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Study of Seasonal Variability of Ground Water Quality in Sarguja District (C.G.), India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Water is the vital essence, miracle of nature and the great sustainer of life. It is extremely essential for survival of all living organism. Ground water serves as a major source for drinking, irrigation and industrial purpose all over the world. Many factors affect the quality of groundwater and cause major health issues. Therefore regular monitoring of ground water quality is necessary. Present paper has formulated on the basis of assessment of impact of geological features and agricultural runoff in ground water sources of Sarguja district (C.G.) India. Water samples were collected from ten environmentally significant spots for analysis of physical, minerals, nutrients, agricultural qualities and toxic metallic and non metallic elements. The procured experimental values were subjected for the statistical evaluation and compared with the standard values prescribed by the

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water monitoring agencies BIS (2012) and WHO (2011). The result for pH recorded up to 10.0, turbidity (15.67 NTU), TS (720 mg/L), F^- (15.67 mg/L), Fe (2.366 mg/L), Na (115 mg/L), in maximum concentration. The statistical parameter such as mean, standard deviation, standard error, % CV, correlation matrix and water quality index (WQI) were systematically calculated for pre monsoon, monsoon and post monsoon session. The obtained results are far away from the standard values which showed the investigated water samples are not suitable for drinking and agricultural purpose without prior treatment.

Keywords: Ground water quality; toxic metal; pH; turbidity; standard deviation; correlation matrix; water quality index.

1. INTRODUCTION

Ground water is a crucial renewable natural resource having several innate advantages over surface water (Tailor and Chandel 2011) as purity point of view. The surface water is contaminated by the natural and anthropogenic means. Ground water is the major source for drinking purposes in India. The existing ground water source in our country is estimated to be more 45000 million cubic meter (Rao 1979). Ground water plays a crucial and vital role for the society of mankind (Paul and Mishra 2011, Subba 2006, Silva et al., 2017) flora and fauna. The development of any nation depends upon the quality of ground water sources. Earlier the sources of ground water considered as the purest form but with the time, the sources of water becoming high degree polluted owing to over exploitation and percolation of contaminated surface water owing to development purposes, industrial, domestic drinking and bathing uses. One side the ground water qualities varies by the additive of the undesired materials, 60 million tones organic and inorganic chemicals are added in each year (De 2006) while the other side it varies due to change in chemical composition of rocks and soil (Nativ and Smith 1987).

The study area Sarguja district is known from ancient periods; Ramayana, then come under the Maurya's, and Nand emperors. Sarguja state was a princely state (https://www. Surguja.nic.in). Sarguja become a part of new state of Madhya Pradesh in 1951, while in 2000 one of the district of new state Chhattisgarh. The geographical location of the study area Sarguja district is $23^0$37'25" to $24^0$6'17" north latitude and $81^0$34'40" to $84^0$4'40" east longitude. Sarguja district holds a distinct position as one of the oldest districts in the region, boasting a rich historical and cultural legacy. The district's administrative hub is situated in Ambikapur (About District). During the study period, the annual rainfall was recorded up to 1129.6 mm, the maximum and minimum temperature was recorded 41.8^0C and 4.6^0C respectively. The investigated area spread over 5732 sq. km. with 244.62 km long and 67.37 km broad. The height of the area is maximum 600 meters. The soil of the area is yellow, derived from the parent rocks of the Gondwana system and sedimentary rocks which are abound by bauxite, coal, pyrite, minerals, sulphur, mica, beryllium, copper and galena. 90 % working population depends upon the agricultural activity in which 50.36% of working population is of cultivated while about 12.77% of the region is agricultural workers. 41.67% of total geographical area is under cultivation. Owing to minerals rich rocks of the area, the ground water sources are abundantly contaminated by the dissolved minerals and metallic and non metallic ions (Jain et al., 2023). So we have taken a comprehensive study of the ground water of the Sarguja district. In this paper we have discussed the seasonal comparative study of the physicochemical and some selected toxic elements in ground water sources of the entire Sarguja district (C.G.).

2. MATERIALS AND METHODS

2.1 Collection of Water Samples

On the basis of environmental significance point of view, total ten sampling spots were selected from entire district. These sampling spots are assigned as SD-1 To SD-10.The ground water samples were collected from these sampling spots (shown in Fig. 1 and Table 1) in pre cleaned polythene bottles of one liter capacity in pre monsoon (2023), monsoon (2023) and post monsoon (2023).the samples were kept in refrigerator maintained at 4^0C.and subsequently analyzed the collected water samples for the following water quality parameters [Table 2], as per the standard methods recommended by (APHA 2005, Trivedi and Goyal 1986, and NEERI manual 1987).

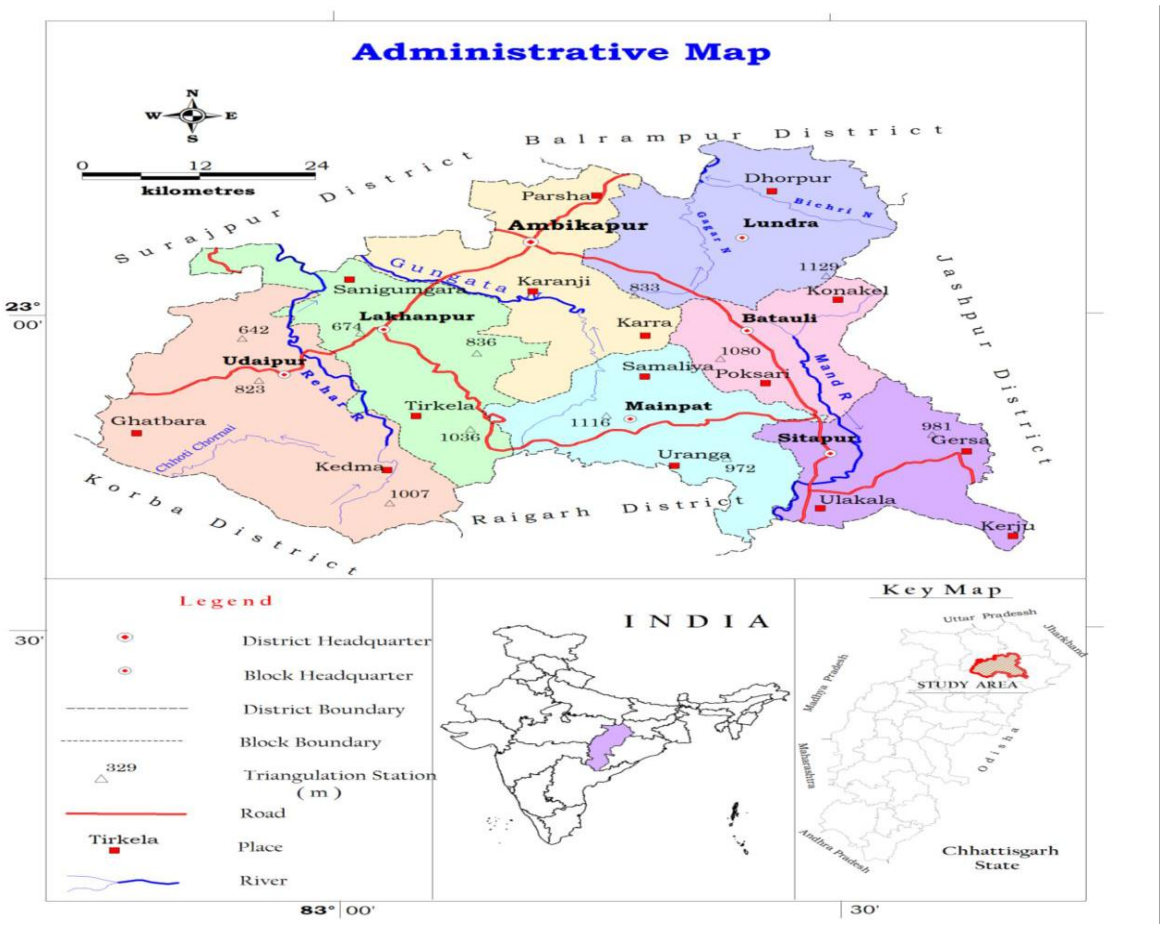

Fig. 1. Administrative map of study area

Table 1. Geographical locations of sampling spots

S.NO.	Sampling Station	Block	Sample ID	Latitude (N)	Longitude (E)	Source
1	Bada Damali	Ambikapur	SD-1	22.90292^0	83.17651^0	Hand pump
2	Bhapouli	Ambikapur	SD-2	23.212538^0	83.272436^0	Bore Well
3	Telaidhar	Batouli	SD-3	22.851884^0	83.494918^0	Bore Well
4	Soyda	Lakhanpur	SD-4	22.955073^0	83.124002^0	Hand pump
5	Tunguri	Lakhanpur	SD-5	22.95706^0	83.134014”	Bore Well
6	Ajirma	Lundra	SD-6	23.201027^0	83.284214^0	Hand pump
7	Udumkela	Mainpath	SD-7	22.822063^0	83.405113^0	Hand pump
8	Devgarh	Sitapur	SD-8	22.825361^0	83.451642^0	Hand pump
9	Dandgaon	Udaipur	SD-9	22.898328^0	82.840955^0	Hand pump
10	Gumga	Udaipur	SD-10	22.881629^0	82.831235^0	Bore Well

Table 2. Methods used for analysis of physicochemical parameters and toxic elements

S. No.	Name of Parameter	Method
1	pH	pH metry
2	EC	Conductometry
3	Turbidity	Nephelometric
4	Total solid	Gravimetric
5	Total dissolved solid	Gravimetric
6	TSS	Mathematical method
7	Total alkalinity	Titrimetric

S. No.	Name of Parameter	Method
8	Total Hardness	EDTA Titrimetric
9	Ca-Hardness	Titrimetric
10	Mg-Hardness	Titrimetric
11	Fluoride	Ion selective electrode
12	Chloride	Silver nitrate
13	Nitrate	Spectrophotometically
14	Sulphate	Turbidimetrically
15	Na	Flame photometric
16	K	Flame photometric
17	Fe, Cr, Pb, Cd	AAS
18	SAR, PS, RSC	By mathematical method

The obtained experimental results were compared with the standard values stipulated by the (BIS 2012 and WHO 2011).

3. RESULTS AND DISCUSSION

3.1 pH

The ideal value of pH for drinking water is 7, which below and higher value of this causing of acidic and basic properties of water. It has no direct adverse affect on health (Boominathan and Khan 1994) At the study period the observed value of pH note down for pre monsoon 7.75 to 9.515 and 6.5 to 8.875 for monsoon while 6.75 to 8.57 for post monsoon session. These procured values are slightly beyond the standard value 6.5 to 8.5 as per the guidelines of BIS (2012) and WHO (2011) the maximum concentration of pH gradually decreases from pre monsoon to monsoon and post monsoon due to vary in atmospheric temperature.

3.2 Electrical Conductivity

Electrical conductivity is a function of ion concentration and use for a quick checking of dissolve ionic substances in water (Elango et al. 2023). Electrical conductivity of collected water samples was observed instantly in three different season, pre monsoon, monsoon and post monsoon orderly. The finding results were 190.5 to 579 micros/cm for pre monsoon, 261 to 773 micros/cm for monsoon whereas for post monsoon 256 to 739 micros/cm. these ranges values are under desirable and permissible value as per guidelines of water monitoring agencies.

3.3 Turbidity

The interference of the penetration of light increases due to the turbidity of the aquatic system as resulting damage the aquatic life and decline the quality of water (Gupta et al., 2017). In study period the value of turbidity was estimated by the standard methods (https://www. Surguja.nic.in, Jain et al. 2023) 2.315 to 34.2 NTU in pre monsoon 2023 session while in monsoon session this parameter was 10.8 NTU to 50.1 NTU. 9.5 NTU to 41.55 NTU ranges was detected in post monsoon 2023. The lower ranges of the estimated value was under desirable value but the higher ranges was crossed the upper limit as per prescribed by the standard value stipulated by the BIS (2012) and WHO (2011).

3.4 Dissolved cum Suspended Solids

The dissolved ionic species and suspended materials are measure in aquatic system as the TDS, TS and TSS qualities. Total solids and total dissolved solids in is the analysis of agricultural waste water. Suspended solid play an important role in water samples causes duplication of oxygen level (Kumar 2010) in this study we have measured cum gravimetrically calculated as ranging from 330 to 530 mg/L in the pre monsoon session while in monsoon these ranges were increased from 444 to 795.50 mg/L. due to mixing of agricultural run off followed slightly reduced the ranges from 402.5 mg/L to 771 mg/L. The TDS was measured after the filtration of collected water samples as under desirable quantities 117 to 371 mg/L in pre monsoon and 253.5 to 609mg/L in monsoon however in post monsoon the TDS value was note down 280.5 mg/L to 609 mg/L. TSS was calculated mathematically in ranges from 119 to 213 mg/L in pre monsoon while in monsoon 59.5 mg/L to 252 mg/L and in post monsoon calculated 89.5 mg/L to 186 mg/L.

Table 3. Ground water analysis result of Sarguja District Year 2023

Ground Water Analysis Result of Sarguja District Year …2023…													
Season	**Stat. Parameter**	**Tem**	**pH**	**EC**	**Turbi**	**TS**	**TDS**	**TSS**	**TA**	**TH**	**Ca2+**	**Mg2+**	**F-**
Pre - Monsoon (April - May 2023)	Range	23.25 - 24.2	7.75 - 9.515	190.5 - 579	2.315 - 34.2	330 – 530	117 – 371	119 - 213	152.01 - 285.18	119.75 - 225.65	62.52 - 99.78	12.65 - 61.15	0.95 - 15.51
	Mean	23.580	8.542	364.600	10.131	418.950	261.400	157.550	227.685	162.450	74.159	38.802	5.866
	SD	0.256	0.519	120.228	8.692	59.804	73.295	34.196	42.369	28.457	9.963	13.686	5.114
	%CV	1.086	6.081	32.975	85.792	14.275	28.039	21.705	18.609	17.518	13.434	35.272	87.176
	STD.ERR	0.081	0.164	38.020	2.749	18.912	23.178	10.814	13.398	8.999	3.150	4.328	1.617
Monsoon (July - August 2023)	Range	21.95 – 23	6.5 - 8.875	261 - 773	10.805 - 50.1	444 - 795.5	253.5 – 609	59.5 - 252	357.5 - 586	305.5 – 428	103 - 191.5	41.5 - 95.5	1.46 - 6.75
	Mean	22.595	7.946	438.400	25.626	631.000	451.300	179.700	454.650	382.400	128.050	72.600	3.573
	SD	0.378	0.847	131.769	11.492	132.456	110.274	56.311	68.857	31.742	23.955	16.154	1.529
	%CV	1.675	10.660	30.057	44.844	20.991	24.435	31.336	15.145	8.301	18.707	22.250	42.810
	STD.ERR	0.120	0.268	41.669	3.634	41.886	34.872	17.807	21.775	10.038	7.575	5.108	0.484
Post-Monsoon (November - December 2023)	Range	22.6 - 23.7	6.75 - 8.57	256 - 739	9.5 - 41.55	402.5 – 771	280.5 – 609	89.5 - 186	325.5 - 463	184.5 – 403	97 - 170.5	25 - 91.5	1.576 - 5.286
	Mean	23.080	7.580	403.000	18.837	554.100	424.500	129.600	398.350	293.600	116.900	65.250	2.669
	SD	0.349	0.610	128.945	9.135	129.675	114.690	25.778	52.660	56.158	20.996	17.883	1.313
	%CV	1.511	8.054	31.996	48.497	23.403	27.018	19.890	13.219	19.127	17.961	27.407	49.182
	STD.ERR	0.110	0.193	40.776	2.889	41.007	36.268	8.152	16.652	17.759	6.640	5.655	0.415

3.5 Total Alkalinity

Alkalinity is due to the presence of carbonate and bicarbonate ions (Singh and Rai 2003) alkaline water has little public health substance highly alkaline water are unsuitable and are not used for domestic water supply (Patil et al. 2003). In our experimental study in subject of total alkalinity in pre monsoon the recorded value in the ranges from 152.01 mg/L to 285.18 mg/L are low and high value while in monsoon season the value was note down from 357.5 mg/L to 586 mg/L was recorded. In post monsoon the value was note down 325.50 mg/L to 463 mg/L as low and high value orderly.

3.6 Total Hardness

The total hardness indicates the concentration of calcium and magnesium only. This shows in terms of calcium carbonate (Bhargva 2009) the hardness has no adverse effect on health in one side but on another side bathing with hard water the residue of hardness the soaps is precipitated may remains in the pores of skin causing roughness and discomfort. In our study period the procured results were compared in pre monsoon, monsoon and post monsoon as ranging 119.75 to 225.65 mg/L 305.5 to 428 mg/L 184.5 to 403 mg/L respectively.

3.6.1 Chloride

High concentration of chloride content cause undesirable taste to water and may affect the delicate kidney tissues of infants and children (Mishra and Sahoo 2003) in study field at the period of pre monsoon, monsoon and post monsoon the observed value seen in varying amount 130 mg/L to 185.50 mg/L, 235.50 mg/L to 310 mg/L and 201.50 mg/L to 284.50 mg/L the maximum concentration in the entire session crossed the permissible limit 250 mg/L.

3.6.2 Sulphate

The excess quantity of Sulphate causes diarrhea and objectionable taste of water. Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals. Discharge from industrial wastes and domestic sewage trends to increase its concentration (Jain and Bargah 2024). Sulphate is unstable and causes a laxative effect on human system. During the period of study, the results were note down for pre monsoon 12.5 to 153.605 mg/L and for monsoon 29.5 mg/L to 125 mg/L whereas for post monsoon 25.665 mg/L to 97.8 mg/L.

3.6.3 Nitrate

The excess amount of nitrate may cause methemoglobinemia in infants which is characterized by blood changes (Jain and Bhatia 2003). The average value was recorded 0-12.5 mg/L in pre monsoon, 0- 5.00 mg/L in monsoon and in post monsoon the amount of nitrate ions is 0.00 mg/L. the concentration of nitrate ion is very low.

3.6.4 Fluoride

Fluoride is an important nutrition for the successfully conducted base metabolic activities (Thillaiarasu et al. 2014, Vaishnav and Sahu 2006) its balance amount 0.5 mg/L to 1.50 mg/L.The beyond concentration is leading to different types of fluorosis disease. At the period of searching the fluoride concentration was estimated in ranges from 0.95 mg/L to 15.51 mg/L as low and high concentration in pre monsoon session year 2023 while in monsoon the ranges covered from 1.46 mg/L to 6.75 mg/L as min. and max. concentration. The post monsoon season possess the ranges 1.576 mg/L to 5.286 mg/L as min. and max. concentration. The high conc. was crossed the desirable and excessive permissible in entire session due to weathering of rocks phosphates abundantly occurs in the study field.

3.6.5 Alkaline metallic ions

The sources of sodium entering in drinking water from natural geological sources, detergents, industrial discharges and mining wastes. Sodium controls intercellular and extra cellular osmosis, maintain pH balance of blood within the body and controls the normal activities of muscles and nerves (Jothivnkatachalam and Nithiya 2011). The finding results of the studied period 17.5 mg/L to 81.15 mg/L in pre monsoon, in monsoon the sodium conc. was covered from 10.05 to 76.45 mg/L. the post monsoon session possess the concentration was ranges as 16.20 mg/L to 76.30 mg/L. The source of potassium in drinking water is geologically, detergents, mining and agricultural sources. The result of potassium as quantitatively estimation shown in pre monsoon 0.145 – 6.195 mg/L in monsoon 0.325 -7.26 mg/L and in monsoon 0-3.75 mg/L all these procured concentration was under the desirable limit.

Table 4. Ground water analysis result of Sarguja District Year -2023

Ground Water Analysis Result of Sarguja District Year …2023…													
Season	**Stat. Parameter**	**Cl-**	**SO42-**	**NO3-**	**Fe**	**Na**	**K**	**Cr**	**SAR**	**PS**	**RSC**	**Pb**	**Cd**
Pre - Monsoon (April - May 2023)	Range	130 - 185.5	12.5 - 153.605	0 - 12.5	0.299 - 1.556	17.5 - 81.15	0.145 - 6.195	0.003 - 0.048	0.927 - 4.383	34.388 - 67.389	0.312 - 2.566	0.02 - 0.075	0.003 - 0.006
	Mean	156.400	51.396	2.850	0.845	40.320	1.319	0.027	2.358	47.390	1.486	0.037	0.004
	SD	16.126	40.057	3.627	0.389	22.160	1.698	0.012	1.225	9.774	0.706	0.015	0.001
	%CV	10.311	77.939	127.250	45.992	54.960	128.749	44.089	51.943	20.625	47.490	41.573	28.234
	STD.ERR	5.099	12.667	1.147	0.123	7.008	0.537	0.004	0.387	3.091	0.223	0.005	0.000
Monsoon (July - August 2023)	Range	235.5 - 310	29.5 - 125	0 - 5	0.288 - 2.067	10.05 - 76.45	0.325 - 7.26	0.03 - 0.115	0.31 - 2.407	9.672 - 46.496	1.755 - 4.287	0.01 - 0.08	0.002 - 0.009
	Mean	267.500	73.050	1.000	1.030	38.425	2.015	0.069	1.178	26.071	3.464	0.033	0.005
	SD	22.501	28.481	1.466	0.624	24.921	1.986	0.026	0.733	11.118	0.991	0.025	0.002
	%CV	8.412	38.988	146.629	60.543	64.856	98.547	37.002	62.261	42.647	28.619	76.072	45.341
	STD.ERR	7.115	9.007	0.464	0.197	7.881	0.628	0.008	0.232	3.516	0.314	0.008	0.001
Post-Monsoon (November - December 2023)	Range	201.5 - 284.5	25.665 - 97.8	0 - 0	0.196 - 2.639	16.2 - 76.3	0 - 3.75	0.004 - 1.312	0.503 - 2.527	14.827 - 48.945	1.226 - 4.002	0.174 - 1	0 - 0.015
	Mean	241.650	60.611	0.000	0.734	38.390	0.375	0.145	1.227	28.909	2.909	0.472	0.002
	SD	25.818	22.648	0.000	0.701	21.867	1.125	0.389	0.677	10.588	0.888	0.255	0.005
	%CV	10.684	37.366	0.000	95.581	56.961	300.000	267.894	55.177	36.625	30.511	53.960	300.000
	STD.ERR	8.164	7.162	0.000	0.222	6.915	0.356	0.123	0.214	3.348	0.281	0.081	0.001

3.6.6 Alkaline earth metallic ions

Calcium and magnesium ions are mainly present in aquatic system as sulphate, phosphate and chloride form. In the period of investigation the conc. of Ca^{2+} and Mg^{2+} were detected as min. 62.52 mg/L and 12.65 mg/L whereas 99.78 mg/L and 61.15 mg/L as high conc.in pre monsoon season. In monsoon session 103 to 191.50 mg/L for Ca^{2+} ions while 41.5 mg/L to 95.50 mg/L for Mg^{2+} ions detected. In post monsoon season the min. and max. Concentration for Ca^{2+} and Mg^{2+} ions were observed 97 to 170.50 mg/L and 25 to 91.50 mg/L respectively.

3.6.7 Iron

Iron has little direct toxicological significance. It often controls the conc. of other elements including toxic heavy metals (Budasha and Santosh 2021). Iron was estimated quantitatively in the ranging from 0.299 mg/L to 1.556 mg/L in pre monsoon season and 0.288 mg/L to 2.067 mg/L in monsoon season while in post monsoon season 0.196 mg/L to 2.639 mg/L the max. conc. was exceeds than the upper limit of iron 1.00 mg/L as per (BIS 2012 and WHO 2011).

3.6.8 Chromium

It is an essential micronutrient for animals and plants chromium is considered as a little biological and pollution significance (Agarwal et al. 2011). In study field the procured experiment value was calculated in the ranging from 0.003-0.048 mg/L in pre monsoon while in monsoon 0.03mg/L to 0.115 mg/L whereas in post monsoon the ranges were covered in 0.004-1.312 mg/L. These values are under the desirable and max. concentration.

3.6.9 Lead

Lead is found in soil, vegetation, animals and food. It is body poison which is inhibits several key enzymes involved in the overall process of haemo synthesis whereby metabolic intermediates accumulates (Verma 1995). The lead conc. was measured in ranging from 0.02 mg/L to 0.075 mg/L in pre monsoon and in monsoon the conc. was detected in the ranging from 0.01 mg/L to 0.08 mg/L whereas in post monsoon the conc. was detected as 0.174-1.00 mg/L in post monsoon.

3.6.10 Cadmium

Cadmium is not biodegradable, can accumulate in humans vital organs producing progressive toxicity (Boarh and Mishra 2010). The observed results of cadmium ion conc. was computed as ranging from 0.003 mg/L to 0.006 mg/L in pre monsoon whereas in monsoon the ranges covered from 0.002 mg/L to 0.009 mg/L in post monsoon season the ranges were spread from 0-0.015 mg/L all these max. conc. were under the desirable and upper limit.

3.7 Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio is an important parameter for determination of suitability of irrigation water. It is responsible for the sodium hazard (Sunitha et al. 2005). The calculated value for SAR in pre monsoon 0.927-4.383, while in monsoon 0.31 to 2.407 whereas for post monsoon 0.503-2.527.

3.8 Percentage Sodium (PS)

Percentage Sodium in water is a parameter computed to evaluate the suitability for irrigation. Excess sodium combining with carbonate will lead to the formation of alkaline soil while with chloride the saline soils are formed (Dvshiyanthan et al. 2011). The PS was calculated as 34.388-67.389 in pre monsoon, in monsoon 9.672-46.496 however in post monsoon 14.827-49.945.

3.9 Residual Sodium Carbonate (RSC)

Residual sodium carbonate has been calculated to determine the hazardous effect of carbonate and bicarbonate as the quality of water for agricultural purposes (Wilcox 1948, Sethi et al. 2010). The RSC has calculated in pre monsoon season, 0.312 mg/L to 2.566 mg/L whereas in monsoon 1.755 mg/L to 4.287 mg/L however in post monsoon 1.226-4.002 mg/L.

3.10 Correlation Matrix

In pre monsoon 300 relations have been calculated out including positive and negative. The highest correlation was established with high degree between temperature and pH (+ 0.680), pH and Fluoride (0.729), EC and TS (0.788), EC and TDS (0.811), EC and Cl- (0.704), TS and TDS (0.887), TS and Fe (0.846), TDS and Fe (0.751), F^- and Fe^{2+} (0.845), F^- and PS (0.808), SO_4^{2-} and K^+ (0.897), NO_3- and K^+ (0.862), Na and SAR (0.954), Na and PS (0.925), SAR and PS (0.917) Fig. 2.

In monsoon, the positive relationship have been found between EC and NO_3- (0.726), EC and K (0.810), TS and TDS (0.908), TA and RSC (0.847), TH and Mg^{2+} (0.828), NO_3- and K^+ (0.855), Na and SAR (0.987), Na and PS (0.964), SAR and PS (0.983) Fig. 3.

In post monsoon the value of r has been computed between F^- and Turbidity (0.820), TDS and TS (0.925), Cd^{2+} and Ca^{2+}(0.856). Cd^{2+} and F^-(0.608). RSC and TA (0.756), TSS and TS (0.647) Fig. 4.

3.11 Water Quality Index

Water quality index is a statistical parameter used for the interpretation the composite influence of individual water quality parameter on the overall quality of water. In our study periods, pre monsoon, monsoon and post monsoon the WQI was computed as the ranging from 129.57 (SD-2) to 240.99 (SD-10) for pre monsoon 2023, 76.18 (SD-3) to 263.88 (SD-6) for monsoon 2023 while for post monsoon 2023, 730.11 (SD-6) to 2186.86 (SD-3). These ranging values are just beyond from the standard parameters (Tables 5, 6, 7).

Table 5. Water Quality Index (WQI) Pre – monsoon 2023

Water Quality Index (WQI) Pre - monsoon 2023			
Sampling Spots	**∑QiWi**	**∑Wi**	**WQI = ∑QiWi / ∑Wi**
SD-1	354504.85	2244.90	157.92
SD-2	290873.20	2244.90	129.57
SD-3	514355.49	2244.90	229.12
SD-4	398946.18	2244.90	177.71
SD-5	403195.00	2244.90	179.61
SD-6	416582.69	2244.90	185.57
SD-7	405184.72	2244.90	180.49
SD-8	378010.05	2244.90	168.39
SD-9	434273.37	2244.90	193.45
SD-10	540990.52	2244.90	240.99

Table 6. Water Quality Index (WQI) Monsoon – 2023

Water Quality Index (WQI) Monsoon 2023			
Sampling Spots	**∑QiWi**	**∑Wi**	**WQI =∑QiWi / ∑Wi**
SD-1	266515.47	2244.90	118.72
SD-2	369897.06	2244.90	164.77
SD-3	171010.65	2244.90	76.18
SD-4	477452.73	2244.90	212.68
SD-5	497669.25	2244.90	221.69
SD-6	592385.41	2244.90	263.88
SD-7	410512.88	2244.90	182.87
SD-8	442126.30	2244.90	196.95
SD-9	824360.43	2244.90	367.22
SD-10	551823.47	2244.90	245.81

Table 7. Water Quality Index (WQI) Post – monsoon 2023

Water Quality Index (WQI) Post-Monsoon 2023			
Sampling Spots	**∑QiWi**	**∑Wi**	**WQI = ∑QiWi / ∑Wi**
SD-1	2123312.34	2244.90	945.84
SD-2	2927458.71	2244.90	1304.05
SD-3	4909276.17	2244.90	2186.86
SD-4	4260109.45	2244.90	1897.69
SD-5	1903129.04	2244.90	847.76
SD-6	1639030.72	2244.90	730.11
SD-7	853669.34	2244.90	380.27
SD-8	1742470.82	2244.90	776.19
SD-9	2041926.59	2244.90	909.59
SD-10	1895905.15	2244.90	844.54

GROUND WATER ANALYSIS RESULT OF SARGUJA DISTRICT FOR THE MONTH ...APRIL - MAY (PRE MONSOON) OF YEAR ...2023...																							
	Tem	*pH*	*EC*	*Turbi*	*TS*	*TDS*	*TSS*	*TA*	*TH*	*Ca2+*	*Mg2+*	*F-*	*Cl-*	*SO42-*	*NO3-*	*Fe*	*Na*	*K*	*Cr*	*SAR*	*PS*	*RSC*	*Pb*	*Cd*
Tem	**1.000**																							
pH	**0.680**	**1.000**																						
EC	0.022	-0.254	**1.000**																					
Turbi	-0.326	-0.292	-0.224	**1.000**																				
TS	-0.090	-0.320	**0.778**	0.233	**1.000**																			
TDS	-0.095	-0.259	**0.811**	0.167	**0.887**	**1.000**																		
TSS	0.045	-0.005	-0.378	0.050	-0.153	**-0.591**	**1.000**																	
TA	0.316	-0.024	0.448	-0.035	0.127	0.409	**-0.655**	**1.000**																
TH	0.005	-0.370	0.273	0.064	0.057	0.288	**-0.517**	**0.695**	**1.000**															
Ca2+	0.487	0.244	0.466	-0.074	0.448	**0.565**	-0.428	0.304	0.429	**1.000**														
Mg2+	**0.531**	0.190	-0.032	0.190	-0.103	-0.167	0.179	0.137	0.134	0.362	**1.000**													
F-	**0.533**	**0.729**	0.045	-0.366	-0.134	0.137	**-0.529**	0.241	-0.212	0.348	0.100	**1.000**												
Cl-	0.280	-0.119	**0.704**	-0.125	**0.508**	0.402	0.028	**0.552**	0.279	0.182	0.211	-0.149	**1.000**											
SO42-	-0.302	-0.488	**0.589**	-0.235	0.449	0.349	0.037	0.022	0.306	0.150	-0.047	-0.391	**0.558**	**1.000**										
NO3-	-0.286	-0.492	**0.509**	0.132	**0.676**	**0.628**	-0.165	-0.134	0.235	0.488	0.071	-0.195	0.159	**0.701**	**1.000**									
Fe	-0.176	-0.467	**0.625**	0.491	**0.846**	**0.751**	-0.130	0.143	0.332	**0.529**	0.165	-0.374	0.369	0.383	**0.685**	**1.000**								
Na	0.299	0.447	0.190	-0.236	-0.034	0.238	**-0.569**	0.231	-0.063	0.381	0.317	**0.845**	-0.036	-0.024	0.167	-0.172	**1.000**							
K	**-0.532**	**-0.590**	**0.611**	-0.002	**0.640**	**0.560**	-0.081	-0.125	0.160	0.158	-0.182	-0.357	0.344	**0.897**	**0.862**	**0.563**	0.027	**1.000**						
Cr	-0.054	**-0.649**	**0.655**	0.202	**0.690**	**0.556**	0.014	0.383	0.454	0.225	0.193	-0.487	**0.747**	**0.646**	**0.577**	**0.706**	-0.237	**0.597**	**1.000**					
SAR	0.151	0.389	0.164	-0.285	-0.003	0.227	-0.492	0.084	-0.167	0.252	0.130	**0.779**	-0.050	0.119	0.250	-0.235	**0.954**	0.184	-0.241	**1.000**				
PS	0.240	**0.599**	-0.044	-0.206	-0.222	-0.028	-0.329	-0.001	-0.327	0.137	0.283	**0.808**	-0.148	-0.134	-0.040	-0.372	**0.925**	-0.094	-0.468	**0.917**	**1.000**			
RSC	-0.030	-0.165	0.322	-0.086	0.038	0.307	**-0.592**	**0.846**	**0.511**	-0.121	-0.349	0.101	0.411	-0.003	-0.296	-0.072	-0.001	-0.098	0.240	-0.038	-0.148	**1.000**		
Pb	-0.378	-0.108	0.028	0.127	0.323	0.387	-0.265	-0.033	-0.040	-0.115	**-0.770**	0.014	-0.064	0.146	0.213	0.025	-0.086	0.310	0.011	0.128	-0.099	0.295	**1.000**	
Cd	-0.128	-0.348	**0.584**	-0.221	0.337	0.304	-0.063	-0.057	-0.052	0.194	0.241	-0.037	0.138	0.296	0.391	0.398	0.182	0.396	0.300	0.092	0.050	-0.203	**-0.535**	**1.000**

Fig. 2. Correlation matrix for the Month April - May (Pre -Monsoon) of Year 2023

GROUND WATER ANALYSIS RESULT OF SARGUJA DISTRICT FOR THE MONTH ...JULY - AUGUST (MONSOON) OF YEAR ...2023...																								
	Tem	*pH*	*EC*	*Turbi*	*TS*	*TDS*	*TSS*	*TA*	*TH*	*Ca2+*	*Mg2+*	*F-*	*Cl-*	*SO42-*	*NO3-*	*Fe*	*Na*	*K*	*Cr*	*SAR*	*PS*	*RSC*	*Pb*	*Cd*
Tem	**1.000**																							
pH	-0.457	**1.000**																						
EC	0.253	-0.195	**1.000**																					
Turbi	-0.452	-0.211	-0.263	**1.000**																				
TS	-0.077	-0.216	0.430	0.280	**1.000**																			
TDS	-0.023	-0.055	**0.532**	0.151	**0.908**	**1.000**																		
TSS	-0.136	-0.400	-0.030	0.362	**0.574**	0.178	**1.000**																	
TA	-0.355	0.434	-0.104	0.027	0.212	0.056	0.389	**1.000**																
TH	-0.061	-0.214	0.099	0.284	0.439	0.291	0.461	**0.542**	**1.000**															
Ca2+	**0.549**	0.050	0.204	-0.187	0.356	0.356	0.141	0.236	0.343	**1.000**														
Mg2+	-0.460	-0.094	-0.052	0.372	0.453	0.285	**0.507**	**0.552**	**0.828**	0.102	**1.000**													
F-	**0.514**	0.123	0.189	-0.324	-0.430	-0.315	-0.396	0.227	0.177	0.437	-0.182	**1.000**												
Cl-	-0.412	0.067	0.243	-0.061	0.229	-0.041	**0.619**	0.340	0.048	-0.140	0.262	-0.341	**1.000**											
SO42-	0.076	0.329	0.433	-0.484	-0.159	-0.043	-0.289	-0.217	-0.152	0.197	-0.204	0.161	0.328	**1.000**										
NO3-	-0.050	-0.299	**0.726**	0.272	**0.666**	**0.735**	0.127	-0.247	0.167	0.180	0.256	-0.230	0.149	0.196	**1.000**									
Fe	-0.097	0.046	-0.375	0.197	0.316	0.286	0.182	-0.151	-0.089	-0.117	-0.140	**-0.612**	-0.160	-0.230	-0.204	**1.000**								
Na	0.477	-0.214	0.447	-0.105	0.238	0.114	0.338	0.414	**0.542**	**0.505**	0.076	**0.594**	0.111	0.048	0.023	-0.206	**1.000**							
K	-0.124	-0.199	**0.810**	-0.031	0.393	**0.537**	-0.127	-0.319	-0.091	-0.178	0.057	-0.212	0.221	0.301	**0.855**	-0.317	-0.111	**1.000**						
Cr	**0.547**	0.214	-0.160	-0.277	-0.385	-0.314	-0.291	0.015	0.136	**0.615**	-0.246	**0.688**	-0.370	0.384	-0.389	-0.079	0.406	**-0.555**	**1.000**					
SAR	0.480	-0.269	0.461	-0.097	0.185	0.064	0.310	0.336	0.477	0.383	-0.003	**0.570**	0.105	0.028	0.002	-0.182	**0.987**	-0.081	0.353	**1.000**				
PS	0.442	-0.181	0.421	-0.059	0.076	-0.033	0.242	0.321	0.382	0.349	-0.098	**0.623**	0.103	0.066	-0.046	-0.218	**0.964**	-0.119	0.404	**0.983**	**1.000**			
RSC	**-0.522**	0.499	-0.200	0.002	-0.076	-0.200	0.212	**0.847**	0.185	-0.246	0.258	0.106	0.371	-0.276	-0.450	-0.070	0.203	-0.296	-0.201	0.199	0.229	**1.000**		
Pb	0.277	-0.194	-0.244	-0.307	-0.423	-0.496	-0.024	-0.321	-0.066	-0.253	-0.309	-0.023	-0.003	0.262	**-0.545**	0.370	0.100	-0.399	0.361	0.175	0.167	-0.144	**1.000**	
Cd	0.318	-0.304	**0.540**	0.033	0.367	0.367	0.144	-0.434	-0.448	0.034	**-0.568**	-0.210	0.160	0.078	0.453	0.195	0.182	0.441	-0.245	0.245	0.266	-0.328	-0.071	**1.000**

Fig. 3. Correlation Matrix for the Month July- August (Monsoon) of Year 2023

GROUND WATER ANALYSIS RESULT OF SARGUJA DISTRICT FOR THE MONTH ...NOVEMBER - DECEMBER (POST MONSOON) OF YEAR ...2023...																							
	Tem	pH	EC	Turbi	TS	TDS	TSS	TA	TH	Ca2+	Mg2+	F-	Cl-	SO42-	NO3-	Fe	Na	K	Cr	SAR	PS	RSC	Pb	Cd
Tem	1.000																							
pH	0.427	1.000																						
EC	-0.234	-0.077	1.000																					
Turbi	-0.052	-0.086	-0.142	1.000																				
TS	-0.479	-0.339	**0.684**	0.366	1.000																			
TDS	**-0.536**	-0.350	**0.672**	0.263	**0.985**	1.000																		
TSS	-0.024	-0.148	0.448	**0.672**	**0.647**	**0.507**	1.000																	
TA	-0.309	-0.217	0.326	0.082	**0.528**	0.478	**0.530**	1.000																
TH	-0.043	0.173	0.277	-0.297	0.124	0.111	0.131	**0.651**	1.000															
Ca2+	0.474	0.029	-0.026	-0.376	-0.295	-0.318	-0.065	0.137	0.269	1.000														
Mg2+	0.153	-0.443	0.217	0.303	0.398	0.345	0.467	0.396	0.406	0.279	1.000													
F-	0.176	0.149	-0.027	-0.307	-0.013	0.069	-0.371	0.140	**0.507**	0.344	0.436	1.000												
Cl-	0.471	0.332	0.431	-0.054	0.388	0.371	0.302	0.362	0.363	0.249	0.361	0.483	1.000											
SO42-	-0.041	0.379	0.191	**-0.720**	-0.273	-0.236	-0.324	0.022	0.177	0.093	**-0.701**	-0.245	-0.011	1.000										
NO3-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000									
Fe	0.095	0.196	-0.264	**0.820**	0.257	0.162	**0.574**	0.118	-0.254	-0.096	0.060	-0.269	0.101	-0.420	0.000	1.000								
Na	-0.094	-0.247	0.231	-0.482	0.296	0.381	-0.208	0.345	**0.582**	0.139	0.437	**0.662**	0.423	0.033	0.000	-0.444	1.000							
K	-0.459	-0.235	**0.869**	-0.012	**0.558**	**0.536**	0.419	0.222	0.056	-0.094	0.079	-0.278	-0.002	0.123	0.000	-0.243	-0.118	1.000						
Cr	-0.272	**0.540**	-0.243	-0.337	-0.382	-0.316	**-0.516**	-0.203	0.009	0.044	**-0.746**	0.006	-0.343	**0.545**	0.000	-0.008	-0.236	-0.104	1.000					
SAR	-0.183	-0.255	0.214	-0.474	0.316	0.413	-0.251	0.290	**0.508**	-0.007	0.335	**0.589**	0.352	0.070	0.000	-0.449	**0.985**	-0.120	-0.194	1.000				
PS	-0.223	-0.174	0.220	**-0.532**	0.254	0.358	-0.316	0.222	**0.515**	-0.099	0.210	**0.527**	0.278	0.184	0.000	**-0.513**	**0.949**	-0.101	-0.099	**0.983**	1.000			
RSC	**-0.586**	-0.048	0.242	0.137	0.494	0.478	0.361	**0.751**	0.345	-0.450	-0.144	-0.199	0.091	0.256	0.000	0.135	0.097	0.229	0.079	0.152	0.180	1.000		
Pb	-0.328	-0.181	-0.138	**0.622**	0.461	0.464	0.255	0.355	-0.080	**-0.507**	0.250	0.192	0.142	**-0.601**	0.000	0.419	0.010	-0.114	-0.243	0.044	-0.022	0.486	1.000	
Cd	0.497	0.172	0.109	-0.341	-0.140	-0.170	0.050	0.409	**0.649**	**0.851**	0.489	**0.608**	**0.553**	0.035	0.000	-0.149	0.385	-0.111	-0.106	0.229	0.143	-0.198	-0.271	1.000

Fig. 4. Correlation Matrix for the Month November –December (Post Monsoon) of Year 2023

4. CONCLUSION

In this paper, we have over emphasized the seasonal variation of different water qualities with some selected toxic non-metallic and metallic elements in the ground water sources of Sarguja district. in perspective of some parameters *Viz* fluoride and iron was observed up to the alarming level, 15 mg/L and 2.639 mg/L respectively which is many folds greater than the standard accepted values as per the water monitoring agencies BIS (2012) and WHO (2011). The computed WQI is also many times greater than the accepted limit. From this study the conclusion has come the ground water of the study field is mandatory to purify before the used in different purposes.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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