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A Study on Physico-Chemical Parameter Variations in Vellar Basin, Cuddalore District, Tamil Nadu, India

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ABSTRACT

The present study was the suitability and quality of groundwater for irrigation and domestic purposes in premonsoon and postmonsoon. Groundwater samples were collected in seventy locations in both the seasons in the year of 2016. Various physicochemical tests were carried out and WQI was calculated based on pH, TDS, Ec, TH, Ca, Mg, Na, K, Cl, So_4, $HCo_3$and F. The comparison between the premonsoon and postmonsoon reveals that very good range 27% and 6%, and good to permissible range in premonsoon 73% and in postmonsoon 94% of the water samples were fit for drinking.

Introduction

Groundwater is one of the most important precious natural resources required for human consumption, domestic purposes, irrigation, industrialization, urbanization, etc. (Rokade et al. 2004). Overexploitation and unabated pollution of this vital resource is threatening our ecosystems and even the life of the future generation (MadhanJha et al. 2007). Groundwater is available in various permeable geologic formation called aquifers which can store and transmit water. Groundwater is not available in the same quality and quantity everywhere. It varies depending upon the geological, geomorphological, type of soil and the amount of water mined. The increase in population, industrialization and the pressure for development in agriculture has led to the overexploitation and pollution of groundwater in most of the places.

Methodology

Seventy ground water samples were collected from open wells and bore wells in the study area (Figure: 1). Sampling and analysis was carried out using standard procedures (APHA 2012; Ramesh and Anbu 1996;). Five hundred milliliters of water samples was collected in polyethylene bottle. Bore water was collected by pumping out the stagnant water for 20 min with hand pump, to get representative samples. Then, it was sealed and brought to the laboratory for analysis, stored properly and filtered with 0.45lm filter paper before analysis. The Temperature, Electrical conductivity (EC), and pH were measured using a Digital Water and Soil Analysis Kit Model-161 Aristocrat at the sample collection site itself. SO4 of the samples were determined by ELICO SL 27 Spectrophotometer. Na and K of the samples were determined by ELICO CL 354 Flamephotometer. The carbonate and bicarbonate were determined by titration with 0.2 N sulphuric acid using phenolphthalein and methyl orange indicators. The analytical precision of the measurements of ions was determined by calculating the ionic balance error, which was observed to be within the standard limit of ±10 %.

Determination of Water Quality Index (WQI): Water Quality Index was calculated by the below mentioned procedure.

Step 1: The unit weight (wn) was calculated as given below:

$Wn = K/ S_n$

Where, K - Constant of proportionality

S_n - Standard value of the n^{th} parameter

Step 2: The quality rating (q_n) was calculated by the following formula:

$q_n = V_n - V_{id} / S_n - V_{id}$

Where, V_n- Observed value of the n^{th} parameter; V_{id}- Ideal Value of the n^{th} parameter (7.0 for pH and 0 for all other parameters).

Step 3: The WQI was calculated by the below mentioned formula.

$WQI = [(q_n wn)/w_n]$

Where, qn- Quality rating of the n^{th} parameter

Wn- Quality Unit weight of the n^{th} parameter

Determination of unit weight:

The WQI was calculated based on eleven influencing parameters in the study area and their unit weights are given in Table 2. The different categories of water for drinking based on WQI are depicted in Table: 1. the value of Sn was based on the desirable limits of all the parameters based on IS: 10500-1991 (Indian Standard Drinking Water Specification).

Study area

The vellar river basin originates from shavraiyan hills and its flow towards of salem, Perambalur and Cuddalore in the northern part of Tamilnadu which draining the near Parangipettai into Bay of Bengal. An approximately, total length of the vellar river is about 150 km, and its total area of basin 2520 Sq.km. The vellar river basin is located on northern part of Tamilnadu, southern India and between the latitudes 11° 13'N -12° 00' N and longitude 78° 13'E -79° 47'E. This basin is streams flow between the Ponnaiar,

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Paravanar and Cauvery river basins and the topography lying on Kalrayan hills, Attur Taluk of Salem District is drained by river upper vellar, VasistaNadhi known as upper Vellar joined with to form the Vellar in the Perambalur Taluk of Permabalur District (Fig: 1).

Table. 1 Indian Standard Drinking Water Specification

Parameters	Weight (Sn)	Relative Weight (Wn)
Ca	4	0.085
Mg	3	0.064
Na	4	0.085
K	3	0.064
Cl	5	0.106
Hco3	1	0.021
So4	3	0.064
pH	5	0.106
EC	5	0.106
TDS	5	0.106
TH	5	0.106

Hydrogen Ion Activity (pH mole/L)

pH values in Premonsoon are being recorded and their minimum is 7.2 and maximum is 8.2. Its average is 7.7, and Standard deviation is 0.26. During Postmonsoon, it is being recorded and their minimum is 7.1 and maximum is 8.4. Its average is 7.9 and Standard deviation is 0.26. All samples being recorded within the permissible limit for the both seasons. The Tables 2 & 3 show minimum, maximum and other statistical parameters. Spatial distribution of pH diagram (Fig. 2) shows that most of high alkaline concentration is occurred along central part of study area. pH of the groundwater of the area, which is mostly influenced by the seasonal changes, water resident time and the anthropogenic influence of the local area (Srinivasamoorthy et al. 2011).

Electrical Conductivity (EC µS/cm)

During Premonsoon, its minimum is 460 and maximum is 1250. Its average is 897, and Standard deviation is 204 (Table 2). During postmonsoon, EC values are being recorded and their minimum is 621 and maximum is 1433. Its average is 1110, and Standard deviation is 204 (Table 3). The higher concentration of EC is being observed in the central part of the district which same like TDS distribution in the groundwater of the area (Fig. 3). There is no permissible recommended for drinking purpose for EC by BIS (2012).

Total Dissolved solids (TDS mg/L)

During Premonsoon the TDS values shows minimum is 294 and maximum is 800. Its average is 574, and Standard deviation is 131 (Table 2).TDS in Postmonsoon are being recorded their minimum is 398 and maximum is 917. Its average is 711, and Standard deviation is 131 (Table 3). No samples being recorded above permissible limit of 2000 mg/L (BIS, 2012) for both seasons. Spatial distribution of TDS shows (Fig. 4) that the concentration increases towards flow direction of groundwater that affected by some anthropogenic sources, like, sewage, urban and agricultural runoff and industrial wastewater (Baride et al., 2015; Arulbalaji et al., 2017).

Calcium (Ca-mg/L)

Calcium concentration in premonsoon shows its minimum is 10 and maximum is 95. Its average is 54 and Standard deviation is 21. During postmonsoon, its values are being recorded and their minimum is 44 and maximum is 100. Its average is 74 and Standard deviation is 21. Only one samples being recorded above required limit of BIS (2012). The concentration increases toward the eastern direction of the area (Fig. 5).

Magnesium (Mg-mg/L)

Concentration of magnesium during premonsoon, its minimum is 20 and maximum is 69, its average is 42 and Standard deviation is 12 (Table 2), and postmonsoon are being recorded and their minimum is 24 and maximum is 79. Its average is 53 and Standard deviation is 12 (Table 3). There is no samples exceeding their permissible limits and its spatial diagram shows that higher concentration were distribute unevenly that could be reason of agricultural activities existing in the area may also directly or indirectly influence mineral dissolution in groundwater Srinivasamoorthy et al (2014) (Fig. 6).

Sodium (Na-mg/L)

Sodium concentration lies between 37 and 138 with an average of 74 and standard deviation of 19, from 44 to 109 with an average of 86 and standard deviation is 19 during premonsoon and postmonsoon seasons, respectively (Table 2&3). No samples were exceeding the permissible limit for drinking purpose (WHO 2013). Most of high concentrations of the samples were occurred along the central parts of the study area (Fig. 7). Presence of sodium in the groundwater of the area is from dissolution of source rock by rock water interaction process and also it can be the infiltration of domestic waste water at some locations (Feth et al. 1964; WHO 2013).

Potassium (K-mg/L)

The potassium concentration in the groundwater samples, ranged from 0.5 to 6.2 with an average of value of 2.9 and standard deviation is 1 during the premonsoon, 2.2 to 5.9 with average value of 4.3 and standard deviation is 1 during the postmonsoon. 20 mg/L is recommended as required limit for drinking purpose by BIS (2012) (Table 2&3). As per BIS recommendation for potassium, all samples from were under the required limit for drinking. Distribution of the ion during both seasons were shows uneven distribution probably due to weathering source rock influence by some anthropogenic with respect to location and seasons (Fig. 8).

Chloride (Cl-mg/L)

Chloride concentration of groundwater ranged from 73 to 237 with an average of 156 and standard deviation of 37, 76 to 234 with an average value of 168 and standard deviation of 37 premonsoon and postmonsoon, respectively (Table 2&3). There no samples exceeding the permissible limit of 1000 mg/L for drinking purpose of groundwater of the area which is recommended by BIS (2012). Spatial diagram shows that the higher concentration occurs towards eastern direction of the study area because of the slope of the basin toward that direction (Fig. 9).

Sulphate (SO_4-mg/L)

During postmonsoon, its values are being recorded and their minimum is 57 and maximum is 149. Its average is 113 and Standard deviation is 25 (Table 2&3). BIS (2012) required limit is 200 mg/l, permissible limit is 400 mg/L. No samples were recorded more than permissible limit for drinking purpose. Concentration of sulphate increases towards the eastern direction that’s due to surface contamination sources such as fertilizers and also from the oxidation of sulphide minerals (Narasimha and Sudarshan 2013) (Fig. 10).

Bicarbonate (HCO_3 – mg/L)

The Tables show premonsoon season, its minimum is 93, maximum is 268 and average is 168l. But, in the season of postmonsoon, bicarbonate concentration increases in groundwater and minimum value is 122, maximum value is 323 and average is 214 (Table 2&3). No values recommended by BIS (2012) for the purpose of drinking purpose. HCO_3 values also show the increasing trend towards the eastern direction the study area for both seasons (Fig. 11). Concentration of such element in groundwater dissolved from the carbonate contained minerals by availability of CO_2 and carbonic acid subsurface of the lithology (Lakshmanan et al. 2003).

Fluoride (F – mg/L)

Fluoride in premonsoon, its minimum is 0.1 and maximum is 3.6. Its average is 2.7 and Standard deviation is 0.79, and during postmonsoon, its minimum is 0.1 and maximum is 3.8. Its average is 2.7 and Standard deviation is 0.73. Totally 65 samples were exceeding the permissible for consumption of human for both seasons (Table 2&3). Fig. 4.12 shows the uneven distribution of fluoride during the pre and post monsoon season. There are many research has been conducted and reported for the high fluoride concentration in groundwater in the same lithology especially in southern India. Fluoride concentration from 0.8mg/l to 14.7mg/l in Salem and Namakkal districts, Tamilnadu Srinivasamoorthy et al 2010 reported the concentration ranges from 0.1mg/l to 4mg/l in Mettur, Salem district Tamilnadu.

Wilcox diagram

Where the ions mentioned in the formula are expressed in mille equivalents per liter (meq. Fig. 13 and Table 4 explained that 27% of samples in Premonsoon and 6% of samples in postmonsoon were fall in "very good to good" condition and 73% of samples in premonsoon and 94% of samples in postmonsoon were fall in "Good to permissible" condition for irrigation purposes. During the both seasons shows that most of groundwater samples in the study area were suitable for irrigation purposes.

U. S. Salinity Diagram

In the U.S.S.L. diagram, the plots of ground water chemistry in the research area are shown in Fig. 14 and Table 5. The majority of samples in the research area during both seasons fell into the C3S1 category, with 79 percent in the premonsoon and 97 percent in the postmonsoon. C2S1 is the next most common group in both seasons, accounting for 15% of premonsoon samples and 3% of postmonsoon samples. The C3S1 category samples show significant salinity in groundwater, which means it can't be utilized on land with limited drainage. However, special salinity management may be required, and plants with high salt tolerance ability should be planted. Low sodium water can also be utilized for irrigation on practically all soils with little risk of dangerous exchangeable sodium levels (Aravinda 1999), As well as, this category indicates that the quality of groundwater used for irrigation in the research area is moderate in all seasons.

Permeability Index (PI)

Values of PI shows, 99% of samples are of class I category and 1% of samples are of class II category during both pre and postmonsoon seasons (Fig. 15), which explained that most of the groundwater samples in the study area were excellent condition for irrigation purpose.

Sodium Absorption Ratio (SAR)

All of the samples throughout both monsoons are in "excellent" condition, according to SAR observations in the study region (Table 7). As a result, it implies that all of the study area's locations were suitable for irrigation purposes.

Total Hardness

Total hardness, given as $CaCO_3$, measures the amount of calcium and magnesium in water, as well as other minor elements including aluminum, manganese, iron, and zinc (Prasanth et al. 2012). Table 4.8 shows the results and classification. In the study area, Total Hardness (TH) concentration in groundwater was classified as "very hard" in 49 percent of premonsoon samples and 89 percent of postmonsoon samples, and "hard" in 50 percent of premonsoon samples and 11 percent of postmonsoon samples. Only 1% of premonsoon samples reveal "moderate" conditions suitable for industrial application (Sawyer and McCarty 1967). The distribution of hardness of groundwater shows the values increases toward eastern direction in premonsoon and during postmonsoon it shows the concentration in high in all locations expect few locations in western direction of study area (Fig. 16).

Mechanisms controlling the chemistry of groundwater (Gibb's plots)

In both the cation and anion plots, the samples from the research area during the premonsoon and postmonsoon (Fig. 17) fall quite close to the Rock-water interaction zone with high evaporation conditions, and some of the samples fall outside the plot. Despite the fact that evaporation considerably increases the concentrations of ions created by chemical weathering, resulting in greater salinity, the majority of samples were under saturated with aquifer medium source rock for both seasons (Gibbs 1970).

Hydrochemical facies of the groundwater (Piper-Trilinear diagram)

Based on the Piper-Trilinear diagram, the groundwater samples fall in the field 6 (Ca–Mg–Cl type, Ca–Mg dominant Cl type, or Cl dominant Ca–Mg type waters) during both monsoon (Fig. 18). The diagram indicate that reverse ion exchange and dissolution and mixing zone in the majority of the samples; such water will have a permanent hardness and will not deposit residual sodium carbonate in irrigation use, preventing foaming. The most of the sample of the mechanisms described showed weathering of magnesium-bearing minerals in various rock types, particularly ultrabasic rocks. Very few samples shows Na-Cl types during premonsoon that probably due to long resident of time groundwater in subsurface.

Conclusion

EC values in the study area show that the groundwater in the study area is excellent and good as such suitable for irrigation purpose and recommended for drinking purpose. The groundwater in the study area is also within the class of none and Slight to moderate based on TDS classification. The Ec of the study area being recorded within the permissible limit for the both seasons. The major like Ca, Mg, Na, K, So4 are in the permissible limit and Hco3 & F are slightly above in permissible limit due to Concentration of such element in groundwater dissolved from the carbonate contained minerals by availability of CO2 and carbonic acid subsurface of the lithology. The Wilcox, U.S Salinity, SAR and PI results indicates the both season's shows that most of groundwater samples in the study area were suitable for irrigation purposes. As per GIIBS plot the majority of samples were under saturated with aquifer medium source rock for both seasons. The most of the sample of the mechanisms described showed weathering of magnesium-bearing minerals in various rock types, particularly ultrabasic rocks. Very few samples shows Na-Cl types during premonsoon that probably due to long resident of time groundwater in subsurface.

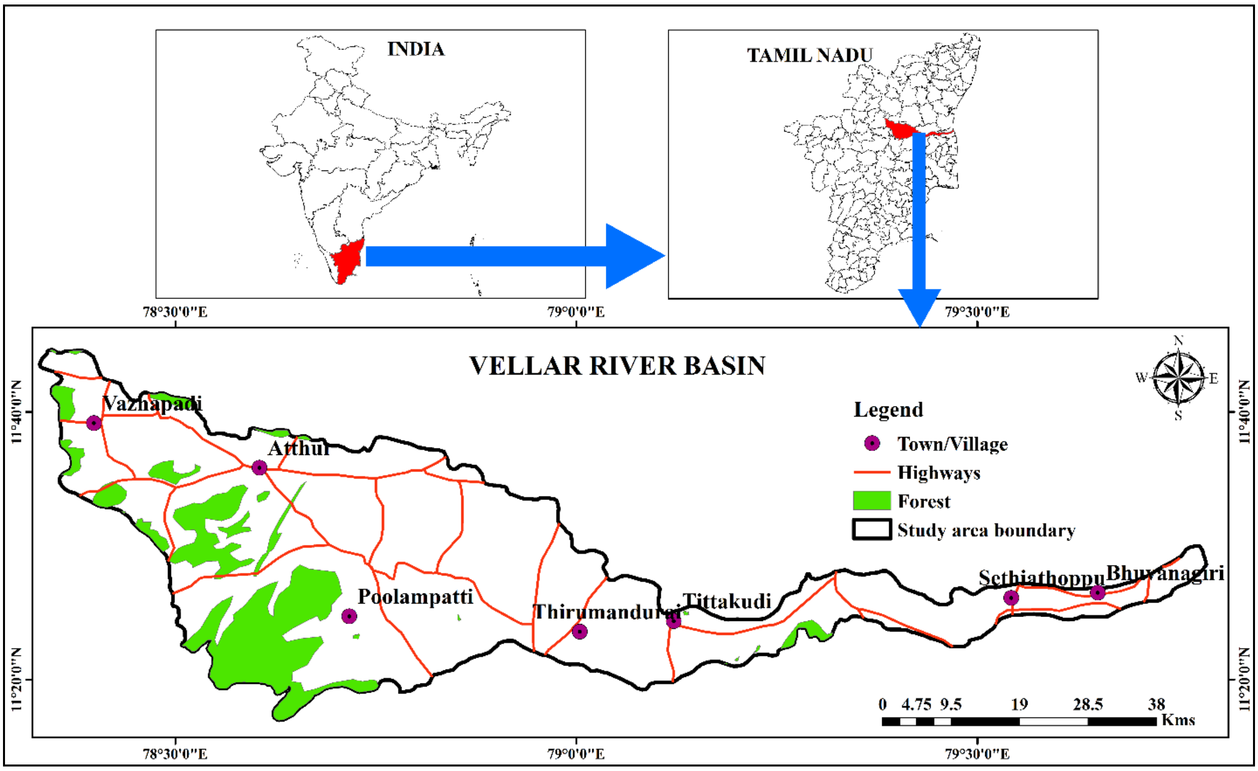

Fig: 1 Study area Map

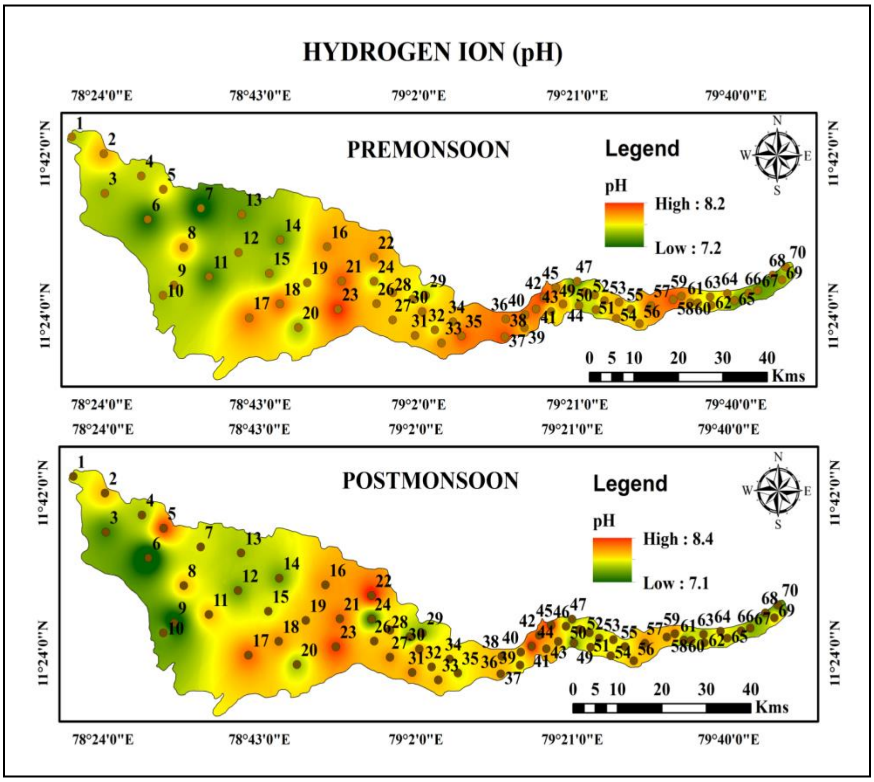

Fig 2. Spatial distribution of Hydrogen Ion activity (pH).

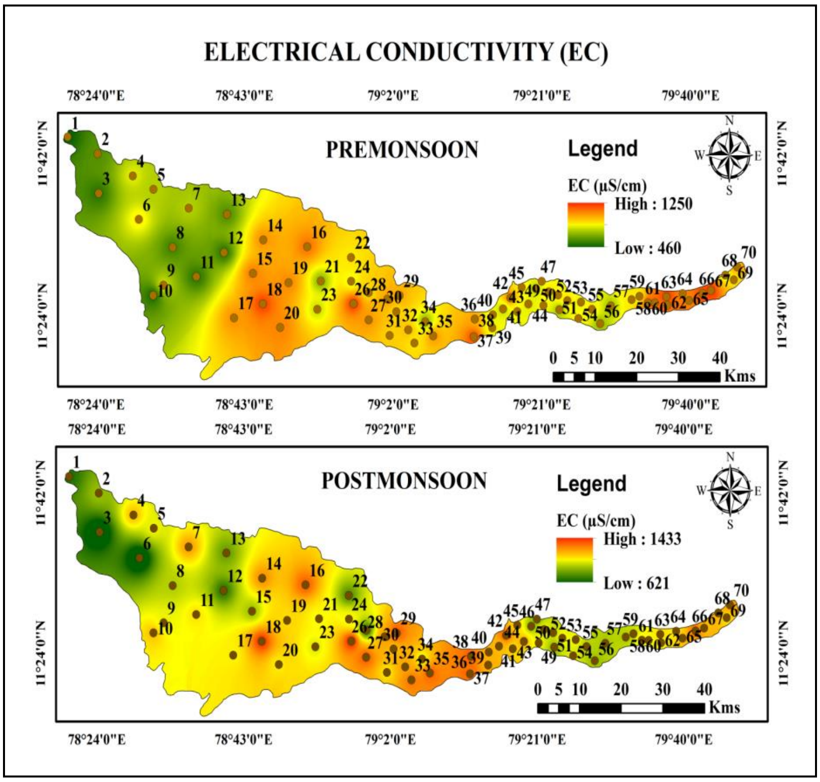

Fig 3. Spatial distribution of Electrical conductivy.

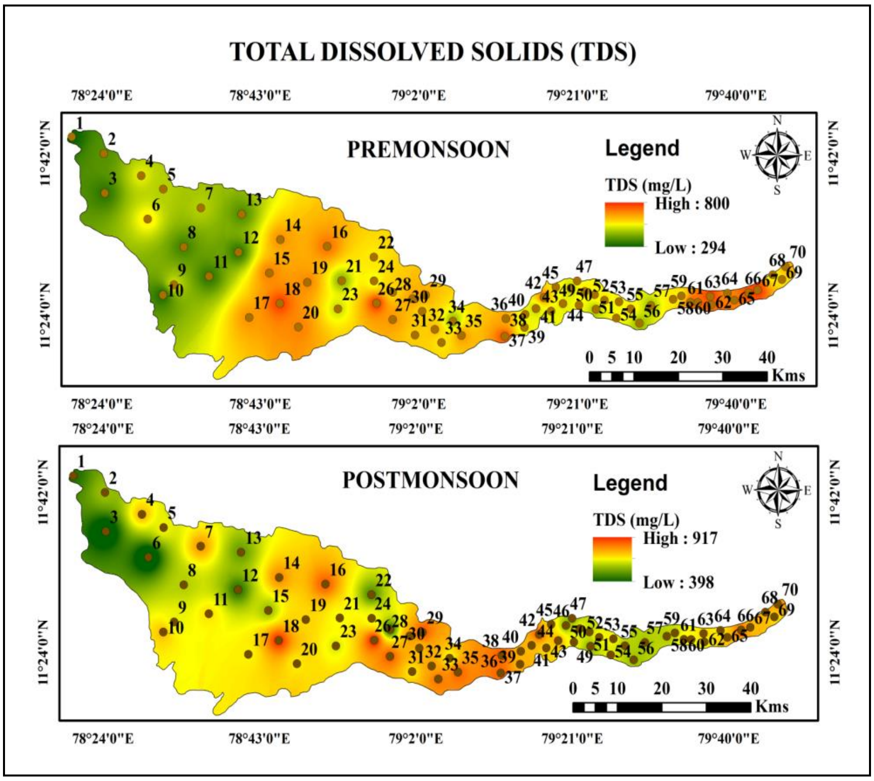

Fig 4. Spatial distribution of Total Dissolved Solids.

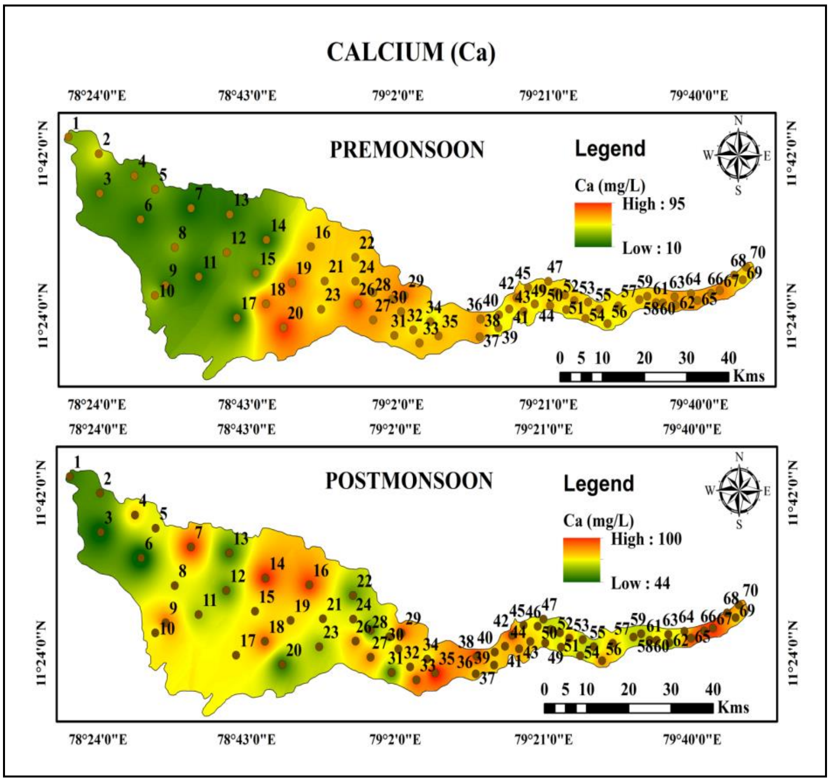

Fig 5. Spatial distribution of Calcium.

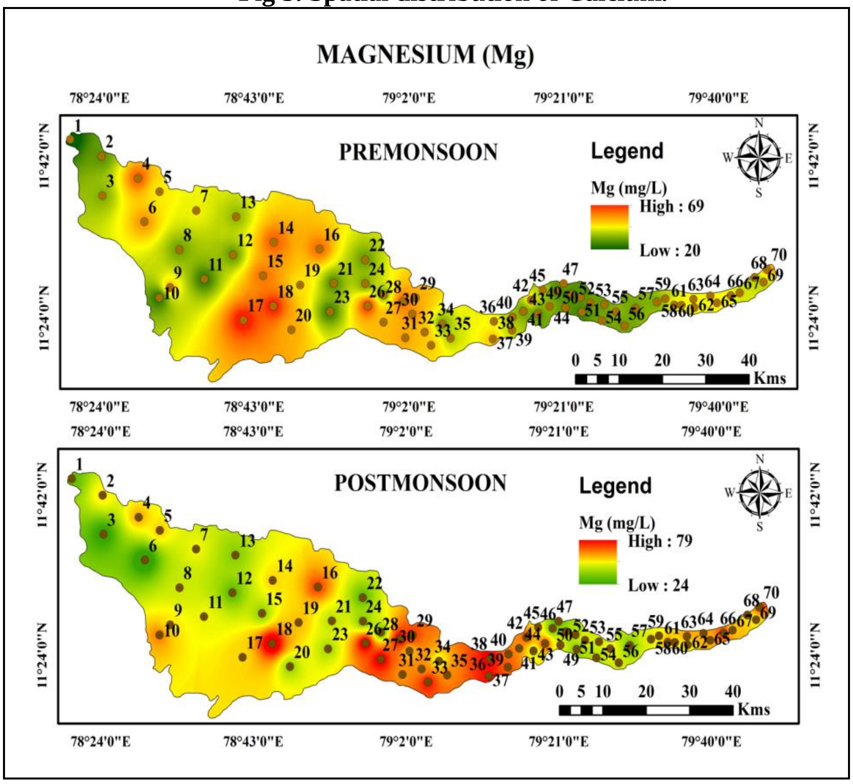

Fig 6. Spatial distribution of Magnesium

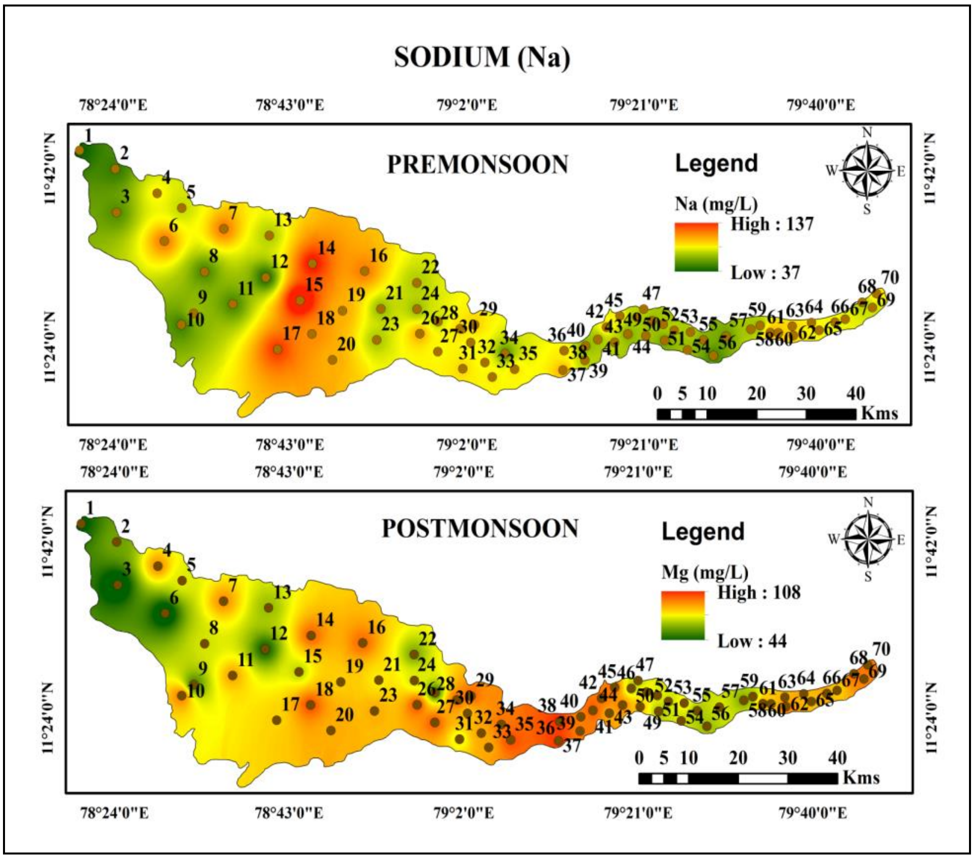

Fig 7. Spatial distribution of Sodium.

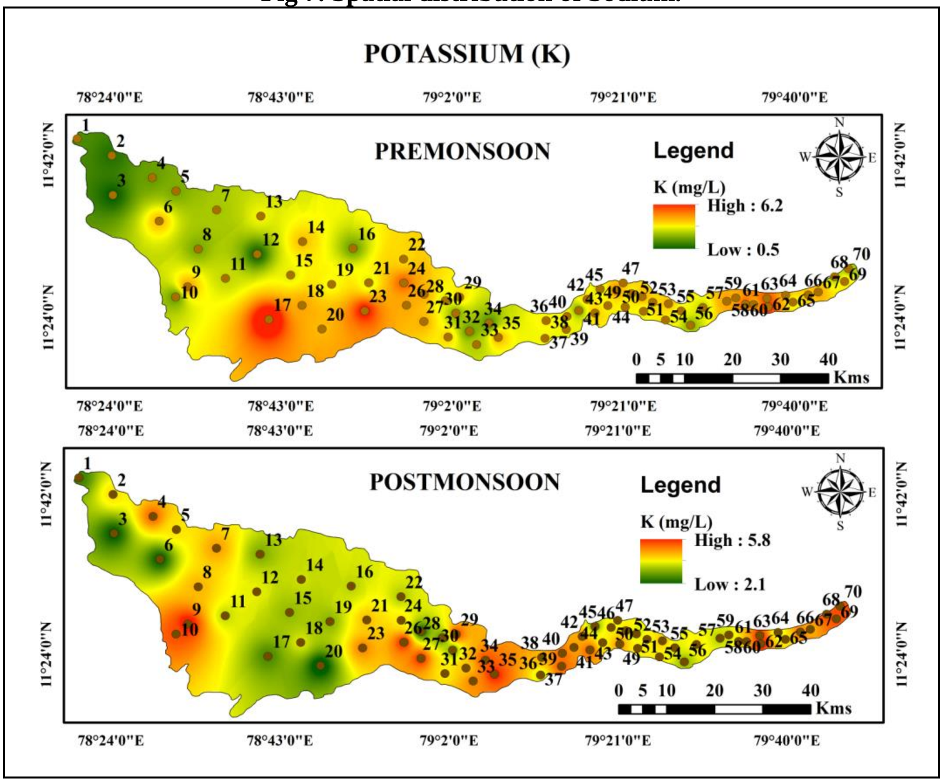

Fig 8. Spatial distribution of Potassium.

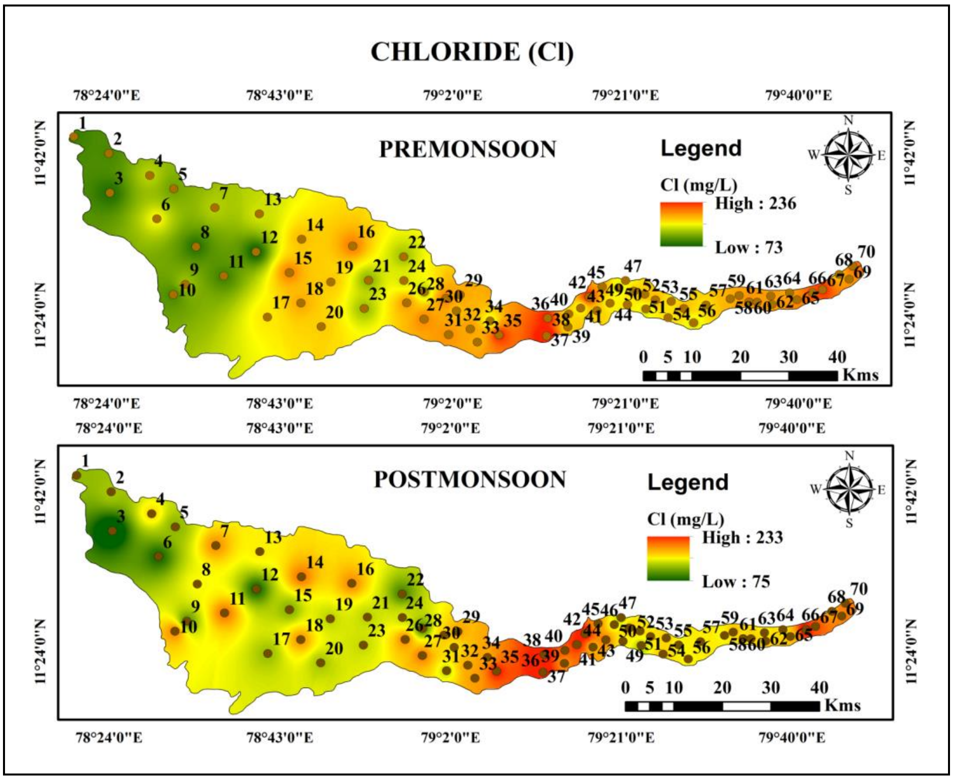

Fig 9. Spatial distribution of Chloride.

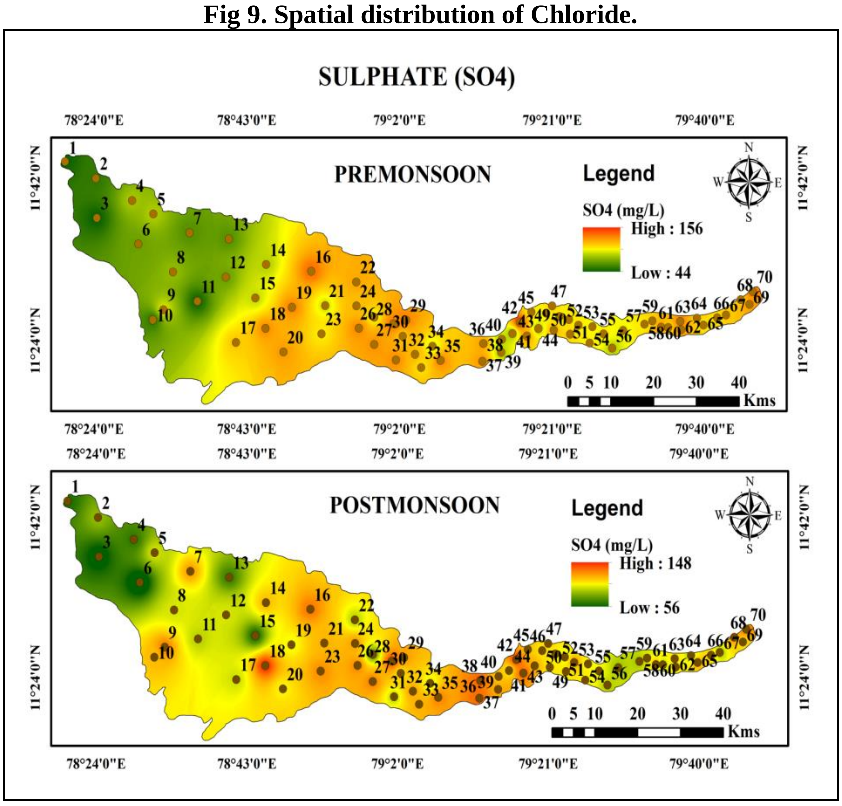

Fig 10. Spatial distribution of Sulphate.

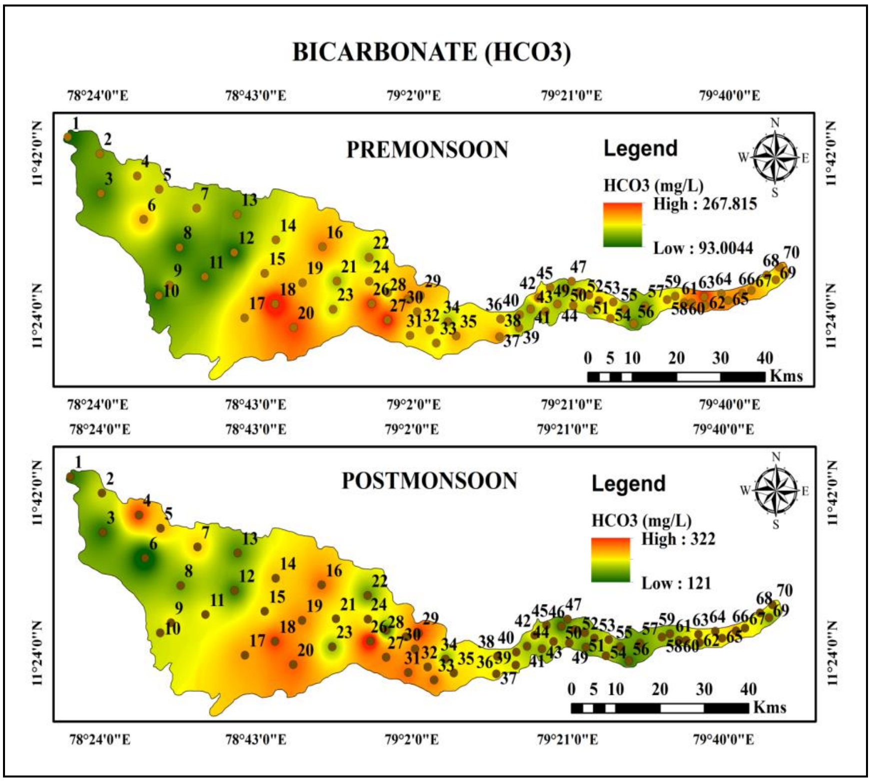

Fig 11. Spatial distribution of Bicarbonate.

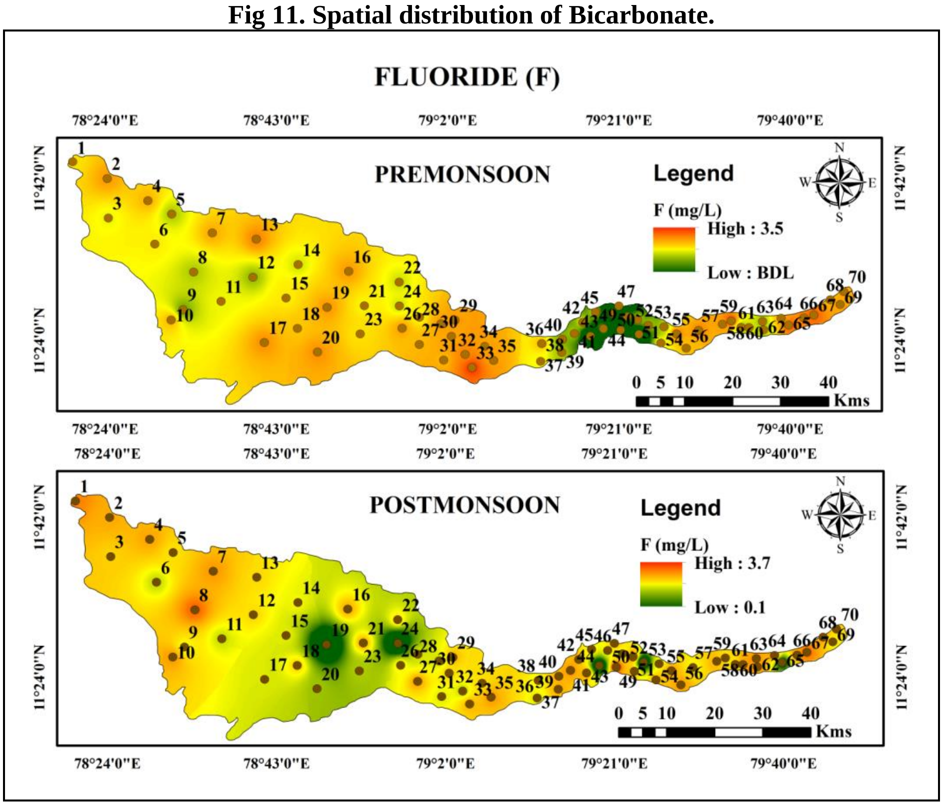

Fig 12. Spatial distribution of Fluoride.

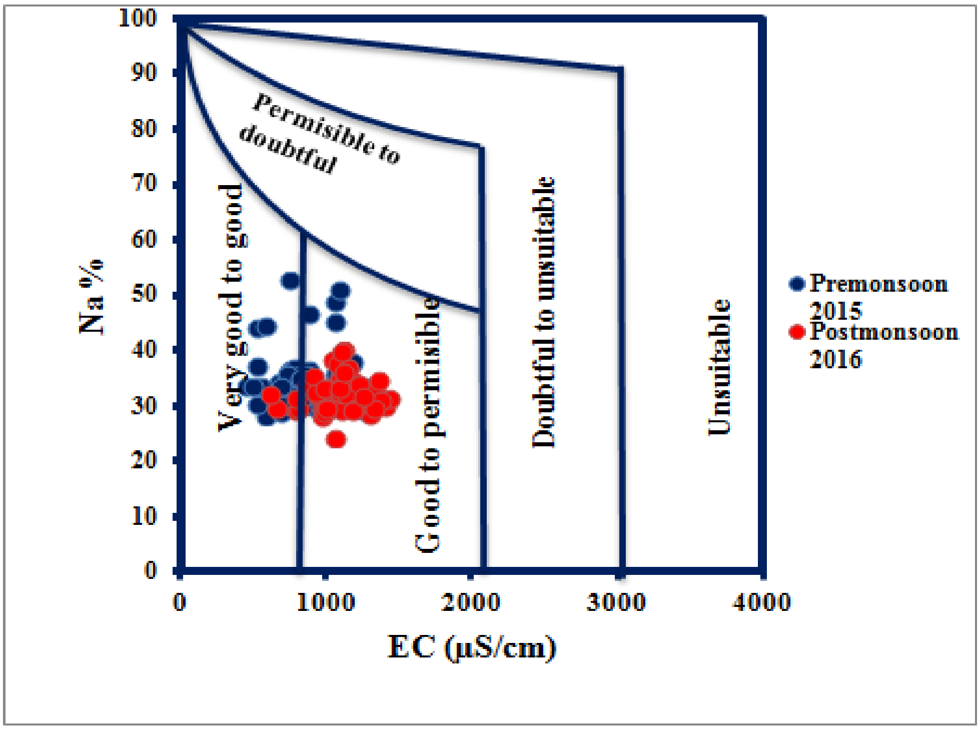

Fig 13. Wilcox diagram for classification of groundwater for irrigation purpose.

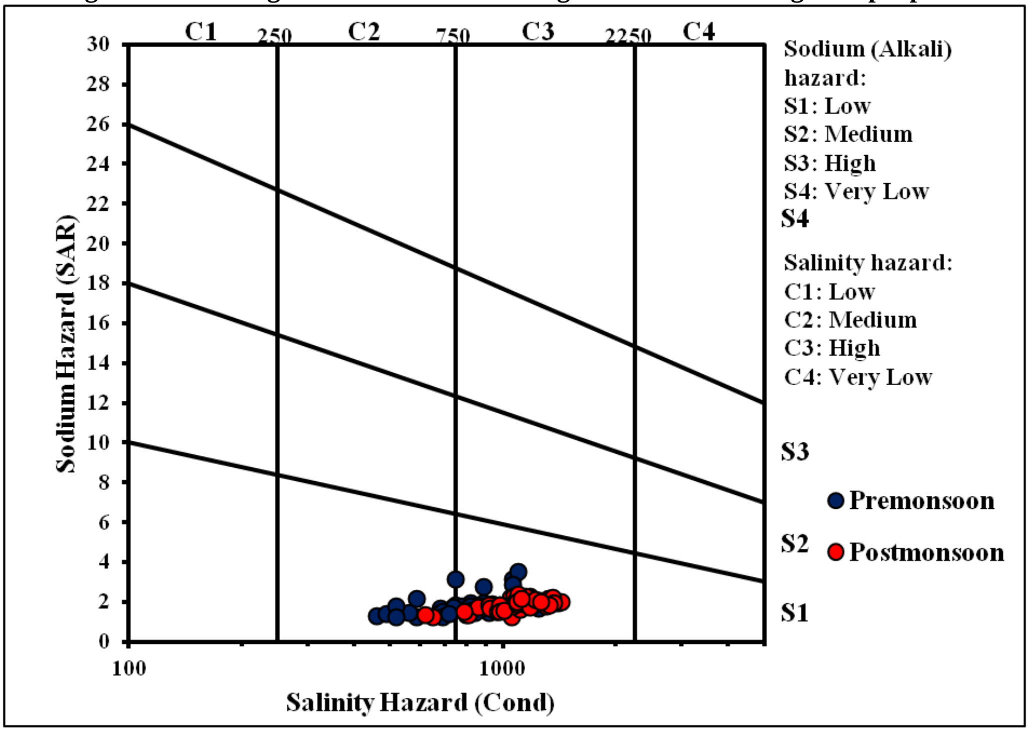

Fig 14. USSL diagram for classification of groundwater for irrigation purpose.

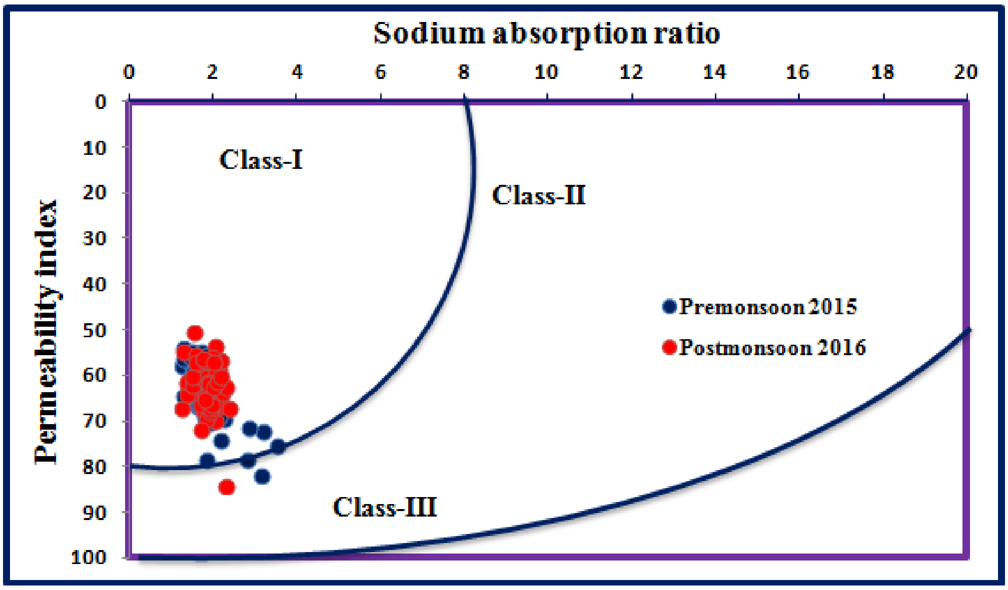

Fig 15. Permeability Index for classification of groundwater for irrigation purpose.

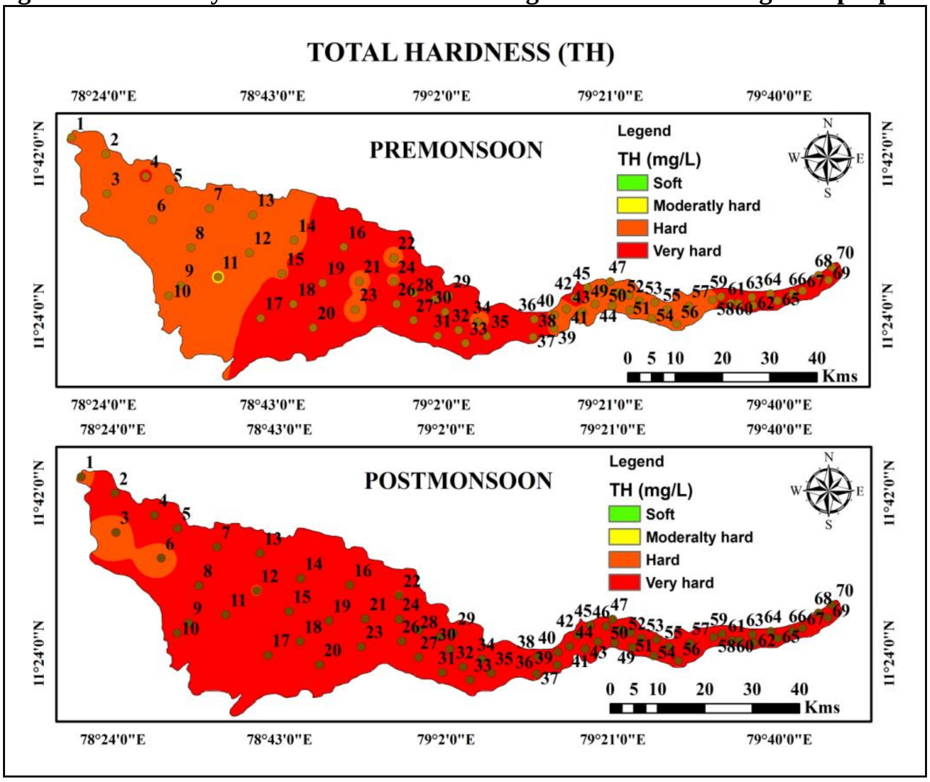

Fig 16. Classification of Total Hardness for Industrial and domestic purpose.

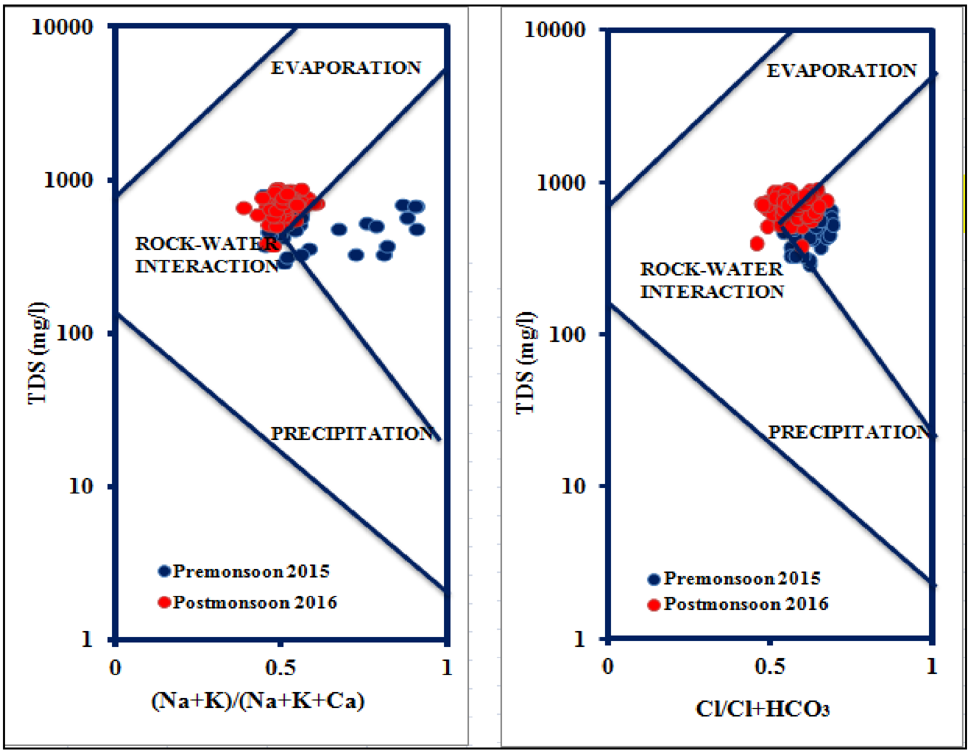

Fig 17. Mechanisms controlling the chemistry of groundwater (Gibb's plots).

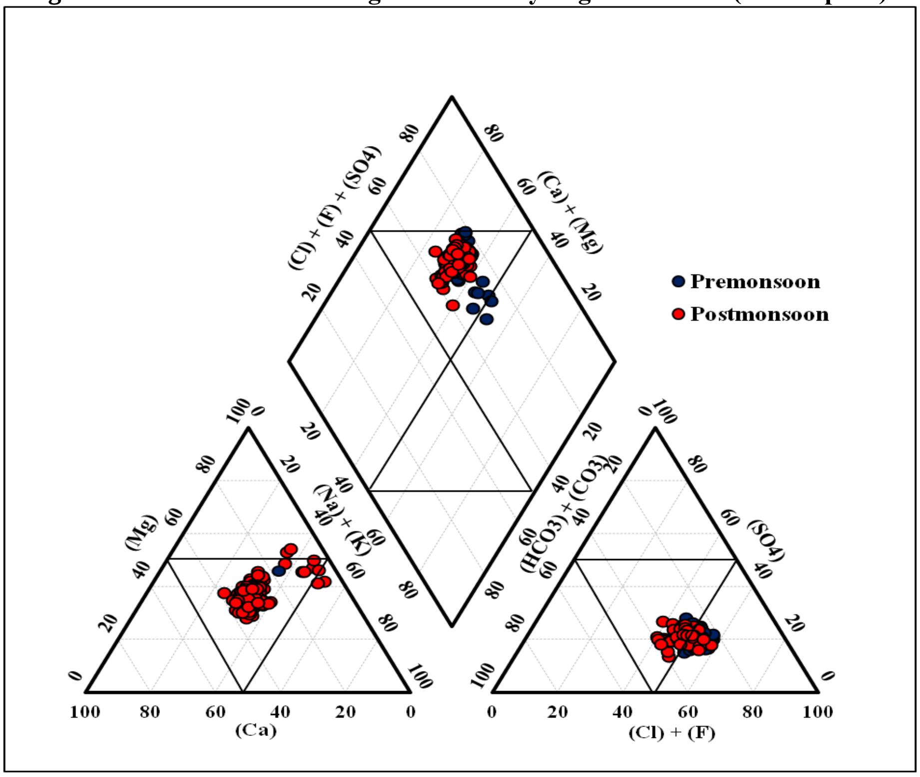

Fig 18. Hydrochemical facies of the groundwater (Piper-Trilinear diagram)

Table 2. Min, max, and ave BIS (2012) guideline value for groundwater parameters during Premonsoon.

Parameters	Min	Max	Ave	Std.Dev.	R. Limit	P. Limit	< R. limit	>R.Limit	> P. Limit
pH	7.2	8.2	7.7	0.26	6.5-8.5	-		70	
EC (µS/cm)	460	1250	897	204	No limits recommended				
TDS (mg/L)	294	800	574	131	500	2000	18	52	0
Ca (mg/L)	10	95	54	21	75	200	61	9	0
Mg (mg/L)	20	69	42	12	30	100	7	63	0
Na (mg/L)	37	138	74	19	200 (WHO 2013)		200	0	
K (mg/L)	0.56	6.26	2.93	1	20	-	70	0	0
Cl (mg/L)	73	237	156	37	250	1000	70	0	
SO4 (mg/L)	44	157	101	25	200	400	70	0	0
NO3 (mg/L)	0	0	0	0	45	-			
HCO3 (mg/L)	93	268	168	41	No limits recommended				
F (mg/L)	0.1	3.6	2.7	0.79	1	1.5	5	0	65

Table 3. Min, max and ave BIS (2012) guideline value for groundwater parameters during Postmonsoon.

Parameters	Min	Max	Ave	Std.Dev.	R. Limit	P. Limit	< R. limit	>R.Limit	> P. Limit
pH	7.1	8.4	7.9	0.26	6.5-8.5		0	70	0
EC (µS/cm)	621	1433	1110	204	No limits recommended				
TDS (mg/L)	398	917	711	131	500	2000	2	68	0
Ca (mg/L)	44	100	74	21	75	200	38	31	1
Mg (mg/L)	24	79	53	12	30	100	2	68	0
Na (mg/L)	44	109	86	19	200 (WHO 2013)		70	0	0
K (mg/L)	2.2	5.9	4.3	1	20	-	70	0	
Cl (mg/L)	76	234	168	37	250	1000	70	0	0
SO4 (mg/L)	57	149	113	25	200	400	70	0	0
NO3 (mg/L)	0.0	0.0	0.0	0	45	-			
HCO3 (mg/L)	122	323	214	41	No limits recommended				
F (mg/L)	0.1	3.8	2.7	0.73	1	1.5	4	1	65

Table 4. Groundwater classification for irrigation purpose based on Wilcox diagram.

Category	Premonsoon		Postmonsoon	
	No. of samples	% of samples	No. of samples	% of samples
Very good to good	19	27	4	6
Good to Permissible	51	73	66	94
Permissible to Doubtful	0	0	0	0
Doubtful to Unsuitable	0	0	0	0
Unsuitable	0	0	0	0

Table 5. Groundwater classification for irrigation purpose based on U. S. Salinity Diagram.

Category	Premonsoon		Postmonsoon	
	No.of samples	% of samples	No.of samples	% of samples
C1S1	0	0	0	0
C2S1	15	21	2	3
C3S1	55	79	68	97
C4S1	0	0	0	0
C3S2	0	0	0	0
C4S2	0	0	0	0
C4S3	0	0	0	0
C4S4	0	0	0	0

Table 6. Groundwater classification for irrigation purpose based on Permeability Index (PI).

Category	Premonsoon		Postmonsoon	
	No. of samples	% of samples	No. of samples	% of samples
Class-I	69	99	69	99
Class- II	1	57	1	57
Class-III	0	0	0	0

Table 7. Groundwater classification for irrigation purpose based on Sodium Absorption Ratio (SAR).

Range	Category	Percentage of samples falling this category	
		Premonsoon	Postmonsoon
<10	Excellent	70	70
18-Oct	Good	5	0
18-26	Doubtful	0	0
>26	Unsuitable	0	0

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