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Suitability of groundwater quality for irrigation purpose in Chittorgarh district, Rajasthan

NL Mali, KK Yadav, DP Singh, Manjeet Singh, Prakrati Malakar, Anju Kanwadiya and Lokesh Kumar Prajapat

Abstract
A survey was conducted during pre-monsoon season of the year 2017 in Chittorgarh district of Rajasthan to assess the groundwater quality and it was found that the well depth of groundwater varied from 7.00 m to 30.20 m with an average value of 16.69 m while groundwater levels of Chittorgarh district varied from 3.00 m to 25.00 m with an average value of 12.34 m. TDS of groundwater of Chittorgarh district varied from 110 to 2920 ppm with a mean value of 600 ppm. pH of groundwater found in the range of 7.00 to 9.40 with mean value of 7.70. The electrical conductivity of groundwater varied from 0.17 to 4.56 dSm^{-1} with a mean value of 0.94 dSm^{-1}. Based on the electrical conductivity of groundwater 1.49% groundwater sample falls under low salinity class (C_1), 44.03% samples falls under medium salinity class (C_2), 50.00% groundwater samples falls under high salinity class (C_3) and 4.48% falls under very high salinity class (C_4). Concentration of cations Ca^{2+}, Mg^{2+}, Na^+ and K^+ were found 0.20 to 6.20, 0.60 to 7.20, 0.25 to 28.52 and 0.10 to 3.60 meL^{-1}, respectively. The concentration of anions CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} were recorded in the range of 0.00 to 4.80, 0.40 to 12.20, 1.00 to 24.00 and 0.15 to 4.50 meL^{-1}, respectively. Hence, it is concluded that the nature of groundwater of Chittorgarh district is Na-Mg-Ca and Cl-HCO_3-SO_4 type.

Keywords: Groundwater quality, cations, anions, water level, well depth

Introduction
During the past two decades, the water level in several parts of the country has been falling rapidly due to an increase in extraction. The number of wells drilled for crop irrigation has rapidly and indiscriminately increased. For example Maharashtra states Sonwati village have groundwater within 6 meters but in present time 244 meters bore wells dry [1]. India's rapidly rising population and changing lifestyles has also increased the domestic need of water [2]. The water requirement for the industry also shows an overall increase. Irrigation system consumed 84% available water and rest 12% and 4% use in industries and domestic purpose respectively [1]. Users of agriculture, industry and domestic sectors are intense competition to each other for groundwater. The quality of groundwater is getting severely affected due to human activities through discharge of untreated industrial waste water, dumping of waste over the lands and application of chemicals on agricultural lands [3]. These contaminants affected groundwater and reducing the quality of fresh water resources. The quality of groundwater may also vary with depth of water table, seasonal changes and composition of dissolved salts depending upon sources of the salt and subsurface environment. Groundwater quality also affected by intensively irrigated agricultural discharges into the groundwater. Scarcity and mistreat of groundwater cause a serious danger to sustainable development [4].
Climate change will be impact on agriculture production. If poor quality water used in irrigation then it will affect the crop production and deteriorate the soil quality and health. So it is necessary that available water which is used in irrigation should be good quality and it is mainly depended on the amount and dissolved material in the water. Groundwater content important chemical elements like Ca^{2+}, Mg^{2+}, CO_3^{2-}, HCO_3^-, Cl^-, Na^+, K^+, SO_4^{2-}. Such type chemical parameters play a major role in deciding quality of groundwater and good quality water gives better yield and has good impact on soil and its environment.
So this study will be helpful for police maker and local body to understanding the situation and characteristics of groundwater in Chittorgarh district. In the study also describes chemical characterises of groundwater for drinking as well as irrigation purpose.

Study area

Chittorgarh is located in the southern part of the state of Rajasthan, in the north-western part of India (Fig. 1).The district is located between 24°13' to 25°13' N latitude and 74°04' to 75°53' E longitude. Average annual rainfall of the district is 762.7 mm. The climate of the district is quite dry except S-W monsoon season. The district experiences either mild or normal drought once in two years. Severe type of drought has never occurred in the district.

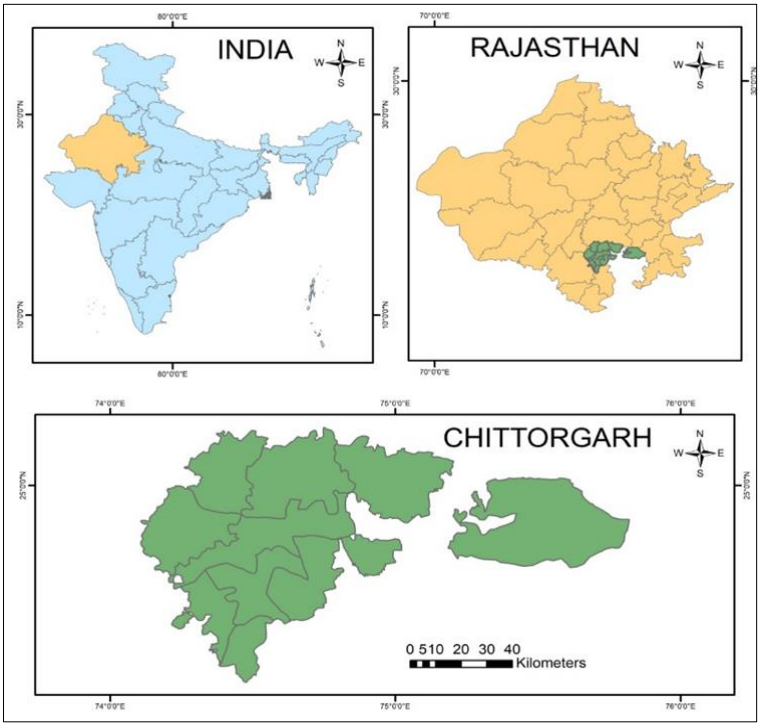

Fig 1: Location map of study area

Materials and Methods

Collection of Groundwater samples

The whole Chittorgarh district was divided into 7x7 km square grids (Fig.2) and from this grid one open dug well was randomly selected (Fig.3) which is used in irrigation. Wells locations were recorded with the help of Global Positioning System (GPS). Then after well depth was measured with the help of weight tagged measuring tape and the groundwater level was measure with the help of water level indicator. Sampling device were used to drawn the groundwater samples and then collected in properly cleaned and wall labelled plastic bottles and brought to the laboratory for analysis. Total 134 groundwater sample were collected during pre-monsoon season (June, 2017) which is show the proper situation of Chittorgarh district.

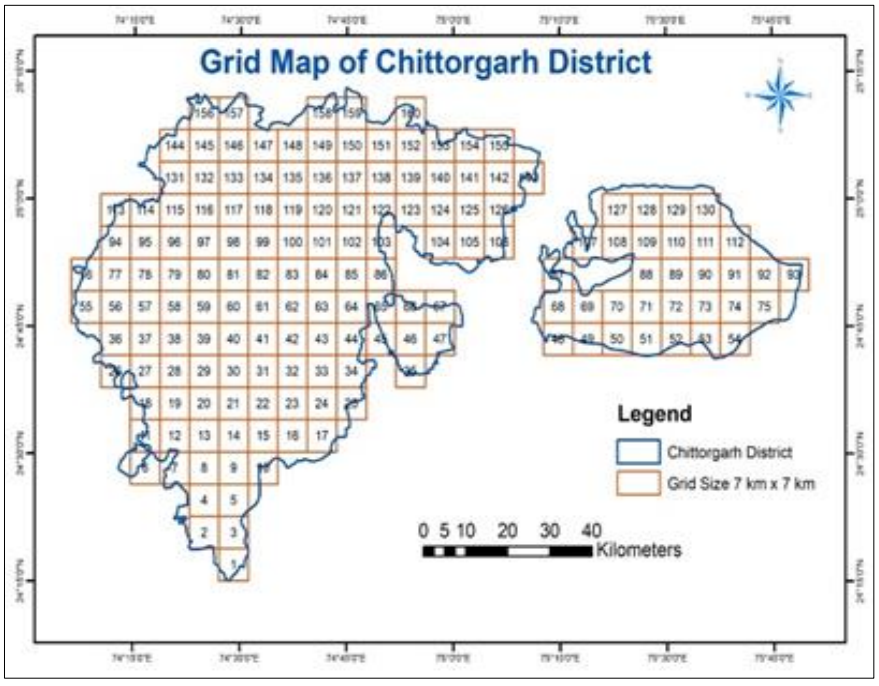

Fig 2: Grid map of Chittorgarh district

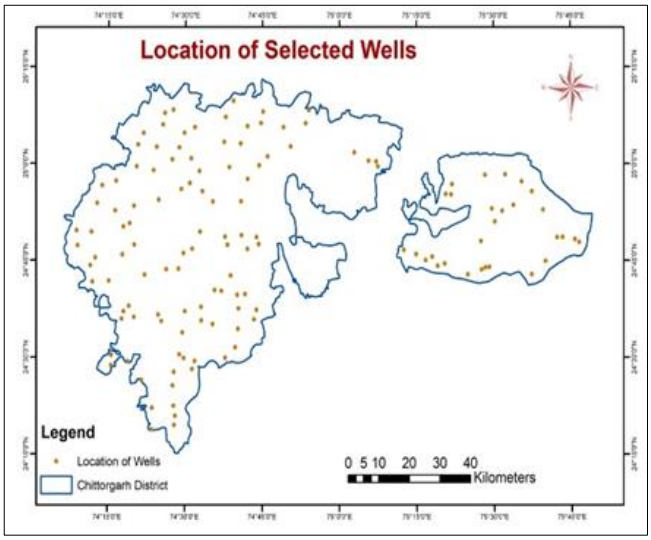

Fig 3: Location of selected wells in study area

Analysis of water sample

Collected water sample analysed for 11 parameters like pH, EC, TDS, cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions(HCO_3^-, SO_4^{2-}, Cl^-, CO_3^{2-}). To analysing water, samples following standard methods are adopted.

For determination of pH, EC, cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (CO_3^{2-}, HCO_3^- and Cl^-) standard method is provided by Richards [5]. The water pH is determined using glass electrode pH meter and EC is evaluated by Conductivity meter. Ca^{2+} and Mg^{2+}both are determinate by versenate titration method. Na^{+} and $K^{+}$are analysed using flame photometer. Used titration method with standard H_2SO_4 for calculating $CO_3^{2-}$and $HCO3^-$.Cl^- evaluated by titration carried with standard $AgNO_3$. Chesnin and Yien [6], use Tuirbidometeric Method for SO_4^{2-} estimation, which is provided.

Preparation of maps

The point information for different water quality parameters were used to generate the spatial information in the form of groundwater quality maps using Arc GIS 10.1 software.

Classifications of irrigation water

Water is classified in various classes on the bases of various criteria. In the analysis of water samples getting various data which is arranged in proper manners and grouped in various classes using prior describe classification. Classification is following-

Salinity hazard or Electrical Conductivity (EC)

According to U.S. Salinity Laboratory [5] water is classified in following four classes-

S. No.	Name of class	EC range (mS/m)	Suitability
1.	C_1	0 – 25	Suitable for irrigation
2.	C_2	25 – 75	Suitable for irrigation
3.	C_3	75 – 225	Not suitable
4.	C_4	225 – 500	Not suitable

Chloride concentration: Chloride ion caused most common crop toxicity through irrigation water. It is occurs in all water and necessary for plant growth but high concentration inhibit plant growth. When water quality is assessing than Cl^- concentration must be analysed. Result is interpreted with following table-

Chloride concentration

S. No.	Chloride concentration (me/L)	Water quality
1.	<4	Excellent
2.	4 – 7	Moderate good
3.	7 – 12	Slightly suitable
4.	12 – 20	Not suitable
5.	>20	Not suitable, cause severe problems

Results and Discussion

Status of Groundwater

Groundwater is a main source of drinking and irrigation and their availability is most important. Low groundwater availability is show that the area is scared in the availability of water and high groundwater is show sufficient availability of water. During survey in Chittorgarh, district total 134 locations were selected according to the systematic grid square pattern and well depth and water levels were recorded.

Well depth and water level

Well depth show depth below ground level. It shows that in how much depth water is available in sufficient amount. The data presented in Table 1 revealed that the well depth of groundwater of Chittorgarh district varied from 7.00 m to 30.20 m with an average value of 16.69 m below ground level. The spatial variation in the well depth of groundwater of the study area also shown in Fig.4.As the study area falls under the hard rock region of southern Rajasthan where the average well depth ranges from 15-20 m below ground level.

The level of water which seen in well is commonly known as water level. It represents states of water in the specific area. If low water level in the area it indicate water scarcity and high level of water show water availability in adequate amount. The data presented in table 1 showed that the groundwater levels of Chittorgarh district varied from 3.00 m to 25.00 m with an average value of 12.34 m bgl. The spatial variation in the groundwater level of the study area also shown in Fig.5.The above results are the typical characteristics of hard rock area. Water level is a temporally bases characteristics of groundwater which is varied with time and rainfall. Similar results were also reported by Gurjer *et al*. for Bhilwara district and Yadav and Singh for Rajsam and districts who reported the water level changes from place to place [7, 8].

Table 1: Well depth and Groundwater level of study area

Block	Well Depth (m bgl)		Groundwater Level (m bgl)	
	Range	Mean	Range	Mean
Bari Sadri	11.00-5.70	20.18	7.70-23.00	16.95
Begun	10.00-2.00	15.49	5.60-16.20	10.56
Bhadesar	9.00-26.70	15.81	3.00-22.20	12.19
Chittorgarh	8.00-23.00	16.81	4.20-16.20	11.77
Dungla	7.00-26.20	17.87	6.50-20.90	13.87
Gangrar	9.00-25.00	15.55	5.80-19.00	10.05
Kapasan	9.00-30.20	18.63	3.00-25.00	13.99
Nimbahera	11.00-0.00	15.38	7.20-18.00	11.54
Rashmi	8.50-27.00	17.30	5.00-23.30	12.17
Rawatbhata	7.00-22.00	14.93	4.60-14.70	10.93
District	7.00-30.20	16.69	3.00-25.00	12.34

Assessment of Groundwater Quality

Groundwater properties influenced by various factor on spatially and temporally bases. Groundwater is containing excessive soluble salts which are unsuitable for irrigation. If sodium is the dominating ion, frequent application of such water deteriorates the physical conditions of soil causing soil

dispersion, reduced infiltration and poor soil aeration. On the other hand presence of soluble salts of calcium plus magnesium in excess, increase the osmotic pressure of soil solution thereby causes disturbance in the mechanism of uptake of water and nutrients by plants. So it is necessary to understanding the quality of water to use for either drinking or irrigation. The groundwater quality of present study on the basis of chemical characteristics is discussed below.

Total dissolved solids (TDS), pH and Electrical Conductivity (EC)

TDS represent the total soluble salt, which is dissolved in water. The high TDS is an indicator of high salt concentration. The data presented in table 2 revealed that the TDS of groundwater of Chittorgarh district ranged from 110 ppm to 2920 ppm with an average value of 600 ppm. The lowest value of TDS (110 ppm) was observed in Rawatbhata block whereas; the highest value (2920 ppm) was recorded in Kapasan block. The spatial variation in the TDS of groundwater of the study area also shown in Fig.6.Groundwater TDS is different in different regions due to region's own soluble minerals [9], leaching of soil soluble salt, anthropogenic activities (Ward, 1994) and domestic sewage water which is percolated in groundwater and increase TDS [10].

Water pH affects various soil properties and thinking this point groundwater pH of study area is recorded. A perusal of data presented in table 2 revealed that pH of groundwater of Chittorgarh district varied from 7.00 to 9.40 with an average value of 7.70. Further in reference to data presented in table 2 and shown in Fig.7. It is clear that the groundwater of Chittorgarh and Rawatbhata block is comparatively good and the mean value are near neutral whereas, Kapasan block is affected by high pH of groundwater followed by Rashmi block. This show that groundwater in study area is neutral to moderate alkaline in nature. Moderate alkaline nature of groundwater is due to present of HCO_3^- ions which are produced by the free combination of CO_2 with water to form carbonic acid, which affects the pH of the water [11].

Electrical conductivity (EC) is the total amount of soluble salt which is present in the water. It expressed as millimhos/cm or desi Simmons/m (dSm^{-1}). A critical observation of the data presented in table 2 revealed that the electrical conductivity of groundwater of Chittorgarh district varied from 0.17 to 4.56 dSm^{-1} with the mean value of 0.94 dSm^{-1}.

As electrical conductivity is one of the most important quality parameter of groundwater for irrigation point of view. It shows total soluble ions concentration in water. According to USDA classification of irrigation water quality 2 (1.49%), 59 (44.03%), 67 (50.00%) and 6 (4.48%)samples of Chittorgarh district falls under C_1 C_2 C_3 and C_4 class,respectively. The spatial variation in electrical conductivity of groundwater of Chittorgarh district is shown in Fig.8. These results are fairly supported by the finding of Abdul Bari *et al*. (2016) who show large variations in EC [12]. Similar results were also reported by Gurjer *et al*. (2015) for Bhilwara district and Yadav and Singh (2018) for Rajsamand district [7, 8].

Table 2: TDS values of groundwater of study area

Block	TDS (ppm) of groundwater			pH of groundwater			EC (dSm^{-1}) of groundwater		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max	Mean
Bari Sadri	204	1030	542	7.30	8.20	7.73	0.32	1.62	0.85
Begun	346	1060	548	7.10	8.50	7.70	0.54	1.66	0.86
Bhadesar	405	711	555	7.00	8.60	7.74	0.63	1.11	0.87
Chittorgarh	315	678	444	7.00	8.40	7.50	0.49	1.06	0.69
Dungla	406	1730	827	7.00	9.20	7.84	0.63	2.70	1.30
Gangrar	228	1050	688	7.40	8.60	7.95	0.36	1.64	1.08
Kapasan	310	2920	887	7.10	9.40	7.99	0.48	4.56	1.39
Nimbahera	313	1380	627	7.00	9.20	7.72	0.49	2.16	0.98
Rashmi	254	1880	685	7.20	8.50	7.92	0.40	2.94	1.07
Rawatbhata	110	635	364	7.00	8.20	7.32	0.17	1.00	0.57
District	110	2920	600	7.00	9.40	7.70	0.17	4.56	0.94

Cations

A critical observation of the data in table 3 revealed that the cationic composition of groundwater of Chittorgarh district varied to a great extent in different blocks and locations. The spatial variation in the cationic concentration is also shown in Fig. 9 (a to d).

The calcium is present in water play important role in plants growth and structure. As a Calcium pectate, it is constituent of the cell wall, role in mitosis, growth of meristems, protects the root cells against ion imbalance etc. The calcium content in groundwater of Chittorgarh district varied from 0.20 to 6.20 meL^{-1} with the mean value of 1.86 meL^{-1} (Table 3).The calcium concentration is also shown in Fig. 9(a). The variation in the calcium content of groundwater is an indicator of variation in hardness of groundwater. In many areas Ca amount present in water is show deficiency such water produce many disease in plant like blossom end rot in tomato, tip hooking in cauliflower, cavity spots in carrot, bitter pit and water corn in apple etc. Magnesium is constituent of chlorophyll, which is indicating that it is the powerhouse behind photosynthesis in plants. This show it is important in groundwater. The magnesium content in groundwater of Chittorgarh district varied from 0.60 to 7.20 meL^{-1} (Table 3). The magnesium concentration is also shown in Fig. 9(b). Mg is required for green colour of leaves, promotes uptake and translocation of phosphorus and activator of many enzyme systems [13].

Table 3: Calcium, Magnesium, Sodium and Potassium content (meL^{-1}) of groundwater of study area

Block	Calcium		Magnesium		Sodium		Potassium	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Bari Sadri	1.20-3.60	2.11	1.40-4.80	2.69	0.50-7.51	3.46	0.10-0.62	0.24
Begun	1.20-3.20	1.98	1.20-3.00	1.93	1.75-9.78	4.33	0.10-0.52	0.30
Bhadesar	0.80-2.00	1.54	1.40-2.60	2.04	2.25-6.34	4.81	0.10-0.53	0.28
Chittorgarh	1.00-2.80	1.78	1.20-2.20	1.72	0.45-5.42	3.11	0.18-0.80	0.33
Dungla	1.40-3.60	2.56	2.20-5.60	3.58	2.00-17.92	6.27	0.12-1.78	0.57
Gangrar	0.60-3.60	2.42	1.20-4.20	2.85	1.25-8.76	4.99	0.20-0.72	0.44
Kapasan	0.60-6.20	2.16	1.00-7.20	2.57	1.25-28.52	8.29	0.20-3.60	0.84
Nimbahera	0.80-3.20	1.78	1.40-4.40	2.18	2.10-13.25	5.48	0.15-0.77	0.35
Rashmi	0.40-2.40	1.09	0.80-3.20	1.38	2.32-21.62	7.63	0.10-2.00	0.63
Rawatbhata	0.20-3.20	1.49	0.60-2.80	1.70	0.25-6.28	2.21	0.10-0.75	0.30
District	0.20-6.20	1.86	0.60-7.20	2.21	0.25-28.52	4.86	0.10-3.60	0.44

Sodium ion absorbed by plant is accumulating in the vacuoles of cell and play a major role in maintaining the solute potential. Plantsgrow under dry/arid climate or where the water available in limited amount on the place it improve water balance of plant [13]. The sodium content in groundwater of Chittorgarh district varied from 0.25 to 28.52meL^{-1} with the mean value of 4.86meL^{-1}. The sodium concentration is also shown in Fig. 9(c).The variation in the sodium content is closely associated with the alkalinity and sodicity of groundwater [14]. High sodium content is not good for water which uses in irrigation it injurious for crops and harmful for soil. Potassium is important for opening and closing of stomata, transport of water and nutrient. It is unique element which is accumulating in plants in abundant amount without any toxicity symptoms [13]. The potassium content in groundwater of Chittorgarh district varied from 0.10 to 3.60 meL^{-1} with the mean value of 0.44meL^{-1}. The potassium concentration is also shown in Fig. 9(d).

On the basis of average values of cationic concentration in groundwater of Chittorgarh district it was found that sodium is the dominating cation with the average concentration of 4.86meL^{-1} followed by magnesium is (average concentration 2.21meL^{-1}), calcium (average concentration 1.86 meL^{-1}) and potassium (average concentration 0.44 meL^{-1}).The results of the present investigation are strongly supported by the findings of Bhange *et al*., Abdul Bari *et al*., Gurjer *et al*.**,** Hanipha and Hussain & Yadav and Singh [15, 12, 7, 16, 8].

Anions

The ions which present in anion forms in water is also influenced water properties. Anions which is studied in the research is Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^-), Chloride (Cl^-) and Sulphate (SO_4^{2-}).The anionic composition of groundwater of Chittorgarh district is presented in table 4 and the spatial variation is shown in Fig. 10 (a to d).

A critical observation of the data given in table 4 revealed that carbonate content in groundwater of Chittorgarh district varied from 0.00 to 4.80meL^{-1} with the mean value of 0.70meL^{-1}. The high value of carbonate found at few places which is an indication of slight alkalinity and it increase the pH. The bicarbonate content in groundwater of Chittorgarh district varied from 0.40 to 12.20 meL^{-1} with the mean value of 2.03meL^{-1}. According to FAO (1994) water, which is content bicarbonate, less than 1.5 me/L is suitable for irrigation. 1.5 to 8.5 me/L bicarbonate is moderate suitable and more than 8.5 me/L is not suitable for irrigation [17].

Table 4: Carbonate, Bicarbonate, Chloride and Sulphate (meL^{-1}) content of groundwater of study area

Block	Carbonate		Bicarbonate		Chloride		Sulphate	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Bari Sadri	0.00-2.40	0.55	0.80-4.60	1.64	2.00-8.00	5.36	0.20-2.70	0.99
Begun	0.00-0.80	0.60	0.80-3.00	1.78	3.00-11.00	5.25	0.20-2.60	0.95
Bhadesar	0.00-0.80	0.44	0.80-4.20	1.68	4.00-7.00	5.60	0.20-2.20	1.02
Chittorgarh	0.00-0.80	0.37	0.60-2.00	1.11	3.00-7.00	4.62	0.30-1.50	0.90
Dungla	0.00-3.20	1.00	0.60-6.80	3.16	4.00-15.00	7.30	0.34-4.30	1.50
Gangrar	0.00-1.60	0.73	0.60-5.20	2.16	3.00-12.00	6.73	0.20-2.40	1.20
Kapasan	0.00-4.80	1.18	0.80-12.2	3.29	3.00-24.00	7.76	0.20-4.50	1.68
Nimbahera	0.00-2.40	0.63	0.80-6.60	2.02	3.00-10.00	6.00	0.52-2.62	1.19
Rashmi	0.40-2.00	1.11	1.00-7.40	2.29	2.00-17.00	6.11	0.20-3.20	1.28
Rawatbhata	0.00-2.40	0.44	0.40-3.80	1.36	1.00-6.00	3.45	0.15-1.60	0.51
District	0.00-4.80	0.70	0.40-12.2	2.03	1.00-24.00	5.63	0.15-4.50	1.08

Chloride play a major role in osmoregulation and charge compensation [13]. It is evident from the data presented in table 4 that the chloride content in groundwater of Chittorgarh district varied from 1.00 to 24.00meL^{-1} with the mean value of5.63meL^{-1}. Cl^- value high than 10 are not suitable for irrigation [17]. The chloride content normally increases as the mineral content increases [18]. Sulphur involved in metabolic activities of vitamins. It increasing oil quality of oilseed crops and essential constitute of sulphur containing amino acids [19]. The data presented in table 4 revealed that the sulphate content in groundwater of Chittorgarh district varied from 0.15 to 4.50meL^{-1} with the mean value of 1.08meL^{-1}. High concentration of sulphate in groundwater due to the presence of sulphur in reduced forms in sedimentary rocks as metallic sulphides. This sulphur converted in sulphate when it contact with aerated water [20]. On the basis of average values of anionic concentration in groundwater of Chittorgarh district it was found that the chloride is dominating anion with the average concentration of 5.63meL^{-1} followed by bicarbonate (average concentration 2.03 meL^{-1}), sulphate (average concentration 1.08meL^{-1}) and carbonate (average concentration 0.70meL^{-1}), respectively. The anionic

composition of groundwater decides the water type. Based on relative proportion of different anions, it is concluded that the nature of groundwater is Cl-HCO_3-SO_4-CO_3 type. The results of the present investigation are strongly supported by the findings of Gurjer *et al*., 2015, Abdul Bari *et al*., 2016, Bhange *et al*., 2016 and Yadav and Singh, 2018 [7, 12, 15, 8].

Suitability for Irrigation

The suitability of groundwater for irrigation is based on the presence of undesirable substances like high salinity. Electrical conductivity and Na plays a key role for suitability of irrigation water. The concentration of dissolved salts in water can be categorized in to low, moderate, high, very high salinity conditions.

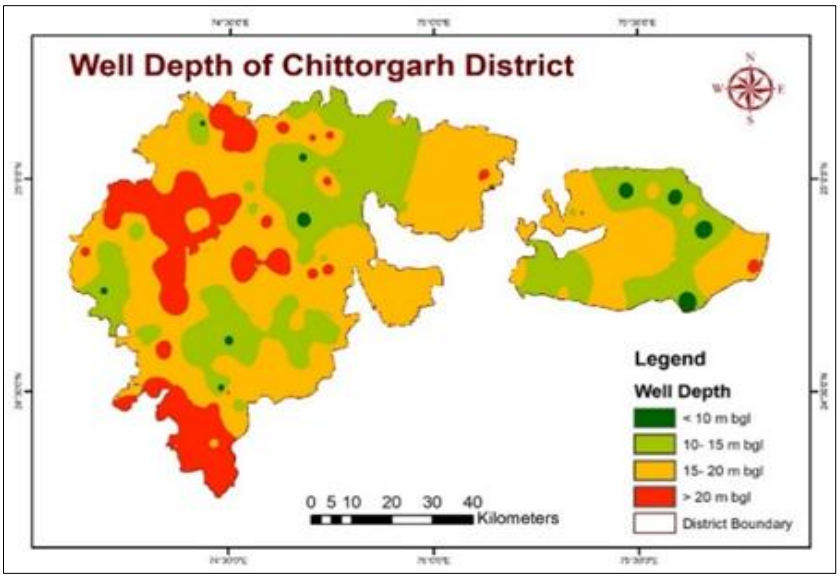

Fig 4: Well depth of the Chittorgarh district

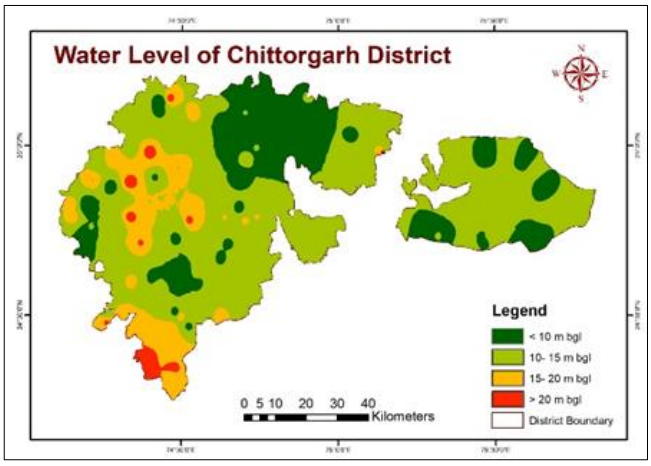

Fig 5: Water level of Chittorgarh district

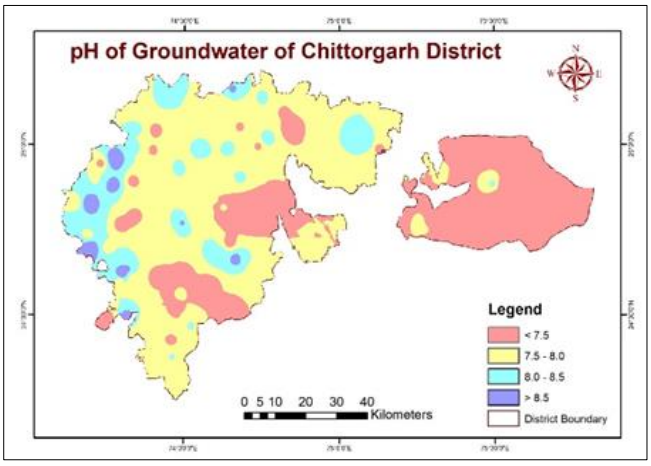

Fig 7: pH of Groundwater of Chittorgarh district

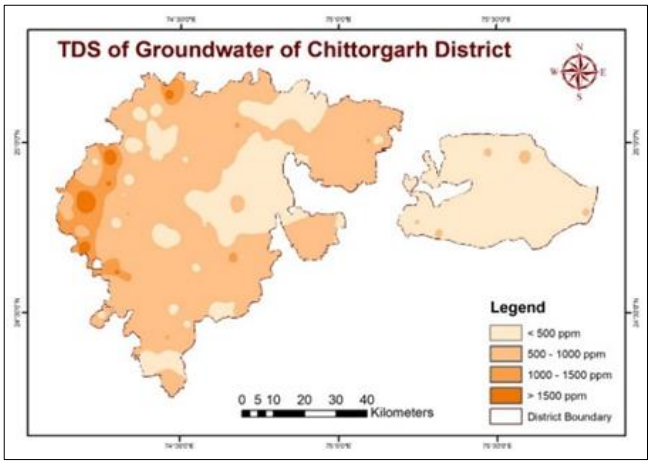

Fig 6: TDS of groundwater of Chittorgarh district

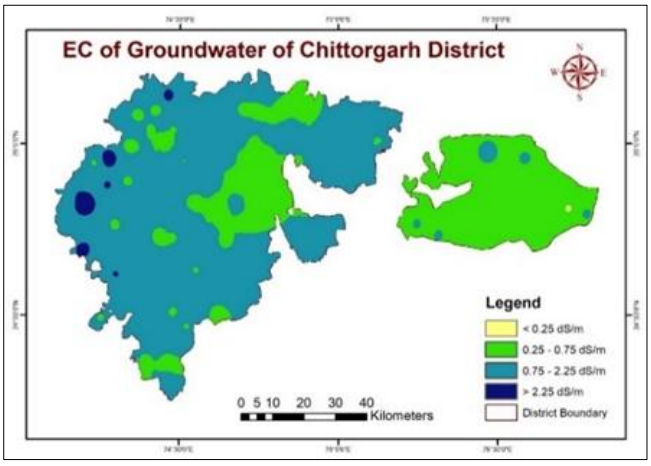

Fig 8: EC of Groundwater of Chittorgarh district

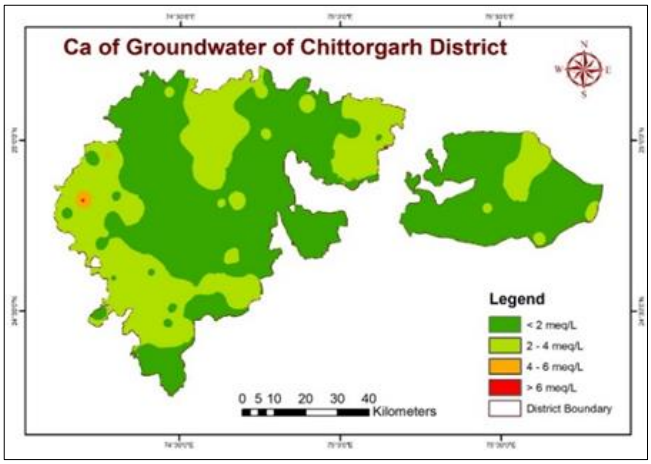

Fig 9a: Caof Groundwater of Chittorgarh district

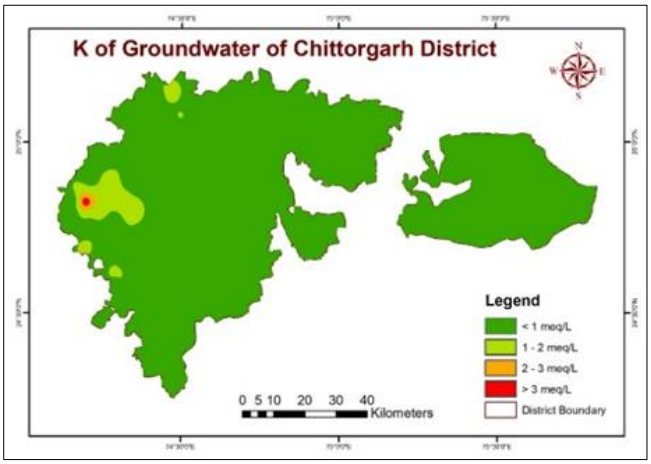

Fig 9d: K of Groundwater of Chittorgarh district

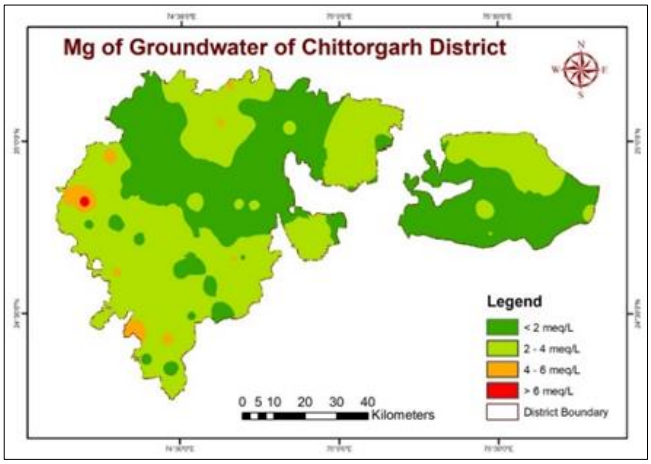

Fig 9b: Mg of Groundwater of Chittorgarh district

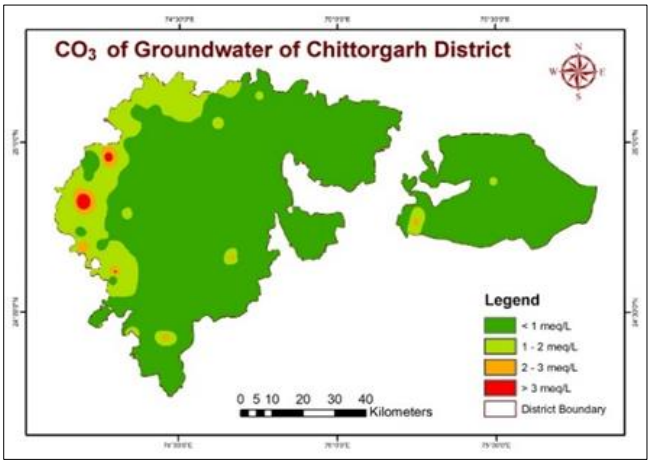

Fig 10a: CO_3 of Groundwater of Chittorgarh district

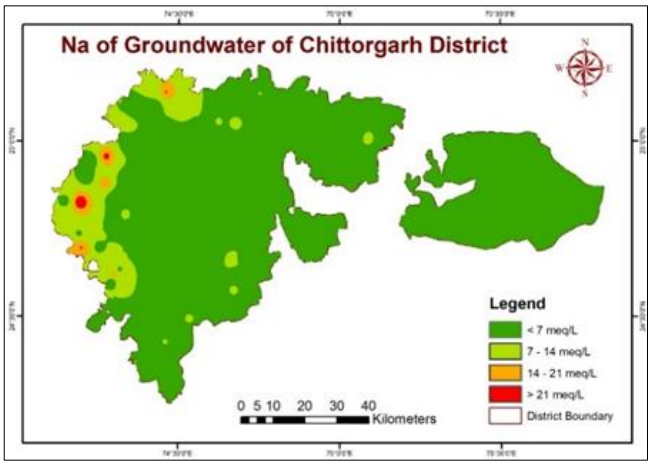

Fig 9c: Na of Groundwater of Chittorgarh district

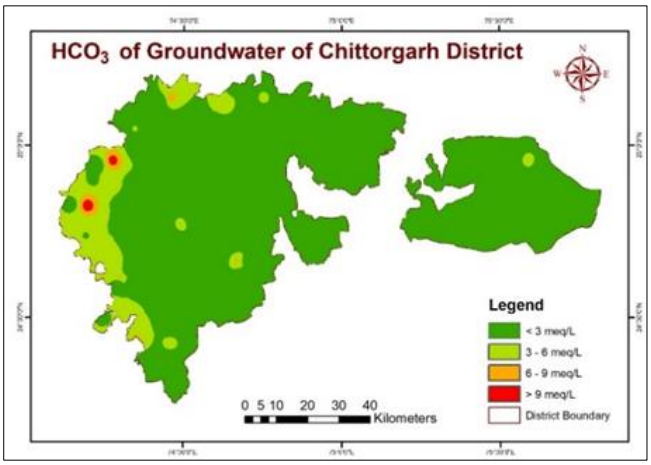

Fig 10b: $HCO_3$of Groundwater of Chittorgarh district

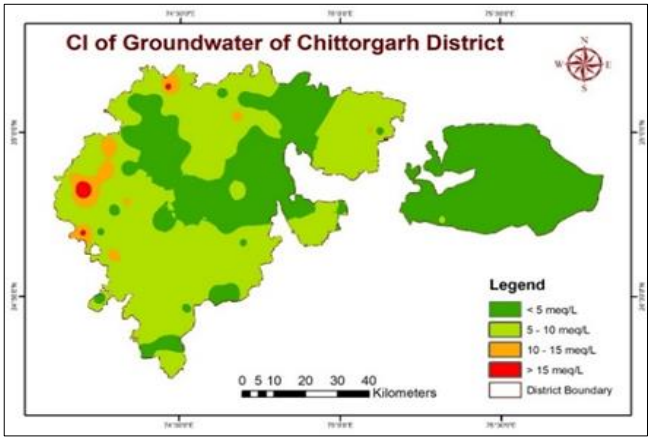

Fig 10c: Cl of Groundwater of Chittorgarh district

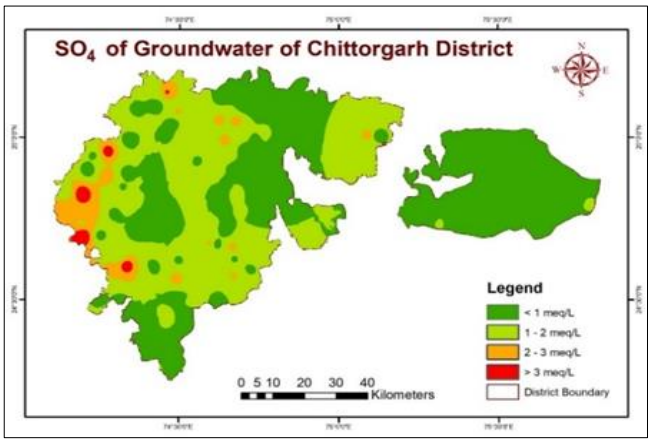

Fig 10d: SO_4 of Groundwater of Chittorgarh district

Conclusions

The study discloses the changes in groundwater level during pre-monsoon season. The majority of groundwater samples, on the basis of salinity (EC) were found to be medium to high salinity class. In these areas only salt tolerant crops like Guava, Date palm, Spinach, Cotton, Sunflower, Safflower, Millet, can be grown with intensive salinity management practice Irrigation parameters indicates that pre monsoon are good. Further it was found that the quality of groundwater in Kapasan block was worst affected followed by Dungla, Rashmi and Gangrar blocks.

On the basis of cationic and anionic composition of groundwater, it can be concluded that the groundwater of Chittorgarh district is affected by anthropogenic activities apart from lithology.

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