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Variation in Groundwater Quality with Seasonal Fluctuation in Jharia Coal Mine Region, Jharkhand, India

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ABSTRACT

Jharia coal mining areas is one of the most important coal mining area in India. It is roughly elliptical or sickles – shaped, located in Dhanbad district of Jharkhand. For the assessment of groundwater quality, Twenty Nine groundwater samples were collected from Jharia coalfield. The pH of the analysed water samples is slightly acidic to slightly alkaline in nature in both the season. In majority of the samples, the analyzed parameters are well within the desirable limits and water is potable for drinking purposes. However, concentrations of EC, TDS, TH, SO_4^{2-}, Na^+, Ca^{2+} and Mg^{2+} exceed the desirable limit at few sites. The water level fluctuation shows in the study area for year 2013 is 1.29 to 6.9 mbgl. West and some part of the northern area are facing extreme scarcity due to lower availability of groundwater resource. However, eastern region of the study area has sufficiently available of groundwater resources in the Jharia coalfield. This study is useful for utilization of groundwater resources in mining area and helps in future water resource planning for the area.

Key words: Groundwater, Water fluctuation, Cations, Anions, Cracks and Fissure, Jharia coalfield.

INTRODUCTION

Water is an essential and vital component for our life-support system. Rapidly deleting of groundwater supplies as a consequence of continued population growth and industrialization threaten the quality of many aquifers in India. For evaluating the suitability of groundwater for different purpose, understanding the chemical composition of groundwater is necessary. Further, it is possible to understand the change in quality due to rock-water interaction (weathering) or any type of anthropogenic influence (Todd 1980, Kelly 1940). The definition of water quality is much depending on the desired use of water. Therefore different uses require different criteria of water quality as well as standard method for reporting and comparing result of water analysis (Babiker 2007). Access to safe drinking water remains an urgent necessity, as 30 % of urban and 90 % of the rural Indian population still depends completely on untreated surface or groundwater resources (Kumar *et al.* 2005). Scarcity of clean and potable drinking water has emerged in recent years as one of the most serious developmental issues in many parts of West Bengal, Jharkhand, Orissa, Western Uttar Pradesh, Andhra Pradesh, Rajasthan and Punjab (Tiwari & Singh 2014). The rate of depletion of groundwater level and deterioration of groundwater quality is of immediate concern in major cities and towns of country (Meenkumari and Hosmani 2003, Dhindsa *et al.* 2004, Ramakrishnaiah *et al.* 2009: Jain *et al.* 2010; Singh *et al.* 2011; Singh *et al.* 2012; Singh *et al.* 2013; Tiwari and Singh 2014, Singh *et al.* 2014, Tiwari *et al.* 2014). The objective of this study is to assess groundwater quality with reference to seasonal fluctuation and primarily investigation; an attempt has been made to assess its suitability for drinking and domestic uses and also evaluate of availability of groundwater resources of the area.

MATERIALS AND METHODS

Study area

Jharia coal mining area is one of the most important Coal mining area in India. It is roughly elliptical or sickles – shaped, located in Dhanbad district of Jharkhand lies between latitude 23°39′ N and 23°48′ N and longitudes 86°11′ E and 86°27′ E. It stretches from Chandanpura on the west to Sindri on the east. The main component of the natural drainage in Jharia coalfield (JCF) is the Damodar River. There are eight major streams, a few perennials and the rest intermittent, which drains the JCF from north to south to join the Damodar River. They are Tisra, Chatkari, Katri, Khudia, Jamuniya, Kumari and Bansjora etc. The climate in the Jharia coal mining area is very pleasant during cold weather months starting from November to February. The occasional rain during the hot weather from March to June makes the climate, but from June to October the conditions are not on the whole very unpleasant during October to November. The general climate may broadly be described as the of the tropical monsoon belt. The annual rainfall in Jharia and adjacent region varies from 1197 mm to 1382 mm. This is the most exploited coal mining area because of available metallurgical grade coal reserves. The temperature range in coal filed area varies between 5°C and 48 °C.

Sample collection and preservation

A systematic sampling was carried for the assessment of groundwater quality of Jharia coal mining area. Representative 29 groundwater samples were collected from different mines of Lodna, Bastacolla, Sijua, Western Jharia, Block-II, Barora etc of the study area (Fig 1). The groundwater samples were collected in one litre narrow-mouth pre-washed polyethylene bottles. Prior to each field work polyethylene bottles were washed in the laboratory with dilute hydrochloric acid and then rinsed twice with double distilled water. Suspended sediments were separated from the water samples in the laboratory by using 0.45 µm Millipore membrane filters. The water samples were analyzed for various-Physico-chemical parameters. The sampling and analysis was made following standard method (APHA, 1998).

RESULT AND DISCUSSION

Rainfall and water table characteristics

Study area receives more rainfall due to coal dust, which attracts clouds and brings rainfall to the area. Rainfall is the principal method of recharge to groundwater. Southwest monsoon brings rainfall to this area during the months of June to October mainly. The annual average rainfall pattern from the year 2000 to 2013 has been assessed (Fig 2). The maximum rainfall 2311mm and the minimum rainfall is 921mm.

Comparative analysis of WLF using GIS

In comparative analysis, depth to water level data of 29 monitoring wells located in the study area for pre and post-monsoon in the year

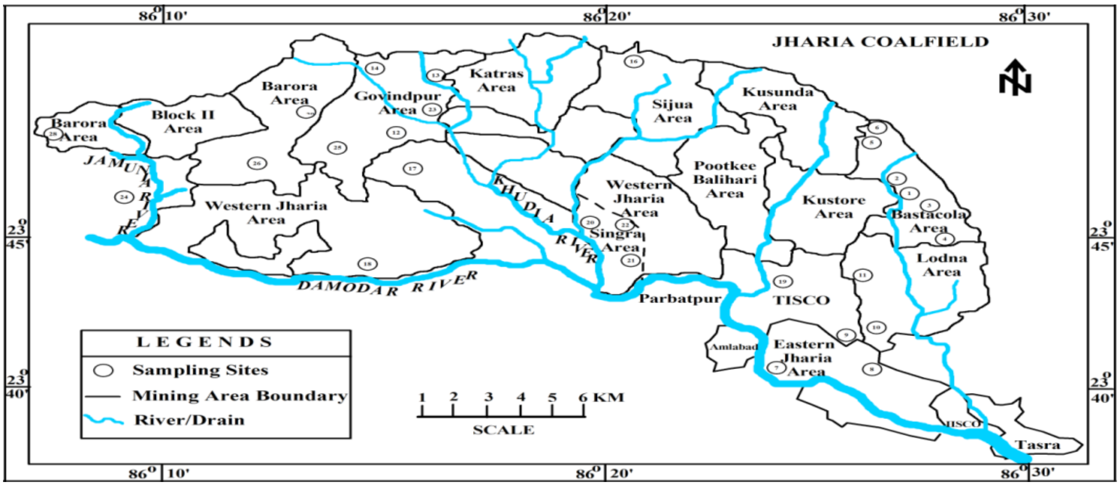

Fig. 1: Sampling sites in the study area

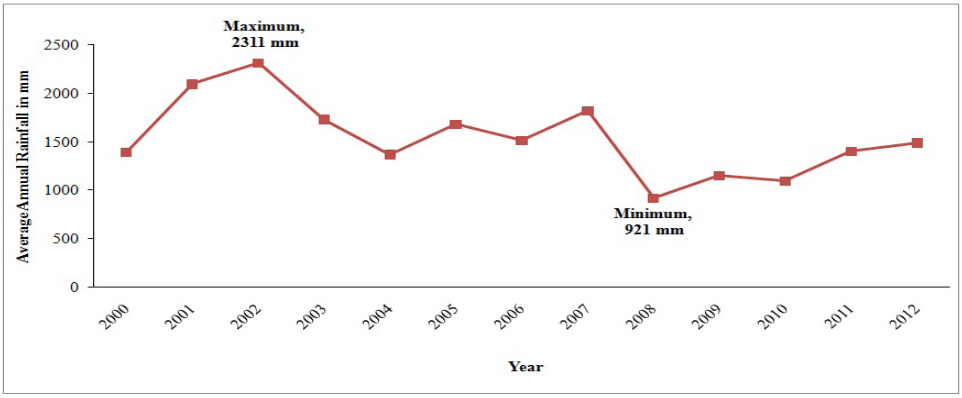

Fig. 2: Annual Rainfall of the study area

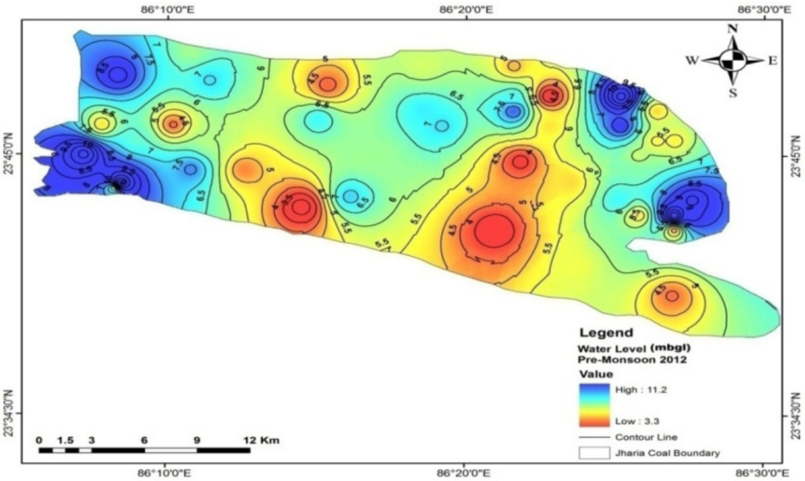

Fig. 3: Depth to water level of study area during Pre – Monsoon period 2013

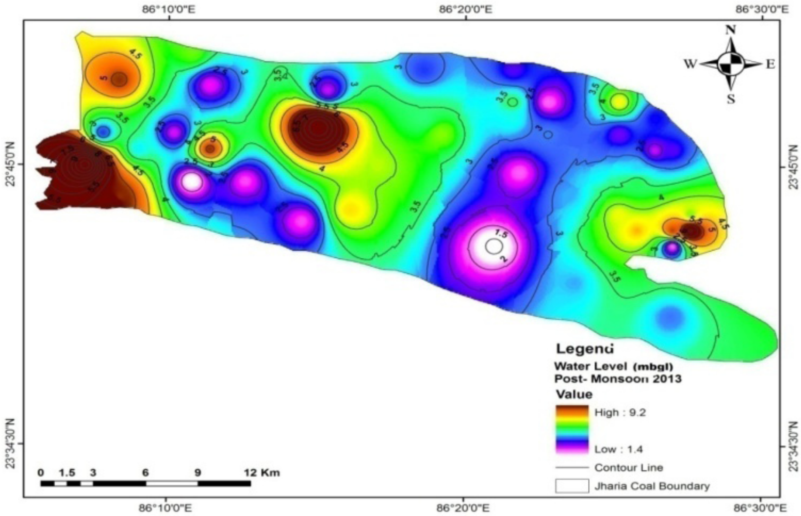

Fig. 4: Depth to water level of study area during Post – Monsoon period 2013

2013. Pre-monsoon data of depth to water level had been collected in the month of June and the post monsoon data of depth to water level had been collected in the month of December (Table 1). Data is plotted on thematic contour map it can observed the trend of depth to water level in unconfined aquifers. From the contour map it can be observed that the maximum depth to water level shown by wells in the pre-monsoon is 3.05 to 11.10 mbgl (Fig 3) and minimum in post-monsoon it shows 1.4 to 7.5 mbgl (Fig. 4) in year 2013. The water level fluctuation shows in the year 2013 is 1.29 to 6.9 mbgl (Fig 5). There are six blocks in the Jharia coal field such as Londna, Bastacolla, Kuskunda.BlockII, Barora and western Jharia. The maximum water level fluctuation shows in Bastocalla area and Londna area due to some lithological features which affect groundwater fluctuation. The good recharge of groundwater shows in the eastern Jharia area, which shows less groundwater fluctuation. The Damodar River is the main sources of recharge of the groundwater in the study area. The groundwater is recharged through by cracks, fissure and planes discontinuity. Thus, from above studies, we found that west and some part of the northern part are facing extreme scarcity due to lower availability of groundwater and eastern region of the study area has sufficiently available of groundwater resources.

Major ion chemistry

Among major cations for Post-monsoon, calcium was the dominant ions representing on average 46% of total cations. Magnesium and sodium ions were of secondary importance, representing on average 26% and 23% of total cations, respectively. Potassium was least dominant cation and representing 5% of the total cations (Figure 6). The order of cation for post-monsoon abundance was Ca^{2+}> Mg^{2+}> Na^{+}>K^{+}. However, in pre- monsoon season calcium was the dominant ions representing on average 39% of total cations. Sodium and magnesium ions were of secondary importance, representing on average 29% and 26% of total cations, respectively. Potassium was least dominant cation and representing 6% of the total cations (Figure 7). The order of cation abundance was Ca^{2+}> Na^{+}>Mg^{2+}>K^{+} in pre-monsoon season. Among the major anions, bicarbonate was generally dominant and representing on average 43% of the total anions. Sulphate is the second dominant anion, representing on an average 39% of the total anions. Chlorides were less dominant ions and contributing

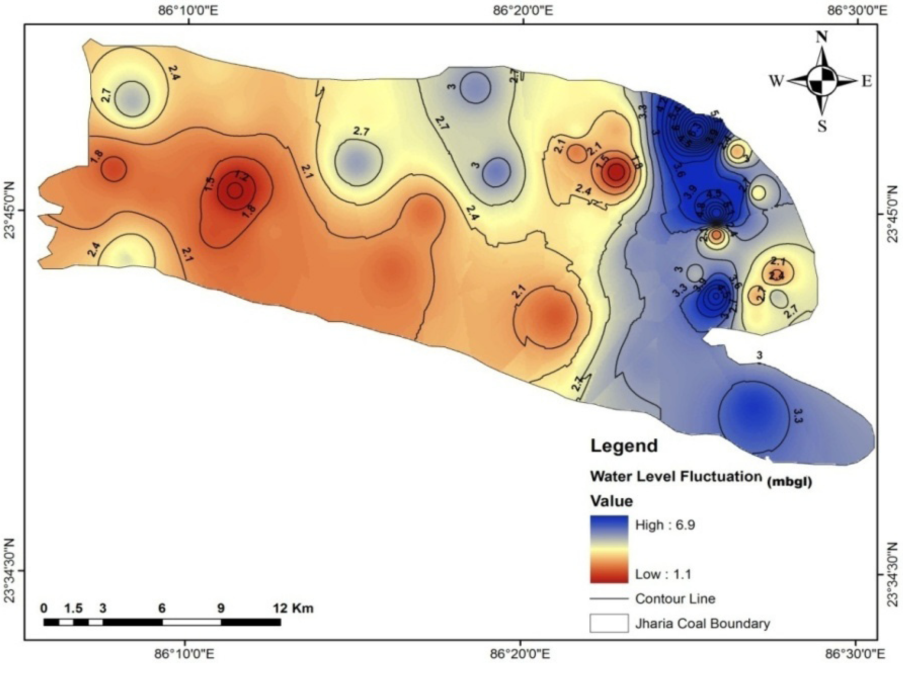

Fig. 5: Depth to water level fluctuation period 2013

17% to the total anions respectively (Figure 8). Nitrate and fluoride are the least dominant anion of the total anions. The order of anions for post-monsoon abundance in the groudwater was found as HCO_3^-> SO_4^{2-}> Cl^->NO_3^->F^-. However, in pre-monsoon season bicarbonate is the dominant anion, representing on an average 43% of the total anions. Sulphate is the second dominant anion, representing on an average 37% of the total anions. Chlorides were less dominant ions and contributing 18% to the total anions respectively. Nitrate and fluoride is the least dominant anion of the total anions. The order of anions abundance in the groudwater was found as HCO_3^-> SO_4^{2-}> Cl^->NO_3^->F^- (Figure 9).

Suitability of groundwater for drinking and domestic purposes

The physico-chemical parameters of the analytical results of groundwater were compared with the standard guideline values recommended by the World Health Organization (WHO, 1997) and Bureau of Indian Standards (BIS, 2003) for drinking and public health standards (Table 2). The pH of the groundwater samples were found to be ranging from 6.5 to 8.2 and with mean of 7.2 for post-monsoon season, while the pre-monsoon season water samples range 6.5 to 8.3 and mean 7.3**.** The water samples indicate is slightly acidic to alkaline in nature. The overall conductivity ranges from 480 µS/cm to 1300 µS/cm and mean 862.3 for post –monsoon season, while the pre-monsoon season water samples range 630 µS/cm to 1590 µS/cm in groundwater of study area. The TDS were varied from 350 mg/L to 1150 mg/L for post –monsoon season while the pre- monsoon season water samples 532 mg/L to 1377 mg/L. The values of TDS exceed the desirable limit of 500 mg L^{-1} in 96 % samples of groundwater in post-monsoon, while 100% in pre-monsoon season. The total hardness (TH) of the analyzed water samples of the study area varies between 210 mg/L to 752 mg/L and (Avg. 444 mg/L) in post-monsoon. However, pre-monsoon season water samples it varied 294 mg/L to 917 mg/L and (Avg. 546 mg/L) respectively indicating hard to very hard types of water. The chloride content in the study area varied from 39 mg/L to 198 mg/L in the groundwater in post –monsoon season. However, the pre-monsoon season water

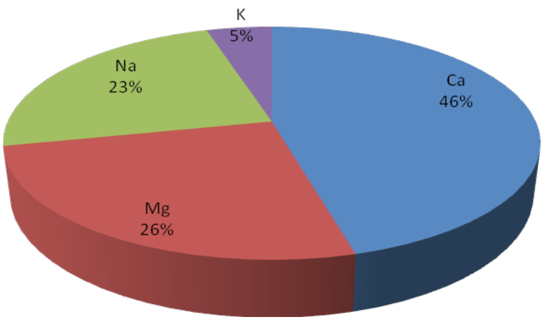

Fig. 6: Percentage contribution of cation to total cationic balance (TZ^+) for post-monsoon

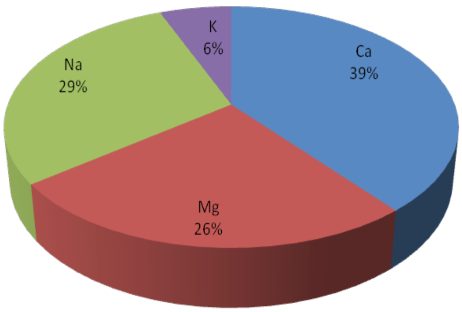

Fig. 7: Percentage contribution of cation to total cationic balance (TZ^+) for pre-monsoon

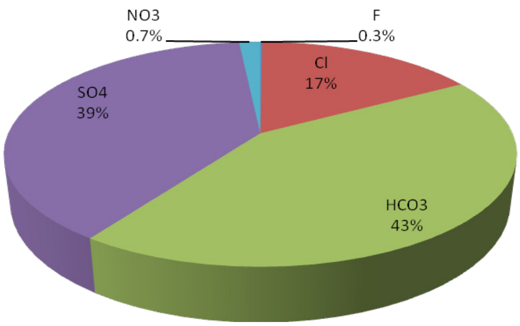

Fig. 8: Percentage contribution of anion to total anionic balance (TZ^-) for post-monsoon

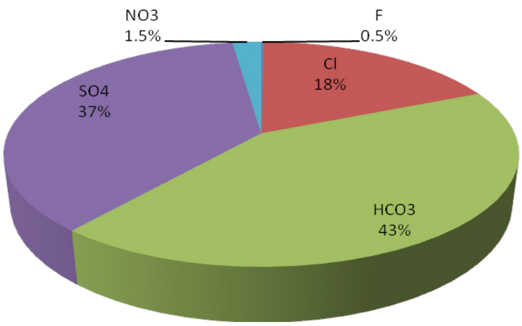

Fig. 9: Percentage contribution of anion to total anionic balance (TZ^-) for pre-monsoon

samples it varied 54 mg/L to 254 mg/L. Chloride presents in a lower concentration in common rock types as compared to other constituents of natural water. It is assumed that bulk of the chloride in water is primarily either from atmospheric source or from seawater. Nitrate content in groundwater samples varied from 1.1 mg/L to 30 mg/L in post-monsoon. However, the pre-monsoon season water samples it varied from 2.1 mg/L to 46 mg/L. Concentration of NO_3^- exceeding the desirable limits of 45 mg L^{-1} in 3 % of the groundwater samples in pre-monsoon season. Sulphate in the water samples ranged from 47 mg/L to369mg/L in post-monsoon. While, the pre-monsoon season water samples it varies from 90 mg/L to 397 mg/L. The values of SO_4^{2-} exceed the desirable limit of 200 mg L^{-1} in 45 % samples of groundwater in post-monsoon, while 51% in pre-monsoon season. Higher concentration of sulphate may be attributed to rock weathering or anthropogenic sources like industrial and agricultural effluents (Berner and Berner 1987). Higher F^- concentration causes dental and skeletal fluorosis such as mottling of teeth, deformation of ligaments and bending of spinal cord (Tiwari and Singh 2014). Concentration of F^- is within recommended limit of 1.5 mg L^{-1} in groundwater samples in post-monsoon season. However, in pre-monsoon season, values of F^- exceed the permissible limit of 1.5 mg L^{-1} in 21% samples of groundwater. The range of calcium ions was 28 mg/L to 192 mg/L for post monsoon

Table 1: Water table fluctuation of Jharia coalfield

S.No	Location	Latitude	Longititude	Elevation	Pre Monsoon water level	Post – Monsoon Waterlevel	Water level fluctuation
W1	Near Bararee Colliery	23°43’26"	86°24’35"	623	4.25	2.65	1.6
W2	Bhoolan Bararee	23°43’27"	86°24’36"	642	8.91	6.06	2.85
W3	Jealgora-7 No.	23°47’42"	86°19’40"	731	7.18	5.00	2.18
W4	Bhowrah South	23°40’41"	86°24’26"	526	3.50	1.03	2.47
W5	Digwadih Campus	23°41’46"	86°25’19"	552	9.06	4.50	4.56
W6	Bararee	23°43’25"	86°24’34"	622	7.10	4.20	2.9
W7	Bhagamor	23°47’37"	86°18’07"	599	5.50	3.60	1.9
W8	South Tisra	23°47’38"	86°19’08"	613	6.20	3.10	3.1
W9	Joyrampur	23°47’40"	86°19’20"	588	6.60	3.00	3.6
W10	Ghanudih 4-No	23°44’47"	86°26’14"	667	4.10	2.10	2.00
W11	Ghanudih 4-No	23°44’48"	86°26’25"	665	6.20	2.30	3.9
W12	Ghanudih 4-No	23°44’47"	86°26’24"	661	4.00	2.00	2.00
W13	Bera Colliery	23°46’06"	86°25’53"	656	6.20	3.10	3.1
W14	Chandmari Colliery	23°45’38"	86°25’15"	784	11.20	4.30	6.9
W15	Bengali Kothi	23°45’38"	86°25’15"	645	8.51	3.14	5.37
W16	Victory	23°45’50"	86°24’44"	690	6.24	2.50	3.74
W17	Goluckhdih	23°44’80"	86°26’33"	637	4.3	3.01	1.29
W18	Dobari	23°45’20"	86°25’57"	638	4.20	2.00	2.20
W19	Khas Kusunda	23°44’82"	86°26’37"	642	3.15	1.50	1.65
W20	East-Basseria	23°45’30"	86°26’41"	650	5.25	3.28	1.97
W21	Bhalgora	23°47’37"	86°18’07"	584	6.90	3.8	3.1
W22	Tetulmari Road	23°48’5.8"	86°20’07"	675	3.80	2.10	1.7
W23	Akashkinari	23°47’48"	86°16’11"	640	6.00	4.10	1.9
W24	Sonardih	23°46’37"	86°14’21"	794	7.20	4.00	3.2
W26	Phulawartar	23°46’37"	86°14’12"	690	10.50	7.50	3.00
W27	Loyabad	23°47’49"	86°16’13"	698	8.20	5.50	2.7
W28	Mooraidih	23°48’16"	86°13’59"	330	6.25	3.50	2.75
W29	Baghmara	23°47’37"	86°18’07"	590	5.10	2.60	2.5

Table 2: Summary statistics of the analytical data and compare with WHO and Indian Standard (IS: 10500) for domestic purposes

		Post-Monsoon		Pre-Monsoon		WHO (1997)	WHO (1997)	BIS 2003 (IS 10500)	BIS 2003 (IS 10500)
Water quality para-meters	Units	Range	Mean	Range	Mean	Max. desirable	Highest Permissible limits	Max. desirable	Highest Permissible limits
pH	-	6.5 - 8.2	7.2	6.5-8.3	7.3	7.0-8.5	6.5-9.2	6.5-8.5	8.5-9.2
EC	µS/cm	480 - 1,300	862	630-1590	1080	750	1,500	-	-
HCO_3^-	mg L^{-1}	144 - 357	214	192-451	268	200	600	200	600
F^-	mg L^{-1}	0.23 – 1.5	0.7	0.46-1.9	1.1	0.6-0.9	1.5	1.0	1.5
Cl^-	mg L^{-1}	39 – 198	83	54-254	116	250	600	250	1,000
NO_3^-	mg L^{-1}	1.1 – 30	8	2.1-46	14	-	50	45	100
SO_4^{2-}	mg L^{-1}	47 – 369	193	90-397	232	200	600	200	400
Na^+	mg L^{-1}	14 – 143	48	28-189	79	50	200	-	-
Ca^{2+}	mg L^{-1}	28 – 192	92	35-205	106	75	200	75	200
Mg^{2+}	mg L^{-1}	38 - 129	52	38-138	68	30	150	30	100
K^+	mg L^{-1}	1.3 – 35	9.5	4-39	16	100	200	-	-
TDS	mg L^{-1}	350- 1150	705	532-1377	901	500	1,500	500	2,000
TH	mg L^{-1}	210 - 752	444	294-917	546	100	500	300	600

and while, the pre-monsoon season water samples it varies 35 mg/L to 205 mg/L. The magnesium ranged from 38 mg/L to 129 mg/L for post-monsoon water samples of the study area. While, the pre-monsoon season water samples it varies 38 mg/L to 138 mg/L. The sodium concentration in the water samples was found between 14 mg/L to 143 mg/L for post-monsoon and while, the pre-monsoon season water samples it varies 28 mg/L to 189 mg/L. The permissible limit for sodium is given as 200 mg/L according to WHO guidelines. Concentration of Na^+ is within recommended limit of 200 mg/L in groundwater sample. A higher sodium intake may cause hypertension, congenial heart diseases and kidney problems (Singh *et al*. 2008, Tiwari et al. 2013).

CONCLUSION

The good recharge of groundwater shows in the eastern Jharia area, which shows less groundwater fluctuation. The groundwater is recharged through by cracks, fissure and planes discontinuity. The water level fluctuation shows in the year 2013 is 1.29 to 6.9 mbgl. West and some part of the northern part are facing extreme scarcity due to lower availability of ground water and eastern region of the study area has sufficiently available of ground water resources. The groundwater of Jharia coalfield is slightly acidic to alkaline in nature. In majority of the samples, the analyzed parameters are well within the desirable limits and water is potable for drinking purposes. However, concentrations of EC, TDS, TH, SO_4^{2-}, Na^+,Ca^{2+} and Mg^{2+} exceed the desirable limit at few sites and needs treatment before its utilization. The groundwater of this area is very much affected by various natural sources and mining activity.

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