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Hydro Chemical Analysis of Ground Water of Korba Chhattisgarh, India

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ABSTRACT
The quality analysis of ground water and their use in drinking, agricultural etc. was assessed in Korba Chhattisgarh, India, based on various water quality parameters. Total 30 ground water samples in three seasons: pre-monsoon, monsoon and post monsoon were collected randomly and investigate hydro chemical nature through analysis of major cations (Ca^{2+},Mg^{2+}, K^{+}), anions (HCO_3^-, Cl^-, F^-,SO_4^{2-}, NO^{3-}, PO_4^{3-}, CO_3^{2-}) and trace heavy metals (Pb^{2+}, Cr^{2+}, Zn^{2+}, Fe^{2+} and As) besides few physical and chemical parameters (pH, electrical conductivity, alkalinity, total hardness, TDS, turbidity, DO, BOD and COD). Preliminary tests of them also showed all samples were colourless, odourless, and tasteless. As well as micro organisms like E. coli also absent in it. Resultant, all experiments of water samples via various methods indicated that majority of the ground water in the study area was chemically suitable for use in drinking, agricultural and other purposes, specially in monsoon season. In comparisons of monsoon season, it also revealed that the quality of ground water was low in pre and post monsoon.
Keywords: *Physico-chemical parameters, hydro chemical, ground water, major cations, major anions and trace heavy elements.*

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INTRODUCTION

Ground water, one of the important and vital natural resource in biosphere. It used for the different domestic, agricultural and industrial purposes. The quality of water highly important for water supply. Water quality influenced via natural and anthropogenic effects with local climate, geology and irrigation. Due to global population growth and climate changing conditions, water scarcity in many areas which were growing fast and located in unfavourable places [1].Various scientists in India, carried out extensive studies on water quality. Laluraj and co-workers described ground water chemistry of coastal zones of Cochin and explained that ground waters present in the shallow aquifers were poor in quality[2]. Due to increase in urbanization and industrialization which leads to deterioration in ground water quality. Srinivas *et.al.* and Jha *et. al.* described the degradation of water quality in Hyderabad and Bihar, respectively[3, 4]. The untreated industrial waste also influenced ground water, with discharged waste in unlined drains could percolate underground and directly affecting the quality of ground water. Patnaik and co-workers described, water pollution generated from major industries[5]. Abbasi and co-workers described the impacts of waste water on to water quality[6]. Jagtap *et. al.*and Sunitha *et al.*described the classification of assessing water quality for various applications[7, 8].

Presently, in India, water pollution exhibited a serious problem. Due to human activities ,contamination in groundwater lead to adverse effects on human health and ecosystem[9].In India, around 70% of surface water resources and large number of groundwater reserves present which already contaminated via biological, organic and inorganic pollutants. The difference in concentration of dissolved ions in groundwater, generally examined through lithology. And observed velocity of groundwater flow, as well as examined quantity, nature of geochemical reactions, solubility of salts and human activities[10, 11]. Generally, ground water contaminated through pollutants, for example, excess of fertilizers, pesticides, effluents, discharged from industries and sewage etc. Today, nearly around 70% rivers and stream of world had maximally polluted water because of disposal of sewage, industrial waste, radioactive waste etc.

Today, direct source of water supply for human consumption from ground water without any biochemical treatment and pollution level get high concern. Due to industrialization and urbanization increase the

contamination of heavy metal in ground water, also increased the water pollution. Heavy metal contamination because of presence of high concentration of mercury, cadmium, lead, zinc, nickel including arsenic, cadmium, copper, zinc etc, showed potential impact on ground water. For drinking water, ground water should be non-toxic, living and free from non-living organisms and excessive amount of minerals and elements. Non-toxic and existed suitable quantity of minerals in ground water become more crucial alternative resource for drastic use in social, agricultural, and industrial development. Thus, hydro-chemical experiments were main objectives for ground water quality.

In present study, water samples collected from cased wells during three different periods: pre-monsoon, monsoon and post-monsoon, in order to determine their physical and chemical properties. The location of the samples showed in Figure 1. Chemical analysis were carried out based on procedures stipulated by APHA [12, 13]; and Hem [14, 15]. The chemical analysis data described in Table 1, Table 2 and Table 3. Concentration of total dissolved solids (TDS), total hardness (TH), and chloride (Cl^-)etc were determined via standard methods [15-17].

Study area:

The study area of my proposed work is Korba, Chhattisgarh. Korba, well known place in India as well as highly important in global map. That place famous for energy hub of India. Due to provided electricity to different parts of India, called "Urjadhani" of Chhattisgarh. Korba,The city situated on bank of Hasdeo River. Geographically, Korba city located at 22° 20' north latitude and 82° 42' east longitudes with height 304.8 meters above the sea level. Average temperature was around 44.8 °C including rain fall of city 1504.7 mm, respectively. Here, thermal power plants were conducting, and aluminium smelter plants also running smoothly. Including that, explosive and fertilizer plants also stabilized in Korba city and surrounding areas. During development of city, dumping of solid wastage material and discharging of wastewater indifferent water also received undesired toxic material, consequently. Water quality were regularly declined field. Thus, we explored active metallic and non-metallic elements in different ground water sources during three different periods: pre-monsoon, monsoon and post-monsoon, in Korba and adjoining areas.

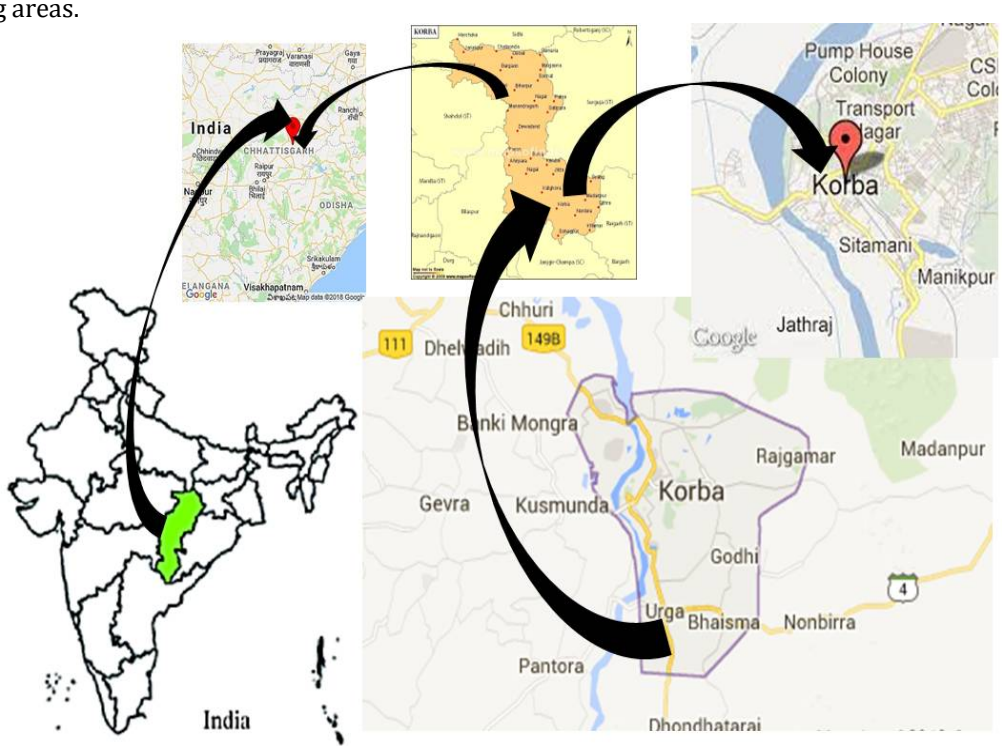

Figure 1: Location of Korba, Chhattisgarh in India.

MATERIAL AND METHODS

Effluent samples were collected from ten different sampling spot which located to Korba, Chhattisgarh in India during three different seasons like pre monsoon, monsoon and post monsoon, respectively. Borosilicate glassware, distilled water and related chemical reagents used as analytical grade and received from Merck 99.8% and Fischer Scientific and used them without any further purification.Samples collected in sterilized, one litre capacity screw-capped polyethylene bottles which used to analyse physico-chemical parameters. Underground water bodies were collected and analysed through standard protocol [12, 13, 18-21]. 2 liter water samples collected in polyethylene bottles which

previously soaked 8M HNO_3 and cleaned with detergent followed by rinsing with double distilled water. The collected ground water samples preserved in ice cooled chamber and kept in dark room[18].Double distilled water used for further analysis and solution preparation.

Various physiochemical parameters were analysed via standard procedures[22]. Physical parameters of water were colour, odour and turbidity. Due to presence of mineral and organic matters, colour in ground water observed. Turbidity was measuring of suspended materials in water like clay, silt and microscopic organism. Taste and odour derived from bacterial and dissolved gases. Temperature, pH, alkalinity, hardness, turbidity, conductivity measured via thermometer, pH meter, conductometry, EDTA titration, turbidity meter, respectively. For quality assessment, estimation of nitrate (NO_3^-) used ion selective electrode method, phosphate (PO_4^{3-})and sulphates(SO_4^{2-}), fluoride (F^-)used spectrophotometer, carbonate (CO_3^{2-}),bicarbonate (HCO_3^-).Total hardness estimated through calcium (Ca^{2+}), magnesium (Mg^{2+}), and chloride (Cl^-) by titrimetric methods. Sodium (Na^+) and potassium (K^+) were determined via flame photometer[12].TS was determined by gravimetrically. And TSS determined subtracting TS and TDS. BOD estimated through incubation method and COD determined by reflux method. Cl^- determined by $AgNO_3$ titration method with $K_2Cr_2O_7$ indicator [23]. F^-,SO_4^{2-}, NO_3^- and Fe^{2+}were determined by spectrophotometer.

Result and Discussion

Here, we explained quality of groundwater in three different rainy seasons: pre monsoon, monsoon and post monsoon. That described in three different parameters; physico-chemical, major anions and major cations. According to preliminary tests, all 30 samples in three seasons were colourless, odourless, and tasteless. Including that microorganisms like E. coli also absent in those samples.

Table 1: Analytical data for ground water samples in pre-monsoon season using IS 3025.

Parameters	Acceptable limit	Permissible limit	RPN	MP	RSN	PP	AGC	SV	RR	SM	BW	PB
Temperature	-	-	32.6	33.0	32.1	33.6	33.1	30.0	31.7	32.1	33.0	31.6
pH@25 pH scale	6.5-8.5	6.5-8.5	6.4	6.0	6.1	6.5	6.1	7.3	6.6	7.5	6.3	6.1
Conductivity@25 μS	750-2250	400-2000	265	550	335	281	379	278	698	191	312	408
Turbidity NTU	1	5	1.5	10.5	41.5	2.5	20.5	1.7	2.0	1.9	1.2	32.6
DO mg/L	5	5-6	6.5	6.4	5.9	6.3	5.9	6.3	6.4	6.7	6.4	6.7
BOD mg/L	5	5	1.5	1.3	1.6	1.1	1.4	1.6	1.2	1.4	1.1	1.3

3.7	293	240	53	58.2	248.6	19.0	12.5	0.157	65.1	0.032	1.0
3.6	223	163	60	79.3	164.0	23.4	17.8	0.027	87.1	0.052	4.9
3.3	193	130	63	70.1	128.9	22.0	15.2	0.011	84.1	0.043	5.0
3.5	482	423	59	210.2	423.1	47.8	23.5	0.216	58.4	0.019	11.8
3.3	235	180	55	189.3	178.4	23.0	14.0	0.010	53.1	0.023	3.9
3.1	318	257	61	82.3	235.9	23.9	16.2	0.046	35.2	0.065	6.3
3.3	213	149	64	175.4	145.0	21.0	19.9	0.002	38.1	0.070	3.6
3.5	261	201	60	101.2	130.0	24.6	15.2	0.012	39.1	0.023	0.5
3.1	389	328	61	47.5	132.2	25.0	12.5	0.231	91.5	0.037	39.5
3.7	247	189	58	152.2	138.1	20.3	18.2	0.020	34.2	0.040	7.9
10	4000	2000	-	600	600	200	100	1.5	1000	0.1	45
10	700	500	-	200	200	75	30	1	250	0.1	45
COD mg/L	**TS** mg/L	**TDS** mg/L	**TSS** mg/L	**Total Alkalinity** mg/L	**Total Hardness** mg/L	**Calcium as Ca^{2+}** mg/L	**Magnesium as Mg^{2+}** mg/L	**Fluoride** mg/L	**Chloride** mg/L	**Phosphate** mg/L	**Nitrate** mg/L

Sulphate mg/L	**Sodium** mg/L	**Potassium** mg/L	**Carbonate** mg/L	**Bicarbonate** mg/L	**Pb** mg/L	**Cr** mg/L	**Zn** mg/L	**Iron** mg/L	**Arsenic** mg/L
5.48	7.50	9.00	Nil	89	0.004	0.002	0.30	2.45	BDL
20.00	8.79	5.43	Nil	96	0.050	0.001	0.45	0.19	BDL
28.57	5.90	4.00	Nil	123	0.008	0.00	0.51	0.07	BDL
27.45	7.00	8.61	Nil	140	0.005	0.00	0.37	1.10	BDL
18.10	7.84	9.53	Nil	84	0.001	0.01	0.40	0.01	BDL
22.00	6.23	4.28	Nil	92	0.011	0.01	0.52	1.41	BDL
8.50	8.45	5.00	Nil	112	0.001	0.02	0.35	0.01	BDL
8.12	9.36	7.84	Nil	106	0.009	0.01	0.35	4.08	BDL
19.00	5.23	7.52	Nil	96	0.008	0.00	0.41	1.20	BDL
15.20	12.30	8.59	Nil	98	0.010	0.01	0.23	0.14	BDL
-	200	25	-	-	0.01	0.05	15	0.30	0.01
400	75-200	10	-	-	0.01	0.05	5	0.30	0.01

Table 2: Analytical data for ground water samples in monsoon season using IS 3025 method.

Parameters	Acceptable limit	Permissible limit	RPN	MP	RSN	PP	AGC	SV	RR	SM	BW	PB
Temperature	-	-	22.7	21.6	20.9	21.5	22.4	22.1	21.7	22.0	21.7	22.6
pH@25 pH scale	6.5-8.5	6.5-8.5	6.7	6.8	7.0	6.9	6.6	7.1	6.6	7.2	6.7	6.8
Conductivity@ 25 μS	750-2250	400-2000	120	146	124	97	142	112	175	45	80	150
Turbidity NTU	1	5	1.0	4.5	12.1	1.5	4.5	1.0	1.0	1.2	1.0	8.0
DO mg/L	5	5-6	7.1	6.9	6.9	7.1	6.9	7.0	7.0	6.9	6.9	6.9
BOD mg/L	5	5	2.2	2.3	2.6	2.1	2.4	2.6	2.2	2.4	2.1	2.3
COD mg/L	10	10	6.5	6.9	7.8	6.3	7.2	7.8	6.7	7.2	6.3	6.9
TS mg/L	700	4000	198	322	578	158	221	165	151	114	147	178
TDS mg/L	500	2000	154	274	178	120	182	130	210	74	111	145
TSS mg/L	-	-	44	48	40	38	39	35	41	40	36	33
Total Alkalinity mg/L	200	600	112.2	41.6	104.4	147.4	74.1	145.1	195.0	75.1	45.3	74.2
Total Hardness mg/L	200	600	120.1	110.2	112.3	98.0	85.9	60.4	178.1	90.9	80.0	100.6
Calcium as Ca^{2+} mg/L	75	200	15.2	41.0	18.6	20.1	12.9	31.0	19.8	20.0	18.4	16.1.
Magnesium as Mg^{2+} mg/L	30	100	16.2	10.5	14.2	9.2	14.1	13.2	20.5	17.2	14.5	10.5
Fluoride mg/L	1	1.5	0.001	0.120	0.011	0.001	0.020	0.000	0.123	0.010	0.027	0.120
Chloride mg/L	250	1000	30.2	55.5	35.1	31.1	28.2	45.1	25.4	79.1	80.1	61.2
Phosphate mg/L	0.1	0.1	0.070	0.041	0.026	0.067	0.071	0.029	0.023	0.040	0.048	0.043
Nitrate mg/L	45	45	4.2	32.0	0.2	1.9	6.1	2.9	10.2	4.2	4.1	0.5
Sulphate mg/L	400	-	15.32	14.00	8.10	2.50	19.45	17.02	23.25	21.45	15.12	2.60
Sodium mg/L	75-200	200	10.20	4.23	5.20	7.46	2.23	3.80	6.90	5.00	8.00	6.90
Potassium mg/L	10	25	1.50	4.56	5.14	4.50	4.12	7.50	2.56	3.50	7.10	4.50
Carbonate mg/L	-	-	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Bicarbonate mg/L	-	-	68	230	293	119	108	155	31	293	98	266
Pb mg/L	0.01	0.01	0.001	0.001	0.003	0.000	0.020	0.001	0.004	0.008	0.030	0.001
Cr mg/L	0.05	0.05	0.00	0.00	0.001	0.003	0.005	0.004	0.00	0.00	0.001	0.009
Zn mg/L	5	15	0.17	0.15	0.25	0.12	0.10	0.01	0.13	0.18	0.45	0.30
Iron mg/L	0.30	0.30	0.15	1.20	1.08	0.01	1.32	0.01	1.10	0.07	0.19	1.25
Arsenic mg/L	0.01	0.01	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Table 3: Analytical data for ground water samples in post-monsoon season.

Parameters	Acceptable limit	Permissible limit	RPN	MP	RSN	PP	AGC	SV	RR	SM	BW	PB
Temperature	-	-	18.4	18.9	19.0	18.2	19.1	18.4	18.4	19.6	19.1	19.0
pH@25 pH scale	6.5-8.5	6.5-8.5	6.6	5.9	6.4	6.9	6.1	7.6	6.8	7.9	6.5	6.3
Conductivity@25 μS	750-2250	400-2000	296	688	341	280	408	305	745	198	342	423
Turbidity NTU	1	5	2.0	2.8	20.62	2.6	23.6	2.9	3.0	2.1	1.9	20.1
DO mg/L	5	5-6	7.5	7.4	7.2	6.9	7.3	6.9	6.9	7.1	6.9	7.2
BOD mg/L	5	5	3.1	3.3	3.2	3.5	3.1	3.4	3.6	3.5	3.6	3.3
COD mg/L	10	10	9.2	9.4	9.3	10.5	9.3	10.3	10.7	10.5	10.6	9.9
TS mg/L	700	4000	252	426	270	207	297	250	497	201	227	310
TDS mg/L	500	2000	197	368	208	156	248	185	434	135	167	256
TSS mg/L	-	-	55	58	62	51	49	65	62	66	60	54
Total Alkalinity mg/L	200	600	156.3	49.4	102.7	82.4	86.9	200.5	217.3	72.6	81.6	61.2
Total Hardness mg/L	200	600	145.2	133.4	135.3	121.8	137.4	190.6	227.1	126.6	133.6	125.4
Calcium as Ca^{2+} mg/L	75	200	23.5	29.5	25.5	21.9	26.3	25.5	48.6	23.3	24.6	23.1
Magnesium as Mg^{2+} mg/L	30	100	21.6	14.5	17.4	20.5	17.4	14.4	25.6	16.7	18.5	16.4
Fluoride mg/L	1	1.5	0.054	0.451	0.061	0.010	0.086	0.040	0.276	0.020	0.025	0.357
Chloride mg/L	250	1000	34.6	96.4	39.9	40.6	38.9	56.6	61.3	85.6	88.91	75.97
Phosphate mg/L	0.1	0.1	0.050	0.041	0.028	0.065	0.068	0.029	0.023	0.044	0.057	0.038
Nitrate mg/L	45	45	12.6	44.9	1.0	5.6	7.2	4.5	13.7	8.8	6.9	1.2
Sulphate mg/L	400	-	19.50	21.71	10.77	10.61	24.79	21.61	34.53	30.33	22.45	9.00
Sodium mg/L	75-200	200	13.34	10.65	12.61	10.51	8.12	11.50	7.21	9.32	11.60	10.50
Potassium mg/L	10	25	10.65	11.21	9.42	10.60	6.93	11.87	10.56	9.34	6.32	9.34
Carbonate mg/L	-	-	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Bicarbonate mg/L	-	-	55	68	99	108	116	86	190	88	96	102
Pb mg/L	0.01	0.01	0.012	0.009	0.011	0.010	0.014	0.011	0.008	0.013	0.011	0.008
Cr mg/L	0.05	0.05	0.02	0.02	0.01	0.02	0.03	0.02	0.02	0.01	0.01	0.01
Zn mg/L	5	15	0.30	0.33	0.41	0.36	0.61	0.44	0.38	0.54	0.66	0.37
Iron mg/L	0.30	0.30	0.16	1.25	5.08	0.02	1.98	0.12	1.25	0.09	0.21	5.55
Arsenic mg/L	0.01	0.01	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Physico-chemical parameters

(i) Temperature: The temperature range of ground water observed in three different rainy season as: 32-33°C in pre monsoon, 22-24°C in monsoon and 18-19°C in post monsoon, respectively.

(ii) pH: The pH of solution defined as negative logarithmic of hydrogen ion concentration and generally used parameter in moles per litre at given temperature. Other elements and their toxicity affect pH of solution. The desirable pH range of drinking water was 7.0 to 8.5. The pH range of ground water samples in study area at three different rainy seasons as;6.0 – 7.5 pH in pre-monsoon, 6.6 – 7.2 pH in monsoon and 5.92 – 7.91 pH in post monsoon, respectively. However, pH value fall under 7 indicate the acidic nature of ground water, which accelerate corrosion rate of metallic substances in water. And rise above 7 pH, it also indicated alkaline nature of ground water due to waste contamination of OH^- and HCO_3^-. The average pH value of pre-monsoon, monsoon and post-monsoon were 6.492, 7.5 and 6.745, respectively (i.e. nearly neutral to slightly alkaline, which indicate the suitable for drinking with addition of irrigation). It showed that in monsoon season, the pH values for samples were within the limits, as prescribed for drinking water standard.

(iii) Electrical Conductivity: The electrical conductivity (EC) belongs to concentration of ionized substance in water, as well as depends on contamination of excessive hardness and other mineral. EC of ground water sample varying in different rainy seasons. In pre monsoon the minimum and maximum EC value of samples, varies from 265 µS – 408 µS (Table 1), which were decrease in monsoon as 45 µS – 150 µS (Table 2). As well as again increase in post monsoon season as 296 µS – 688 µS (Table 3).

(iv) Total Hardness: Total hardness (T.H.) was estimated through calcium and magnesium concentrations, which calculated via following equation:

T.H. = 2.497 Ca + 4.11 Mg

Hardness of water did not suitable for domestic use, as well as also show somehow adverse effect in heart diseases [24]. Sawyerand McCarthy described, hardness of water generally classified into four terms [25], which were as follows: (1) Soft: 0 - 75 mg/L, (2)Moderate: 75 mg/L - 150 mg/L; (3) Hard: 150 mg/L - 300 mg/L, and (4) Very hard: >300 mg/L. Here we explain, total hardness of ground water samples in three different rainy seasons. In pre monsoon season, the average T.H. was 192.42 mg/L which had lesser than minimum acceptable limit (200 mg/L). Thus, it comes in hard level. Whereas, in post monsoon season, the average T.H. was 147.672 mg/L, which also less than minimum acceptable limit but it comes under moderate level. Other hand, in monsoon season, the average T.H. was 204.72 mg/L, which comes under acceptable limit and also comes in hard.Resultant; it showed that in all three seasons, the ground water samples were moderate and hard. This hardness because of contamination of Ca^{2+}, Fe^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and other organic and inorganic matters.

(v) Total dissolved solids: Total dissolved solids(TDS) were because ofcontamination of ionic matters and their relationship with electrical conductivity of water [26]. According to Hem, TDS calculated through following equation:

TDS (ppm) = 0.64 * EC (micro mhos/cm)

According to Carroll, based on total dissolved solids water divided into four classes [27], as follows: (i) Fresh water: 0 – 1000 ppm; (ii) Brackish water: 1000 ppm – 10,000 ppm; (iii) Salty water: 10,000 ppm – 100, 000 ppm and (iv) Brine: > 100, 000 ppm. Here, we explained, total dissolved solids of ground water of study area in three different rainy seasons which revealed that in pre-monsoon season, TDS value varies from 130 – 328 mg/L (Table 1)and average value was 22.6 mg/L.In monsoon season, TDS value varies from 74.5 – 274 mg/L(Table 2) and average value was 15.785 mg/L . Whereas, in post monsoon, TDS value varies from 135 – 434 mg/L (Table 3) and average value was 235.4 mg/L.

(vi) Turbidity: Turbidity of different samples during pre-monsoon was 1.5, 10.5, 41.5, 2.5, 20.5, 1.7, 2.0,1.9, 1.2, 32.6 NTU for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Turbidity of different samples during monsoon was 1.0, 4.5, 12.1, 1.5, 4.5, 1.0, 1.0, 1.2, 1.0 and 8.0 NTU for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Turbidity of different samples during post-monsoon was 2.0, 2.8, 20.61, 2.6, 23.6, 2.9, 3.0, 2.1, 1.9 and 20.1 NTU for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively

(vii) Total Alkalinity: Alkalinity of ground water was capacity to neutralize a strong acid because the contamination of bicarbonate, carbonate and hydroxide compound of calcium sodium and potassium. BIS recommended 200 mg/L - 600 mg/Las acceptable permissible limit for drinking water [28].Here we described alkalinity of ground water samples of study area in three rainy seasons which revealed that in pre monsoon season the alkalinity value varies from 58.2 mg/L – 210.2 mg/L. Whereas in monsoon season, alkalinity value varies from 41.5mg/L – 195.0mg/L. And in post monsoon the value varies from 49.4mg/L – 217.36mg/L (Table 1, 2 and 3).

(viii) Total suspended solids: We explained here, total suspended solids (TSS) of ground water samples of study area in different rainy seasons. In pre monsoon season, the TSS value varies from 53 mg/L – 64

mg/L. whereas, it was decreased in monsoon season which varied from 33 mg/L – 48 mg/L. On other hand, TSS value again increased in post monsoon season which varied from 49 mg/L – 66 mg/L.

(ix) DO: the DO data for the 10 different drinking water samples during pre-monsoon, monsoon and post-monsoon, respectively. DO of different samples during pre-monsoon was 6.5, 6.4, 5.9, 6.3, 5.9, 6.3, 6.4, 6.7, 6.4 and 6.7 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. DO of different samples during monsoon was 7.1, 6.9, 6.9, 7.1, 6.9, 7.0, 7.0, 6.9, 6.9 and 6.9 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. DO of different samples during post-monsoon was 7.5, 7.4, 7.2, 6.9, 7.3, 6.9, 6.9, 7.1, 6.9 and 7.2 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively.

(x) BOD: The BOD data for the 10 different drinking water samples during pre-monsoon, monsoon and post-monsoon, respectively. BOD of different samples during pre-monsoon was 1.5, 1.3, 1.6, 1.1, 1.4, 1.6, 1.2, 1.4, 1.1 and 1.3 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. BOD of different samples during monsoon was 2.2, 2.3, 2.6, 2.1, 2.4, 2.6, 2.2, 2.4, 2.1 and 2.3 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. BOD of different samples during post-monsoon was 3.1, 3.3, 3.2, 3.5, 3.1, 3.4, 3.6, 3.5, 3.6 and 3.3 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively.

(xi) COD: The COD data for the 10 different drinking water samples during pre-monsoon, monsoon and post-monsoon, respectively. COD of different samples during pre-monsoon was 3.7, 3.1, 3.5, 3.3, 3.1, 3.3, 3.5, 3.3, 3.6 and 3.7 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. COD of different samples during monsoon was 6.5, 6.9, 7.8, 6.3, 7.2, 7.8, 6.7, 7.2, 6.3 and 6.9 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. COD of different samples during post-monsoon was 9.2, 9.4, 9.3, 10.5, 9.3, 10.3, 10.7, 10.5, 10.6 and 9.9 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively.

Major cations:

(i) Ca^{2+}: Calcium (Ca^{2+}) was major ion in natural waters which comes from rocks, seepage, wastewater etc. The calcium contents in ground water, dependent upon solubility of calcium carbonate, sulphide and rarely chloride .The acceptable limit of calcium for domestic applications were 75 mg/L – 200 mg/L[29]. Those water samples were estimated by EDTA titration method. Firstly acidified those ground water samples of study area by concentrated nitric acid and then evaporate it [30]. After chelation, extraction and mineralization, Ca^{2+}determined by atomic adsorption spectrophotometer. Resultant, in pre-monsoon season, Ca^{2+} value varies from 19 mg/L – 47.8 mg/L. The average of Ca^{2+} observed in study samples was 25 mg/L. whereas in monsoon season, average was slightly decreased up to 21.312 mg/L and varies the values in samples from 15.2 mg/L – 41.0 mg/L. And in post monsoon season, the average value enhanced 27.193 mg/L and value varies from 21.9 mg/L – 48.65 mg/L.

(ii) Mg^{2+}: Magnesium (Mg^{2+}), highly important constituent and essential nutrient for plants and animals. It's solubility in water was around five times higher than calcium. Ca^{2+} and Mg^{2+} both were cause of hardness of water. Mg^{2+} determine through EDTA titration in ground water samples of study area in three different seasons. In pre monsoon, the range of Mg^{2+} varies from 12.5 mg/L – 23.5 mg/L and average value was 16.525 mg/L. Whereas, in monsoon season, the average value decreased 14.03 mg/L and value of samples varies from 9.23 mg/L – 20.5 mg/L. In post monsoon, the average again enhanced 18.327 mg/L and increased values varies from 14.4 mg/L – 25.65 mg/L.

(iv) Na^{+}: Sodium concentration of different samples during pre-monsoon was 12.30, 5.23, 9.36, 8.45, 6.23, 7.84, 7.00, 5.90, 8.79 and 7.50 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB respectively. Sodium concentration of different samples during monsoon was 10.20, 4.23, 5.20, 7.46, 2.23, 3.80, 6.90, 5.00, 8.00 and 6.90 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Sodium concentration of different samples was 13.34, 10.65, 12.61, 10.51, 8.12, 11.50, 7.21, 9.32, 11.60 and 10.50 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively.

(v) K^{+} : Potassium concentration of different samples during pre-monsoon was 8.59, 7.52, 7.84, 5.00, 4.28, 9.53, 8.61, 4.00, 5.43 and 9.00 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Potassium concentration of different samples during monsoon was 1.50, 4.56, 5.14, 4.50, 4.12, 7.50, 2.56, 3.50, 7.10 and 4.50 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Potassium concentration of different samples was 10.65, 11.21, 9.42, 10.60, 6.93, 11.87, 10.56, 9.34, 6.32 and 9.34 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively.

Major anions:

(i) Cl^{-}: The major sources of chloride (Cl^{-}) in natural water were sedimentary rocks, industries and domestic waste water etc. The fixed limit of Cl^{-} was 250mg/L. It determined in samples by 0.1N $AgNO_3$ solution. In pre-monsoon, analysis of water samples in the study area indicates that chloride value varies from 34.2 mg/L – 91.56 mg/L (Table 1) and the average value was 58.615 mg/L. Whereas, in monsoon season, values of Cl^{-} decreased in samples and values varied from 25.4 mg/L – 80.1 mg/L (Table 2). The

average value of Cl^-present in ground water samples was 47.124 mg/L .In post monsoon season, values of Cl^- in ground water samples comparatively increased. It varied from 34.65 mg/L – 96.42 mg/L (Table 3) and the average of Cl- values were 61.908 mg/L.

(ii) HCO_3^-: The concentrations of bicarbonate ions (HCO_3^-) were more than chloride concentration and higher than carbonate (CO_3), but, had less tolerance value because of original mineral sources [31].Here we explained analysis of water samples of study area in three different seasons. However, bicarbonate concentration of different samples during pre-monsoon period was 98, 96, 106, 112, 92, 84, 140, 123, 96 and 89 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Carbonate concentration of different samples during monsoon was 68, 230, 293, 119, 108, 155, 31, 293, 98 and 266 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Carbonate concentration of different samples was 55, 68, 99, 108, 116, 86, 190, 88, 96 and 102 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively.

(iii)Phosphate: Higher concentration of phosphate (PO_4^{3-}) showed the pollution or contamination of pollutants. The major source of anthropogenic phosphorus were sewage, detergents, agricultural effluents, and fertilizers [32, 33]. Here we explained. Analysis of water samples of study area in three different seasons. Which indicates that, in pre monsoon season, phosphate value varies from 0.019 mg/L – 0.07 mg/L (Table 1) and the average value was 0.0404 mg/L. Whereas, in monsoon season, concentration of PO_4^{3-}varied from 0.02 mg/L – 0.07 mg/L (Table 2). The average concentration of PO_4^{3-} present in ground water samples was 0.0458 mg/L. In post monsoon season, concentration of PO_4^{3-} in ground water samples comparatively increased. It varied from 0 – 0.06 mg/L (Table 3) and the average of phosphate values were 0.0443 mg/L.

(iv) Nitrate: The acceptable and permissible limit for nitrate as per IS-3025 were 45 mg/L. Nitrate concentration of different samples during pre-monsoon was 7.9, 39.5, 0.5, 3.6, 6.3, 3.9, 11.8, 5.0, 4.9 and 1.0 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Nitrate concentration of different samples was 4.2, 32.0, 0.2, 1.9, 6.1, 2.9, 10.2, 4.2, 4.1 and 0.5 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Nitrate concentration of different samples was 12.6, 44.9, 1.0, 5.6, 7.2, 4.5, 13.7, 8.8, 6.9 and 1.2 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively.

(v) Sulphate: Sulphate (SO_4^{2-}) present naturally in ground water due to leaching from gypsum and other common minerals. The sulphate concentration changed significantly with time during rainfall in ground water. The maximum allowable limit of sulphate was 400 mg/L. However, the sulphate concentration of study area in pre-monsoon season was varied between 5.48 mg/L – 28.57 mg/L (Table 1) and the average value was 17.242 mg/L. Whereas, in monsoon season, values of SO_4^{2-} decreased in samples and values varied from 2.5 mg/L – 23.25 mg/L (Table 2). The average value of SO_4^{2-} present in ground water samples was 13.881 mg/L. In post monsoon season, concentration of SO_4^{2-} in ground water samples comparatively increased. It varied from 9.0 mg/L – 34.53 mg/L (Table 3) and the average concentration of SO_4^{2-} were 20.53 mg/L.

(vi) Fluoride: At low concentration (1 mg/L) of fluoride (F^-) in drinking water were beneficial but high concentration caused of dental fluorosis (tooth mottling) and more serious skeletal fluorosis [40]. The fluoride concentration of study area in pre-monsoon season varied between 0 – 0.23 mg/L and average concentration was 0.0731 mg/L. Whereas, in monsoon season, values of F^- decreased in samples and values varied from 0 – 0.120 mg/L (Table 2). The average value of F^- present in ground water samples was 0.0432 mg/L. In post monsoon season, concentration of F^- in ground water samples comparatively slightly increased. It varied from 0 – 0.0616 mg/L (Table 3) and the average concentration of F^- were 0.1381 mg/L.

(vii) Carbonate: Carbonate concentration of different samples during pre-monsoon, monsoon and post-monsoon was NIL. Carbonate was totally absent in the water samples collected from different sites of Korba.

Trace heavy elements:

(i) Lead: However, lead concentration of different samples during pre-monsoon period was for samples 0.010, 0.008, 0.009, 0.001, 0.011, 0.001, 0.005, 0.008, 0.050, 0.004mg/LRPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Lead concentration of different samples during monsoon was 0.010, 0.001, 0.003, 0.000, 0.020, 0.001, 0.004, 0.008, 0.030, 0.001mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Lead concentration of different samples was 0.012, 0.009, 0.011, 0.010, 0.014, 0.011, 0.008, 0.013, 0.011, 0.008mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively

(ii) Chromium: However, chromium concentration of different samples during pre-monsoon period was for samples 0.01, 0.00, 0.01, 0.02, 0.01, 0.01, 0.00, 0.00, 0.001, 0.002mg/L RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Chromium concentration of different samples during monsoon was 0.00,

0.00, 0.001, 0.003, 0.005, 0.004, 0.000, 0.000, 0.001, 0.009mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Chromium concentration of different samples was 0.02, 0.02, 0.01, 0.02, 0.03, 0.02, 0.02, 0.01, 0.01, 0.01 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively

(iii) Zinc: However, zinc concentration of different samples during pre-monsoon period was for samples 0.23, 0.41, 0.35, 0.35, 0.52, 0.40, 0.37, 0.51, 0.45, 0.30 mg/L RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Zinc concentration of different samples during monsoon was 0.17, 0.15, 0.25, 0.12, 0.10, 0.01, 0.13, 0.18, 0.45, 0.34mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Zinc concentration of different samples was 0.30, 0.33, 0.41, 0.36, 0.61, 0.44, 0.38, 0.54, 0.66, 0.37 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively.

(iv) Iron: However, iron concentration of different samples during pre-monsoon period was for samples 0.14, 1.20, 4.08, 0.01, 1.41, 0.01, 1.10, 0.07, 0.19, 2.45mg/L RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Iron concentration of different samples during monsoon was 0.15, 1.20, 1.08, 0.01, 1.32, 0.01, 1.10, 0.07, 0.019, 1.25mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively. Iron concentration of different samples was 0.16, 1.25, 5.08, 0.02, 1.98, 0.12, 1.25, 0.09, 0.21, 5.55 mg/L for samples RPN, MP, RSN, PP, AGC, SV, RR, SM, BW and PB, respectively.

(v) Arsenic: Arsenic is in water present in below detection limit.

CONCLUSION

Based on this study, it can be concluded that the ground water of the study area were highly contaminated and differentiate in three different seasons: pre-monsoon, monsoon and post-monsoon seasons. Resultant, in comparisons with monsoon season, pre and post monsoon season had high concentration of total solids and ground water loses its portability and reduces the solubility of oxygen in water. Ground water from all study areas in all three seasons contaminated with hardness due to industries and pollution. all observations which get from all water samples via various methods showed that majority of the ground water in the study area was chemically suitable for drinking and agricultural purpose specially in monsoon season. In comparisons of monsoon season, it also revealed that the quality of ground water was low in pre and post monsoon.

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