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Research Article

ASSESSMENT OF MINE WATER FOR DOMESTIC AND AGRICULTURE USES IN PART OF RANIGANJ COALFIELD AREA

RANI BIBHA[1]* AND SINGH ABHAY KUMAR[2]

[1]Department of Agricultural Biotechnology and Molecular Biology, Dr. Rajendra Prasad Central Agriculture University, Samastipur, Pusa, 848125, Bihar
[2]Geo-Environment Division, (Council of Scientific and Industrial Research), Barwa Road, Dhanbad, 826015, Jharkhand, India
*Corresponding Author: Email-bibha9rani@gmail.com

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Abstract- Under the present investigation the physio-chemical characteristics of mine water of the upper catchments of Raniganj coalfield area of West Bengal, India were evaluated. Mine water samples were collected from underground coal mine discharged pumps and open cast coal mines. A total number of 27 Mine water samples were collected from total eight areas during the month of February (17.02.2009-19.02.2009). Efforts were made to provide drinking water, safe domestic uses, industrial and agriculture uses. Mine water samples were analyzed for pH, EC, Dissolved oxygen, Anions (Cl, HCO3, and SO4) and Dissolve Silica and cations (Na, K, Ca, Mg). Some parameters of water chemistry like Turbidity, Alkalinity, Bicarbonate, and Sulfate reflect continental, weathering, mining have been tested which is limiting anthropogenic use of mine water for domestic and agricultural purposes and other anthropogenic impacts, limiting mine water use for domestic purposes.

Keywords- Total Dissolved Solid (TDS), Dissolved Oxygen (D.O), Sodium Absorption Ratio, Magnesium Hazard (MH), Alkalinity, pH

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Introduction

Water is a basic human need and a precious National asset. It is one of the most stable compound as well as universal solvent for a wide variety of chemical substances and facilities for industrial cooling and transportation, approximately 70% of fresh water is consumed by agriculture. Clean and fresh drinking water is essential to human and other living life, however in many parts of the world especially developing countries there is a water crisis [1]. It is estimated that around seven billion people out of the projected 9.3 billion in the entire world will face water shortage and out of these 40% will suffer acute water crisis. In case of India, the future is a bit more-worse, since we have only 2.45% of the world's landmass supporting 16% of the world population and fresh water resource does not exceeding 4% of the global resources [2]. Continuous water pollution threatens to reduce the available quantity of usable water and more and more our lakes, ponds and rivers are being characterized as polluted due to disposal of sewage industrial and mining wastes and a host of other human activities [3].

Population growth, urban expansion and industrial development have persistently raised the demand for water supply and consequently increased the exploitation of groundwater. This has not been followed by equal expansion in water supply and sanitary drainage, thus resulting in water scarcity and poor environmental conditions in many parts of the country. Overexploitation of groundwater and disposal of domestic wastes and industrial effluents poses threats to the groundwater resources of the area, both in terms of quality and quantity. Surface and sub-surface water resources are at risk from contamination due to rapid and unplanned urbanization [4].

Mining is one of the major activities causing water pollution and threatens the quality and quantity of surface and groundwater resources in many part of the country. Damping of overburden (OB) and spoils or spreading of OB through rolling and washing may cause the chemical pollution. In the mining areas large volume of water is pumped out daily from ground. Being underground water mine water is expected to be comparatively less polluted. However, in practice this water is also polluted due to mining as well as human activities. The term mine water encompassing all natural water emanating from mine site including mine pit, waste rock piles and tailing dam leachates. As there is no proper water management plan in most mines, major parts of this water is discharged into the open channel. There it pollutes the channel and become unused. Not only this, the mining and related activities also damage the aquifers and make the area as water scare. Mine water can vary greatly in the concentration of contaminants present, and in some cases it may even meet the drinking water specification. Mining by its nature consumes, diverts and can seriously pollute water resources [5].

In Raniganj coalfield area, coal deposits are extracted by both opencast and underground mining methods since long times. In the mining process huge quantity of water are generated and discharged on the surface or in natural water bodies without any productive use and many times without any prior treatment. This discharge of mine water has a visible detrimental effect on the surface water quality and aquatic lives of the region and many times it also affects the underground water resources of the region. This discharge mine water as such may not be usable and contain unacceptable levels of heavy metals, toxic anions, organic and biological contaminants. However many times concentration of the contaminants are not very high and it may possible to utilize the mine water for human need after treatment. However, for proper utilization of available water resources of the mining areas for different uses and its management, a baseline water quality data and continuous monitoring of water quality of the mining regions is pre-requisite [6].

In the present study, an attempt has been made to carry out quality assessment of mine water discharges from the coal mines of the Raniganj coalfield area. The hydrochemical data of the water of these areas have been evaluated in terms of its suitability for domestic, industrial and irrigation uses.

Materials and Methods:

For the assessment of mine water quality of Raniganj coalfield area, the systematic sampling was carried out during the month of February 2009. Representative 27, (underground as well as pump discharge) mine water samples were collected from different mines of Satgram, Kunusturia, Pandeshwer, Sonepur Bazari, Kajora, Bankolla, Jhajra and Nirsha mining areas of Raniganj coalfield.

Sampling:

The mine water samples were collected from both underground as well as open cast mines in one litre narrow mouth prewashed 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. At the sampling sites, before collecting the samples bottles were also washed with mine water. About one litre samples were collected from each site. List of sampling sites and Mining areas is discussed below:

Table-1

Sl. No.	Sampling site	Areas
1	Amkola colliery	Satgram
2	J.K.Nagar Colliery	Satgram
3	J.K.Nagar-3 pit Colliery	Satgram
4	Rati Bati Colliery	Satgram
5	Nimcha Colliery plant no. 3	Satgram
6	Nimcha Colliery	Satgram
7	Nimdanga project	Satgram
8	Satgram project	Satgram
9	Tirat Colliery	Satgram
10	Tirat Colliery	Satgram
11	Kunusturia Colliery	Kunustria
12	Amrit Nagar Colliery	Kunustria
13	Amadasuta Colliery	Kunustria
14	Pandeshwer Colliery	Pandeshwer
15	Pandeshwer Colliery PB pit	Pandeshwer
16	Dulurbandh OCP	Pandeshwer
17	South Samla Colliery	Pandeshwer
18	Sonepur Bazari project	Sonepur Bazari
19	Khaskajora Colliery	Kajora
20	Masudanpur Colliery	Kajora
21	Lachhipur Colliery	Kajora
22	Moyra Colliery	Bankola
23	Nag Kajora Colliery	Bankola
24	Shyamsundernagar Colliery	Bankola
25	Lakra Khanda Colliery	Jhajra
26	Jhajra Colliery	Jhajra
27	Raja Colliery	Nirsa

Laboratory methods [7]:

Separation of suspended sediments: suspended sediments were separated from the water samples in the laboratory by using 0.45 micro meter Millipore membrane filters of 47 mm diameter. Vacuum pump was used for faster filtration. Volume of the samples was measured by glass measuring cylinder before filtration and after filtration. Total suspended matter was calculated for one litre of water samples from the volume of filtered water and the weight of the sediment.

pH:

pH is a measurement of intensity of acidity or alkalinity and the concentration of H+ ions in a water sample. pH was measured using ph meter. Reference electrode was calibrated against standard buffer solution of 4.0, 7.0, and 9.2. Equilibrium was established between electrode and sample by stirring sample to ensure homogeneity.

Electrical conductivity:

Electrical conductivity was measured by using CONSORT E.C meter. It provides measurement of E.C. by a cell consisting of two platinum electrodes to which an alternating potential is applied.

Turbidity:

Suspension of particles in water interfering with passage of light is called turbidity. Turbidity of the samples was analyzed by using turbidity meter.

Total suspended solids:

Suspended solid is one of the most common forms of pollution being present in sewage and majority of industrial wastewater. The dry weight of the material was removed from a measured volume of water sample by filtration through standard filter paper which was initially weighed. Temperature of hot air oven was adjusted at 103 c for one hour and then it was dessicated for one hour and then final weight was taken.

Calculation:

$$TSS\ mg/l = (A-B) \times 1000 \times 1000/V,$$

Where A = final weight of the filter paper (in gm)

B = initial weight of the filter paper (in gm)

V = volume of the sample taken (ml)

Total dissolved solids (TDS):

The material remains in the water after filtration for the suspended solids analysis considered to be dissolved. A well-mixed, measured portion of sample was filtered in an initially weighed beaker trough standard Whatman No. 42 filter paper and the filtrate portion was evaporated to dryness on the hot plate. The hot beaker was dessicated for `1 hr. then final weight of the beaker was taken.

Calculation:

$$TDS\ mg/l = (W2 - W1) \times 1000 \times 1000/V,$$

Where, W1 = initial weight of the evaporating dish (gm).

W2 = final weight of the evaporating dish (gm).

V = volume of the sample taken (ml).

Total Hardness:

Total hardness was measured directly by titration with EDTA using Eriochrome Black T (EBT) as an indicator.

Calculation:

$$\text{Hardness (EDTA) as mg/l calcium carbonate} = (A \times 100)/V.$$

Where A = ml of titrant used.

V = ml of sample

Alkalinity:

Alkalinity of water was measured by potentiometer method.2-3 drop of phenolphthalein indicator was added into 100 ml of sample. It was then titrated with 0.02N HCl, till orange color disappears. After those 2-3 drops of methyl orange was added to the sample. Continued titration with 0.02N HCl till orange color changed to pink. The volume of HCl consumed was noted.

Calculation:

Total alkalinity (mg/l as $CaCO_3$) = {(T × N) × 1000 × 50} × ml of sample

Phenolphthalein alkalinity (mg/l as $CaCO_{3)}$ = {(T × N) × 1000 × 50} × ml of sample

Where T = ml of titrant required for sample

N = normality of titrant

Chloride: (argentrometric titration method)

Chloride in the sample was measured directly by titrating 50ml of sample with 0.02N $AgNO_3$ solution using 2ml of 5% $K_2Cr_2O_4$ solution. The color changes from yellow to brick red, which was end point of titration.

Calculation:

$$\text{Chloride as } Cl_2\ mg/l = \{T \times N \times 35.5 \times 1000\}/\ \text{ml of sample}$$

Bicarbonate:

Bicarbonate was determined by potentiometer titration method. Standards of HCO_3 were prepared for concentration ranging from 20 to 60 ppm. 50 ml of each standard and samples were titrated against 0.006N HCl. A graph was plotted for standard concentrations against the volume of HCl consumed.

Sulphates:

Sulphate ion concentration was measured by turbidimetric method. 100 ml of filtered sample was taken. 20 ml of buffer solution was added and mixed with the help of magnetic stirrer. While stirring spoon full of $BaCl_2$ crystal was added. Then the sample was analysed by UV-Visual Spectrophotometer.

Calculation:

$$SO_4 \text{ mg/l} = \{SO_4 \text{ (mg)} \times 1000\}/\text{ml of sample}$$

Dissolved Oxygen (DO):

Dissolved oxygen of water samples was determined by Winkler's method. In 300 ml of water sample 2 ml of $MnSO_4$ was added followed by 2ml of alkali azide. The precipitate formed was dissolved with 2ml of sulphuric acid. 203 ml of sample was titrated against 0.01 N $Na_2S_2O_3$ till the initial blue color turned to colorless.

Calculation:

$$\text{DO in mg/l} = (\text{ml of } Na_2S_2O_3 \times 0.08 \times 1000)/V$$

Where, V = Volume of sample

Dissolve silica:

The dissolve silica concentration was determined by molybdosilicate. Standard solution of different concentration ranging from 10-40 ppm was prepared by dissolving Na_2SiO_3. 20 ml of each standard and water sample, 10 ml of Aluminium molybdate in 10 ml distilled water and 6 ml of conc. HCl and total volume made upto 100 ml by diluting it with distilled water. The sample were stirred well and kept for three hours to complete the reaction. The optical density was measured for standards and water sample using UV-visible Spectrophotometer (SHIMADZU).

Cations by AAS:

Major cations measured are K, Ca, Mg and Na by AAS.

Sodium Adsorption Ratio (SAR):

The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of Sodium Adsorption Ratio. It was estimated by following formula:

$$SAR = Na/[(Ca+Mg)/2]^{0.5}$$

Residual Sodium Carbonate (RSC):

The quantity of HCO3 and CO3 in excess of alkaline earths (Ca+Mg) also influences the suitability of water for irrigation purposes. To quantify the effects of carbonate and bicarbonate, RSC was computed by equation:

$$RSC = (CO3+HCO3) - (Ca+Mg) \text{ in mg/l}$$

Magnesium Hazard (MH):

Szabols and Darab (1964) proposed magnesium hazard (MH) value for irrigation water as given below:

$$MH = Mg/(Ca+Mg) \times 100$$

MH>50% are considered harmful and unstable for irrigation use

Result and Discussion

The data obtained by chemical analyses were evaluated in terms of its suitability for drinking and irrigation, livestock and industrial uses:

Suitability for drinking and general domestic uses:

To assess the suitability for drinking and public health purposes, the hydrochemical parameters of the Mine water of the study area were compared with prescribed specification of WHO (1993) and Indian Standard for Drinking water (IS 1991). The result of most mine water shows that they are not suitable for drinking water purposes and need a proper treatment before its utilization for domestic uses. The values of Total Dissolved Solid exceeds the desirable limit (500mg/l) of WHO (1997) and IS: 10500 in some 66.66% of the samples indicating higher ionic concentration of dissolved ions.

Caroll (1962) proposed four classes of water based on TDS, of which water belongs to fresh, brackish, saline and brine water. The TDS of the analyzed water samples are fall in the category of fresh and brackish water.

Table-2

TDS (mg/l)	Water Quality
0-1,000	Fresh water
1,000-10,000	Brackish water
10,000-100,000	Saline water
> 100,000	Brine water

Hardness of water is the property attributed to the presence of alkaline earths. Hardness defined as the concentration of multivalent metallic cations in the solution. On the basis of hardness water can be classified in to soft, moderately hard, hard and very hard.

Table-3

Hardness (mg/l)	Water class
0-75	Soft
75-150	Moderately hard
150-300	Hard
>300	Very hard

The Total Hardness (TH) of the analyzed mine water samples vary between 20mg/l to 220mg/l and average is about 81mg/l.

Table-4

Parameters	Mining Areas							
	Sat.	Kun.	Pand.	Son.	Kaj.	Ban.	Jha.	Nir.
pH	7.5	7.4	7.8	7.6	7.4	7.8	7.5	7.2
Temp (^{0}C)	26.2	24.9	25.3	25.2	25.3	26.0	25.1	25.4
DO (mg/l)	8.3	8.3	8.4	8.4	8.4	8.2	8.4	8.3
EC (µS/cm)	910.0	666.3	794.8	1282	781.7	915.7	638.0	568
TDS (mg/l)	591.5	433.1	516.6	833	508.1	595.2	414.7	369
Bicarbonates (mg/l)	539.3	208.5	303.8	310.24	506.9	450.9	436.9	585.92
Turbidity (NTU)	1.2	1.6	3.2	1.3	1.5	1.1	1.7	1.2
Chloride (mg/l)	53.2	36.7	61.8	30.0	58.3	63.3	43.0	36.0
Sulphate (mg/l)	68.0	79.7	51.0	263.88	50.7	44.2	22.9	147.76
Sodium (mg/l)	56.5	26.6	43.5	51.97	38.1	54.8	41.6	13.45
Hardness (mg/l),(as CaCO3)	126.1	153.1	62.0	287.09	109.4	139.0	142.8	267.09
Potassium (mg/l)	5.0	4.0	2.8	7.53	2.9	5.3	4.5	5.18
Magnesium (mg/l)	23.8	24.1	8.6	68.13	16.7	22.1	14.8	49.13
Calcium (mg/l)	11.2	21.7	10.6	2.63	5.3	19.2	32.7	25.95
Dissolved Silica (mg/l)	30.5	28.8	34.0	30.57	27.2	34.6	30.3	16.45
Alkalinity (mg/l)	347.6	109.3	204.0	264.0	259.5	190.7	175.0	208.0

Note: Sat.- Satgram, Kun.- Kunustria, Pan. – Pandeshwer, Son. – Sonepur Bazari, Kaj. – Kajora, Ban. – Bankolla, Jha. – Jhajra, Nir. – Nirsa.

Range in values of chemical parameters in mine water of study area and WHO and Indian Standards (IS: 10500) for drinking water.

Table-5

Sl.No.	parameters	Range (ppm)	WHO 1993		BIS (1991) IS: 10500	
			Highest permissible	Max. Desirable	Highest permissible	Max. Desirable
1	PH	6.5-8.2	6.5-8.5	7.0-8.5	8.5-9.2	6.5-8.5
2	D.O (mg/l)	7.4-10.0				
3	EC (µS)	331-1386	2000	400	--	--
4	TDS (mg/l)	66-856	1000	500	2000	500
5	HCO3 (mg/l)	81.53-1136	--	--	600	200
6	Turbidity (NTU)	0.15-16.86				
7	Cl^- (mg/l)	30-76	600	200	1000	250
8	SO_4^{2-} (mg/l)	1.8-263.9	400	200	400	200
9	Na (mg/l)	4.2-137.7	200	--	--	--
10	TH (mg/l)	41.6-287.4	500	100	600	300
11	K (mg/l)	0.0-7.5	--	--	--	--
12	Mg (mg/l)	0.0-68.1	150	50	100	75
13	Ca (mg/l)	0.0-60.1	200	75	200	75
14	Alkalinity (mg/l)	50-662				

Suitability for irrigation uses:

Calculated parameters for water quality assessment of mine water of Rniganj Coalfield Areas:

Table-6

Sl. No.	Mining Area	Type	%Na	SAR	RSC	MH
1	Satgram	P/W	31.2	1.14	5.4	75.5
2	Satgram	P/W	28.0	0.99	3.6	79.9
3	Satgram	P/W	69.4	3.62	1.8	81.8
4	Satgram	P/W	23.9	0.79	5.5	82.5
5	Satgram	P/W	24.7	0.76	3.8	74.0
6	Satgram	P/W	57.7	2.04	7.6	66.7
7	Satgram	P/W	59.6	3.29	11.4	70.6
8	Satgram	P/W	47.8	1.89	7.6	82.0
9	Satgram	P/W	86.7	8.75	18.2	82.7
10	Satgram	U/W	62.5	3.12	10.8	83.0
11	Kunustria	P/W	23.4	0.79	5.0	70.1
12	Kunustria	P/W	39.3	1.43	1.0	79.4
13	Kunustria	P/W	23.5	0.59	-0.4	36.2
14	Pandeshwer	P/W	71.8	3.46	8.7	81.9
15	Pandeshwer	P/W	64.9	2.97	3.6	62.6
16	Pandeshwer	P/W	20.9	0.29	0.9	45.8
17	Pandeshwer	P/W	59.4	2.66	4.2	44.7
18	Sonepur Bazari	P/W	30.0	1.33	2.2	97.7
19	Kajora	P/W	100.0	-	8.0	-
20	Kajora	P/W	40.0	1.36	7.7	87.6
21	Kajora	P/W	30.6	0.89	6.7	80.1
22	Bankolla	P/W	77.7	5.01	11.7	78.3
23	Bankolla	P/W	21.4	0.84	-0.4	60.0
24	Bankolla	P/W	59.0	2.31	6.7	77.9
25	Jhajra	P/W	69.2	3.36	10.2	78.3
26	Jhajra	P/W	19.8	0.66	1.2	33.1
27	Nirsa	P/W	11.9	0.36	6.9	75.7

Note: P/W: Pump Water, U/G: Underground Water, SAR: Sodium Adsorption Ratio, RSC: Residual Sodium Carbonate, MH: Magnesium Hazards.

High salinity, sodium adsorption ratio, %Na, residual sodium carbonate, and excess Mg restrict its suitability for agricultural uses in the study area.

Some of the major finding of this study is summarized in following points:

1. The pH values of water samples range from 6.5 to 8.2, which are within the permissible limit of 6.5 to 8.5 as compared to drinking water standards IS: 10500.
2. Conductivity in mine water varied from 331-1386 µS/cm. The spatial differences between EC values may reflect the wide variation in lithology, mining activities and hydrological processes prevailing in the region.
3. Turbidity in the mine water varied from 0.15 to 16.86 NTU. The turbidity exceeds from desirable limits can affects clarity and productivity of that systems and undesirable from aesthetic point of view.
4. The values of chloride content of all mine water samples were also found to be within the desirable limit.
5. Sulphate content in underground mine discharged water ranged from 1.77 to 263.87 mg/l. some samples exceeds from the desirable limit i.e. 200mg/l which can affect the health of the people of that area, by causing gastro-intestinal irritations.
6. The alkalinity content in the mine water samples varied from 50.0 to 662 mg/l. the desirable limit of alkalinity is 200mg/l. the alkalinity beyond this limit can cause unpleasant taste of water.
7. The sodium and potassium concentration in mine water varied from 4.24 to 137.66 mg/l and 1.39 to 7.53 mg/l respectively.
8. The calcium and magnesium concentration in underground mine water varied from 3.25 to 60.13 mg/l and 4.63 to 68.13 mg/l. the analytical results of mine water samples revealed that mine water, in general, was satisfactory for domestic and agriculture uses. High level of calcium causes adverse effect on domestic use and water supply structure.
9. Dissolve oxygen ranges from 7.4 to 10mg/l. the average D.O was 5mg/l. thus all covered region has microbial contamination.
10. The silica content of natural water most commonly is in the 1 to 30mg/l range. Although concentrations as high as 100mg/l are not unusual and concentration exceeding 1000mg/l are found in some brackish water and brines. The average silica content for sample collected is 30.39mg/l.
11. The assessment of water for irrigation use show that water good to permissible quality and can be used for irrigation uses. However, high

salinity, %Na, SAR, RSC and MH at certain sites restricts its suitability for agricultural uses. The majority of the samples have high value of %Na, Salinity and MH values which become unsuitable for irrigation uses for the most of the crops and soils.

Conclusion

To assess the water quality of mine water of Raniganj Coalfields, 27 samples were collected from underground and opencast coal mines during the month of February 2009. The mine water samples were analyzed for physiochemical characteristics by the standard prescribed methods and using sophisticated analytical equipments. The mine water evaluated in terms of major ion chemistry, spatial variation in concentration of dissolved ions, sources of different elements and the possibility and suitability of the mine water of the area for domestic uses and irrigation uses. For drinking water assessment, the mine water quality data was compared with prescribed limits of WHO and Indian Standard for drinking water (IS-10500). The different parameters like %Na, RSC, SAR, salinity and Alkalinity Hazard, Magnesium Hazard (MH) were calculated for assessing the suitability of mine water for irrigation uses.

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