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ORIGINAL ARTICLE

Ground Water Quality Study for irrigation in Upper Berach River Basin, Rajasthan State

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ABSTRACT
The present study was conducted to study suitability of ground water for Irrigation purposes. The water samples for the physico-chemical analysis were collected from the open well of the 95 locations from Upper Berach river basin to analyzed for TDS, pH, EC, Ca, Mg, Na, K, CO_3, HCO_3. The suitability of groundwater for irrigation use was evaluated by calculating Sodium Adsorption Ratio (SAR), Kelly's Ratio (KR), Residual Sodium Carbonate (RSC), Percent sodium (%Na) and Permeability Index (PI). The different water quality parameter maps of the Upper Berach river basin were prepared under GIS environment and the spatio-temporal variations of these parameters were analyzed.
Keywords: *Physico-chemical, Electrical conductivity, Percent sodium, SAR and Salinity*

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INTRODUCTION

Water, no doubt, is a boon of nature for the whole living world and is essential for variety of purposes to human beings as well as to plants and animals. Its many uses include drinking and other domestic uses, irrigation, power generation, transportation, industrial cooling, fishing, mining and fire fighting etc. Groundwater is one of the most valuable natural resources, which supports human health, socio-economic development, and functioning of ecosystems [7; 14]. Water pollution is the contamination of water bodies such as lakes, rivers, oceans, and groundwater [8]. It occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful constituents. Water pollution is a major problem in the global context [10]. Sometimes pollutants like plant nutrients, bacteria, viruses, pesticides, herbicides, hydrocarbons, heavy metals and other toxic chemicals can enter through the groundwater thereby polluting it. Shallow groundwater is often affected by the land use. The quality of groundwater has been affected through domestic, agricultural and industrial pollution. Nitrates is predominant in western of Delhi [3]. Groundwater in deeper aquifers beneath the layers of rock or clay that do not let water through has better protection from pollution because it is not directly connected to the surface environment. Contaminants that may be present in source water include: Microbial contaminants such as viruses and bacteria, from sewage treatment plants, septic systems, agricultural livestock operations and wildlife. Inorganic contaminants, such as salts and metals can be naturally occurring or come from urban storm-water runoff (streets and parking lots), industrial or domestic wastewater discharges, oil and gas production, mining or farming. Pesticides and herbicides from a variety of sources such as agriculture, urban storm-water runoff and residential uses. Organic chemical contaminants, including synthetic and volatile organic chemicals, are byproducts of industrial processes and petroleum production.They can also come from gas stations, urban storm-water runoff and septic systems. The Water Quality Index (WQI) is a simple method utilized as a part of surveying the general water quality using a group of parameters which reduce the large amounts of information to a single number, usually dimensionless, in a simple reproducible manner [2].Groundwater also discharges into streams and rivers. Nutrients and contaminants in groundwater can enter wetlands and streams, feed algal blooms and cause pollution. The problem of groundwater pollution has become so acute that unless urgent steps for abatement are taken groundwater resources may be damaged. The degradation of water quality has severe effects in context with drinking, agriculture and industrial purposes. Drinking impure

water results in various harmful diseases like diarrhea, blue baby diseases if excess of nitrate is present in water. In industries if water has more hardness due to chlorides and sulphides it is not suitable for the cleaning purposes. In agriculture if water has more salt concentrations then it reduces permeability of soil and infiltration is reduced. More nitrate concentration is harmful for drinking but safe for irrigation purposes. Keeping these facts in view a study on ground water study for irrigation purpose was carried out in the Upper Berach River Basin, Rajasthan State.

MATERIALS AND METHODS

Study Area

The upper Upper Berach is a river flowing through the state of Rajasthan in the western part of Rajasthan. It lies on the western part of India between the latitudes of $24^0 33'37.75"$ to $24^0 56'36.532"$ N and the longitudes of $73^0 38'6.256"$ to $74^0 5'33.104"$ E. In this study, the Upper Berach river originates in the hills of Udaipur and Rajasmand districts. The total catchments area of the basin is 1095.98 km^2. The area is characterized by sub-humid climate with an average annual rainfall of 630 mm. The general topography of the area is hilly and undulating.

Sample Collection

The study area was divided in 5 km x 5 km square grid. At least one water sample for the physico-chemical analysis was collected in each grid during post-monsoon and pre monsoon season of 2016-17. The locations of wells were recorded with the help of global positioning system (GPS). Total 95 ground water samples were collected from open wells using plastic bottles and were kept in the incubator at a temperature of so that no or minimum changes occur in the physico-chemical properties of the water samples.

Physico-Chemical Analysis

The physic-chemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Bicarbonate (HCO_3), Carbonate (CO_3), Chloride (Cl^{-}), and Sulphate (SO_4) were determined using standard methods. The methods used for estimation of various physic-chemical parameters are given in Table 1.

Table 1: Methods used for estimation of physiochemical parameters

S.No.	Parameters	Method	References
1	pH	Using Glass Electrode pH meter	Jackson [8]
2	Electrical Conductivity	Using EC meter	Wilcox [18]
3	Total Dissolved Solids	Using TDS meter	Singh and Kalra [11]
4	Calcium and Magnesium	EDTA titration	Cheng & Bray [5] and Diehl *et al.* [6]
5	Sodium	Flame Photometric method	Toth *et al.* [16]
7	Potassium	Flame Photometric method	Stanford and English [13]
8	CO_3 and HCO_3	Titration with standard H_2SO_4	A.O.A.C. [1]

Irrigation Water Quality Parameters

Water quality parameters such as RSC, SAR, %Na, PI and KR were calculated using standard formulae to check the suitability of ground water for irrigation purpose. Water quality parameters map was prepared under the GIS environment with ARC/GIS-10.1 software using IDWMA interpolation technique. Formulae to calculate irrigation water quality parameters as follows,

Residual sodium carbonate (RSC)

The residual sodium carbonate was calculated simply by subtracting the quantity of Ca + Mg from the sum total of carbonates and bicarbonates determined separately in a given sample and expressed in meq/l. Thus,

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+}) \quad \ldots 1$$

Sodium adsorption ratio (SAR)

Sodium adsorption ratio was calculated using the formula given below.

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

Where, all ionic concentrations are expressed in meq/l.

Percent sodium (%Na)

Wilcox [18] has proposed classification scheme for rating irrigation water on the basis of percent sodium (%Na). Sodium percent or the proportion of sodium among all the anions is usually expressed in terms of percent sodium. It was estimated that with the help of following relationship

$$\%Na = \frac{(Na+K)}{[Ca+Mg+Na+K]} \times 100 \quad \ldots 3$$

Where, Na, K, Ca, Mg are ion present in the ground water expressed in meq/l.

Permeability index (PI)

The permeability index was calculated by the following formula:

$$PI = \frac{Na + \sqrt{HCO_3}}{(Ca + Mg + Na)} \times 100 \quad \ldots 4$$

Where, all the values are in meq/l.

Kelly's ratio (KR)

Kelly's ratio was calculated by using the following expression:

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \quad \ldots 5$$

Where, concentrations are expressed in meq/l

RESULTS AND DISCUSSION

Groundwater quality for irrigation purposes

The suitability of groundwater for irrigation use was evaluated by calculating SAR, Kelly's Ratio (KR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP) and Permeability Index (PI). The various water quality criteria with classes and area are given in Table 3.

The waters having SAR values less than 10 are considered excellent, 10 to 18 as good, 18 to 26 as doubtful, and above 26 are unsuitable for irrigation use [17]. In the present study, SAR value of water sample for 85 villages, 9 villages and 1 village were found under excellent, good and unsuitable category during pre monsoon. SAR value of water sample for 93 villages were found under excellent category except two village Prakashpura and Bijna which is fall under good and doubtful category during post monsoon for irrigation use (Table 2).

The Kelly's ratio of unity or less than one is indicative of good quality of water for irrigation whereas above one is suggestive of unsuitability for agricultural purpose due to alkali hazards. The map of the variation of Kelly's Ratio (KR) in pre monsoon and post monsoon was prepared in GIS environment and shown from Fig.1a and Fig.1b. From these figures, it is revealed that Kelly's ratio is less than one (safe for irrigation) for 43.89 per cent and 52.36 per cent of total study area during pre and post monsoon period and Kelly's ratio is greater than one (unsafe for irrigation) for 56.11 per cent and 47.64 per cent of total study area during pre and post monsoon period. The Residual Sodium Carbonate (RSC) value exceeds 2.5 meq/l, the water is generally unsuitable for irrigation. If the value of RSC is between 1.25 and 2.5 meq/l, the water is marginally suitable, while a value less than 1.25 meq/l indicates safe water quality [17]. RSC in groundwater varies from -41.98 to 16.36 and -21.82 to 7.82 in pre monsoon and post Negative RSC indicates that Na^{+} buildup is unlikely since sufficient Ca^{2+} and Mg^{2+} are in excess of what can be precipitated as CO_3^{2-}. The map of the variation of Residual Sodium Carbonate (RSC) in pre monsoon and post monsoon was prepared in GIS environment and shown from Fig.1c to Fig.1d. From these figures, it is evident that RSC is less than 1.25 for 97.78 per cent and 98.92 per cent of total study area during pre monsoon and post monsoon period. This indicates that water in this area is safe for irrigation. RSC value varies between 1.25 to 2.5 for 1.07 per cent and 0.58 per cent of total study area. This indicates that water of this area is doubtful for irrigation use. RSC value is greater than 2.5 for 1.15 per cent and 0.50 per cent of total study area. This indicates that water of this area is unsuitable for irrigation use.

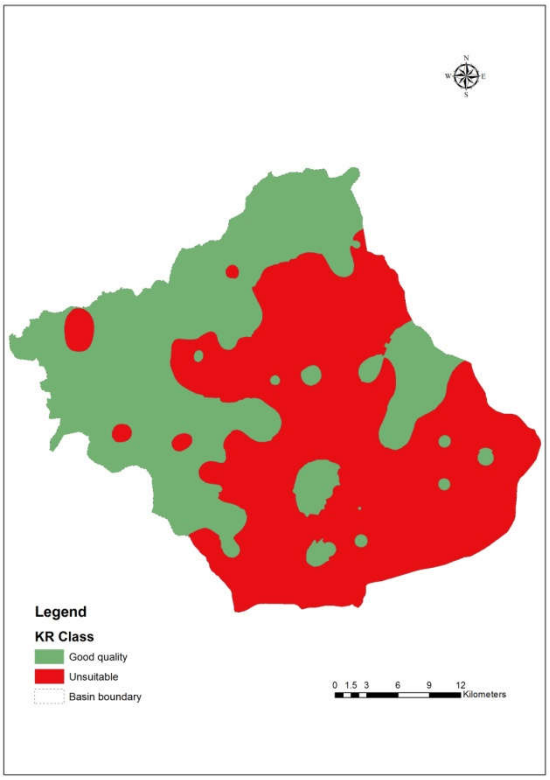

Fig.1 a: Variation of Kelly's ratio during pre-monsoon

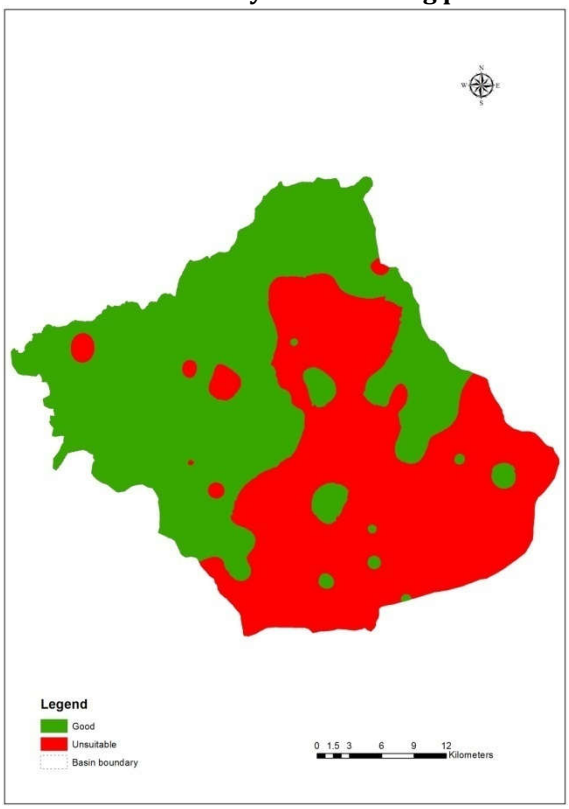

Fig.1b: Variation of Kelly's ratio during post-monsoon

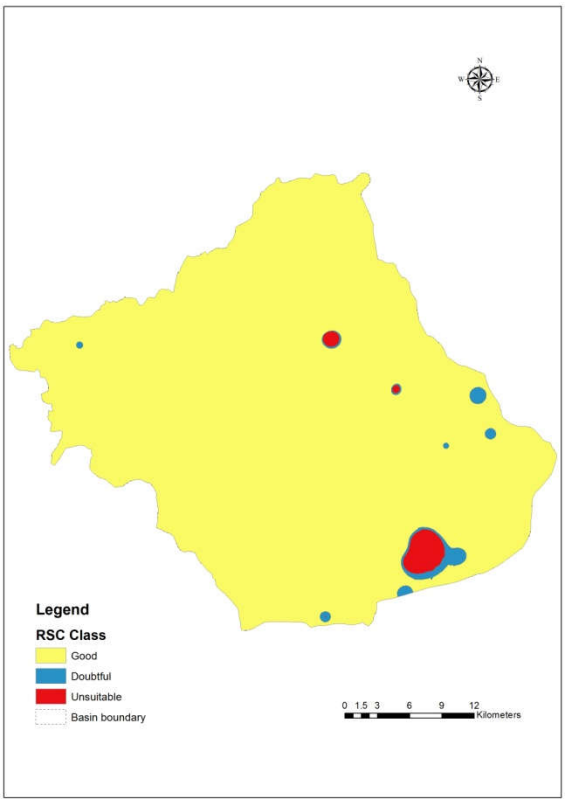

Fig.1 c: Variation of RSC during pre-monsoon

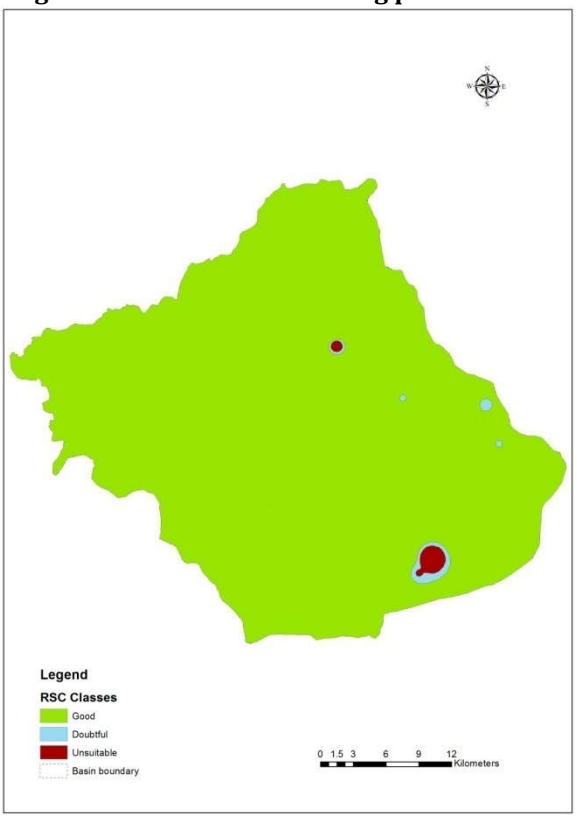

Fig.1 d: Variation of RSC during post-monsoon

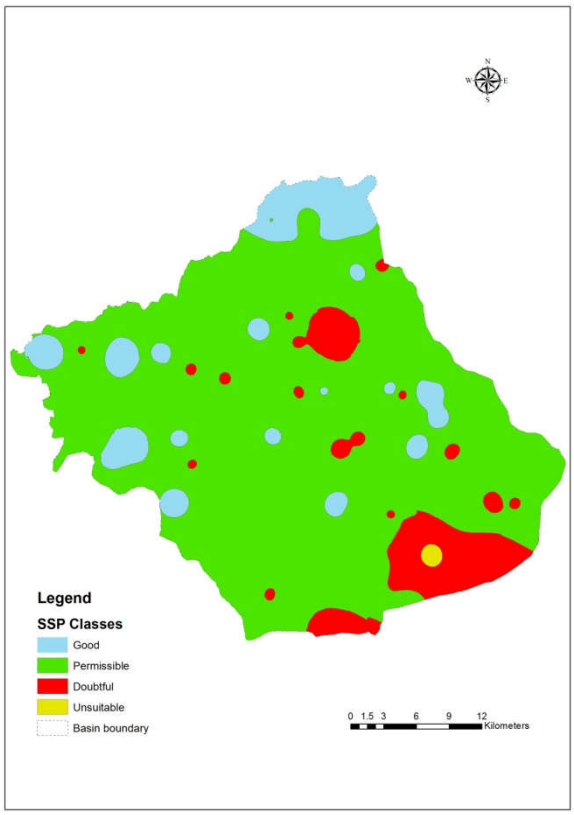

Fig.1 e: Variation of %Na during pre-monsoon

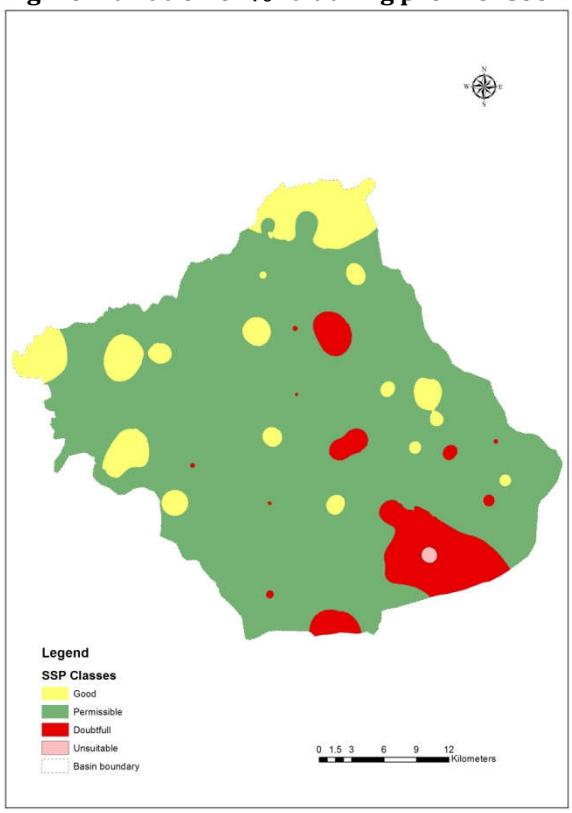

Fig.1 f: Variation of %Na during post-monsoon

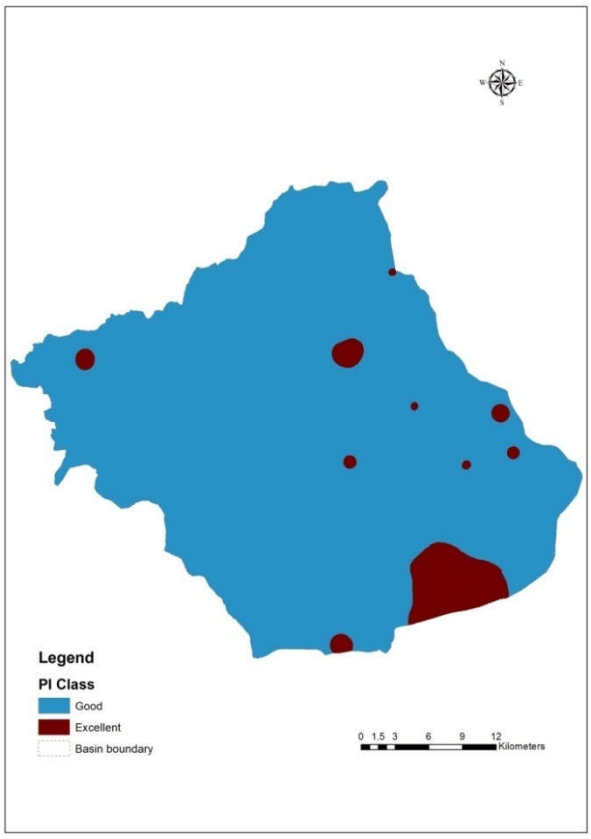

Fig.1 g: Variation of permeability index during pre-monsoon

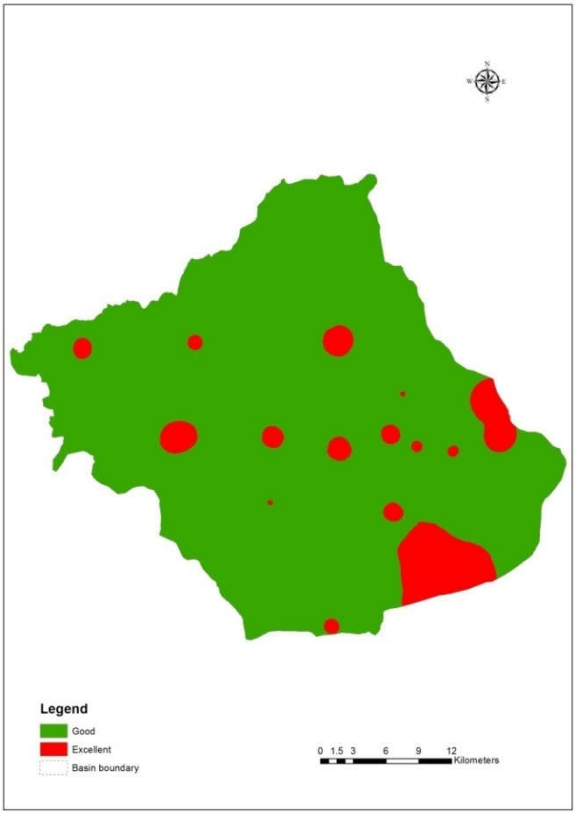

Fig.1 h: Variation of permeability index during post-monsoon

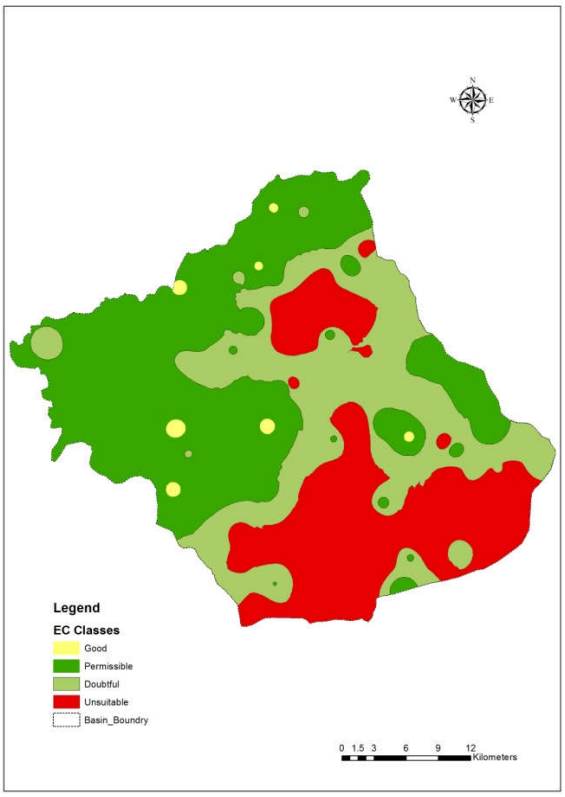

Fig.1 i: Variation of EC during Pre-monsoon

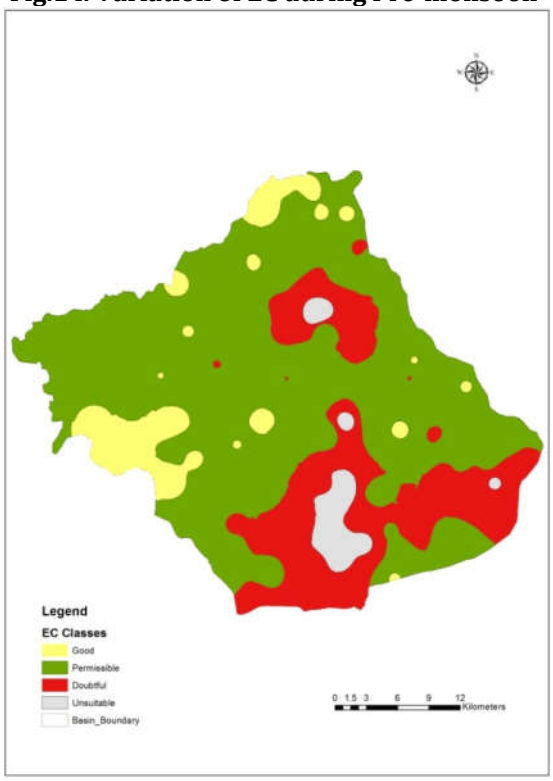

Fig. 1 j: Variation of EC during Post-monsoon

%Na values less than 20 are considered excellent, 20 to 48 as good, 40 to 60 as permissible, 60 to 80 as doubtful and above 80 are unsuitable for irrigation use by Wilcox [18]. The map of the variation of %Na in pre monsoon and post monsoon was prepared in GIS environment and shown from Fig.1e to Fig.1f. From these figures, it is evident that %Na value varies between 20 to 40 for 9.44 per cent and 10.18 per cent of total study area. This indicates that water of this area fall in good category for irrigation use. %Na value varies between 40 to 60 for 81.02 per cent and 82.06 per cent of total study area. This indicates that

water of this area fall in permissible category for irrigation use. %Na value varies between 60 to 80 for 9.27 per cent and 7.63 per cent of total study area. This indicates that water of this area fall in doubtful category for irrigation use. %Na value is greater than 80 for 0.26 per cent and 0.14 per cent of total study area. This indicates that water of this area fall in unsuitable category for irrigation use.

Table 2: Sodium hazard classes based on USSL classification

SAR	Sodium hazard class	Remark on quality	Pre-monsoon samples	Post-monsoon samples
<10	S1	Excellent	0.86-9.43 (85 samples)	0.76-9.43 (93 samples)
10-18	S2	Good	10.03-15.689 (9 samples)	13.82 (1 sample)
18-26	S3	Doubtful	Nil	19.45 (1 sample)
>26	S4	Unsuitable	34.28 (1 sample)	Nil

Table 3: Salinity hazard classes [18]

Salinity hazard class	EC in ds/m	Remark on quality
C1	0.100-0.250	Excellent
C2	0.250-0.750	Good
C3	0.750-2.250	Doubtful
C4	>2.250	Unsuitable

Table 4: Suitability of groundwater for irrigation purpose

Class	Area (km^2)		% Area	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Variation of Kelly's ratio				
i) Good	481.06	573.83	43.89	52.36
ii) Unsuitable	614.92	522.15	56.11	47.64
Variation of RSC				
i) Good	1071.67	1084.19	97.78	98.92
ii) Doubtful	11.71	6.30	1.07	0.57
iii) Unsuitable	12.60	5.49	1.15	0.50
Variation of permeability index				
i) Excellent	54.45	88.01	4.97	8.03
ii) Good	1041.53	1007.98	95.03	91.97
Variation of %Na				
i) Excellent	Nil	Nil	Nil	Nil
ii) Good	103.50	111.53	9.44	10.18
iii) Permissible	887.98	899.32	81.02	82.06
iv) Doubtful	101.62	83.60	9.27	7.63
v) Unsuitable	2.88	1.53	0.26	0.14
Variation of EC during pre monsoon				
i) Excellent	Nil	Nil	Nil	Nil
ii) Good	7.91	89.22	0.72	8.14
iii) Permissible	472.76	724.92	43.14	66.14
iv) Doubtful	317.96	244.02	29.01	22.26
v) Unsuitable	297.36	37.81	27.13	3.45

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The Permeability Index (PI) values > 75 indicate excellent quality of water for irrigation. If the PI values are between 25 and 75, it indicates good quality of water for irrigation. However, if the PI values are less than 25, it reflects unsuitable nature of water for irrigation. The map of the variation of PI was prepared in GIS environment as shown in Fig. 1g and Fig. 1h for pre and post monsoon period respectively. From these figures, it is observed that 95.03 per cent and 91.97 per of basin area has good quality water for irrigation purposes in pre monsoon period and in post monsoon period. PI value is greater than 75 for 4.97 per cent and 8.02 per cent of total study area. This indicates that water of this area fall in excellent category for irrigation use.

For the purpose of diagnosis and classification, the total concentration of soluble salts (salinity hazard) in irrigation water can be expressed in terms of specific conductance. Classification of groundwater based on salinity hazard [18] is presented in Table 3. It is revealed from the Fig.1i and Fig.1j about 29.01 per cent area in pre monsoon and 22.26 per cent area in post monsoon period shows water quality in doubtful range. In pre monsoon period 27.13 per cent and 3.45 per cent area is unsuitable for irrigation during pre monsoon and post monsoon period. In the pre monsoon period 0.72 per cent and 8.14 per cent of total study area has good quality water and in pre monsoon and post monsoon period. 43.14 per cent

and 66.14 per cent of total study area fall under permissible category for irrigation purpose and 29.01 per cent and 22.26 fall under doubtful category during pre monsoon and post monsoon period (Table 4).

SUMMARY AND CONCLUSIONS

The physico-chemical properties of the 95 ground water sample during pre monsoon were determined using standard methods of water quality analysis. These samples were analyzed in the laboratory to find out different water quality parameters such as pH, EC, TDS, Ca etc. Specific conclusions drawn based on the results of the study are listed below.

1. SAR value of water sample for 85 villages, 9 villages and 1 village were found under excellent, good and unsuitable category during pre monsoon.
2. Kelly's ratio is less than one (safe for irrigation) for 43.89 per cent and 52.36 per cent of total study area during pre and post monsoon period
3. RSC is less than 1.25 for 97.78 per cent and 98.92 per cent of total study area during pre monsoon and post monsoon period. This indicates that water in this area is safe for irrigation.
4. %Na value varies between 20 to 40 for 9.44 per cent and 10.18 per cent of total study area. This indicates that water of this area fall in good category for irrigation use.
5. 95.03 per cent and 91.97 per of basin area has good quality water for irrigation purposes in pre monsoon period and in post monsoon period.

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