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Research Paper

SPATIO-TEMPORAL VARIATIONS OF HYDROGEOCHEMICAL PARAMETERS AND QUALITATIVE ASSESSMENT OF GROUNDWATER IN THE CHELLUR WATERSHED, MALAPPURAM DISTRICT, KERALA, INDIA

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The primary objective of this work is to examine the spatio-temporal variations of groundwater quality parameters of Chellur watershed in Kerala and to assess the suitability of groundwater for irrigation purposes. Groundwater samples were collected from 10 open wells and 2 bore wells during pre-monsoon and post-monsoon seasons. The samples were analyzed for Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Total Hardness (TH), major ions such as calcium, magnesium, sodium, potassium, chloride, etc. The spatial variation diagrams of various physico-chemical parameters were drawn using ArcGIS. The suitability of groundwater for irrigation purposes was assessed using the parameters such as EC, SAR (Sodium Adsorption Ratio) and Sodium percentage (Na%). From Wilcox plot, it was observed that all the samples of both pre-monsoon and post-monsoon seasons fall in the excellent to good category. The plot of USSL diagram showed that the groundwater samples from Chellur watershed belongs to C1-S1 (low salinity-low SAR) and C2-S1 (medium salinity-low SAR) categories in both seasons. It could be inferred that majority of groundwater samples in the study area fall within the permissible limits prescribed for irrigation.

Keywords: Chellur watershed, Spatio-temporal variation, Sodium adsorption ratio, Sodium percentage

INTRODUCTION

Water is one of the most essential natural resources for sustaining life. It is likely to become critically scarce in the coming decades, due to continuous increase in its demands, rapid increase in population and expanding economy of the country. The increase of human population leads not only to the decrease in freshwater, but also to the degradation of water quality. The temporal variations in the quantity and quality of

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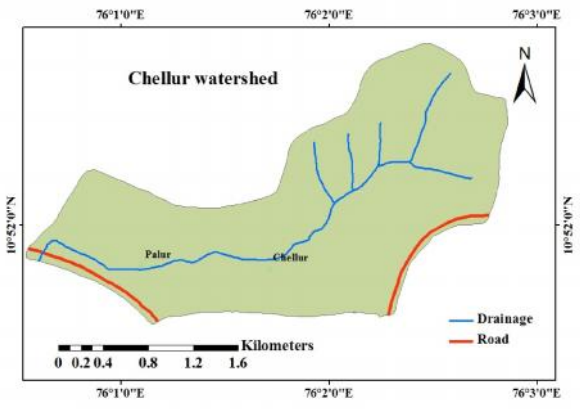
available water can cause significant fluctuations in the economy of a country. Consequently, the need for conservation, optimum utilization and management of this precious resource for the betterment of the economic status of the country is supreme.

Determination of physical, chemical and bacteriological quality of water is essential for assessing its suitability for various purposes like drinking, domestic, agricultural and industrial uses. A number of studies on groundwater quality with respect to drinking and irrigation purposes have been carried out in different parts of the world (Singh and Khare, 2008; Kaka *et al.*, 2011; Thilagavathi *et al.*, 2012; Sarala and Babu, 2012; Jain *et al.*, 2012; Akpoborie and Efobo, 2014; and Goswamee *et al.*, 2015). Specific objectives of the present study are (i) to examine the spatio-temporal variation in the groundwater quality of Chellur watershed and (ii) to assess the suitability of groundwater in the area for irrigation purpose.

The study area, Chellur watershed is located in the Kuttippuram Gramapanchayath of Tirur Taluk in Malappuram District of Kerala (SOI Toposheet No. 58 B/1). It spreads between 10°51'37" and 10°52'48" N latitudes and 76°0'40" and 76°2'50" E longitudes covering an area of 4.75 sq.km (Figure 1). The climate is generally hot and humid; the range of temperature is varying between 20 °C and 30 °C. The average annual rainfall is 2900 mm. Weathered lateritic topsoil, laterite, and crystalline rock formations constitute the major lithology of the study area.

The area under study is experiencing severe water scarcity for about 6 months of a year inspite of the moderate rainfall during the rainy season. So the area is selected for thorough study in respect of geology, water bearing characteristics

Figure 1: Location Map of the Study Area



of the rocks and physiography of the area. High population density, less scope of water recharging, steep slope, extensive laterite mining, etc., are found to be the main reasons for the water stress prevalent in the study area. The majority of the people in this region depend on agriculture. A substantial amount of water is used for domestic and agricultural purposes.

MATERIALS AND METHODS

In order to understand the chemistry of groundwater in the Chellur watershed area, groundwater samples were collected from 10 open wells and 2 bore wells during pre monsoon and post monsoon seasons. The water samples were analyzed for Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Total Hardness (TH), major ions such as Calcium, Magnesium, Sodium, Potassium, Chloride, etc., in the laboratory following standard methods (APHA, 1998). The pH and EC were measured during sampling and noted. Sodium and potassium in the samples were analysed using Flame photometer. Calcium and Magnesium were estimated by the EDTA titrimetric method, whereas Chloride was determined by argentometric titration using standard silver nitrate as reagent.

Base map was prepared from SOI toposheet of 1:50,000 scale in the ArcGIS platform. Spatial interpolation maps of various physico-chemical parameters in the pre monsoon and post monsoon samples were prepared using the Spatial Analyst tool. The analytical results have been evaluated to ascertain the suitability of groundwater of the study area for irrigation purpose. Water quality parameters such as Sodium Adsorption Ratio (SAR), and sodium percentage were calculated and used for the irrigation suitability study. Graphical methods such as Wilcox and USSL diagrams were also employed to verify the irrigation suitability of groundwater in the Chellur watershed.

RESULTS AND DISCUSSION

Physicochemical Parameters of Groundwater

Based on the analytical results, standard physico-chemical parameters such as Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Total Hardness (TH), calcium, magnesium, sodium, potassium and chloride were calculated and is presented in Table 1.

The pH of the samples in the study area was found to vary from 5.5 to 8.5 in the post monsoon season and 3.84 to 8.13 in the pre monsoon season. The low values were reported from two wells near the valley fills in the southeastern part of the study area. The maximum value was found in the well located near the dumping site of Kerala Soaps and Detergent Company (KSDC), which is closed now. The electrical conductivity values in the pre monsoon season ranged from 31 µS to 632 µS showing maximum variation, whereas in the post monsoon except the highest value reported, all values are almost uniform. The spatial variation diagrams of both seasons are represented in Figures 2a and 2b. The TDS values in the pre monsoon varies from 20 ppm to 405 ppm (Figure 2c). Post monsoon values are not showing much variation (Figure 2d).

The groundwater samples collected from the study area in the pre monsoon season have hardness values ranged between 400 to 140 ppm. The maximum values reported from borewell samples (400 ppm and 340 ppm) could be due to the long residence time of ground waters in the rocks. Based on the hardness classification

Table 1: Statistical Details of Physico-Chemical Parameters

Parameters	Pre Monsoon			Post Monsoon		
	Minimum	Maximum	Average	Minimum	Maximum	Average
EC	31	632	168.75	88	506	173.42
pH	3.84	8.13	5.83	5	8.5	6.5
Na	2	25	6.42	1.8	18.3	5.05
K	3	17	8	3.3	16.1	7.62
Ca	10	40	21.5	9.2	36.2	20
Mg	2.1	11	5.3	2.9	21.13	8.05
Cl	46.2	81.65	68.38	18	71.4	48.3
TH	140	400	207.5	23.5	105	53.03
TDS	20	405	107.17	56	324	110.67

(Todd, 1980), most of the groundwater samples fall under hard water category. Bore well samples fall under very hard water category. Post monsoon values of total hardness varied from 21.3 to 105 ppm. The total hardness variation in the study area is shown in Figures 3a and 3b. In the pre monsoon season, maximum and minimum concentration of chloride is noted in the central and southeastern parts of the study area respectively. Spatial variation of chloride is shown in Figures 3c and 3d.

Spatial variation of potassium is shown in Figures 4a and 4b. The concentration of potassium in the pre monsoon and post monsoon season is found to be uniform except one sample with maximum value located at the south central part of the area which may be due to the excessive use of fertilizers in the paddy fields. Spatial variation of sodium is shown in Figures 4c and 4d. In the pre monsoon sample analysis, the concentration of calcium ranged between 10 to 40 ppm.The maximum concentration is seen in the southern part of the study area and the minimum in the southeastern part. Calcium concentration in post monsoon varies from 9.2 to 24 ppm. All values are within the permissible limits and the values are showing gradational increase towards the southwestern part of the study area (Figures 5a and 5b). The concentration of magnesium is found to be maximum in the bore well waters. Spatial variation of magnesium is shown in Figures 5c and 5d.

Suitability for Irrigation Purposes

The quality of water used for irrigation is vital for crop yield, maintenance of soil productivity and protection of the environment (Singh and Singh, 2008). In the present work, to examine the

Figure 2: Spatial Distribution of Electrical Conductivity in Pre Monsoon (a) and Post Monsoon (b); Spatial Distribution of Total Dissolved Solids in Pre Monsoon (c) and Post Monsoon (d)

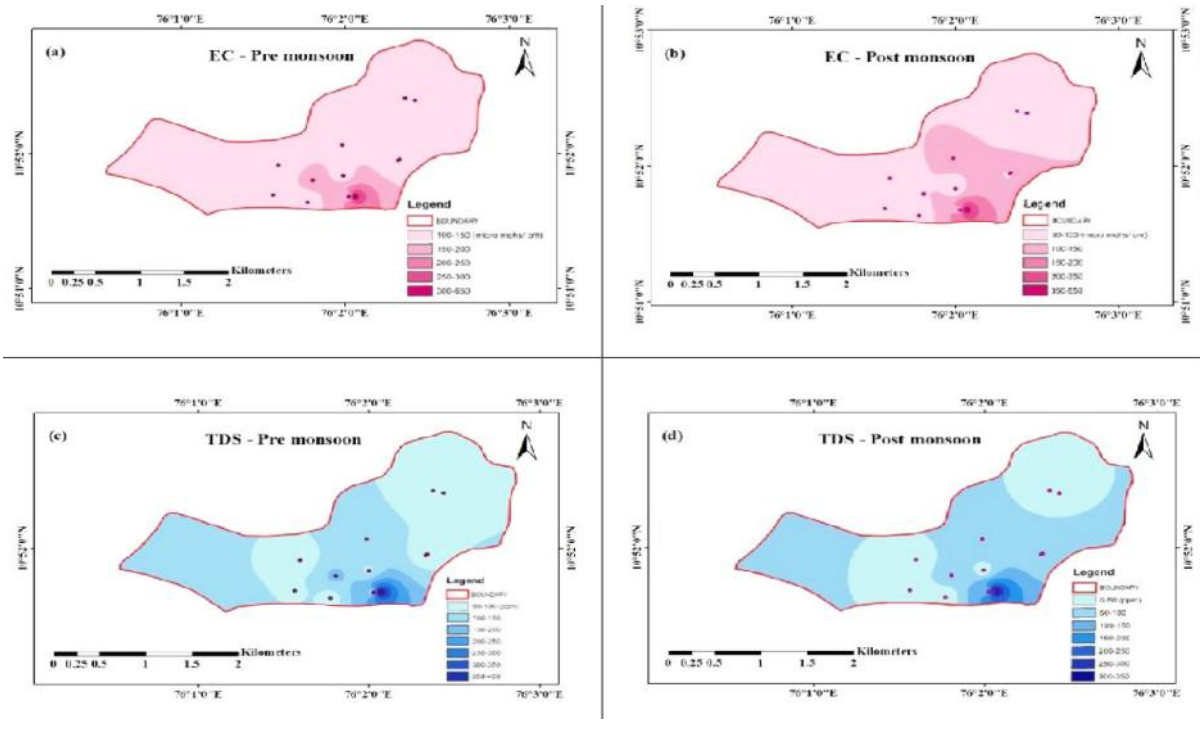


Figure 3: Spatial Distribution of Total Hardness in Pre Monsoon (a) and Post Monsoon (b); Spatial Distribution of Chloride in Pre Monsoon (c) and Post Monsoon (d)

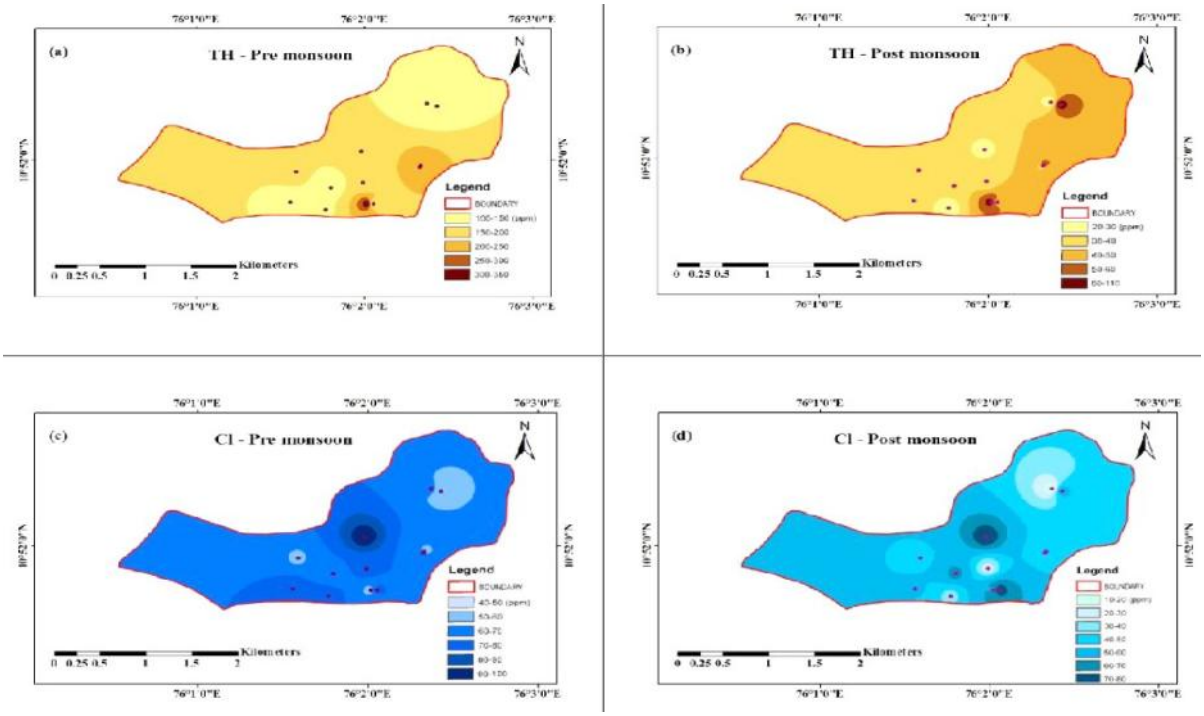


Figure 4: Spatial Distribution of Potassium in Pre Monsoon (a) and Post Monsoon (b); Spatial Distribution of Sodium in Pre Monsoon (c) and Post Monsoon (d)

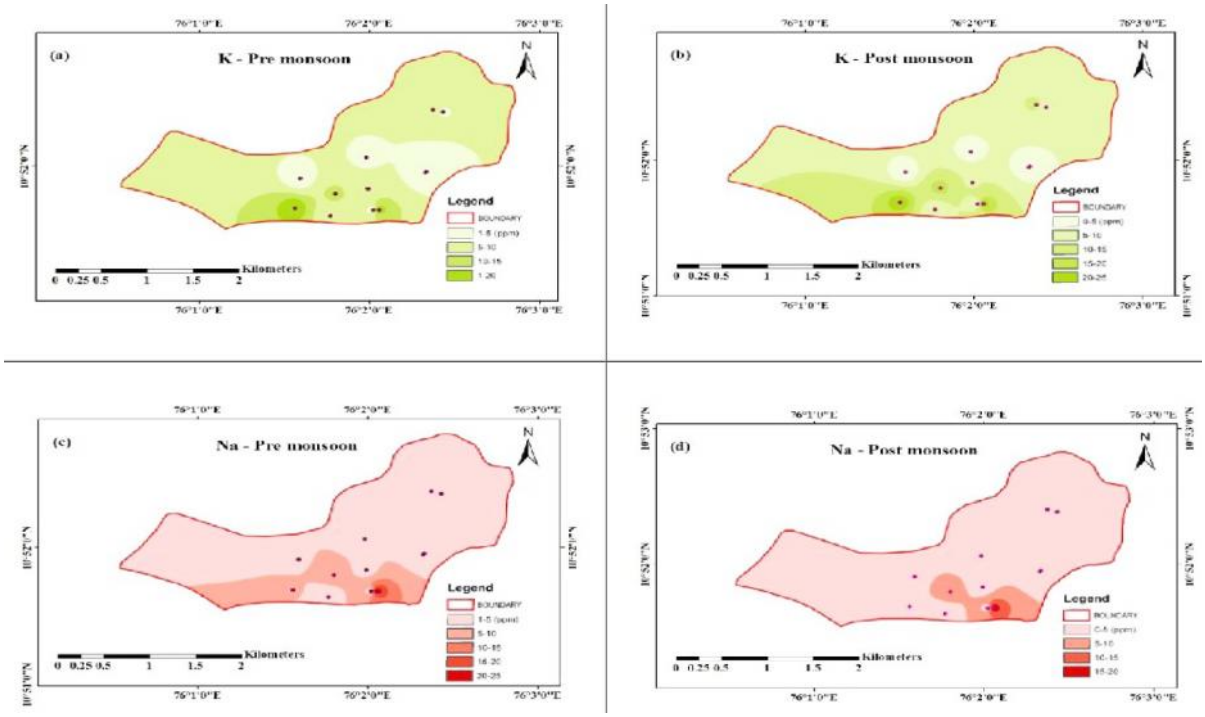
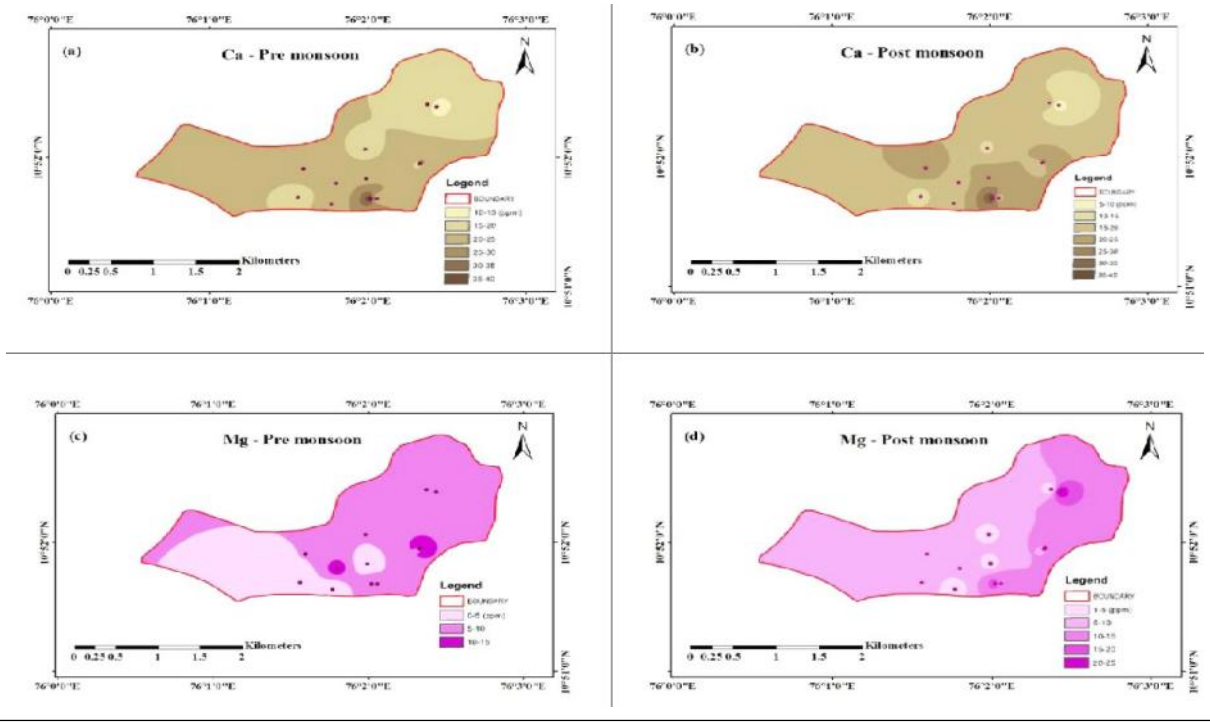


Figure 5: Spatial Distribution of Calcium in Pre Monsoon (a) and Post Monsoon (b); Spatial Distribution of Magnesium in Pre Monsoon (c) and Post Monsoon (d)



suitability of groundwater for irrigation purposes, the parameters such as EC, SAR and Sodium percentage were used. Graphical methods such as Wilcox and USSL diagrams were also employed to verify the irrigation suitability of groundwater in the Chellur watershed.

Electrical Conductivity (EC)

Electrical conductivity is a good measure of salinity hazard to crops as it reflects the TDS in groundwater. The total concentration of soluble salt or salinity hazard in irrigation water can be expressed in terms of Electrical Conductivity (EC). Classification of groundwater based on electrical conductivity is shown in Table 2. Based on this classification, the water samples from the present study area belongs to the excellent and good waterclass types.

Percent sodium (% Na)

Sodium concentration is important in classifying the water for irrigation purposes because sodium concentration can reduce the soil permeability and soil structure (Todd, 1980; and Domenico and Schwartz, 1990). Sodium percentage is calculated by the formula:

$$\%Na = [Na+K]\times100/[Ca+Mg+Na+K]$$

The values of sodium percent vary from 7.34% to 54.27% in pre-monsoon and 6.42% to 40.77% in post-monsoon season. Based on the sodium percentage, the groundwater sampes in the study area belongs to excellent, good and permissible classes (Table 3).

Wilcox diagram

Wilcox diagram is a graphical method used to verify the suitability of water quality for irrigation purpose. In this diagram, percent sodium is plotted against electrical conductivity (Wilcox, 1955). The chemical analysis data of pre-monsoon and post-

Table 2: Quality of Groundwater Based on Electrical Conductivity

EC (µmhos/cm)	Water Class	Sample Nos.	
		Pre-Monsoon	Pre-Monsoon
< 250	Excellent	OW 3, OW 4, OW 5, OW 6, OW 7, OW 8, OW 9, OW 10, BW 1, BW 2	OW 2, OW 3, OW 4, OW 5, OW 6, OW 7, OW 8, OW 9, OW 10, BW 1, BW 2
250 - 750	Good	OW 1, OW 2	OW 1
750 - 2000	Permissible		
2000 - 3000	Doubtful		
> 3000	Unsuitable		

Table 3: Suitability of Groundwater for Irrigation Based on Sodium Percentage

% Sodium	Water Class	Samples		Percentage	
		PRM	POM	PRM	POM
<20	Excellent	OW 3, OW 5, OW 6, BW 1, BW 2	OW 3, OW 5, OW 6, BW 1, BW 2, OW 7, OW 10	41.67%	58.34%
20 - 40	Good	OW 2, OW 7, OW 8, OW 9, OW 10	OW 2, OW 4, OW 8, OW 9,	41.67%	33.33%
40 - 60	Permissible	OW 1, OW 4	OW 1	16.66%	8.33%
60 - 80	Doubtful				
>80	unsuitable				

monsoon seasons are plotted in the Wilcox diagram (Figure 6). Percentage of sodium plotted on Wilcox diagram indicates that the entire samples of both pre-monsoon and post-monsoon seasons belong to excellent to good category.

Sodium Adsorption Ratio (SAR)

The sodium/alkali hazard is typically expressed as the Sodium Adsorption Ratio (SAR). This index quantifies the proportion of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in a sample (Todd, 1980; and Karanth, 1987). There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. If groundwater used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to the dispersion of the clay particles (Ragunath, 1987). Sodium adsorption ratio can be calculated by the equation,

$$SAR = Na/[(Ca+Mg)/2]^{1/2}$$

where all ionic concentrations are expressed in meq/l.

In the present study, sodium adsorption ratio is calculated for all the samples of both pre-monsoon and post-monsoon seasons. The values are varying from 0.11 to 1.36 in premonsoon and 0.07 to 0.85 in post-monsoon season. The computed values of all the samples are found to be less than 3 in both seasons and so they are classified as excellent for irrigation.

USSL Diagram

US Salinity Laboratory (USSL) has designed a diagram to interpret the combined effect of salinity

Figure 6: Wilcox Diagram

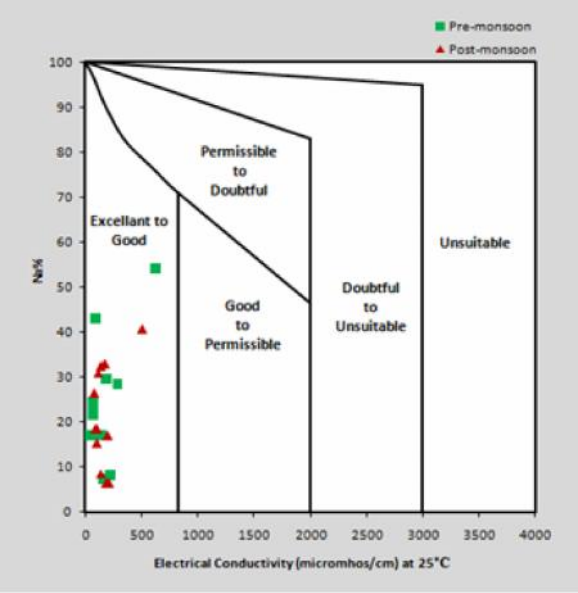
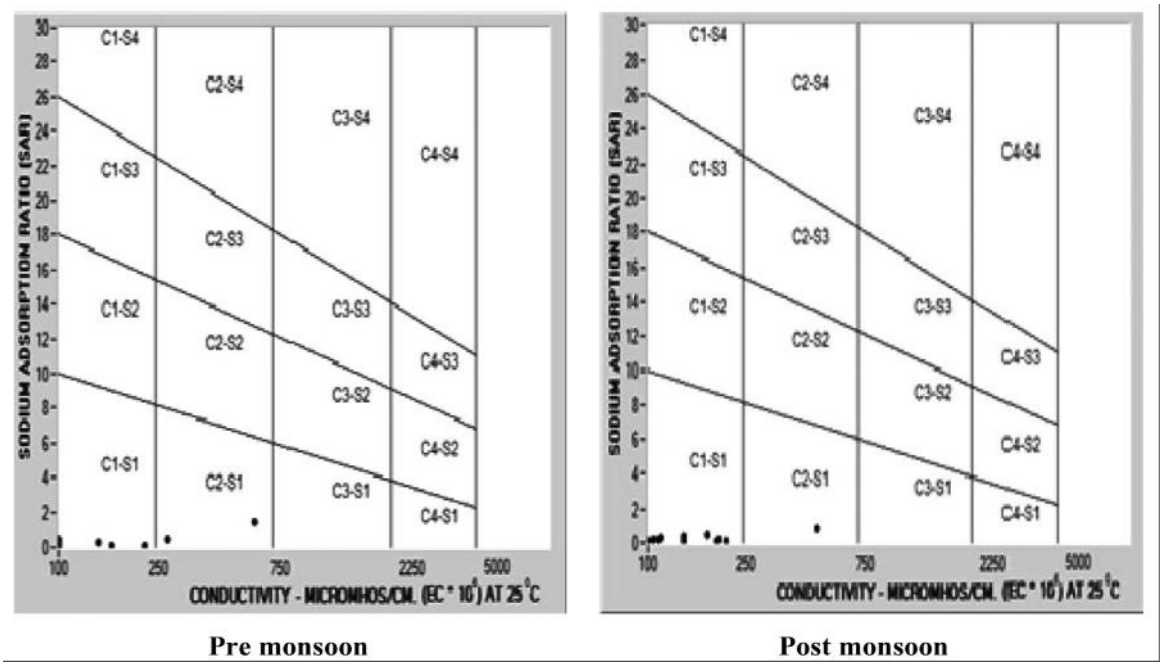


Figure 7: USSL Diagram for Classification of Irrigation Water



hazard and sodium hazard. The diagram classifies groundwater into C1, C2, C3, and C4 categories on the basis of salinity hazard and S1, S2, S3 and S4 categories on the basis of sodium hazard.The SAR and EC values of the water samples of pre-monsoon and post-monsoon seasons are plotted in the USSL diagram as shown in the Figure.7. According to USSL diagram, the groundwater samples from Chellur watershed belongs to C1-S1(low salinity-low SAR) and C2-S1(medium salinity- low SAR) categories in both seasons. Based on this, it is inferred that the groundwater in the study area is suitable for irrigation purpose.

CONCLUSION

The groundwater resources in the Chellur watershed were evaluated for their chemical composition and suitability for irrigation purpose. The analysed physico-chemical parameters were used to examine the spatio-temporal variation in the groundwater quality and also to assess the suitability of groundwater in the area for irrigation purpose. Spatial variation diagrams plotted shows that the highest value of most of the analyzed parameters was recorded in wells near the KSDC dumping site located in the south-eastern portion of the study area. In the Chellur watershed, majority of groundwater samples is within the permissible limits prescribed for irrigation in terms of electrical conductivity, Sodium Adsorption Ratio, Sodium percentage, Wilcox and USSL diagrams. According to USSL, ground water samples of study area fall under two categories, C1-S1 (low salinity-low SAR) and C2-S1 (medium salinity- low SAR). Wilcox diagram shows that all the samples are excellent to good for irrigation purpose. From all these, it is inferred that groundwater in the Chellur watershed is safe for irrigation.

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