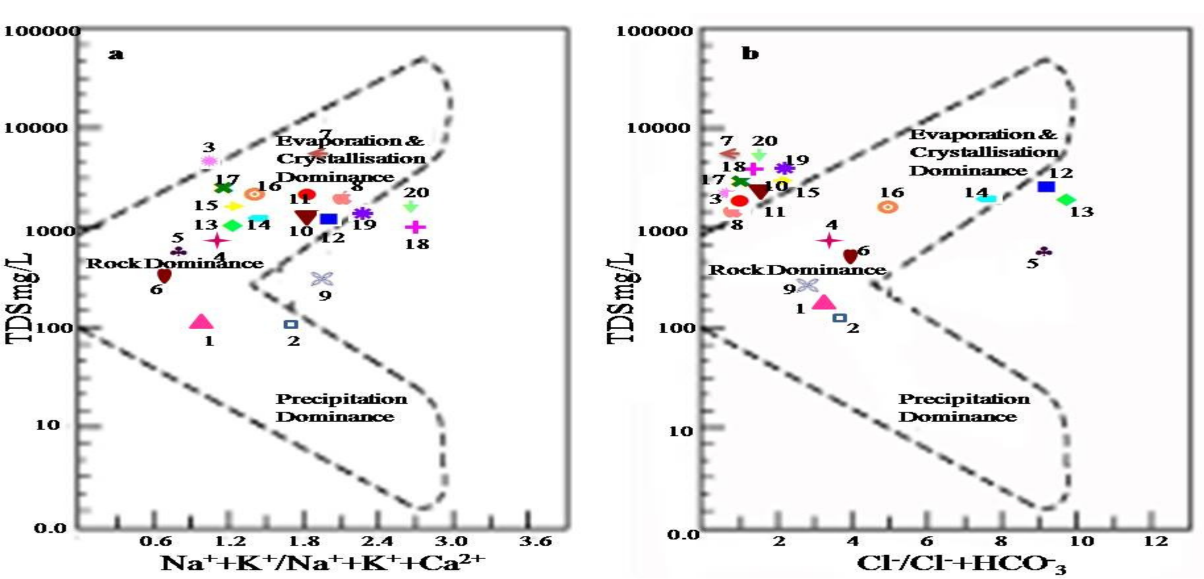

Figure-3a-b
Gibbs plots cations and anions for the average values of two seasons

Piper Diagram: The piper's diagram is extensively used to understand problem about geochemical facies of evaluation of groundwater[25]. The average cations and anions for two seasons plotted on the respective triangle fields (Figure-4) are projected in the diamond shaped field through the software (Aquachem 4.0). The minor alkali like K^+ and strong acid like Nitrate and Fluoride are clubbed with major ones for plotting in order to get information from the piper's diagram. The early researcher classified the diamond shaped diagram into 9 geochemical facies[1,25]. Later, the diamond shaped piper diagram is modified into 6 geochemical facies[3,4]. The chemical data plots fall on the subdivision of 5, 4, 3, 2 and 1 of diamond field indicating that CaCl (35%), Mixed CaMgCl (15%), NaCl (35%), Mixed $CaNaHCO_3$ (10%) and $CaHCO_3$ (5%) are important geochemical facies. Among the above six subdivisions, Alkaline earth (Ca + Mg) exceeds alkalies (Na + K) and Non-carbonate hardness (secondary salinity) exceeds 50% (CaCl) – 35% (NaCl) are the predominant type of ground water facies in the study area.

Ground water quality assessment: The chemical quality standards for drinking, livestock uses and irrigation uses for the study area were discussed[9,10]. The ground water qualities of the study area are shown in the diagram (Figure-5). The chemical quality of the study area is discussed related to the standard value of drinking, live stock uses irrigation uses and USDA diagram for the study area were discussed[9-27]. Drinking water qualities groundwater's of the study area are generally showing within the permissible limit of BIS and WHO, except pH and Cl^-. The Ca^{2+}, Mg^{2+} and SO_4^- (45%) and HCO_3^- (95%) concentrations show higher concentration than the permissible limit of WHO standard. Livestock use of water quality based on TDS is given as follows; Below 2500 mg/L TDS – Fair; Below 3500 mg/L TDS – Poor; Above 4500 mg/L TDS – Not satisfactory, As per the above classification, 80% of the study area is having low TDS shows that it is more suitable for live stock uses. In case of irrigation and Agricultural Quality, the concentration of Na^+ is very important to classify the irrigation purposes. If the water rich in sodium is applied to soils, some of the sodium is taken up by clay which is in exchange gives up calcium and magnesium thereby decreasing the permeability of the soil. It has a great effect on plant growth[2,28,29]. Sodium Adsorption Ratio (SAR) gives a clear idea about the adsorption of sodium by soil and the same has been calculated by using the following formula;

$$SAR = \frac{Na}{[(Ca+Mg)/2\,]^{1/2}} \quad (15)$$

Where all ion concentration is expressed in epm. The Sodium Adsorption Ratio (SAR) parameter evaluates the Sodium Hazard in relation to Calcium and Magnesium concentration. SAR values range from minimum 0.47 to maximum 11.2. The values greater than two indicate that ground water is unsuitable for irrigation purpose[30]. Only 9 ground water samples of the area show higher SAR values which are unsuitable as sources of water for irrigation. The utility of U.S Salinity diagram for irrigation are discussed by numerous researchers[3,24]. The average data plotted for two seasons of the study area indicates that 8 wells fall in C_1-S_1 – excellent water quality, 3 wells in C_2-S_1 and 1 wells in C_2-S_2 – good water quality, 2 wells in C_1-S_3 and 3 well in C_4-S_3 – fair water quality and 1 wells in C_2-S_4 and 2 well C_4-S_4 – bad water quality. The data plotted for the study area indicates that maximum water samples have excellent to good quality water for irrigation.

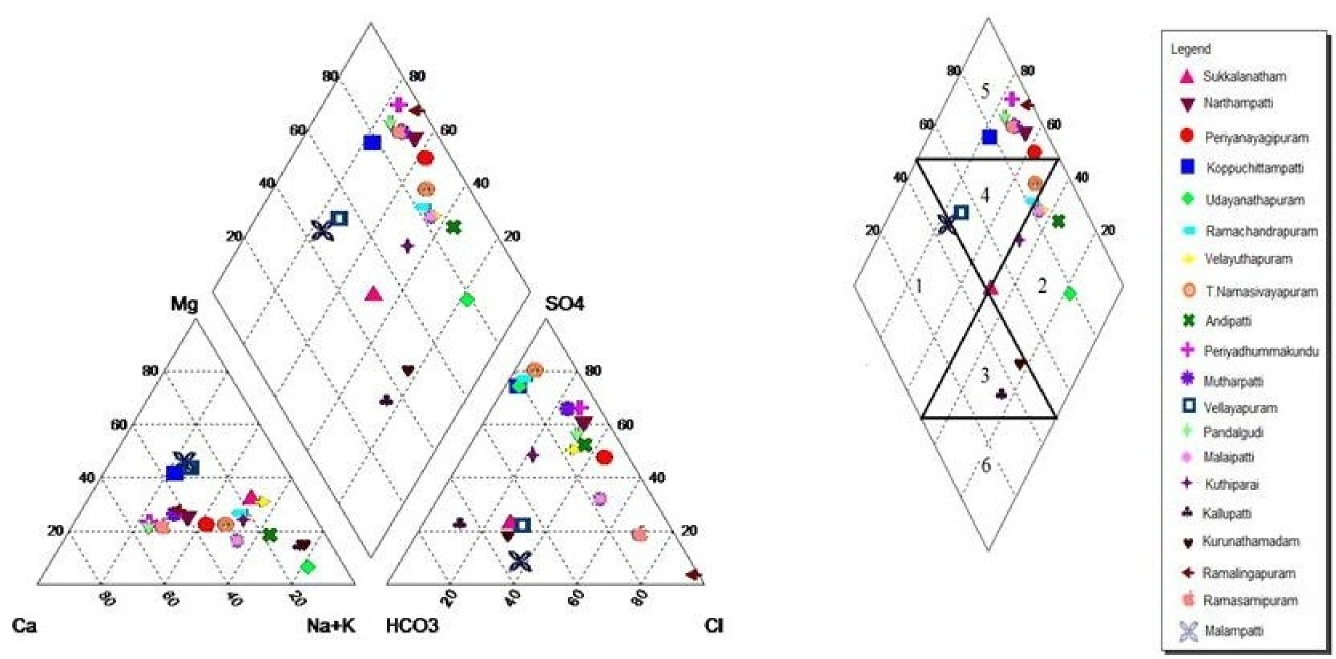

Figure-4
Piper plots diagram in average value of the two seasons

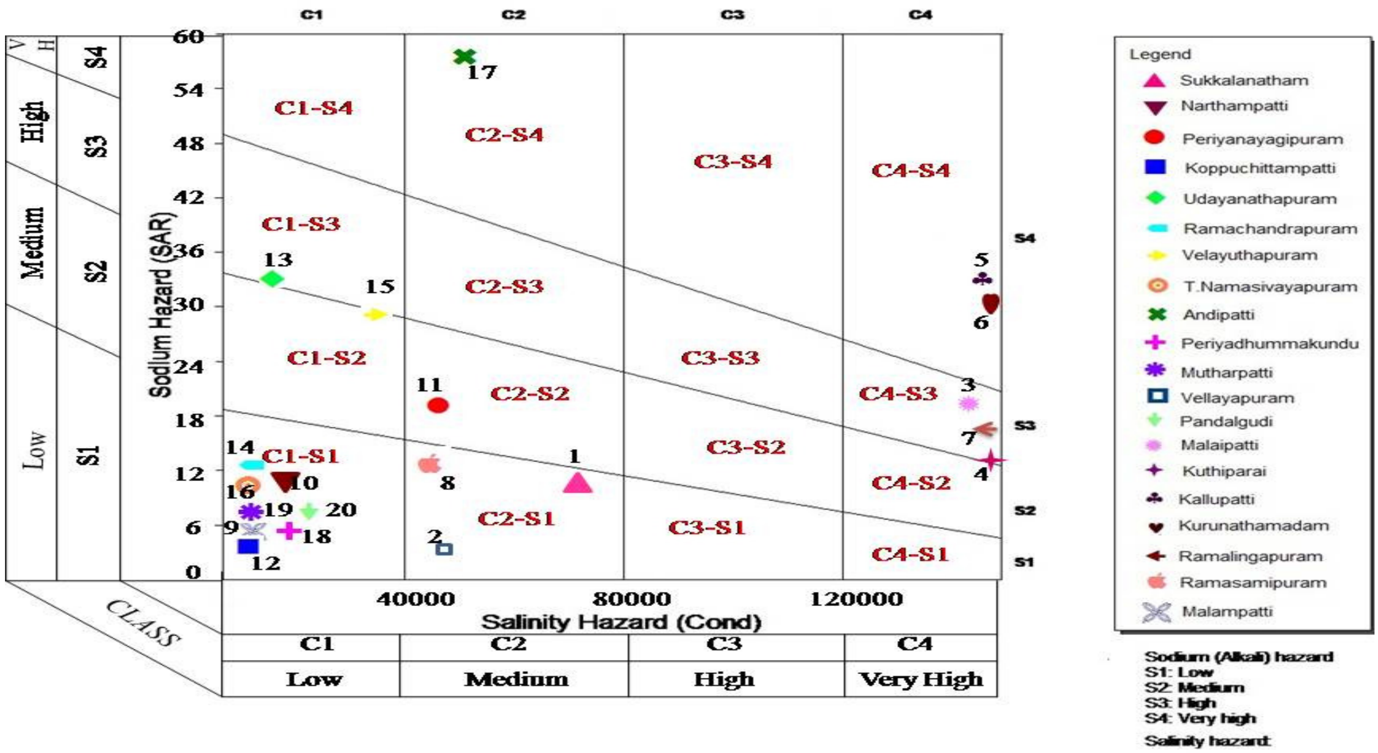

Figure-5
USDA diagram plots in average value of the two seasons (Richard 1954)

Sodium Percentage: Sodium in soil is considered vital for determining groundwater suitability for irrigation purpose, because sodium reacts with soil to reduce its permeability and support little or no growth[30]. Sodium salts in soil, besides affecting the growth of plants directly, also affect soil structure, permeability and aeration which directly assail plant growth. The sodium in irrigation waters is usually denoted as percent sodium and can be determined using the following formula[1,28,29];

$$\% \text{ Na} = (\text{Na}) \times 100/(\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^{2+} + \text{K}^{+}) \quad (16)$$

The Na percentage in the area ranges from minimum 30.3% to maximum 86.06%. Na percentage greater than 35% in ground water is unsuitable for irrigation[30]. Ground water samples 9, 12, 18, 20 of the study area are unsuitable for irrigation purpose, whereas all other samples are suitable for irrigation purposes. In general, 80% of samples are suitable for irrigation purposes. Groundwater quality can be more enhanced for livestock and irrigation and drinking water uses by river basin recharge, land use pattern plan for impounding of water in ayacuts, percolation ponds, check dams and rain water harvesting.

Conclusion

The study area is a hard metamorphic terrain which consists of calc alkaline group of rocks such as calc-granulite, crystalline limestone, hornblende-biotite gneiss, charnockite and pink granite. GIS based evolutions of geochemistry of groundwater illustrate the groundwater quality of the study area. The positive correlation of water quality parameters proves a combined operation of chemical weathering, groundwater movement and river basin change controlling the chemistry of groundwater. Gibbs mechanism reveals evaporation dominance and rock dominance characters controlling water chemistry. The geochemical facies evolved through piper analysis shows the predominance of CaCl and NaCl rich facies. Groundwater samples are generally showing within the permissible limit of BIS and WHO drinking water standard, except pH and Cl 80% of water samples are more suitable for livestock uses. Eight percentage of samples analyzed through U.S.D.A diagram are unsuitable for irrigation purposes. The water quality may be enhanced by river basin recharge, land use pattern plan and rain water harvesting processes.

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