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PHYSICO-CHEMICAL STUDIES ON ASSESSMENT OF GROUND WATER QUALITY NEAR COAL WASHERY OF DISTRICT BOKARO, JHARKHAND.

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ABSTRACT

In the present study an attempt has been made to assess the physico-chemical factors of two ground water samples of selected sampling sites viz, Dugda Ground water (GW1) Near Dugda coal washery and Bhojudih Ground water (GW2) near Bhojudih coal washery areas of district Bokaro, Jharkhand. Sampling sites are nearby Damodar River also.Samples were collected from hand pump (approx. 80 feet deep) on monthly basis from November 2020 to October 2021. A total of 8 parameters were taken into consideration for analysis. The average value of selected parameters of Dugda Ground water and Bhojudih Ground water , the Temperature was 21.30^{0}C-20.50^{0}C, pH 6.97-7.04, Elecrical Conductivity (EC) 778.25-886.83µs/cm, Total Dissolved Solids (TDS) 448.67-513.05 mg/L, Chloride (Cl-) 50.22-52.10 mg/L, Sulphate (SO_4^{2-})29.49-35.51 mg/L, Nitrate (NO_3^-) 3.18-3.49 mg/L, and Turbidity 18.59-18.82(NTU), respectively. Pearson correlation coefficient values shows high, moderate and sometimes low significant positive and negative relationship ($p<0.05$ level..

According to Water Quality Index (WQI), 71.78 for Dugda Ground water shows poor water quality status and 73.36 for Bhojudih Ground water also shows poor water quality status as per Water Quality Index standard rating.

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INTRODUCTION

Water is the most important element for sustaining life on land and regulating the earth's climate. It is one of the most important compounds that profoundly influence all forms of life, from microorganisms to humans. Water is the fundamental necessity for life to survive on Earth [1]. Without water, life cannot exist. Groundwater has become a critical issue for cities and villages both. It is observed that approximately 60% of India's total population uses groundwater for drinking [2]. Groundwater is used for drinking and other uses in numerous Indian states where more than 90% of the population is reliant on it.[3]. Our country is fast moving towards a crisis of ground water over use and contamination. . In many parts of India, the groundwater is the only source of water supply. India ranks second in the world in terms of population as well as usage of groundwater.

Over the decades, increase in population, the growth of industrialization, use of agricultural chemicals, urbanization, and disposal of urban and industrial waste have played a major role in groundwater contamination [4,5]. Water pollution not only affects water quality but also affects human health, economic development and social prosperity [6]. Scarcity of clean and safe drinking water is one of the most serious developmental issues in major parts of West Bengal, Jharkhand, and Orissa etc. [7].

In the Jharkhand State, the quality of water supply drinking water is a major issue due to public ignorance to environmental considerations. Increasing anthropogenic and mining wastes and discharge of improperly treated sewage/industrial effluents results in accumulation of pollutants on the land surface and contamination of available water resources [8, 9,10]. The main basin of the groundwater sample is Damodar basin and some another sub-basins also occur like Jamunia, Gobai, Konar, Bokaro etc. The Damodar River is the main river of the study groundwater samples which flows from west to east direction in the central part of the district. Three- fourth of the ground water sample is occupied by rocks of Chotanagpur granite gneiss.. Coal, Shale and industrial clusters are found in the study area mainly in Bokaro district. [11]

Water Quality Index (WQI) is a unique method of studying water quality. It is a simple expression of water quality status of groundwater through a single number by merging the values of various parameters obtained from the field and comparing them to the concerned citizens and policy makers. [12]. Water Quality Index model was first studied by Horton in the year 1965.[13] Since then, several models were evolved to study and quantify a proper weight for each parameter based on their analysis. That's why WQI has become an important criterion for the assessment and management of groundwater.[14]. It provides the result in a single value.

Another parameter to see the interrelationship between the various parameters is the Correlation Coefficient method [15,16,17].The coefficient correlation is a statistical measure that describes the relationship between the two variables[18,19] The present study (as described above) was made to evaluate the physico-chemical properties of two selected areas

groundwater samples from nearby coal washery and Damodar river viz. Dugda Ground water (GW1) and Bhojudih Ground water (GW2) of district Bokaro, Jharkhand and understand the relationship between different parameters using Correlation Coefficient method and water quality by Water Quality Index (WQI).

MATERIALS AND METHODS

Study area

Bokaro district is located in Jharkhand with latitude of 23.66°N and 85.56°E. It is situated on the Chotanagpur plateau having undulating uplands and the Damodar River valley. It comprises many rivers like Bokaro, Jamunia, Garga, Konar, etc., and covers various Cement and Steel industries. Groundwater sampling was done from Dugda and Bhojudih (GW1 and GW2) with selected coordinates.

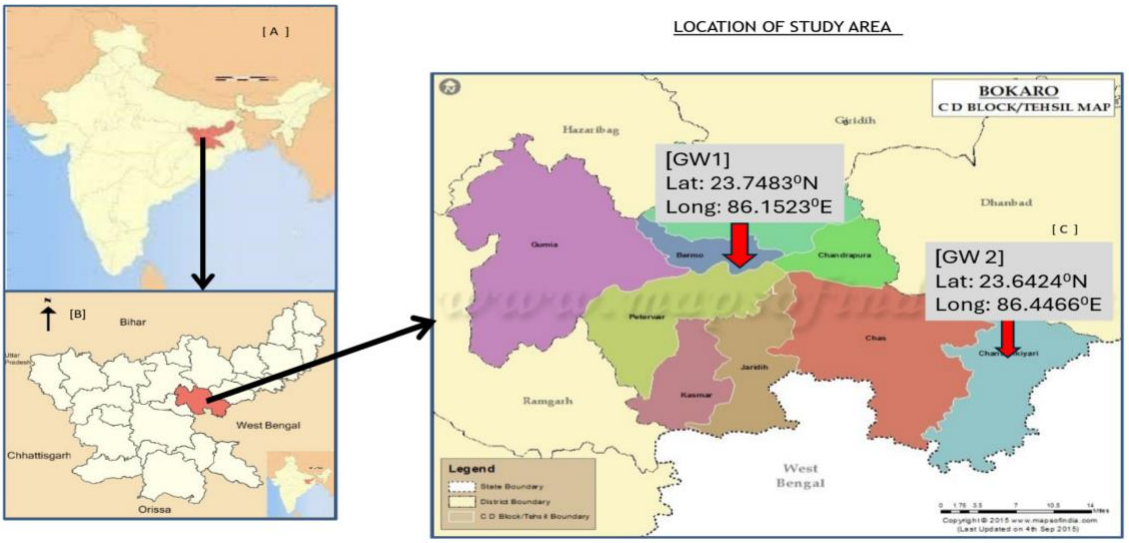


Figure 1: Location of the study area shown on a map. [A] A map of India showing the state Jharkhand. [B] Location of district Bokaro in the map of Jharkhand. [C] Location of two study area i.e., [D] Dugda(GW1) [E] Bhojudih (GW2) in the map of District Bokaro.

Sampling and Analysis:

Water samples were collected from the two selected sampling sites with the help of hand pumps from November 2020 to October 2021. Samples were taken in bottles, sealed and labelled. Samples collected and analysed were from monthly collection of samples (one dozen samples in a year). Some parameters like Temperature, EC, pH were measured in situ with the help of thermometer, portable conductivity and pH meter respectively.

Rest of the parameters like Total Dissolved Solids (TDS), Chloride (Cl-), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), and Turbidity were analysed according to standard methods (APHA, 2005).[20]

STATISTICAL ANALYSIS

Table 1: - showing standards for drinking water as per mentioned BIS and WHO .

Parameters	BIS Standard	WHO Standard
Temp	-	-
pH	6.5 - 8.5	7.0 - 8.5
Total Dissolved Solids (TDS)	500 mg/l	500 mg/l
Electrical Conductivity (EC)	300 µs/cm	180 – 1000 µs/cm
Chlorides (CL^-)	250 mg/l	250 mg/l
Nitrate	45 mg/l	50 mg/l
Sulphate	250 mg/l	250 mg/l
Turbidity	5 NTU	5 NTU

Water Quality Index

The Water Quality Index is a composite indicator that simplifies complex water quality data into a single numerical value to represent the overall quality of water. It is calculated by using parameters such as pH, EC, TDS, Nitrate, Sulphate, Chloride and others , each assigned a weight based on their relative importance to water quality. A lower WQI indicates better water quality, while higher value suggest pollution or unsuitability for drinking or other uses [15] .

For the present investigation Indian Standards BIS for drinking water (IS: 105000)[21] and WHO Standards[22] have been taken into consideration.

For the calculations of WQI, three steps have been taken.

Step -1 To calculate Wn means unit weight factors for each parameter following equation was used

$Wn=k/sn$

Where

Wn is the unit weight for the n^{th} parameters.

Sn is the Standard Value of the n^{th} parameters

K is the constant proportionality

$k=1/1/s1+1/s2+1/s3+1/s4 \ldots\ldots\ldots\ldots 1/sn$

$1/\Sigma 1/sn$

Step-2. To Calculate Sub index (Qn) value, the equation is given below

$Qn=[(Vn-Vi)/(Sn-Vi)]$

Where

Qn is the sub index of n^{th} parameter

Sn is the standard value (I S 10500) for the n^{th} parameter

Vi is the ideal value for each parameter in pure water.

Vi of pH is 7 and Vi of DO is 14.6. Generally, Vi is 0 for other parameters.

Step 3-Finally, WQI is calculated as

=ΣWnQn
Overall WQI=ΣWnQn/ΣWn
Where
Wn is the unit weight for the n^{th} parameter.
Qn is the sub index of n^{th} parameter.

Table 2: seasonal variation in the physico-chemical parameters of two selected Ground water sampling sites near coal washery and near Damodar River during November 2020 to October 2021

	Dugda Ground Water(GW1)			Bhojudih Ground Water (GW_2)		
Parameters	Range (Min-Max)	Mean	Standard Deviation	Range (Min-Max)	Mean	Standard Deviation
Temperature(^{0C})	16.76-25.36	21.307	3.071	16.00-25.10	20.504	3.264
pH	6.38-7.41	6.978	0.371	6.74-7.43	7.04	0.223
EC(µs/cm)	692-929	778.25	89.781	786.-1028	886.83	84.12
Sulphate(mg/L)	21.98-37.78	29.495	6.324	27.68-42.02	35.51	4.380
Nitrate(mg/L)	2.21-4.10	3.184	0.518	2.53-5.03	3.495	0.899
Chloride (mg/L)	43.44-67.73	50.228	6.626	43.48-69.21	52.102	9.254
TDS (mg/L)	415.2-524.8	448.679	37.879	329-614.8	513.05	78.156
Turbidity (NTU)	14.76-22.11	18.595	2.248	17.02-21.91	18.82	1.63

Pearson's Correlation Coefficient
Pearson's Coefficient Correlation is a statistical value that describes the degree to which two variables move in relation to each other. It helps to determine whether an increase in one variable corresponds to an increase or decrease in another variable. .It is denoted as r. Its value ranges from -1 to +1, where +1 indicates a perfect positive correlation , -1 a perfect negative correlation , and 0 no correlation[23,24]. The Pearson's Correlation Coefficient was calculated by using the equation given below [25,26].

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where:

- r = Pearson correlation coefficient
- n = number of data pairs
- x, y = values of the two variables
- $\sum xy$ = sum of the products of paired scores
- $\sum x, \sum y$ = sums of x and y
- $\sum x^2, \sum y^2$ = sums of squares of x and y

RESULTS AND DISCUSSION
Various Physico –Chemical parameters were analysed with the help of relevant statistical tools of two Ground water samples and got the result.
Temperature
Temperature is one of the most important environment factors and parameters that influence almost all the chemical, physical and biological characteristics of water .Temperature groundwater samples ranged between 16.76(°C) to 25.36 (°C) in GW1 and from 16.00(°C) to 25.76(°C) in GW2[27] . In GW1 and GW2 both Temperature shows positive correlation with EC, TDS, Sulphate, Chloride, Turbidity and negative correlation with pH and Nitrate.
pH
pH is a prime parameter of water analysis. pH value indicates the acidity or alkalinity property of the water/solvent/solution. Simply pH is a scale of 0 to 14 where water, pH of 7 is neutral, pH less than 7 is acidic and pH greater than 7 is basic.
The pH of groundwater samples ranged between 6.38 to 7.41 in GW1 and from 6.74 to 7.43 in GW2 [28]..In GW1 and GW2 both pH shows negative correlation with Temperature, EC, TDS, Sulphate, chloride, Turbidity and positive correlation with Nitrate.
Electrical Conductivity (EC):
Electrical conductivity of water indicates the amount of ions, salts and contaminant present within the water29. It is a measure of electric current that water/ solvent/solution carry. In GW1 it ranged from692(µs/cm) to 929(µs/cm) and in GW2 from 786(µs/cm) to 1028(µs/cm).In GW1 and GW2 both EC shows positive correlation with Temperature, TDS, Sulphate, chloride, Turbidity and negative correlation with pH and Nitrate.
Total Dissolved Solids (TDS):

Total dissolved solids are the measure of total dissolved salts, ions, minerals and materials in water. Simply purity of drinking water is measured in terms of TDS. The differences in TDS values may be dependent on geological formations, hydrological processes and prevailing mining conditions in the region [29]. TDS values varied from 418.4 (mg/L) to 524.8(mg/L) in GW1 and from 329 (mg/L) to 614.8(mg/L) in GW2. TDS Shows strong, moderate positive correlation with EC, Sulphate, Nitrate, chloride, Turbidity and negative correlation with pH and Turbidity.

Sulphate:

Sulphate is an important parameter in water. However, the sulphate concentration in water of the study area is within the maximum allowable limit. Generally many sulphate compounds such as sulphate ores, gypsum, shale, industrial waste etc. are readily soluble in water and so sulphate ions usually occur in natural waters. The Sulphate of groundwater samples ranged between 21.98(mg/L) to 37.78(mg/L) in GW1 and from 27.68(mg/L) to 42.02 (mg/L) in GW2.In GW1 and GW2 both Sulphate shows positive correlation with Temperature, EC, TDS, Turbidity, chloride and negative correlation with pH and Nitrate.

Nitrate:

Nitrate is an important parameter in water and it is naturally occurring inorganic ion present in our environment. Nitrate in groundwater is a prime indicator of anthropogenic pollution. The Nitrate of groundwater samples ranged between 2.21(mg/L)to 4.10(mg/L) in GW1 and from 2.53(mg/L) to 5.03(mg/L) in GW2.In GW1 and GW2 both Nitrate shows positive correlation with pH, DO and negative correlation with Temperature, EC, Chloride, TDS, Sulphate and Turbidity.

Chloride:

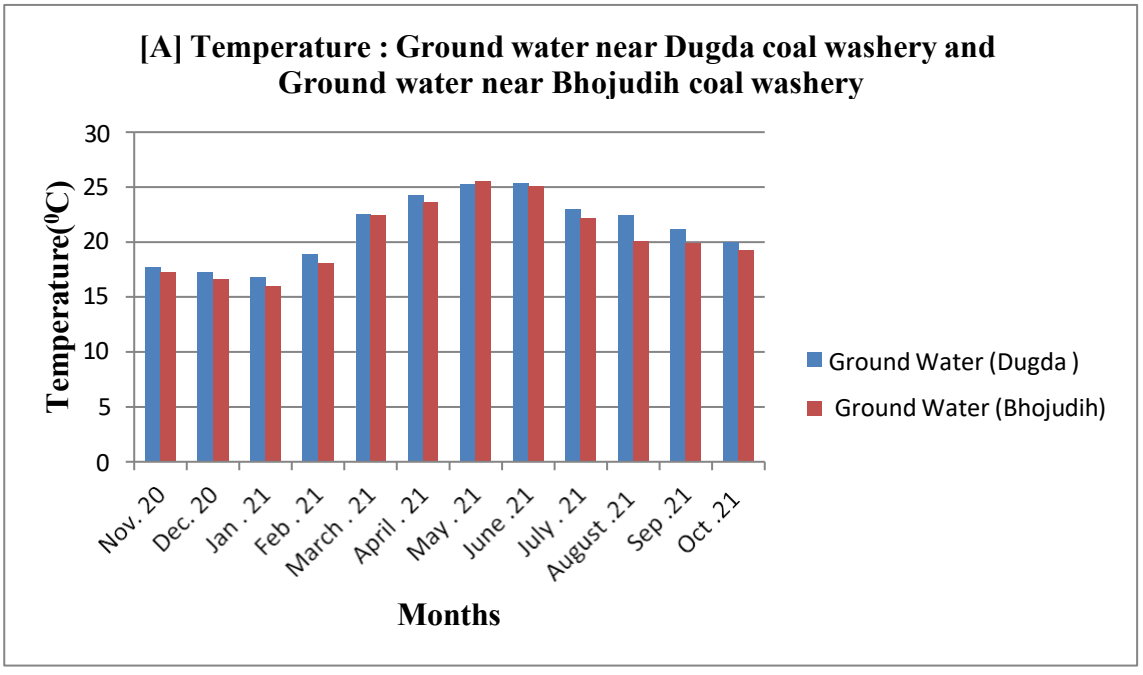
Chloride is one of the most abundant inorganic anion in natural water of various sources. Generally low existence of chloride is shown in normal fresh water due to the dissolution of salts but in sea water chlorine is predominant as an ion in the water.

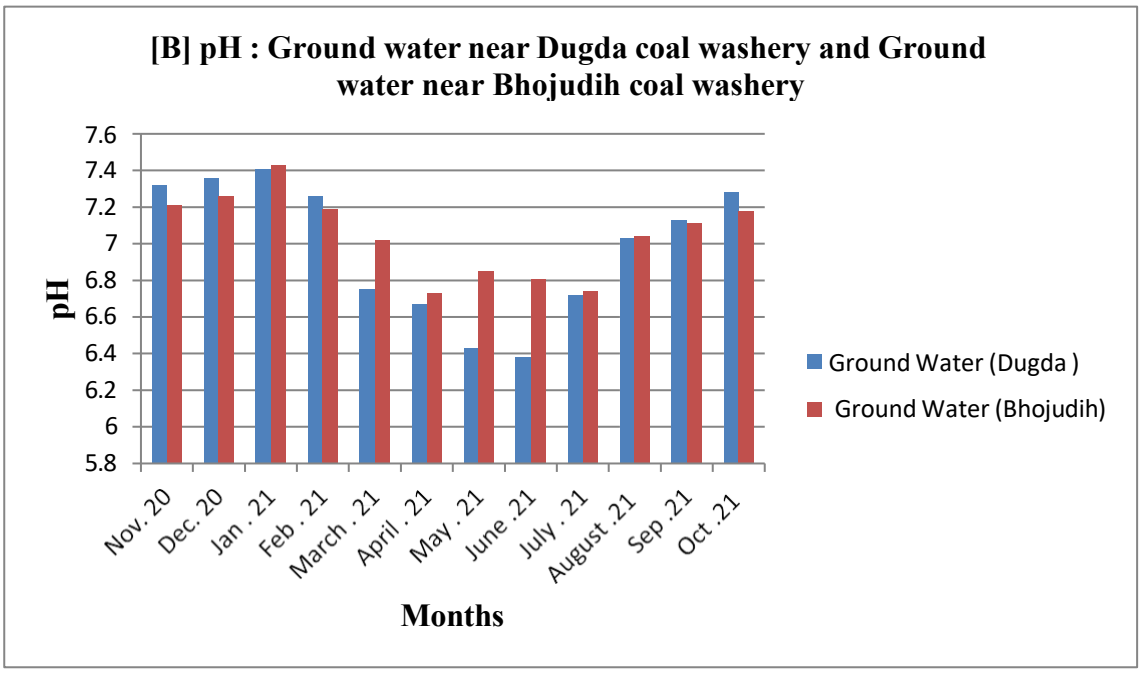
In GW1 it ranged from 43.44(mg/L) to 67.73(mg/L) and in GW2 from 43.48 (mg/L)to 69.21(mg/L).In GW1 and GW2 both Chloride shows positive correlation with Temperature, EC, TDS, Sulphate, Turbidity and negative correlation with pH and Nitrate .

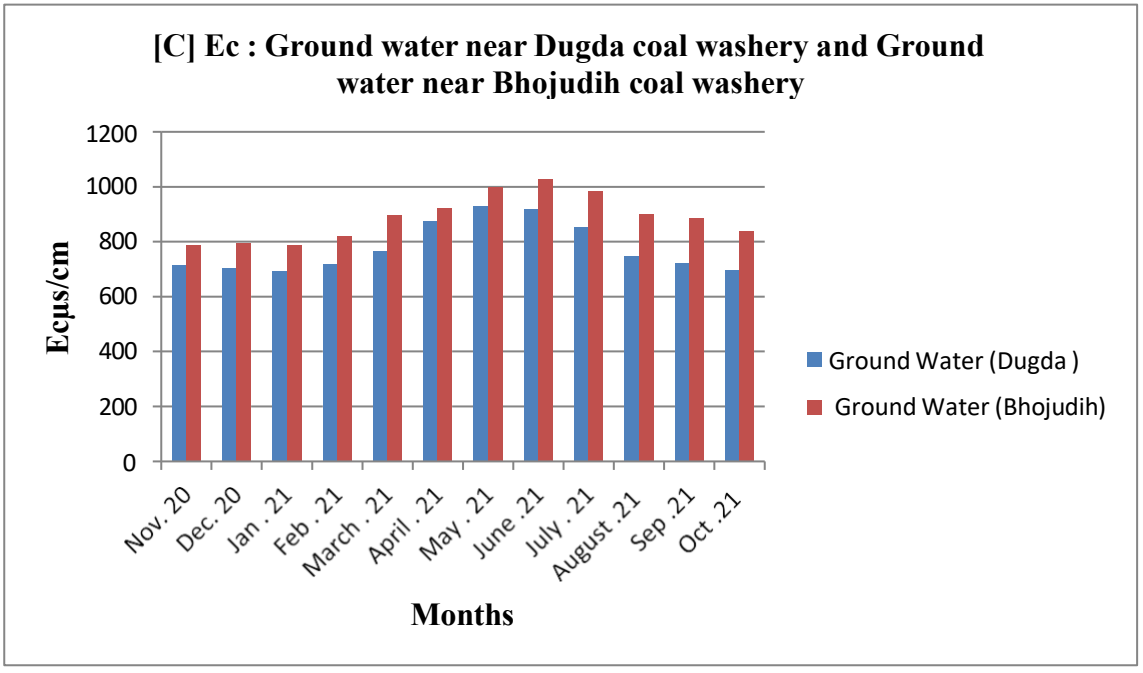
Turbidity:

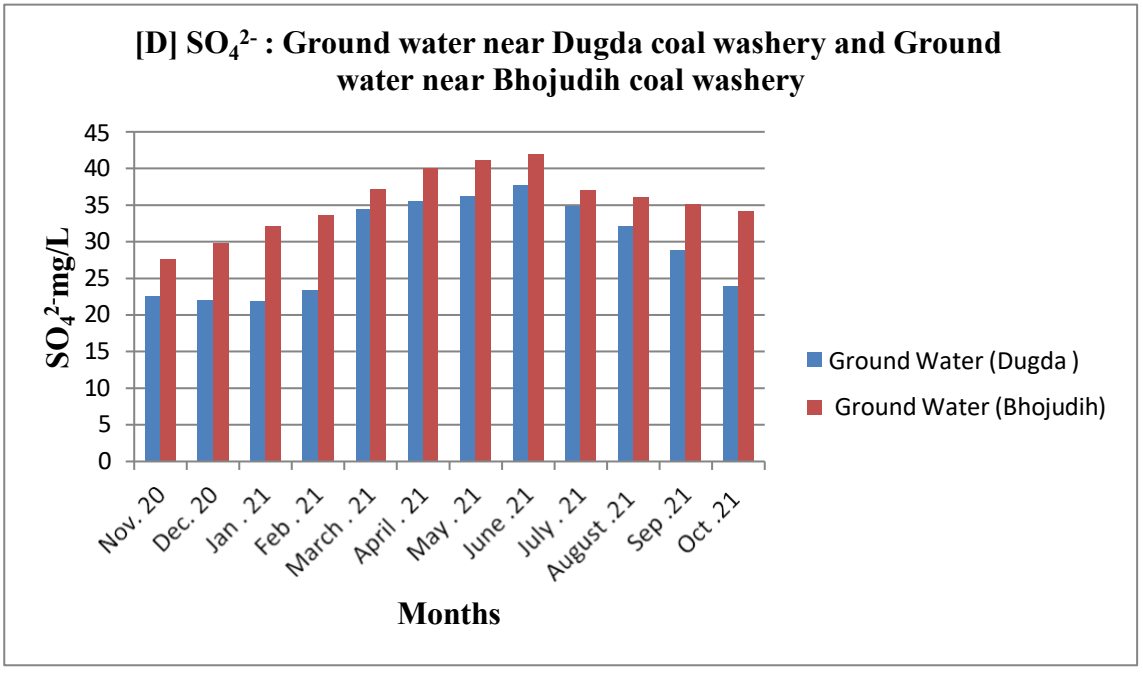
Turbidity is the measure of the cloudiness or haziness of water caused by suspended particles such as silt, clay, microorganisms, and organic matter. It is usually measured in Nephelometric. High Turbidity can reduce light penetration in water, affecting aquatic life and indicating possible pollution. It is an important parameter in assessing water quality for drinking and ecological health.

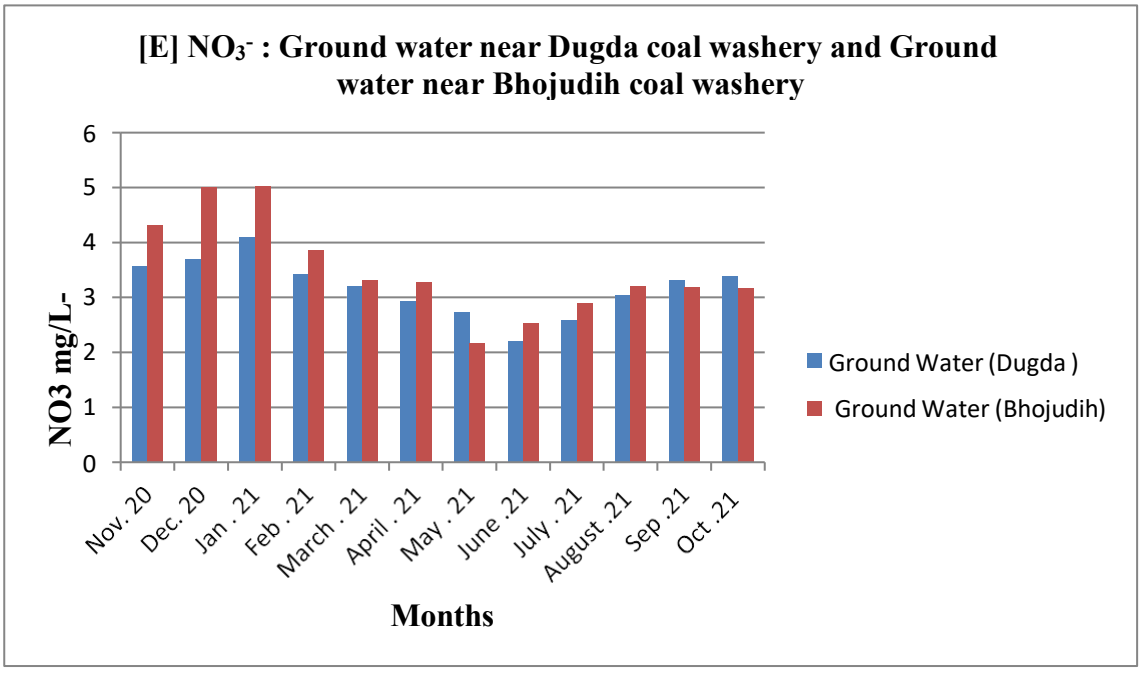
Turbidity values varied from 14.76(NTU) to 22.11(NTU) in GW1 and from 17.11(NTU) to 421.91 (NTU) in GW2. It shows strong, moderate positive correlation with Temperature, EC, TDS, Sulphate, chloride and negative correlation with Nitrate and pH.

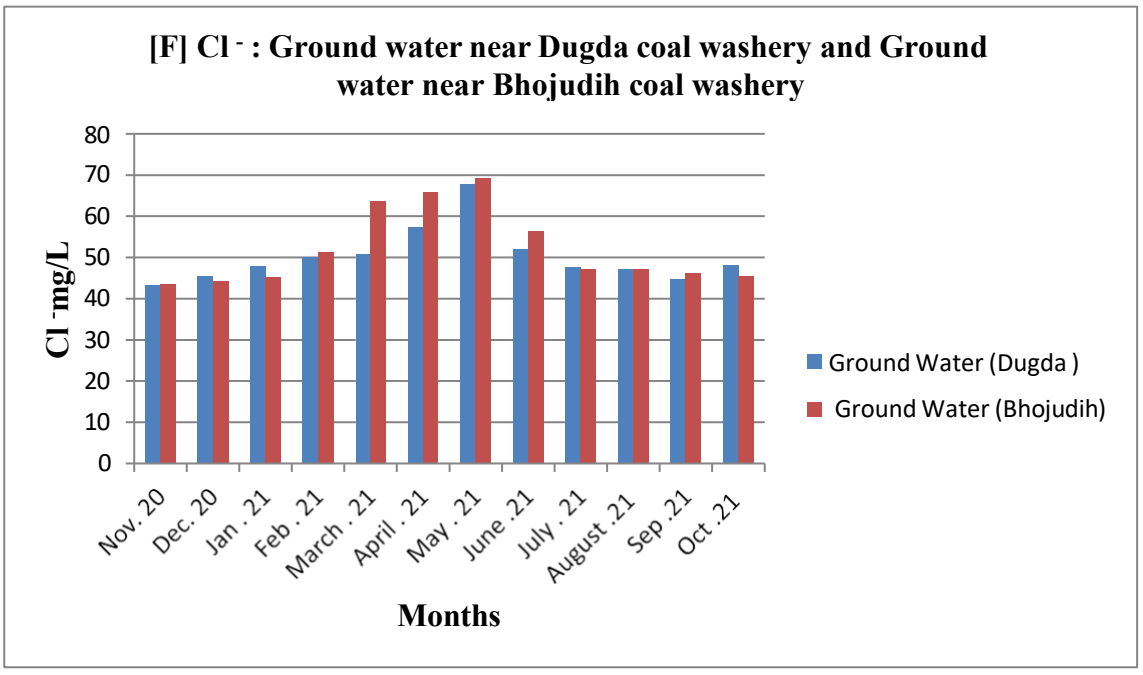


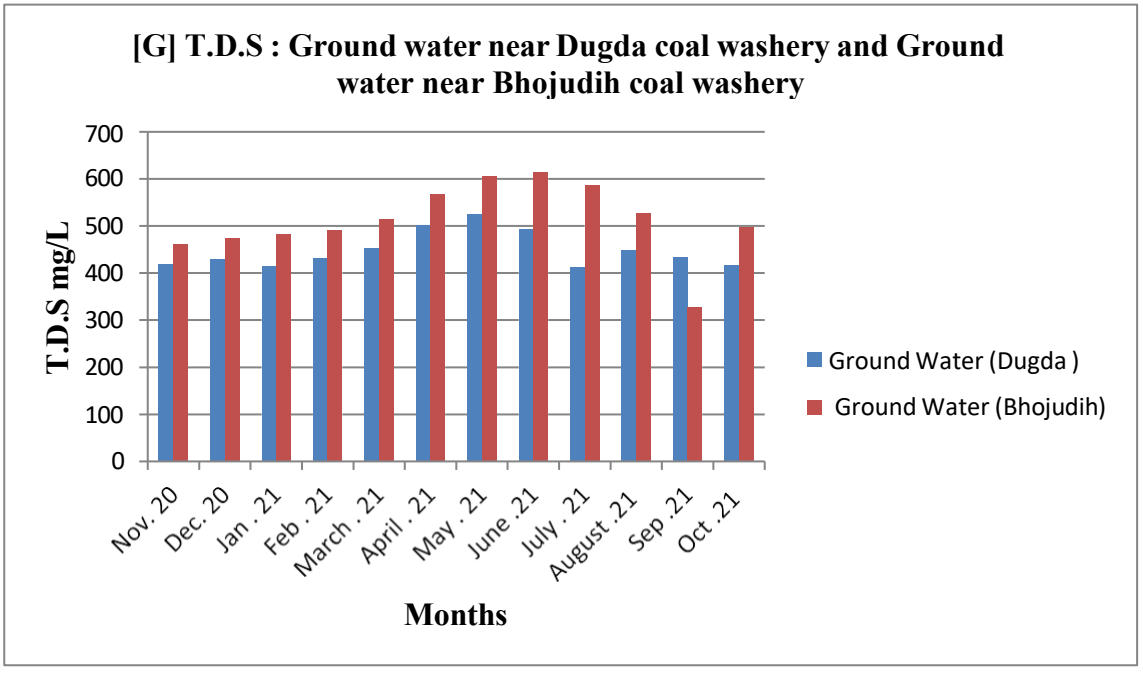

[B] pH : Ground water near Dugda coal washery and Ground water near Bhojudih coal washery
pH
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
Nov. 20
Dec. 20
Jan . 21
Feb . 21
March . 21
April . 21
May . 21
June .21
July . 21
August .21
Sep .21
Oct .21
Months
Ground Water (Dugda)
Ground Water (Bhojudih)


[C] Ec : Ground water near Dugda coal washery and Ground water near Bhojudih coal washery
Ecμs/cm
1200
1000
800
600
400
200
0
Nov. 20
Dec. 20
Jan . 21
Feb . 21
March . 21
April . 21
May . 21
June .21
July . 21
August .21
Sep .21
Oct .21
Months
Ground Water (Dugda)
Ground Water (Bhojudih)


[D] SO_4^{2-} : Ground water near Dugda coal washery and Ground water near Bhojudih coal washery
SO_4^{2-}mg/L
45
40
35
30
25
20
15
10
5
0
Nov. 20
Dec. 20
Jan . 21
Feb . 21
March . 21
April . 21
May . 21
June .21
July . 21
August .21
Sep .21
Oct .21
Months
Ground Water (Dugda)
Ground Water (Bhojudih)


[E] NO_3^- : Ground water near Dugda coal washery and Ground water near Bhojudih coal washery
NO3 mg/L-
6
5
4
3
2
1
0
Nov. 20
Dec. 20
Jan . 21
Feb . 21
March . 21
April . 21
May . 21
June .21
July . 21
August .21
Sep .21
Oct .21
Months
Ground Water (Dugda)
Ground Water (Bhojudih)


[F] Cl⁻ : Ground water near Dugda coal washery and Ground water near Bhojudih coal washery
Cl⁻ mg/L
80
70
60
50
40
30
20
10
0
Nov. 20
Dec. 20
Jan . 21
Feb . 21
March . 21
April . 21
May . 21
June .21
July . 21
August .21
Sep .21
Oct .21
Months
Ground Water (Dugda)
Ground Water (Bhojudih)


[G] T.D.S : Ground water near Dugda coal washery and Ground water near Bhojudih coal washery
T.D.S mg/L
700
600
500
400
300
200
100
0
Nov. 20
Dec. 20
Jan . 21
Feb . 21
March . 21
April . 21
May . 21
June .21
July . 21
August .21
Sep .21
Oct .21
Months
Ground Water (Dugda)
Ground Water (Bhojudih)

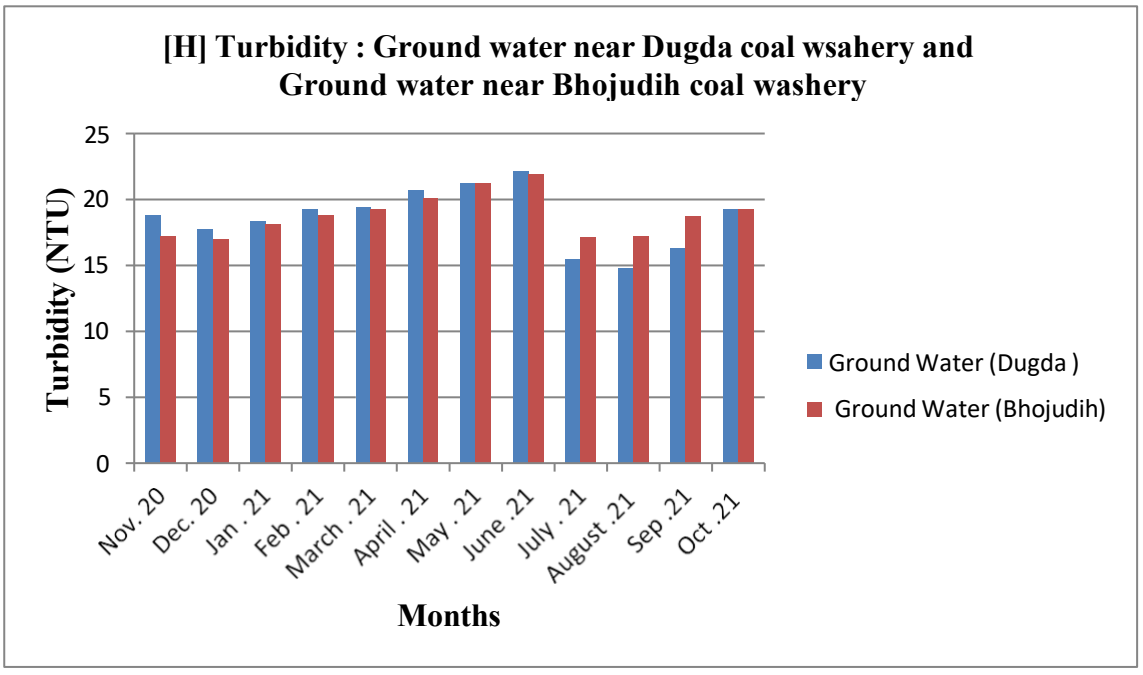


Figure 2: Comparative graphical representation of monthly variations in the physico-chemical parameters of two selected study area viz., [A] Temperature;[B] pH [C] Electrical Conductivity (EC); [D] Sulphate; [E]Nitrate; [F] Chloride; [G] Total Dissolved Solid (TDS); [H] Turbidity.

Table 3: Correlation Matrix (Pearson's correlation method) among physico-chemical parameters of Dugda Ground Water (GW1).

	Temp	*pH*	*EC*	*Sulphate*	*Nitrate*	*Chloride*	*TDS*	*Turbidity*
Temp	1							
pH	-0.95605	1						
EC	0.893831	-0.96005	1					
Sulphate	0.970774	-0.96227	0.886862	1				
Nitrate	-0.918	0.904275	-0.87513	-0.88929	1			
Chloride	0.660066	-0.70309	0.750585	0.589568	-0.46032	1		
TDS	0.784371	-0.81048	0.821012	0.733709	-0.61768	0.868806	1	
Turbidity	0.322854	-0.45162	0.483635	0.247279	-0.2577	0.622642	0.648593	1

Table 4: Correlation Matrix (Pearson's correlation method) among physico-chemical parameters of Bhojudih Ground Water (GW2).

	Temp	*pH*	*EC*	Sulphate	Nitrate	Chloride	*TDS*	*TURBIDITY*
Temp	1							
pH	-0.90532	1						
EC	0.94213	-0.89672	1					
Sulphate	0.938394	-0.8223	0.914115	1				
Nitrate	-0.89475	0.806835	-0.88413	-0.84591	1			
Chloride	0.806839	-0.63861	0.604168	0.767311	-0.58421	1		
TDS	0.664439	-0.66103	0.664049	0.63553	-0.48385	0.561096	1	
Turbidity	0.753319	-0.49205	0.629225	0.787388	-0.64213	0.746164	0.457404	1

Table 5: Calculated WQI (Water Quality Index) for the two Ground Water i.e |Dugda Ground Water (GW1) and Bhojudih Ground Water (GW2).

Parameter	BIS STD (Sn)	K=1/1/Sn	Wn=K/Sn	QN=Vn/Snx100	WnQN

Dugda Ground Water (GW1) WnQn=71.78	Ph	8.5	6.532	0.7685	82.09	63.10
	EC	300	6.532	0.02177	259.42	5.65
	TDS	500	6.532	0.01306	89.736	1.172
	SO_4^{2-}	250	6.532	0.02613	11.796	0.308
	Cl-	250	6.532	0.02613	20.088	0.524
	NO_3^-	45	6.532	0.14516	7.07	1.027

Bhojudih Ground Water (GW2) WnQn=73.36	pH	8.5	6.532	0.7685	82.82	63.54
	EC	300	6.532	0.02177	295.61	6.43
	TDS	500	6.532	0.01306	102.61	1.340
	SO_4^{2-}	250	6.532	0.02613	14.20	0.371
	Cl-	250	6.532	0.02613	20.84	0.544
	NO_3^-	45	6.532	0.14516	7.77	1.127

RESULTS OF WQI

Calculated WQI indicates that both the sampling sites fall under poor categories according to the standard developed by Brown et al, (1972). The Water Quality Index (WQI) of Dugda ground water is 71.78, which is lower than that of Sudamdih Ground water, which has a WQI value of 73.36.

Table 6: Categories for Water Quality Status developed by Brown *et al*.,1972.

Water Quality Index	Water Quality Status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unfit for consumption

CONCLUSION

Analysis of monthly variation sanctioned in the physico- chemical parameters such as Temperature, pH, EC,TDS, SO_4^{2-} NO_3^- Cl^-, Turbidity were found to be in higher concentration compare to permissible limit WHO (2006) in both the sites ,but it was higher in GW2 (Bhojudih Ground water).

WQI shows poor quality status of GW1 and GW2 respectively.

So, on the basis of the above results, it can be concluded that with proper treatment and regular water monitoring by competent authorities can improve the water quality and ground water of hand pump can be utilised for different purposes, and it should be beneficial for the local people living there nearby and the people can be prevented by diseases caused by contaminated water.

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