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Physico-Chemical characteristics of drain-water of open cast coal mining area in the Ledo-Margherita range of Assam.

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Abstract

Coal mine drainage is a major problem in coal mining areas. It may adversely affect the water-bodies in and around mining areas. Oxidation of pyrites, from coal seams and overburdens, in presence of air and water leads to very low pH and results in sulphate and heavy and rare earth metals dissolved into the water. In the present study, Physico-Chemical Characteristics of water of drains carrying mine-waters in Ledo and Tirap open cast coal mining areas have been investigated. Water samples were analysed for pH, Electrical Conductivity (EC), hardness SO_4^{2-}, NO_3^-, dissolved oxygen (DO), Fe^{2+}, Cr, Pb, Ni and Zn. The results indicate highly acidic condition of the drain-water with low DO, high EC, high hardness and higher concentrations of SO_4^{2-}, Fe^{2+} and Pb.

Keywords: Physico-chemical characteristics, drainage water, open-cast coal mining.

1. Introduction

Coal is a major source of energy. To meet the demand for coal for energy requirement, mining is inevitable. However, coal mining has direct impact on surroundings including surface and ground water. Mining operation involves activities such as removal and disposal of overburden, waste rock, uneconomic minerals, crushing and grinding of ores, separation of metal concentrates mill tailing leading to environmental problems (Ahmed, *et al.*, 1994). Oxidation of sulphides through complex geochemical process is one of the most common and single most causes on acidity from coal mining activities (Sahoo, *et al.*, 2010). This leads to acid mine drainage (AMD) characterised by low pH, high SO_4^{2-} and dissolved metal (Equeenuddin, *et al.,* 2013). Drainage from a mine has very low pH (acidity) and contains high concentrations of sulphur, iron and a range of heavy metals (Envis Newletter, 2005). AMD gives rise to several problems of environmental degradation, especially pollution of aquatic environment (Singh & Bhatnagar, 1988). Impacts of AMD on aquatic habitats had also been reported by Koryak (1997).

As reported by Tolar (1982), secondary reactions of sulphuric acid with compounds in adjacent rocks and mine spoil can produce high concentrations of aluminium, manganese, zinc and other constituents in mine drainage waters. This may contribute to the total dissolved solid in the water carrying mine and mine-overburden leachates. Acidic water produced by the AMD reactions may persist for only a short time if sufficient alkalinity is available to neutralise the acid. Once the neutralisation capacity is exceeded, however, acid begins to accumulate and the pH decreases (James I, *et al.*, 2000). Acidic coalmine drainage can seriously degrade the aquatic habitat and water quality because of toxicity, corrosion, incrustation and other affects from dissolved constituents (Baruah, *et al.*, 2005).

In Assam (India), major open cast coal mining area is the Ledo-Margherita Region (Makum Coal

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Field) in Tinsukia District. The coalfield covers an area of 30 Km long and 5 Km wide, and is situated along the outermost flank of the Patkai Range (Baruah, *et al.,* 2003). Coal in these collieries is high in sulphur content (2-7%) (Baruah, *et al.,* 2005), which may reach the aquatic system due to weathering process of rocks, coal overburdens and mine spoil. Tiwary (2001) reported AMD problem in Western Coalfields, Northern Coalfields and Northeastern Coalfields of India. Tertiary coal of Ledo-Margherita range has high sulphur content (Barooah and Baruah, 1996) and oxidation of pyritic sulphur may result in severe AMD problem in this area. As the area is covered by several streams and Tirap and Burhi Dehing River and many ponds, wells and tube-wells, the open cast mining may have great impact on aquatic habitat degrading the water quality and threatening the aquatic organism.

The present study is based on the perception that open cast coal-mining in Ledo-Margherita region of Assam, India have significant impacts in the water regime of the surroundings. Therefore, the quality of water in the drains carrying mine water and leachates of mine-overburdens to the Tirap and Dehing river have been tested to analyse the possible impact on nearby water-bodies.

2. Study area

The mining area in Ledo-Margherita range lies in between $27^{0}15'$ N to $27^{0}20'$N latitudes $95^{0}40'$E to $95^{0}48'$E longitudes, which also includes probable area of influence. For the present study, area influenced by the Ledo and Tirap open cast mining had been chosen. The area extends from the mining area of Ledo and Tirap collieries to the Tirap River and the confluence of Tirap and Dehing River. The area is vast comprising agricultural land area, a tea garden, rural habitation area and a colony of coal mining workers. People in the rural areas mostly use water from tube wells and dug-wells and the area also contains several ponds and small streams coming across coal mining areas. A location map of the study area is shown in Fig.1

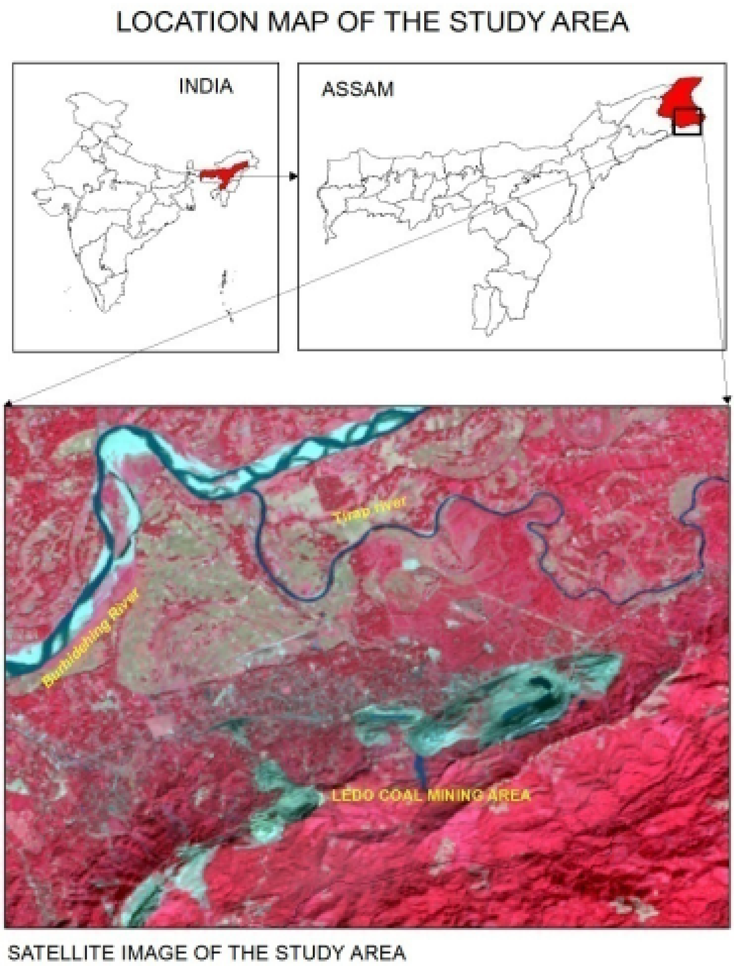

Fig. 1 : Image source: Landsat OLI, January 2016, USGS

To study the physico-chemical parameters of the mine-water three points have been selected at different distance from the mining area, locations of which are tabulated in Table-1 below:

Table 1

Sample No.	Location		Latitude	Longitude	Elevation
S1	Kaccha Nala near Ledo College	Drain carrying mine -discharge	27^0 17’ 978"	95^0 44’ 268"	149 m
S2	Near Ledo Air Field	Drain carrying mine discharge	27^0 18’ 324"	95^0 44’ 550"	132 m
S3	Chipa Nala Ledo	Drain carrying mine discharge	27^0 18’ 102"	95^0 44’ 855"	112 m

3. Materials and method

Water samples were collected from the selected points as shown in (Table 1). Samples were collected during summer (May) and winter (January) period.

Water samples were analysed for the parameters pH, electrical conductivity, TDS, $CaCO_3$ hardness, DO, SO_4^{2-} , NO^{3-}, Fe as Fe^{2+}, Pb, Zn, Cr and Ni. These parameters were selected because of possibility of acidic mine-water discharge, for which it is necessary to assess the level of concentration of these ions and heavy metals.

Collection and analyses of collected samples were done as per standard procedures (APHA, 1995). pH was determined on the spot using digital pH meter and conductivity was determined using conductivity bridge. Iron Fe, Pb, Cr, Ni and Zn were estimated using Atomic Absorption Spectrophotometer.

4. Results and discussion: Physico-chemical parameters of the collected water samples were tabulated in Table 2.

Physico-chemical characteristics of water samples :

Table 2

Sample / Parameter		S1		S2		S3	
		Y1	Y2	Y1	Y2	Y1	Y2
pH	Sm	2.54±0.24	2.66±0.13	3.39±0.13	3.42±0.24	2.61±0.21	2.81±0.21
	W	3.43±0.15	3.54±0.21	4.12±0.07	4.61±0.23	3.12±0.25	3.65±0.27
Electrical Conductivity (µS/cm)	Sm	3266.9±23.6	3175.3±24.1	875.6±19.9	725.4±25.7	2539.9±42.3	2440.8±46.3
	W	3238.0±32.5	3145.3±35.7	684.2±31.2	644.0±28.3	2485.4±32.7	2394.4±37.7
TDS (mg/L)	Sm	2320.3±33.7	1841.2±31.3	1025.4±21.7	988.2±22.3	2518.0±34.2	2074.0±31.3
	W	2415.2±27.7	2152.2±31.2	867.8±19.5	765.0±23.5	2645.0±22.4	1746.5±32.3
$CaCO_3$ hardness (mg/L)	Sm	335.1±12.3	350.0±14.3	133.0±6.2	142.3±6.7	1040.0±25.1	988.3±22.3
	W	385.0±12.3	412.0±14.2	140.0±17.2	135.0±15.4	1089.0 ±16.2	759.0±17.1
DO (mg/L)	Sm	4.88±0.31	4.17±0.16	4.55±0.19	4.3±0.23	2.55±0.21	3.15±0.17
	W	3.63±0.21	3.70±0.09	3.70±0.12	5.12±0.18	3.65±0.16	3.87±0.15
SO_4^{2-} (mg/L)	Sm	952.0±21.3	921.5±22.3	545.2±7.7	585.1±8.3	1341.3±24.7	1365.1±20.3
	W	1021.1±28.2	987.3±25.7	621.2±14.3	654.1±10.1	1310.1±17.7	1445.4±23.3
NO^{3-}	Sm	3.872±0.12	2.85±0.13	2.67±0.35	2.35±0.24	1.67±0.12	1.47±0.08
	W	5.88±0.18	4.24±0.17	3.43±0.15	2.85±0.13	0.81±0.023	1.12±0.018
Fe (mg/L)	Sm	5.40±16.12	4.95±13.45	1.25±0.015	1.38±0.14	5.48±0.17	5.11±0.12
	W	5.46±0.23	5.1±12.35	0.95±0.012	1.59±0.11	5.12±0.14	4.85±0.135
Pb (mg/L)	Sm	3.81±0.19	2.49±0.08	0.21±0.012	1.19±0.034	3.99±0.088	3.53±0.131
	W	5.25±0.16	4.11±0.21	1.12±0.37	0.89±0.014	4.60±0.15	3.85±0.16
Zn (mg/L)	Sm	1.725±0.065	1.525±0.054	0.846±0.033	0.786±0.025	2.501±0.013	2.413±0.011
	W	4.475±0.14	4.134±0.16	1.721±0.054	1.623±0.036	3.385±0.132	3.142±0.161
Cr (mg/L)	Sm	0.194±0.014	0.027±0.001	0.0363±0.018	0.0138±0.001	0.169±0.013	0.013±0.001
	W	0.017±0.002	0.015±0.001	0.0150±0.001	BDL	BDL	BDL
Ni (mg/L)	Sm	1.604±0.013	0.519±0.017	0.104±0.008	0.095±0.006	0.718±0.030	0.684±0.028
	W	1.09±0.021	0.74±0.014	0.022±0.003	0.018±0.003	0.068±0.014	0.018±0.003

Sm: Summer, W: Winter, Y1: first year, Y2: second year, S1,S2,S3: Sample numbers

(i) pH: The study revealed low pH in the range of 2.54 to 4.61. This means higher acidic value of mine drainage. Low pH may be attributed to oxidation of pyritic sulphur present in coal, which results in formation of acidic components leading to higher acidic value of the mine-drainage water. This observation was in the line of Sahoo *et al.*, (2011) while studying geo-chemical discharge in coal mine areas of Jaintia Hills of Northeast India. Winter pH in the entire sample was found higher than the summer pH. This was due to lower rate of oxidation of sulphur in coal due to lower temperature in winter. Sgambet (1980) also reported that low winter temperature reduce the oxidation rate of pyrites in coal, while studying the pyrite oxidation rates in coal mines of United States.

(ii) **Electrical Conductivity(EC) and Total Dissolved Solid (TDS)**: Present investigation showed higher EC and TDS value during the study period. Coal ore has a mixture of inorganic compounds which are dissolved in mine-waters through a series of reactions leading to ionisation and formation of new compounds. Sulphate and metal ions were the contributing factors for EC and TDS value of mine-drainage waters. Similar results were obtained by Sahoo, *et al.*, (2011) while studying coal mining areas in Jaintia Hills and Singh (1987) while studying mine-water quality in some coal mines of north-eastern region of India.

(iii) **Total Hardness**: The hardness values in the present study were found to be towards higher side ranging from 133 mg/L to 988.28 mg/L. This result is in conformity with the fact that the high hardness value, coupled with high acidity and low pH, indicate that the primary cation contributing to it is soluble iron apart from Ca^{2+} and Mg^{2+}. Similar observation was extended by Caruccio (1968) while studying mine-waters in Pensylvannia. In mine-water there is a possibility that sulphate plays a dominant role in contributing to total hardness. Singh (1988) also reported extremely hard water with similar observations in acidic mine water because of coal mining, while studying in mine-water from India's north-eastern coalfields.

(iv) Dissolved Oxygen (DO): Low value of DO makes a water body unsuitable for aquatic life. In the present study the DO varied from low to moderately low. The low DO in acidic water from coal mine discharge may be due consumption of high amount of oxygen for oxidation process taking place in pyritic oxidation. Lower DO in mine-water from abandoned mines pits was also reported by Ojiegbe (2007) in Ishiagu mining zones.

(v) Iron(Fe) and Sulphate (SO_4^{2-}): Dissolved iron in ferrous state and SO_4^{2-} are two important parameters in Acid Mine Drainage (AMD). Pyrite (iron disulphide), is commonly associated with base metal ores and coal deposits (Sheoran, *et al.*, 2011). In the present study both Fe and SO_4^{2-} were found in higher concentrations in all drain-water samples. Higher sulphate content is attributed to high sulphur containing Assam-coal. This result was in conformity with the fact that low pH, high concentrations of sulphate, TDS and heavy metals (trace elements) in drainage are common characteristics of AMD (Sheoran, *et al.*, 2011). Higher concentrations of Fe and SO_4^{2-} in mine waters were also reported by Sahoo, *et al.*, (2011) in mine-waters in Jaintia Hills. Similar observations were also made by Singh (1988) while studying on AMD in problem in Jharia, Raniganj and Northeastern Coalfields (Assam).

(vi) Nitrate (NO_3^-): The values of nitrate in all the samples were found in the range of 0.81 mg/L to 5.88 mg/L. In open cast mining, due to excavation and blasting, nitrogen containing minerals in the bedrock comes in contact with water and atmosphere resulting in formation of nitrates which dissolves in water in a faster rate. Similarly, nitrification process of geological nitrogen continues in mine-overburdens. Nitrate in overburden dissolves in water due to rain and leaching nitrate flows to surface water. Similar explanation was also reported by Bosman (2009) while studying nitrate pollution to open-pit mining in South Africa. Low level of nitrate concentration in the studied sample may be due to lower amount of geological nitrogen in coals of Ledo-Margherita area.

(vii) Lead (Pb), Zinc (Zn), Chromium (Cr), Ni (Nickel): The present study revealed the presence of these metal ions in the water samples. While the presence of Zn, Cr and Ni were low in concentration, concentration of Pb was found to be high. High concentration of Pb in the mine-water is due to presence of high concentration of lead in the coal and coal overburden. Mukherjee and Srivastava (2005) while studying trace elements in high sulphur Assam coal found 5.06T24.13 ppm of Pb present in Assam Coal, which is of great concern. Presence of heavy metals can increase the toxicity of mine drainage and also act as metabolic poison (Sheoran, *et al.*, 2011). Baruah, *et al.*, (2003, 2005) reported the presence of Zn, Cr, Ni and Pb in coal from Makum Coalfields.

4.1 From the above results it is observed that the drains carrying discharge from mine-waters are highly acidic with very low pH, high sulphate, high TDS, high value of EC, low DO, high concentration of Fe and Pb. These constituents may have direct impacts on the surface and ground water near the coal-mining area including, aquatic habitat of nearby streams, rivers, dug-wells, bore-wells, tube-wells and other wetlands. The analysis of the present study is quite indicative of possible contamination of water-bodies in the vicinity of Ledo-Margherita coal mining area. The aquatic organisms of the water bodies and dependent human population are subjected to adversity in terms of health and economy. In this context further study is required to understand the impacts of mining-water drainage on the water quality of water-bodies of coal mining area.

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