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Physico-chemical analysis of pond water of coalfield area, Brijuri, Anuppur district of Madhya Pradesh (India)

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Abstract
Pond water is contaminated around Bijuri district Anuppur coalfield area due to mining and industrial activities. The major cause of the contamination of pond water may be due to improper management. The aim of the present study was to assess the pond water quality and also to have a statistical analysis of physicochemical parameters of pond water coalfield area, Bijuri, Anuppur district of Madhya Pradesh (India). Four water samples were collected from the various sites located around pond of Bijuri coalfields area during pre-monsoons and post monsoons seasons in the year 2020 and analyzed for physicochemical parameters such as pH, TDS, EC, DO, Fluoride, Chlorides, Nitrate, Sulphate and Lithium. A systematic calculation of the correlation coefficient has also been carried out between different analyzed parameters. The pondwater of the study area is alkaline in nature. EC found above maximum permissible limit prescribed by BIS in the pre-monsoon (478 µS/cm) and post-monsoon (562 µS/cm). From correlation analysis it was observed that very strong correlation four sites between NO_3^- and Cl^- (0.944), Cl^- and F^- (0.804), NO_3^- and EC (0.684), NO_3^- and F^- (0.667), during pre-monsoon season and SO_4^{-2} and pH (0.881), F^- and pH (0.854), SO_4^{-2} and DO (0.808) during post-monsoon.

Keywords: Physicochemical parameters, correlation co-efficient, pondwater, bijuri, coalmines, Anuppur district

Introduction
Water is an essential and vital component for our life-support system. Rapidly deleting of water availability as a consequence of continued population growth and industrialization threaten the quality of many aquifers in India. For evaluating the suitability of Coalmines pond water for different purpose, understanding the chemical composition of pondwater 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, 1946) [1-2]. 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) [3]. 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) [4]. The present study was carried out to determine the physicochemical characteristics of groundwater during the pre and post- monsoon seasons in the study area and compared the results with WHO drinking water quality standards (WHO, 2007) [7]. Global Positioning System (GPS) was used to identify the sample location of pondwater coalfield area of Bijuri district Anuppur (M.P.) India.

Material and Methods
Study area: Bijuri is located at Latitude 23.25°N - 82.12°E. The Bijuri Coal Mine is operated by South Eastern Coalfields Limited, a subsidiary of Coal India, in the village of Bijuri, Tehsil Kotma, District Annuppur, Madhya Pradesh India. It has a designed capacity of 0.6 million-tonnes-per-annum.

Sampling Techniques: Pondwater Samples were collected in Polythene bottles of 1.0 liter. In the present investigation, pondwater samples were collected from four different stations around pond of coalfields area during pre-monsoon and post-monsoon seasons in the year 2020.

It was ensured that the concentrations of various water quality parameters do not changes in time that elapse between the drawing of samples and the analysis in the laboratory. Pondwater samples were immediately transferred to the laboratory for the physicochemical analysis. The various water quality parameters such as pH, electrical conductivity, dissolved oxygen and total dissolved solids were analyzed at the sampling station by using the Multiparameter apparatus and other parameters like Fluoride, Chlorides, Nitrate, Sulphate and Lithium, were analyses in the laboratory.

Results and Discussion

The collected pondwater sample was analyzed in the laboratory for various water quality parameters *viz*. pH, TDS, EC, DO, Fluoride, Chlorides, Nitrate, Sulphate and Lithium. The physicochemical characteristics of the analyzed water sample of pre-monsoon and post-monsoon seasons have been presented in Table-1 & 2. Various statistical analysis of the experimental data was performed using Microsoft Excel 2016. The statistical analysis of physicochemical parameters of pondwater quality of Bijuri coalfield region during the pre-monsoon and post-monsoon seasons is presented in Tables-1-4.

Table 1: Physico-Chemical Parameters of pondwater Samples of Bijuri Coalfield of Anuppur district during Pre-monsoon Season (2020).

S. No.	Parameters	S1	S2	S3	S4	Min.	Max.	Mean	Median	SD	Permissible limit by WHO and BIS
1.	pH	7.05	7.03	7.84	6.85	6.85	7.84	7.19	7.04	0.441	6.5-8.5
2.	TDS	235	277	286	329	235	329	281.75	281.5	38.552	500
3.	EC	415	255	266	358	255	415	323.50	312	76.509	300
4.	DO	5.65	5.83	5.21	4.87	4.87	5.83	5.39	5.43	0.434	>5
5.	Fluoride	0.378	0.524	0.412	0.463	0.378	0.524	0.44	0.4375	0.064	1.5
6.	Chlorides	25.621	65.412	52.104	77.328	25.621	77.328	55.12	58.758	22.199	250
7.	Nitrate	5.851	10.201	7.058	18.562	5.851	18.562	10.42	8.6295	5.731	45
8.	Sulphate	16.256	20.471	12.358	28.621	12.358	28.621	19.43	18.3635	6.968	150
9.	Lithium	0.081	0.088	0.072	0.079	0.072	0.088	0.08	0.08	0.007	-

All parameters are given in mg/l, excluding pH and Electrical conductivity (µS/cm).
Note: Min-Minimum, Max-Maximum, SD-Standard deviation

Table 2: Physico-Chemical Parameters of pond water Samples of Bijuri Coalfield of Anuppur district during Post-monsoon Season (2020).

S. No.	Parameters	S1	S2	S3	S4	Min.	Max.	Mean	Median	SD	Permissible limit by WHO and BIS
1.	pH	7.13	6.89	7.08	7.21	6.89	7.21	7.08	7.105	0.136	6.5-8.5
2.	TDS	132	260	248	189	132	260	207.25	218.5	58.988	500
3.	EC	562	476	488	521	476	562	511.75	504.5	38.526	300
4.	DO	5.36	5.21	5.63	5.38	5.21	5.63	5.40	5.37	0.174	>5
5.	Fluoride	0.386	0.314	0.417	0.404	0.314	0.417	0.38	0.395	0.046	1.5
6.	Chlorides	28.84	26.99	29.35	35.07	26.99	35.07	30.06	29.095	3.489	250
7.	Nitrate	17.252	8.522	9.325	12.452	8.522	17.252	11.89	10.8885	3.958	45
8.	Sulphate	20.245	15.362	23.358	26.521	15.362	26.521	21.37	21.8015	4.756	150
9.	Lithium	0.071	0.069	0.072	0.068	0.068	0.072	0.07	0.07	0.002	-

All parameters are given in mg/l, excluding pH and Electrical conductivity (µS/cm).
Note: Min-Minimum, Max-Maximum, SD-Standard deviation

Table 3: Correlation Matrix of pond water Quality Parameters (Pre-Monsoon Season).

S. No.	pH	TDS	EC	DO	F^-	Cl^-	NO_3^-	SO_4^{-2}	Li^+
pH	1								
TDS	-0.163	1							
EC	-0.243	-0.422	1						
DO	-0.096	-0.717	0.022	1					
F^-	-0.255	0.208	0.070	0.253	1				
Cl^-	-0.041	0.167	0.484	-0.054	0.804	1			
NO_3^-	-0.143	0.080	0.684	-0.159	0.667	0.944	1		
SO_4^{-2}	-0.355	0.239	0.261	0.148	0.430	0.513	0.363	1	
Li^+	-0.643	-0.083	-0.310	0.443	0.221	-0.328	-0.304	-0.211	1

Table 4: Correlation Matrix of pondwater Quality Parameters (Post-monsoon Season)

S. No.	pH	TDS	EC	DO	F^-	Cl^-	NO_3^-	SO_4^{-2}	Li^+
pH	1								
TDS	-0.075	1							
EC	0.068	-0.931	1						
DO	0.661	0.229	-0.393	1					
F^-	0.854	0.007	0.048	0.696	1				
Cl^-	0.189	-0.598	0.463	-0.070	0.178	1			
NO_3^-	0.772	-0.273	0.249	0.483	0.474	-0.145	1		
SO_4^{-2}	0.881	-0.040	-0.107	0.808	0.798	0.409	0.527	1	
Li^+	0.008	0.279	-0.009	0.078	0.355	-0.603	0.025	-0.238	1

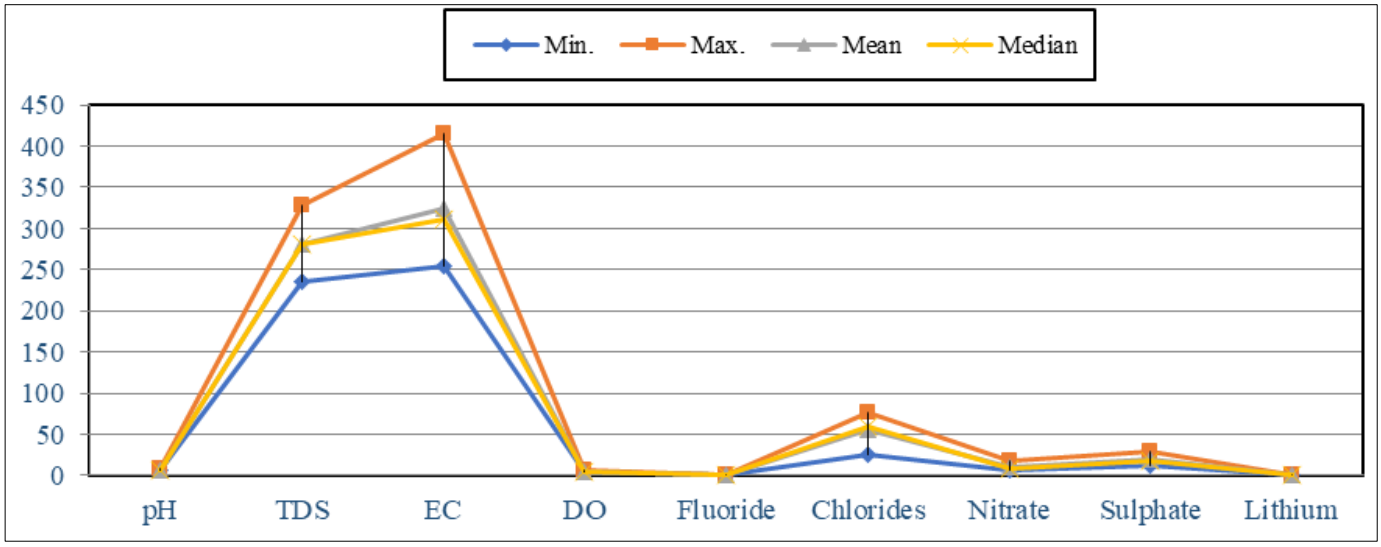

Fig 1: Graph analysis of Physico-Chemical Parameters of pondwater Samples of Bijuri Coalfield of Anuppur district during Pre-monsoon Season (2020).

pH: The pH value of pondwater samples varied between 6.85 to 7.84 during pre-monsoon and 6.89 to 7.21 during post-monsoon seasons (Table-1&2). The sampling points-S3 showed high pH value in the pre-monsoon seasons. In the period of pre-monsoon season correlation coefficient observed between pH & TDS (-0.163), pH & EC (-0.243), pH & DO (-0.096), pH & F^- (-0.255), pH & Cl^- (-0.041), pH & NO_3^- (-0.143), pH & SO_4^{-2}(-0.355) and pH & Li^+(-0.643) (Table 3) and post-monsoon observed between pH & TDS (-0.075), pH & EC (0.068), pH & DO (0.661), pH & F^- (0.854), pH & Cl^- (0.189), pH & NO_3^- (0.772), pH & SO_4^{-2}(0.881) and pH & Li^+(0.008) (Table 3). Hence, it is a helpful tool for the promotion of research activities (Shrivastava and Joshi, 2008; Borkar and Tembhre, 2018; and Verma *et al.* 2021) [10-12].

Total Dissolved Solids (TDS): Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. In the present study TDS value ranged from 235mg/l to 329 mg/l in the pre-monsoon season and 132mg/l to 260mg/l during post-monsoon season (Table-1&2). The sampling points S4 (pre-monsoon) and S2 (post-monsoon) showed high TDS value. In the period of pre-monsoon season correlation coefficient observed between TDS & pH (-0.163), TDS & EC (-0.422), TDS & DO (-0.717), TDS & F^- (0.208), TDS & Cl^- (0.167), TDS & NO_3^- (0.080), TDS & SO_4^{-2}(0.239) and TDS & Li^+(-0.083) (Table 4) and post-monsoon observed between TDS & pH (-0.075), TDS & EC (-0.931), TDS & DO (0.229), TDS & F^- (0.007), TDS & Cl^- (-0.598), TDS & NO_3^- (-0.273), TDS & SO_4^{-2}(-0.040) and TDS & Li^+(0.279) (Table 5). Hence, it is a helpful tool for the promotion of research activities (Shrivastava and Joshi, 2008; Borkar and Tembhre, 2018; and Verma *et al.* 2021) [10-12].

Electrical Conductivity (EC): Electrical conductivity was found to be very high and ranges from 255-415 µs/cm in the pre-monsoon season and 476 – 562 µs/cm during post monsoon. The sampling points-S1, showed high EC value in the pre-monsoon seasons and S1, during post-monsoon (Table-2&3). In the period of pre-monsoon season correlation coefficient observed between EC & pH (-0.243), EC & TDS (-0.422), EC & DO (0.022), EC & F^- (0.070), EC & Cl^- (0.484), EC & NO_3^- (0.684), EC & SO_4^{-2}(0.261) and EC & Li^+(-0.310) (Table 4) and post-monsoon observed between EC & pH (-0.068), EC & TDS (-0.931), EC & DO (-0.393), EC & F^- (0.048), EC & Cl^- (0.463), EC & NO_3^- (0.249), EC & SO_4^{-2}(-0.107) and EC & Li^+(-0.009) (Table 4). Hence, it is a helpful tool for the promotion of research activities (Shrivastava and Joshi, 2008; Borkar and Tembhre, 2018; and Verma *et al.* 2021) [10-12].

Dissolved oxygen (DO): The concentration of Dissolved oxygen of pondwater sample ranges (4.87-5.83) mg/l in the pre-monsoon season and (5.21-5.63) mg/l during post monsoon (Table-1&2). In the period of pre-monsoon season correlation coefficient observed between DO & pH (-0.096), DO & TDS (-0.717), DO & EC (0.022), DO & F^- (0.253), DO & Cl^- (-0.054), DO & NO_3^- (-0.159), DO & SO_4^{-2}(0.148) and DO & Li^+(0.443) (Table 3) and post-monsoon observed between DO & pH (0.661), DO & TDS (0.229), DO & EC (-0.393), DO & F^- (0.696), DO & Cl^- (-0.070), DO & NO_3^- (0.483), DO & SO_4^{-2}(0.808) and DO & Li^+(0.078) (Table 4). Hence, it is a helpful tool for the promotion of research activities (Shrivastava and Joshi, 2008; Borkar and Tembhre, 2018; and Verma *et al.* 2021) [10-12].

Fluoride (F^-): Fluoride content of the study area is ranged from 0.378 mg/l to 0.524 mg/l in the pre-monsoon season and 0.314 mg/l to 0.417 mg/l during post monsoon (Table-1&2). In the period of pre-monsoon season correlation coefficient observed between F^- & pH (-0.255), F^- & TDS (0.208), F^- & EC (0.070), F^- & DO (0.253), F^- & Cl^- (0.804), F^- & NO_3^- (0.667), F^- & SO_4^{-2}(0.430) and F^- & Li^+(0.221) (Table 3) and post-monsoon observed between F^- & pH (0.854), F^- & TDS (0.007), F^- & EC (0.3048), F^- & DO (0.696), F^- & Cl^- (0.178), F^- & NO_3^- (0.474), F^- & SO_4^{-2}(0.798) and F^- & Li^+(0.355) (Table 4). Fluoride is a geochemical contaminant and natural sources account for most of the fluoride in surface and pondwater. Its concentration is dependent on the solubility of fluoride-containing rocks. Intake of excess fluoride causes skeletal and dental fluorosis (Meena and Bhargava, 2012) [8].

Chlorides (Cl^-): The concentration of Chlorides ion of pondwater sample ranges from (25.621-77.328) mg/l in the pre-monsoon season and (26.99-35.07) mg/l during post monsoon (Table-1&2). The sampling points- S4 (Pre-monsoon) and S4 (Post-monsoon) showed high Chlorides value. In the period of pre-monsoon season correlation coefficient observed between Cl^- & pH (-0.041), Cl^- & TDS (0.167), Cl^- & EC (0.484), Cl^- & DO (-0.054), Cl^- & F^- (0.804), Cl^- & NO_3^- (0.944), Cl^- & SO_4^{-2}(0.513) and Cl^- & Li^+(-0.328) (Table 3) and post-monsoon observed between Cl^- & pH (0.189), Cl^- & TDS (-0.598), Cl^- & EC (0.463), Cl^- & DO (-0.070), Cl^- & F^- (0.178), Cl^- & NO_3^- (-0.145), Cl^- & SO_4^{-2} (0.409) and Cl^- & Li^+(-0.603) (Table 4). Chloride is the most important parameter in assessing the water quality and higher concentration of chloride indicates a higher degree of organic pollution (Sonkar, and Jamal, 2018) [9].

Nitrate (NO_3^-): The nitrate content of the pondwater samples ranges from (5.851-18.562) mg/l in the pre-monsoon season and (8.522-17.252)mg/l during post monsoon (Table-1&2). In the period of pre-monsoon season correlation coefficient observed between NO_3^- & pH (-0.143), NO_3^- & TDS (0.080), NO_3^- & EC (0.684), NO_3^- & DO (-0.159), NO_3^- & F^- (0.667), NO_3^- & Cl^- (0.944), NO_3^- & SO_4^{-2} (0.363) and NO_3^- & Li^+(-0.304) (Table 3) and post-monsoon observed between NO_3^- & pH (0.772), NO_3^- & TDS (-0.273), NO_3^- & EC (0.249), NO_3^- & DO (0.483), NO_3^- & F^- (0.474), NO_3^- & Cl^- (-0.145), NO_3^- & SO_4^{-2}(0.527) and NO_3^- & Li^+(0.025) (Table 4). Hence, it is a helpful tool for the promotion of research activities (Shrivastava and Joshi, 2008; Borkar and Tembhre, 2018; and Verma *et al.* 2021) [10-12].

Sulphate (SO_4^{-2}): The sulphate concentration of the pondwater samples varied between 12.358 mg/l (S3) to 28.621 mg/l (S4) in the pre-monsoon season and 15.362 mg/l (S2) to 26.521mg/l (S4) during post-monsoon of the study area (Table-1&2). In the period of pre-monsoon season correlation coefficient observed between SO_4^{-2} & pH (-0.355), SO_4^{-2} & TDS (0.239), SO_4^{-2} & EC (0.261), SO_4^{-2} & DO (0.148), SO_4^{-2} & F^- (0.430), SO_4^{-2} & Cl^- (0.513), SO_4^{-2} & NO_3^- (0.363) and SO_4^{-2} & Li^+(-0.211) (Table 3) and post-monsoon observed between SO_4^{-2} & pH (0.881), SO_4^{-2} & TDS (-0.040), SO_4^{-2} & EC (-0.107), SO_4^{-2} & DO (0.808), SO_4^{-2} & F^- (0.798), SO_4^{-2} & Cl^- (0.409), SO_4^{-2} & NO_3^- (0.527) and SO_4^{-2} & Li^+(-0.238) (Table 4). Hence, it is a helpful tool for the promotion of research activities (Shrivastava and Joshi, 2008; Borkar and Tembhre, 2018; and Verma *et al.* 2021) [10-12].

Lithium (Li^+): The Lithium concentration of the pondwater samples varied between (0.072 mg/l to 0.088 mg/l) in the pre-monsoon season and (0.068 mg/l to 0.072 mg/l) during post monsoon (Table-1&2). In the period of pre-monsoon season correlation coefficient observed between Li^+ & pH (-0.643), Li^+ & TDS (0.083), Li^+ & EC (-0.310), Li^+ & DO (0.443), Li^+ & F^- (0.221), Li^+ & Cl^- (-0.328), Li^+ & NO_3^- (-0.304) and Li^+ & SO_4^{-2} (-0.211) (Table 3) and post-monsoon observed between Li^+ & pH (0.008), Li^+ & TDS (0.279), Li^+ & EC (-0.009), Li^+ & DO (0.078), Li^+ & F^- (0.355), Li^+ & Cl^- (-0.603), Li^+ & NO_3^- (0.025) and Li^+ & SO_4^{-2} (-0.238) (Table 4). Hence, it is a helpful tool for the promotion of research activities (Reza *et al.* 2009 [6], Shrivastava and Joshi, 2008; Borkar and Tembhre, 2018; and Verma *et al.* 2021) [10-12].

Test of Significance of the Observed Correlation Coefficient

The correlation coefficient study is very useful to determine a predictable relationship which can be exploited in practice. It is used for the measurement of the strength and statistical significance of the relation between two or more water quality parameters. Hence, it is a helpful tool for the promotion of research activities (Carlos *et al.* 2011 [5], Shrivastava and Joshi, 2008; Borkar and Tembhre, 2018; and Verma *et al.* 2021) [10-12]. The correlation coefficients (r) among the various water quality parameters of Bijuri coalfields for the pre-monsoon and post-monsoon seasons have been calculated and the numerical values are tabulated as shown in Table-3 and Table-4.

In Pre-monsoon: In the period of Pre-monsoon season, out of 45 correlation coefficients,17 negative and 28 positive correlation coefficients. In table-3, the highly positive correlation is observed between NO_3^- and Cl^- (0.944), Cl^- and F^- (0.804), NO_3^- and EC (0.684), NO_3^- and F^- (0.667), where highly negative correlation is observed between DO and TDS (-0.717), Li^+ and pH (-0.643), EC and TDS (-0.422) and SO_4^{-2} and pH (-0.355). Very poor positive correlation was observed between DO and EC (0.022), F^- and EC (0.070), NO_3^- and TDS (0.080), SO_4^{-2} and DO (0.148), Cl^- and TDS (0.167), F^- and TDS (0.208), Li^+ and F^- (0.221), SO_4^{-2} and TDS (0.239), SO_4^{-2} and EC (0.261), F^- and DO (0.253), SO_4^{-2} and NO_3^- (0.363), SO_4^{-2} and F^- (0.430), Li+ and DO (0.443), SO_4^{-2} and Cl^- (0.513).

In Post-monsoon: In the period of Post-monsoon season, out of 45 correlation coefficients,12 negative and 33 positive correlation coefficients. In Table-4, the highly positive correlation is observed between SO_4^{-2} and pH (0.881), F^- and pH (0.854), SO_4^{-2} and DO (0.808), where highly negative correlation is observed between EC and TDS (-0.931), Li+ and Cl^- (- 0.603) and Cl^- and TDS (-0.598). Very poor positive correlation was observed between F^- and TDS (0.007), Li^+ and pH (0.008), Li^+ and NO_3^- (0.025), while very negative poor correlation was observed between SO_4^{-2} and TDS (--0.040), Cl^- and DO (-0.070).

Conclusion

In the present study, the pond water samples taken from four sites S1, S2, S3 and S4 Coal field present in Bijuri coalfield district Anuppur area were analysed. The correlation of 09 physicochemical parameters of pondwater of the study site revealed that all the parameter were more or less correlated with one another. The pondwater of the study area is alkaline in nature. EC found above maximum permissible limit prescribed by BIS in the pre-monsoon (478 µS/cm) and post-monsoon (562µS/cm). From correlation analysis it was observed that very strong correlation six between NO_3^- and Cl^- (0.944), Cl^- and F^- (0.804), NO_3^- and EC (0.684), NO_3^- and F^- (0.667), during pre-monsoon season and SO_4^{-2} and pH (0.881), F^- and pH (0.854), SO_4^{-2} and DO (0.808) during post-monsoon. The analysis shows that the pondwater of the study area needs some treatment before its consumption.

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