Hydrogeochemical characteristics of Groundwater in parts of Choutuppal mandal Nalgonda District, Telangana State, India

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***Abstract* - Groundwater is almost globally important for human consumption as well as for the support of habitat and for maintaining the quality of base flow to rivers, while its quality assessment is essential to ensure sustainable safe use of the resources for drinking, agricultural, and industrial purposes. Forty-five groundwater samples were collected pre and post-monsoon seasons around Choutuppal area after collection of the all the samples are asses the groundwater quality and investigate hydrochemistry nature by analysis of major cations (Ca^{2+}, $Mg^{2+,}$ Na^{+}, K^{+}) and anions (HCO^{-}_{3}, Cl^{-}, F^{-}, So_4^{-2}, NO_3^{-}) besides some physical and chemical parameters (pH, electrical conductivity and Total hardness). Also, geographic information system-based groundwater quality mapping in the form of visually communicating contour maps was developed to delineate spatial variation in physico-chemical characteristics of groundwater samples. Piper Trilinear diagram was constructed to identify groundwater groups (hydrochemical facies) using major anionic and cationic concentration and it was found that majority of the samples belongs to Ca^{2+}–Mg^{2+-} $Cl^{-}$$SO_4^{-2}$ and $Ca^{2+-}Mg^{2+-}HCO^{-3}$ hydrochemical facies. Wilcox classification and US Salinity Laboratory hazard diagram suggests that 92.86% of the samples were falling under good to permissible category and C3–S1 groups, respectively, indicating high salinity/low sodium.**

***Index Terms* - Groundwater, Choutuppal, Hydrochemistry and Sodium Absorption Ratio (SAR) and Hydrochemical Facies.**

INTRODUCTION

The most abundant and precious nature's gift to the mankind is water. It is being the vital requirement for the successful growth as agriculture, industrial development and domestic purpose since ages man has been enthusiastic to know and understand the nature of occurrence and movement of groundwater. The Vedas and Upanishads recognized "WATER" as one of the five basic elements i.e., vacuum, air, water, fire and soil. Historical evidence of over 5000 years show the records on civilization of groundwater through open wells, springs and other sources especially in India and China. The ancient civilization had utilized the surface water sources and groundwater resources for irrigation purposes. The global water resources 97.2% is comprised to ocean water and 2.8% percentage of the total water available on continents is fresh water, which is distributed to about 75.2% i.e., 2.16% of the hydrosphere on continents is in frozen state. The remaining 22.6% of freshwater i.e., 0.64% of water in the hydrosphere is groundwater, and out of which only a small fraction is retrievable. Exhaustive list of bio-indicators to locate groundwater was provided in Brihat Samhita during 6th Century. The Rapid growth of population all over the world has necessitated an increase in agriculture production at a logarithmic rate. Land and water are the two vital inputs for agricultural development which is the lynchpin of our country's prosperity. Their conservation, preservation, proper distribution and efficient utilization are imperative. The groundwater resources of our country can play a potent role in supplying much needed water for irrigation to a large area. The need is to develop this source of water and exploit it judiciously to ensure sustained discharge from the reserves without causing imbalance in the overall hydrogeology of an area. The rainfall distribution in India is erratic and ranges from scanty areas to one of the wettest places in the world. Although the annual precipitation is estimated to be around 400 million hector meters, but still a vast area of the country is drought prone. The arid and semi-arid regions of India covering 53.9% of the geographical area is drought effected with the absence of soil moisture for greatest part of the year. National water policy was adopted in September 1987. Since then, many issues and challenges have emerged in the development and management of the water resources.

STUDY AREA

The study area is located in the North western part of Nalgonda district .The study area lies between latitudes 17^0 16'30"-17^0 20' 50"N and Longitudes 78^0 49'50"-79^0 0' 0"E.The present study area falls in the Survey of India Toposheet No.56K/15, with Scale of 1:50,000. The total area is 92.11 sq.km (Fig:1).The study area is gently sloping from north-western to south-eastern side and north-eastern to south-eastern.

GEOLOGY AND HYDROGEOLOGY

The drainage in the area is of dendritic and sub dendritic type and is controlled by undulatory topography. The investigated area falls under is a part of the stable Southern Indian shield consisting of Peninsular Gneissic Complex (PGC) and covered by Granite, granodiorite and Granite gneiss.

MATERIALS AND METHODS

Groundwater and surface water samples were collected in cleaned Forty-five polyethylene bottles, following the American Public Health Association (APHA 1995) method, from the tanks (surface water), dug well, hand pump and bore wells in the pre and post-monsoon periods. The location of these samples is shown in (Fig: 1). The water samples from the hand pump and bore wells were collected after pumping out water for about 10 min to remove stagnant water from the well. The methods of collection of samples play an important role in maintaining a high degree of accuracy of analytical data and its application to hydrochemical studies. The water samples were analyzed in the laboratory of Centre for Materials for Electronics Technology (C-MET), Hyderabad, as per the standard APHA (1995) procedures. Samples of pre and post-monsoon were studied for various physical parameters and major chemical constituents are determined. The physical and chemical parameters include pH, EC, TDS, TH, cations such as Ca^{2+}, Mg^{2+}, Na^+, K^+ and anions Cl^-, SO_4^{2-}, F^-, NO_3^-,and HCO_3, which were determined by instrumental procedures. The pH was measured using the digital pH meter of Elico; EC was estimated by the EC analyzer CM 183 model of ELICO; classical methods of analysis were applied for the estimation of Ca^{2+}, Mg^{2+} and Cl^-; Na^+ and K^+ were analyzed by flame photometry using CL-345 flame photometer of ELICO. Sulfate was estimated by the turbidity method using the Digital Nephelo-Turbidity meter 132 model of Systronics. Nitrate was analyzed applying the UV-V is screen method using UV-visible spectrophotometer UV-1201 model of Shimadzu. Fluoride was analyzed by the ion selective electrode method using Orion 290A$^+$ model of Thermo-electron Corporation. The TDS were estimated by the summation of cations and anions (epm) method (Hem 1991). Perkin Elmer inductively coupled plasma optical emission spectrometer (ICP-OES) and inductively coupled plasma mass spectrometer (ICP-MS) instruments were used for analysis of major and trace elements in water samples. The results obtained were tested for accuracy by calculating the normalized inorganic charge balance (Mandal and Shiftan 1981; Huh et al., 1998) and analytical precision was within ±5 % for all the samples. Standard titration method was used for carbonates and bicarbonates. The analytical data of groundwater and surface water samples are presented in (Table: 1)

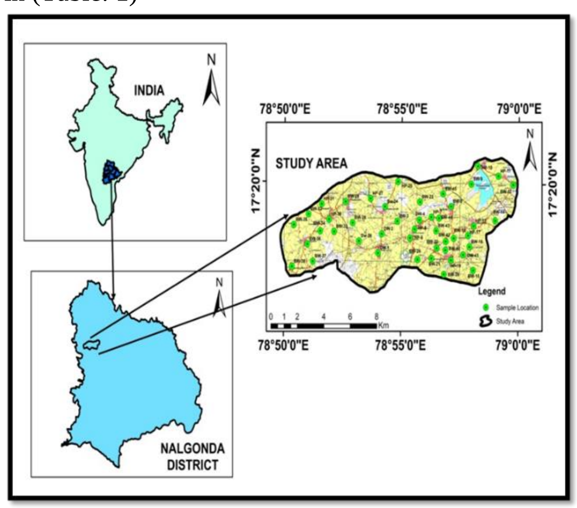


Fig: 1 Location map of the Study Area with sample points

Table: 1 Analytical data of water samples

	Pre-monsoon season					Post-monsoon season	
Parameters	Min	Max	Mean	Min	Max	Mean	WHO, (2011)

pH	5.8	8	6.5	5.6	7.7	6.2	6.5 - 8.5
EC (µS/cm)	397	2021	798.7	347	1819	754.7	1500
TDS (mg/L)	254.1	1293	511.2	222.08	1164.16	483	500
Na^+ (mg/L)	28.91	598.3	178.3	20.11	606.38	168.13	200
K^+ (mg/L)	1.32	54.2	8.734	0.92	53.67	7.64	12
Ca^{2+} (mg/L)	19.87	172.2	78.41	19.82	146.45	69.01	75
Mg^{2+} (mg/L)	21.81	139.3	72.85	13.82	118.93	61.6	50
TH as $CaCO_3$ (mg/L)	230.5	901.4	499.5	156.41	792.71	425.13	600
HCO_3^- (mg/L)	89	712	326.6	78	668	306.5	500
Cl^- (mg/L)	11	1369	385	6.37	1333.2	377.97	250
SO_4^{2-} (mg/L)	6.9	2782	64.41	1.45	270.31	533.85	250
NO_3^- (mg/L)	1.8	542.6	120.8	0.95	538.85	113.41	45
F^- (mg/L)	0.4	2.1	1.02	0.15	1.85	0.86	1.5

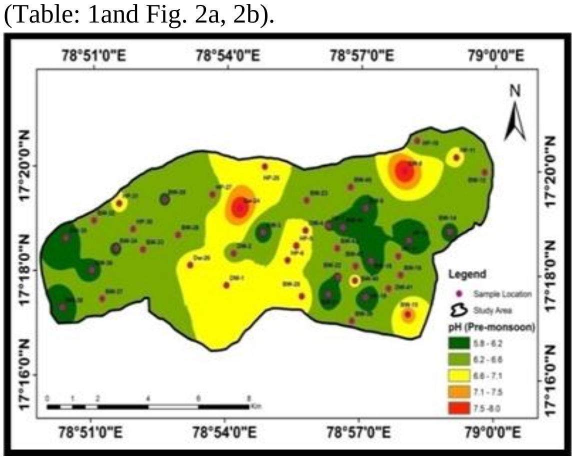
RESULTS AND DISCUSSION

Drinking water purposes

The minimum, maximum, and mean concentrations of physico-chemical parameters of water quality such pH, EC, TDS, and major chemical constituents are presented in (Table:1).

Hydrogen ion concentration (pH)

The pH of water is very important of its quality and provides important piece of information in many types of geochemical equilibrium of solubility calculation (Hem, 1991). The limit of pH values for drinking water is specified as 6.5 to 8.5(WHO, 2011). The pH of the groundwater in the study area lies in the ranges between 5.8 and 8 and 5.6 and 7.7in pre & post-monsoon indicating alkaline nature of the groundwater (Table: 1and Fig. 2a, 2b).



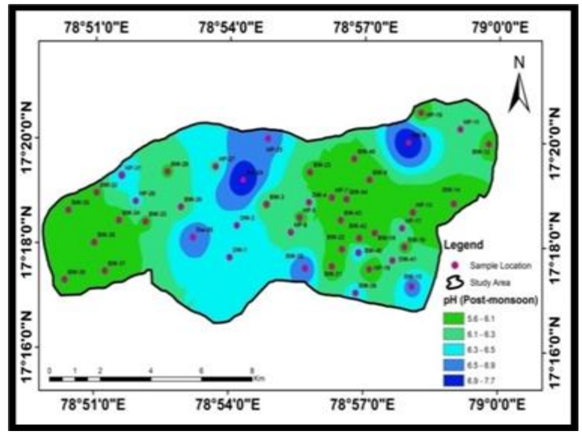
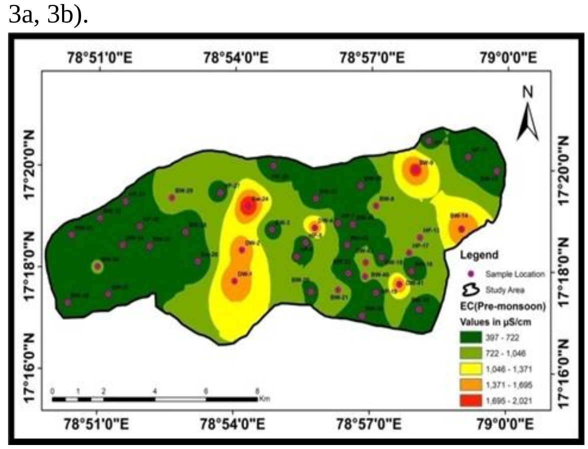


Fig: 2a, 2b spatial variation of a pH in Pre and post-monsoon Seasons

EC (Electrical conductivity)

All natural waters contain mineral salts in solutions. The presence of dissociated ions renders the solutions conductive. In dilute solution of a single salt, a line at relationship exists between the salt concentrations, beyond which the relation is asymptotic. Moreover, conductivities for a given concentration, of different salts are not the same. As natural waters commonly contain several salts in solution, no definite relation exists between the conductance and dissolved solids. Very broadly, the following relation is indicated up to conductivity values of 50,000µS/cm. In the present study, the EC varied from 397 to 2021 average 798.17 and 347to 1819 average is754.17µS/cm in the pre and post-monsoons (Table:1) indicating higher mineralization in the region. As the electrical conductivity is temperature dependent its variability in a given water sample depends on the concentration and types of inorganic ions present (Hem1985) (Fig. 3a, 3b).



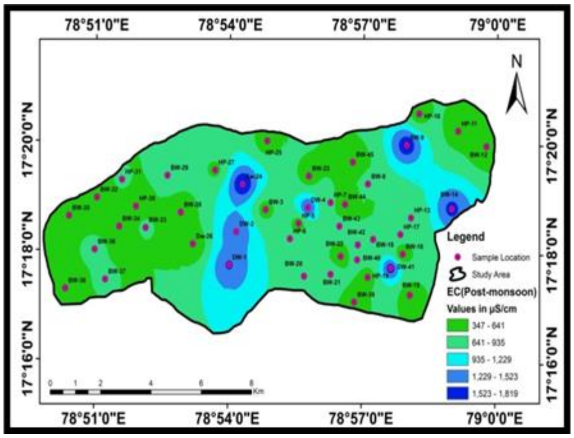
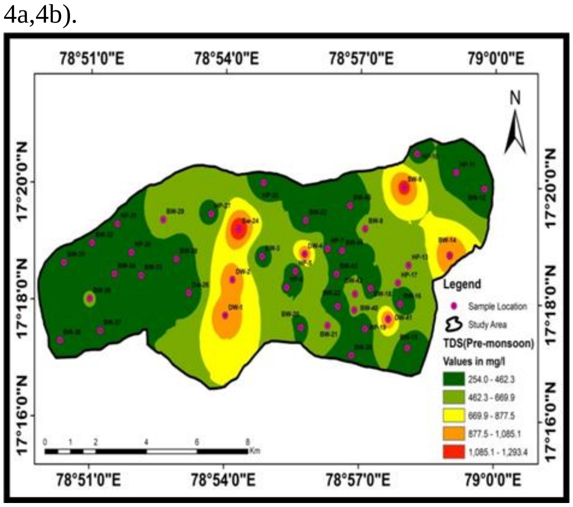


Fig: 3a, 3b spatial variation of a EC in Pre and post-monsoon Seasons.

Total Dissolved Solids (TDS)

The total solids in a liquid sample consist of total dissolved solids and total suspended solids. TDS is mostly due to dissolved ionic matter and bear a relationship with the electrical conductivity of water (Kapil and Bhattacharyya 2008). The bulk of the total dissolved solids include bicarbonate sulphates and chloride has calcium magnesium sodium and silica. Potassium chloride and nitrate and boron premier minor part of the dissolved solids in groundwater. Heavy metals and radioactive conscience occurring trace elements. In the present study, TDS values varied between 254.1-1293 average 511.2and 222.08 - 1164.16 average 483 mg/l in pre and post-monsoon seasons (Table:1) indicating sufficient input of ionic matter into groundwater samples, even though local geological settings, soil characteristics, and even lithology of the study area may also contributed to total dissolved solids content in groundwater(Fig. 4a,4b).



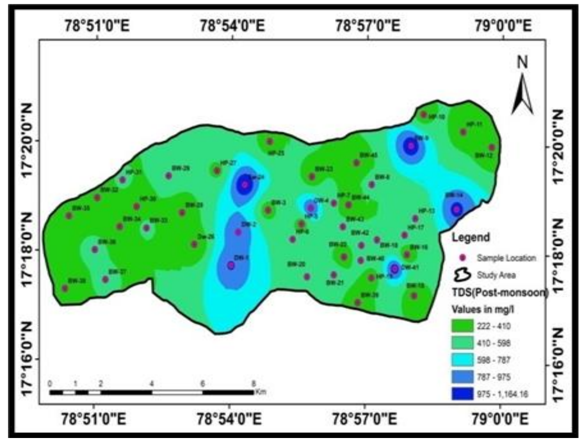
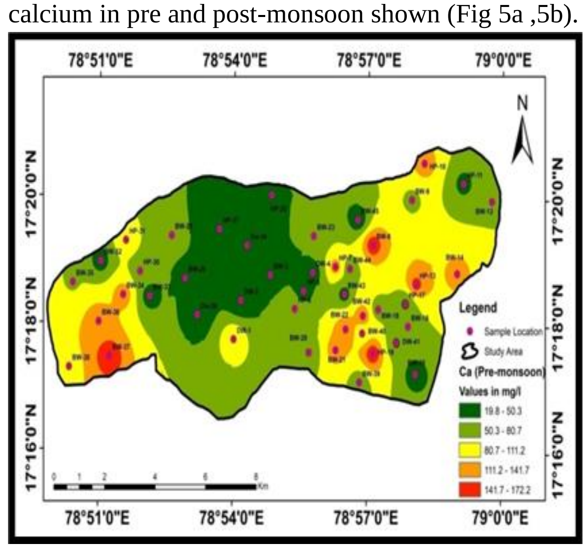


Fig: 4a, 4b spatial variation of a TDS in Pre and post-monsoon Seasons.

Calcium (Ca^{2+})

Calcium concentration in the northeast and west part of the study area is relatively high. This is because of the presence of gneissic rock in this area containing minerals like feldspars, pyroxene and amphiboles, accessory minerals such as apatite, wollastonite and fluorite. Ca^{2+} shows considerable variation in water samples from the pre to post-monsoon period in Ca^{2+} in groundwater for pre and post-monsoon periods varies from 19.87 to 172.2 mg/l and 19.82 to 146.85 mg/l, respectively**(Table:1)**. The average amount of calcium present in water samples of the pre-monsoon season is 78.4 mg/l and in post-monsoon season, 69.01 mg/l. It seems that the average values of Ca^{2+} are within the permissible limits as per (WHO ,2011) standard value of 75 mg/l.Spatial variation of a calcium in pre and post-monsoon shown (Fig 5a ,5b).



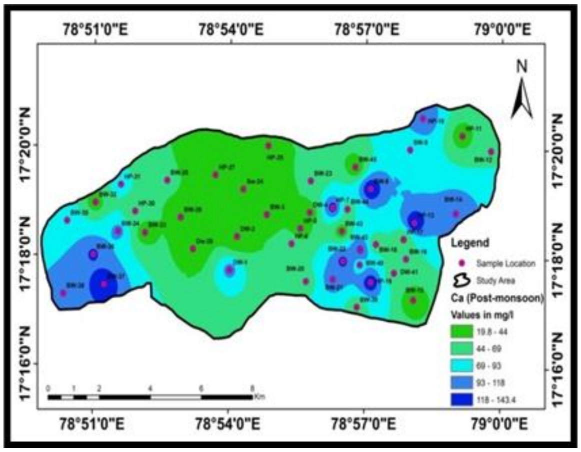
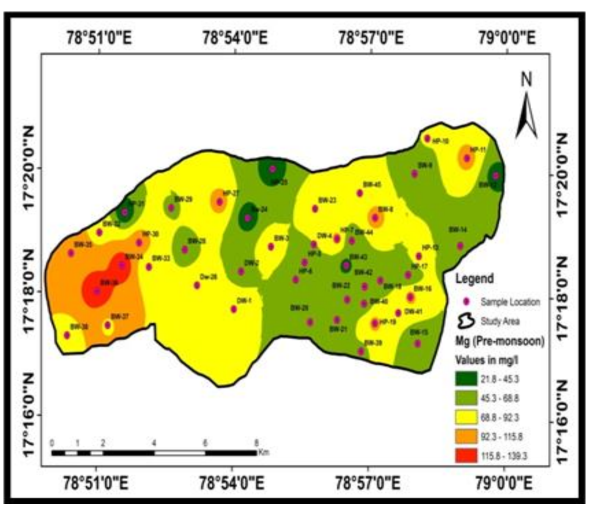


Fig: 5a, 5b spatial variation of a Ca in Pre and post-monsoon Seasons.

Magnesium (Mg^{2+})

Magnesium source in the groundwater is mainly due to ions exchange of minerals in rocks and soils by water (Al-Ahmadi, 2013). The concentration of Mg^{2+} in groundwater ranges from 21.81 to 139.3 mg/l with an average of 72.85 mg/l during the pre monsoon and from 13.82 to 118.93 mg/l with an average of 61.6 mg/l in the post-monsoon period (Table: 1). This hydrochemical feature again a precipitate or seasonal control. 76 % and 64 % water samples are unsuitable for drinking purposes during pre and post-monsoon, the values of Mg^{2+} are within the permissible limits (<50 mg/l) as per the standards (WHO, **2011**). The Mg^{2+} values of all the samples from pre and post-monsoon are shown in distribution maps (Fig. 6 a, 6b).



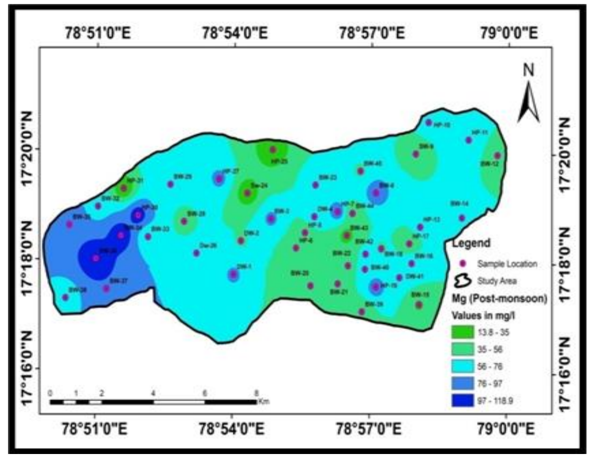
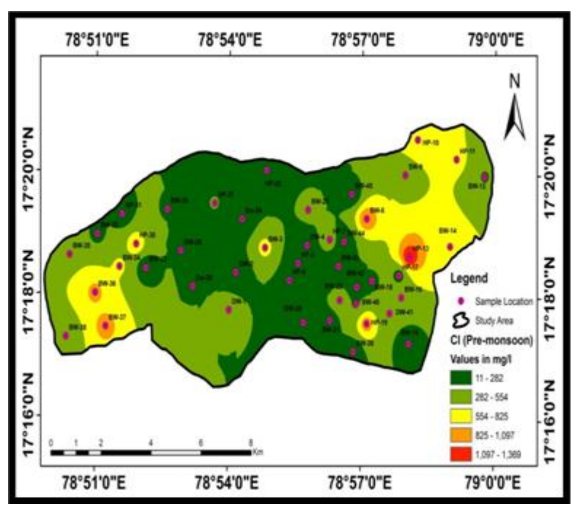


Fig: 6a, 6b spatial variation of Magnesium in Pre and post-monsoon Seasons.

Chloride (Cl^-)

Chloride in groundwater originates from both natural and anthropogenic sources. Chloride content of groundwater samples was much higher than the permissible limits. High chloride content indicates heavy pollution. It can be due to the uses of inorganic fertilizer, landfills leachates, septic tank effluents and industrial and irrigation drainage. The chloride content in the groundwater during the pre-monsoon season varies from 11to 1369 mg/l with a mean of 385 mg/l and in the post-monsoon season from 6.37 to1333.2 mg/l with a mean of 377.97 mg/l (Table: 1).The mean values of chloride from both seasons show that there is little seasonal fluctuation of chloride (Fig. 7 a,7b).



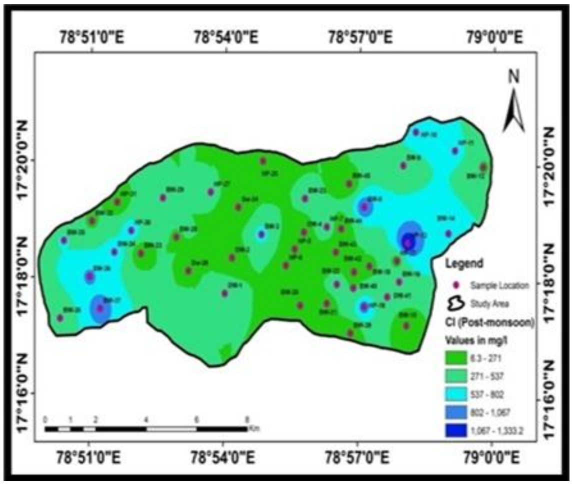
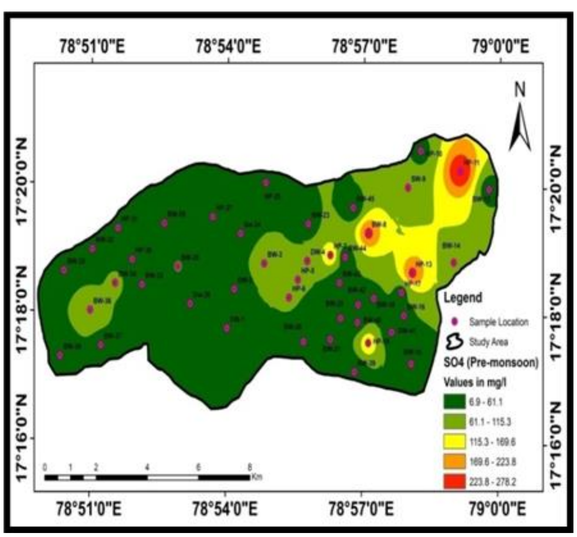


Fig: 7a, 7b spatial variation of Chloride in Pre and post-monsoon Seasons.

Sulfate (SO_4^{2-})

Sulfate concentration is possibly contributed by the type of precipitation and excess use of fertilizers in paddy cultivation places. The sulfate in the groundwater during the pre- monsoon season varies from 6.9 to2782 mg/l with a mean of 64.41 mg/l and in the post-monsoon season from 1.45 to 270.31 mg/l with a mean of 533.85 mg/l (Table: 1).This chemical variation is comparable with that of all major cations and anions. The mean value of sulfate shows that there is seasonal fluctuation in the area. Spatial distribution maps (Fig. 8a&8b) of SO_4^{2-} concentrations show distinct variations from the northeastern to the Eastern part of the study area.



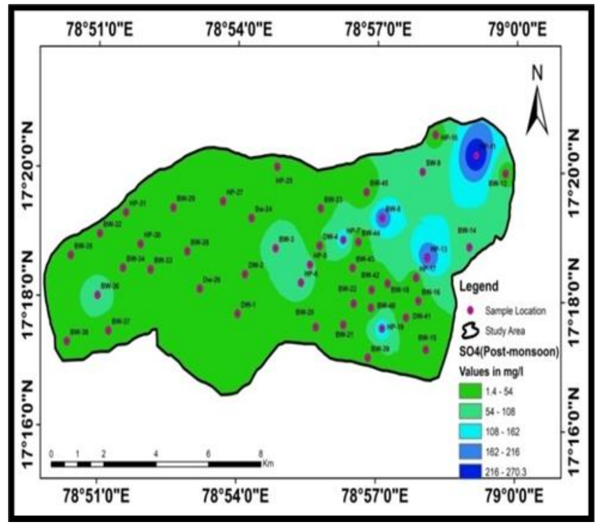


Fig: 8a, 8b spatial variation of a Sulfate in Pre and post-monsoon Seasons.

Water quality criteria for irrigation

Water quality for irrigation refers to its suitability for agricultural use. The concentration and composition of dissolved constituents in water can be determined to know its quality for irrigation use. Quality of water is an important consideration in any appraisal of salinity or alkalinity conditions in an irrigated area. Good quality of water (good soil and water management practices) can promote maximum crop yield. The suitability of groundwater for irrigation use was evaluated by calculating Salinity (EC), Sodium Absorption Ratio (SAR), Percent Sodium (%Na) and Permeability Index (PI).

Sodium Absorption Ratio (SAR)

SAR for the groundwater from the study area was estimated by the formula

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

All the ions are represented in meq/l.Water having SAR values <10 is considered excellent, 10–18 is good, 19–25 is Doubtful and above 26 is unsuitable for irrigation use (USDA 1954). In the present study area all the sample are excellent category in pre and post-monsoon period. The SAR values calculated are presented in (Table 2).The plots also shown that all samples are suitable for irrigation (Fig.9a,9b)

Table: 2 Sodium Absorption Ratio (SAR) in the study area

Range	Water class	Pre-monsoon	Post-monsoon
<10	Excellent	All 45 samples	All 45 samples
18	Good	Nil	Nil
19-25	Doubtful	Nil	Nil
>26	Unsuitable	Nil	Nil

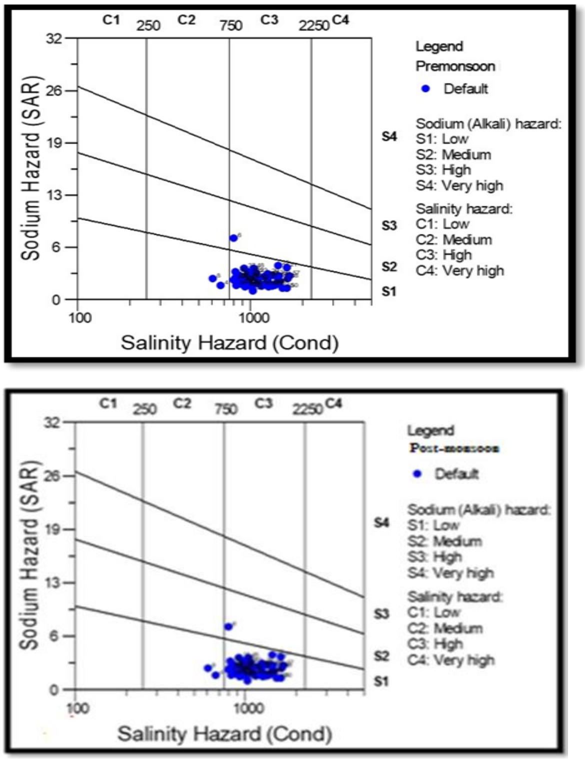


Fig: 9a,9b Wilcox (US salinity) diagram for groundwater and surface water samples of the (a) pre-monsoon and (b) post monsoon.

Permeability Index (PI)

Long term use of irrigation water affects soil permeability. It depends on various factors like total soluble salt, sodium, calcium, magnesium and bicarbonate content of the water. Doneen (1964) classified irrigation waters into three classes based on the permeability index (PI). The PI has been computed and plotted on Doneen Chart (Fig: 10b) and is formula

$$PI = \frac{(Na + K) + \sqrt{HCO_3}}{Ca + Mg + Na + K} \times 100$$

All the ions are represented in meq/l. As per the PI of groundwater samples in the study area, According to PI values, 51% water samples had fallen in class I, 47% in class II and 2% in class III in pre-monsoon and 71% and 29% respectively I and II classes of post-monsoon season of the Doneen's chart.One sample in pre monsoon have PI>75 making those waters unsuitable for irrigation (Fig.10 b).

Percent Sodium (% Na)

Wilcox (1955) has proposed a classification scheme for rating irrigation waters on the basis of percent sodium. The % Na was computed using following formula:

$$\text{Percent Sodium} \quad \%Na = \frac{Na^{+} + K^{+}}{Na^{+} + K^{+} + Ca^{2+} + Mg^{2+}} \times 100$$

Where the concentrations of ions are expressed in meq/l. 33 and 35 samples belong excellent to good category in pre and post-monsoon respectively 9 and 7 samples belonging to good to permissible category pre and post-monsoon respectively. 2 and 3 samples permissible to doubtful category in the pre and post-monsoon seasons. From the diagram it is clear 73 and 77 % (pre & post) water samples are suitable for agriculture (Fig: 10 a).

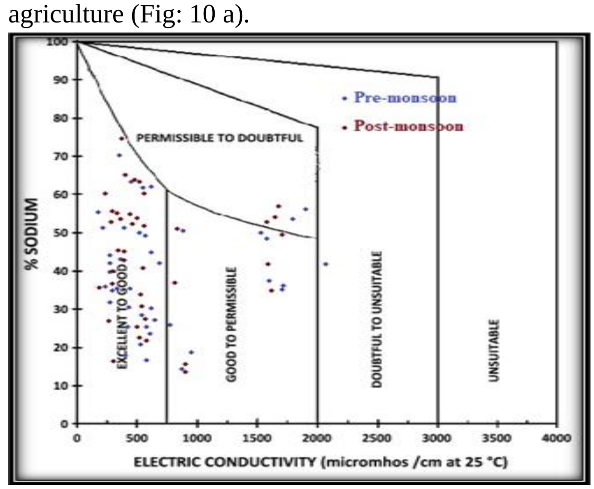
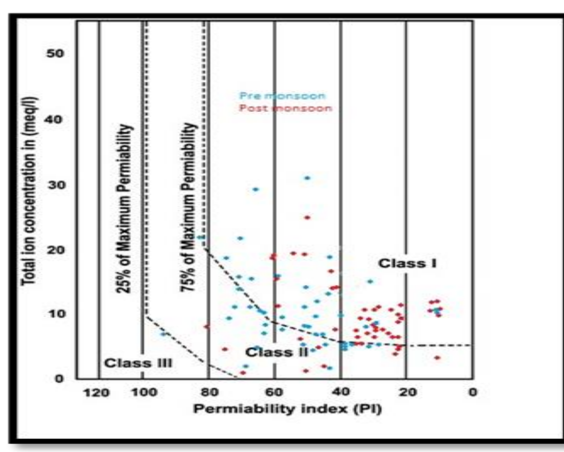


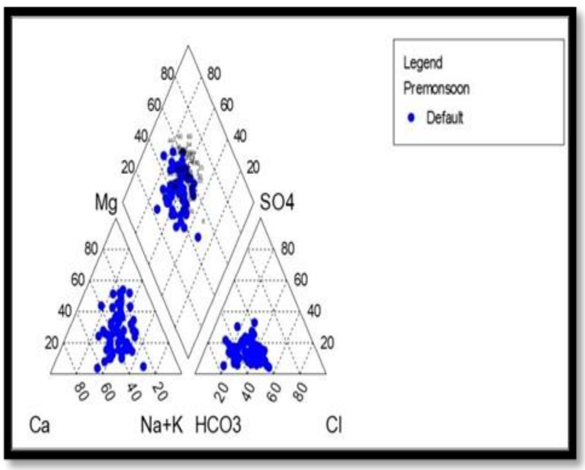
Fig: 10(a) Wilcox diagram for irrigation pre and post -monsoon



10(b) Permeability Index (PI) pre and post-monsoon

Hydrochemical facies

The hydrochemical evolution of groundwater can be understood by plotting the major cations and anions in a Piper Trilinear diagram (Piper 1944). This diagram reveals similarities and dissimilarities among groundwater samples because those with similar qualities will tend to plot together as groups (Todd 2001). This diagram is very useful in bringing out chemical relationships among groundwater in more definite terms (Walton 1970). According to the piper classification, the plot of chemical data on diamond shaped Trilinear diagram Fig:11(a, b). Majority of the samples are fall in the fields of Non carbonate alkali (primary salinity) exceeds chemical properties of the groundwater are dominated by alkalis and weak acids (7) and Mixed type (9) in pre and post-monsoon (Fig: 11 a ,b).



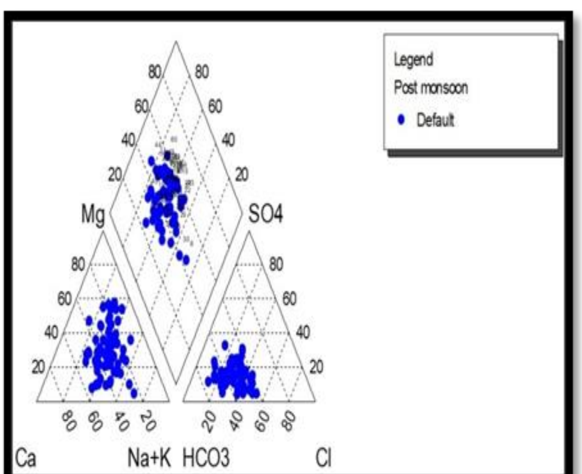


Fig: 11(a, b) Piper Classification of Groundwater in Pre and Post-Monsoons

Sub division number of the diamond shaped fields	Characteristics of corresponding sub division of diamond shaped field	(%) of samples Pre-monsoon	(%) of samples Post-monsoon
1	Alkaline Earths (Ca^{2+} + Mg^{2+}) exceeds alkalis (Na^{+} + K^{+})	62	56
2	Alkalis exceeds alkaline earth	38	44
3	Weak acids (CO_3^{2-} + HCO_3^{-}) exceeds strong acids (SO_4^{2-} + Cl^{-})	31	40
4	Strong acids exceed weak acids	69	60
5	Carbonate hardness (secondary alkalinity) exceeds chemical properties of the groundwater are dominated by alkaline earth and weak acids	22	22
6	Non-carbonate hardness (secondary salinity) exceeds chemical properties of the groundwater are dominated by alkalis and strong acids	9	9
7	Non-carbonate alkali (primary salinity) exceeds chemical properties of the groundwater are dominated by alkalis and weak acids	27	29
8	Carbonate alkali (primary alkalinity) exceeds chemical properties are dominated by alkalis and weak acids	Nil	Nil
9	Mixed type (No one cation-anion exceeds)	42	40

Table: 3 Classification of groundwater based on Piper Trilinear diagram

CONCLUSIONS

Groundwater samples were collected for pre and post-monsoon seasons and analyzed for various physico-chemical parameters. The quality of groundwater in the study area has been assessed through various hydrochemical parameters that are suited for drinking and irrigation applications. All the samples of groundwater from the study area have pH<7 (range from 7 to 8) suggesting that the water is slightly alkaline in character. All groundwater samples in the area are suitable for drinking because the pH values are within permissible limits (6.5–8.5). The EC values of the groundwater in the study area reveal that the low sodium and high salinity hence the groundwater is unsuitable for irrigation. However, the TDS of the groundwater suggest that it was classified as freshwater for many samples in the study area. Total hardness (TH) of the groundwater indicates that the majority of samples are suitable for domestic purposes due to low to medium hardness; however some samples in the pre and post-monsoon contain >500 mg/l TH and therefore these are described as very hard and unsuitable for domestic, drinking and irrigation purposes.

The major cations (Ca^{2+}, Mg^{2+}) from the groundwater samples show considerable variation from the pre to post-monsoon periods. In spite of the variation in their concentration from pre to post-monsoon, the majority of samples show values within the permissible limits. The major cations in groundwater distinctly exhibit decreasing order of their averages abundance as ($Ca^{2+} > Mg^{2+}$). The concentrations and distributions patterns of the cations in the area are controlled by the bulk composition of the granite and its minerals. The anionic concentration is as $SO_4^{2-} < Cl^-$. Chloride is different from other anionic groups, since it is coherent with sodium ion in the study area. Both ions are controlled by the extensive and intensive weathering of granite/gneisses that contain a lot of alkali and plagioclase feldspars, alkali amphiboles, and micas apatite and fluorite minerals. Nitrates and Sulfates are affected by excess uses of fertilizers and organic material. Bicarbonates in the study area are influenced by the precipitation and atmospheric conditions. The groundwater of the study area are classified on the basis of physico-chemical parameters like SAR, % Na, and PI different plots like Piper Trilinear diagrams, Doneen diagrams, Wilcox diagrams for groundwater for the pre and post-monsoon period.

According to Piper classification, The majority of groundwater samples fall into the fields of (7) and (9) in pre and post-monsoon, implying that non carbonate alkali (primary salinity) surpasses chemical characteristics of the groundwater are dominated by alkalis and weak acids, and No one cation - anion exceeds (Mixed type). Based on the permeability index According to Doneen chart classification 98 % and 100 % water samples are suitable for irrigation in pre and post-monsoon periods. According to the (Richaards, 1954) Sodium Adsorption Ratio (SAR) All samples fall in the excellent water class in pre and post-monsoon. Percent Sodium diagram it is clear 73 % in pre monsoon and 77 % in post-monsoon water samples are suitable for agriculture.

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