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IMPACT OF COAL MINING ON MINE WATER QUALITY

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ABSTRACT

The coal mining industry has to dispose of millions of litres of water every day. This water forms main source of various water supplies in the thickly populated coalfields. In this study, water samples from major coalfields were collected and analysed in an attempt to reflect the impact of mining on water quality in these areas. Various physico-chemical characteristics of mine waters as analysed include pH, alkalinity/acidity, specific conductivity, hardness, total solids, sulphate, chloride iron and trace materials.

This investigation reveals that mining activity, markedly pollute the mine waters. Mine waters are of highly complex nature and of widely varying composition. These are nearly neutral, alkaline, mildly acidic and highly acidic in nature. Special emphasis on water quality deterioration due to acid mine drainage which result in significant concentration levels of tract (toxic) metals, is given. A classification of these mine waters is also made.

Introduction

Coal mining operations expose relatively large areas of rock to the action of the environment, with the result that abnormal quantities of water soluble minerals may contaminate the drainage from the mine, and in turn, the local surface drainage system. In many mines, the rate of water percolation, even in critical summer, is heavy and needs to be pumped out to the surface basically as a mine drainage operation.

Mine waters form major source of various water supplies in thickly populated coalfield areas. However very little information has been reported (1-3). This survey attempts to present the impact of coal mining on water quality from underground mines of Indian coalfields.

Experimental Methods

Underground mine water samples collected from Jharia, Raniganj and Northeastern (Assam) coalfields, were analysed for various physico-chemical characteristics by employing standard methods (4). The pH and conductivity values were measured using Philips Ph-meter and Systronics conductivity bridge, respectively. Iron was estimated spectrophotometrically using VS U2 spectrophotometer. The quantitative analyses of trace metals were done using atomic absorption spectrophotometer, SP 1900, Pye Unicam. Dilution has been done wherever necessary in case of some samples.

Results and Discussion

Physico-chemical characteristics of mine waters from Jharia and Raniganj coalfields, are given in Tables 1 and 2 respectively. These reflect the geochemical system of the coal seams and overlying strata from which the water samples have been collected. These underground mine waters are neutral to slightly alkaline in nature and pH values lie within permissible limit. However, coal mining activities significantly cause mineralisation of mine waters as a result of interaction of water with various weatherable minerals present in the geochemical regime.

Alkalinity represents the total bases not neutralised by the acidic components of the water. It is believed that moderate increases in the level of alkalinity favour increased aquatic biological activity and are unimportant for many water uses. Ca and Mg constituents of shales and sandstones, often occur in the cementing materials that bind sedimentary rock particles together and increase considerably in mine waters after mining. The increase in Ca provides an explanation for the increase in pH and alkalinity which favour aquatic flora and fauna, and reduces the concentration of some metallic ions.

Chloride and sulphate were only anions measured specifically, the other likely major anion, bicarbonate would be closely approximated through alkalinity. Chloride concentrations in these waters are in general low and within permissible limits. Sulphate compounds occur in sandstones and shales overlying the coal beds in these watersheds. The overburden rocks are more important sources of sulphate than the waste coal. Sulphate concentrations exceed the permissible Public Health Standards. Iron concentrations of iron are considered undesirable contaminants in terms of aquatic biota and use by man. In these mine waters iron mainly occurred as ferrous iron. Trace metals are found to be either completely absent or present in quantities less than 0.1 mg/litre.

Mine waters from these two major coalfields are quite hard. Hardness is mainly due to the presence of Ca, Mg, bicarbonate and sulphate ions. Soft water are also encountered in a very few sumps. These mine waters also contain very high amount of dissolved solids and hence become corrosive particularly due to sulphate and chloride contents (5). Specific conductance related directly to total dissolved solids. An increase in specific conductance follows any disturbance in a watershed. The dissolved salt content of a mine water is derived from the strata through which the water seaps before entry into the mine. Thus dissolved salt content increases with increasing depth of the mine. Water cloudiness (turbidity) and sediment content (suspended solids) are visually observed. In most of the cases, mine waters are of objectionable odour and colour.

Acidic Mine Waters

Chemical analysis of mine water samples from Northeastern coalfield (Assam) depicted in Table 3 which show that waters are severally polluted. These mine waters are, in general, highly acidic and contain high sulphate and iron contents coupled with low pH Acidity in mine waters results by dissolution of oxidised pyritic materials associated with coal and associated strata during mining operations (6,7). The rate of pyrite oxidation is greatly accelerated by certain iron and sulphur-oxidising chemoautotrophic acidophilic bacteria particularly <u>Thiobacillus</u> <u>ferroxidens</u> (8). This explains the existence of Fe^{3+} in acidic waters.

The pH survey in conjunction with acid and sulphate data show that severe acidic conditions exist at some colliery areas, while mild to less acidic conditions prevail in other areas. These reflect the predominance of reactive pyrite in the seams of these areas and difference of acidity and sulphate contents may be due to variation of occurrence of reactive pyrite minerals in these areas. The less acidity and more sulphate contents indicate that alkalinity produced from calcareous materials subsequently neutralised acid in the drainage. In some sections, however, drainage waters are found to be in near neutral to slightly alkaline range, showing that there is a paucity of pyrites in the particular section of the seam and predominance of calcareous minerals.

These mine waters are typically extremely hard. The high hardness values coupled with high acidity and low pH indicate that primary cation contributing to it is soluble iron apart from Ca^{2+} and Mg^{2+}. Further these waters differ from more common type of hard waters in that sulphate rather than bicarbonate is the dominant anion. Hardness of mine waters either approach of become iron-sulphate type in some cases, while in others these are Ca-Fe-Mg sulphate type.

Toxic trace metals are more soluble at the low pH levels and enter into solution as a result of secondary reactions between iron sulphates, sulphuric acid and compounds in nearby clays, sandstones, limestones, sulphides etc (9). Quantitative determination of trace metals in acidic mine waters, is given in Table 4 which show that they are present at significant concentration levels and exceed the Public Health Standards. Trace metals at these levels are highly toxic and undesirable. These severally polluted acidic waters do not support aquatic life, destroy mining equipment and concrete structures, result land damage and pose various environmental problems.

<u>Classification of Mine Waters</u>

A classification of mine waters on the basis of the physico-chemical characteristics into different categories is given in tabular form in Table 5. This classification is important as it will not only give an idea about the properties of mine waters but also help in studying pollution problems originating due to mine waters. Most of the alkaline mine waters fall in category A-2. They have high to medium concentrations of dissolved solids, hardness and sulphate. Category A-1, which are also slightly alkaline in nature, differ from those of category A-2 in that they are not hard and contain comparatively low concentrations of dissolved solids and sulphate. Chloride concentrations of both the categories are not very different and are generally lower than sulphate concentrations. Mine waters of category A-3 contain very high concentrations of dissolved solids, particularly chloride and are highly corrosive in nature. General water quality characteristics and concentration of various constituents for different types of alkaline mine waters can be summed up in Table 6.

The other class of mine waters comprises of acidic waters. Such waters can either be mildly acidic or highly acidic in nature depending upon the quality of the coal seam and related strata. These mine waters can broadly be classified into two types - those which are soft and mildly acidic and those that are typically hard and acidic. The general characteristics of these types have been shown in Table 7.

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Table 1 Chemical Analyses of Mine Waters from Jharia Coalfield

pH	Sp.conductivity (at 25°C) x 10^{-2}	Total Hardness (as ppm $CaCO_3$)	Calcium (ppm)	Magnesium (ppm)	Total Alkalinity (as ppm of $CaCO_3$)	Dissolved (ppm) solids	Sulphate (ppm)	Chloride (ppm)	Iron (ppm)
7.9	.197	1000	102.20	180.91	271.20	429.33	704.48	14.97	1570
8.1	.176	830	120.24	128.64	304.80	1112.00	457.31	37.43	12.50
8.0	.170	820	124.24	123.78	222.00	1212.00	549.48	19.65	15.00
8.0	.140	685	110.22	99.49	206.40	1040.00	420.00	30.88	8.70
8.1	.128	570	80.16	89.81	294.00	914.66	236.74	31.81	9.20
8.2	.127	558	101.80	73.84	176.80	781.30	325.63	31.35	4.00
7.9	.112	505	74.14	77.67	177.60	926.66	316.30	24.33	17.00
7.4	.122	500	74.14	76.45	158.40	817.33	330.57	38.37	18.50
8.3	.105	450	126.20	32.68	90.84	1374.00	73.65	52.82	10.50
8.2	.095	434	74.96	60.00	304.30	563.90	118.10	33.37	9.20
8.0	.106	405	62.12	60.67	276.00	549.33	129.21	28.07	6.40
7.3	.096	326	59.08	43.38	188.70	790.60	84.49	85.51	24.00
8.2	.095	238	49.68	27.69	329.80	734.60	80.10	29.45	14.20
7.6	.031	90	16.27	12.00	93.50	194.60	45.26	20.90	21.30
7.8	.127	75	12.82	10.43	510.00	798.66	14.81	38.37	7.00
8.4	.117	572	136.24	56.30	35.70	980	535.40	23.75	11.00
6.3	.287	1060	116.67	94.16	8.50	2001	1070.90	304.84	4.96

Table 2 Chemical Analyses of Mine Waters from Raniganj Coalfield

Sample No.	pH	Total hardness (as ppm $CaCO_3$)	Calcium (ppm)	Magnesium (ppm)	Total Alkalinity (as ppm of $CaCO_3$)	Dissolved Solids	Sulphate (ppm)	Chloride (ppm)	Iron (ppm)
1	8.1	382	68	53	420	570	75	35	1
2	7.04	780	162	98	410	990	376	29	16
3	7.82	665	118	90	335	880	368	150	15
4	8.01	380	84	39	85	756	270	41	10
5	8.0	753	156	101	353	949	436	176	19
6	7.4	1248	216	180	448	1622	789	22	28
7	7.42	897	162	125	390	1210	500	18	22
8	8.0	50	16	5	400	576	15	48	15
9	8.2	132	26	17	395	408	30	78	1
10	7.3	92	19	11	130	286	28	26	5

Table 3 Chemical Analyses of Mine Water Samples

Mine water Sample	pH	Acidity (ppm)	Sulphate (ppm)	Hardness (ppm)	Total Fe (ppm)	Ca (ppm)	Mg (ppm)	Dissolved solids (ppm)	Specific Conductivity mhos at $25^{o}C x 10^{-2}$	F^{-} (ppm)
Ledo(Tirap)										
Sample 1	2.7	2040	3050	2300	350	104	108	2518	0.8	1.10
Sample 2	2.7	2100	2500	1800	358	98	78	3180	0.5	0.60
Sample 3	5.3	95	1662	990	120	125	63	1662	0.15	0.60
Sample 4	3.1	1230	2880	3300	670	245	74	4200	0.4	1.10
Sample 5	2.5	980	3210	1130	136	116	75	3060	0.2	1.56
Jeypore										
Sample 1	2.9	1090	2420	2900	545	65	66	4210	0.5	1.36
Sample 2	2.8	1185	3100	3170	760	60	100	3816	0.4	1.27
Sample 3	2.45	2350	3110	2120	388	42	84	2680	0.5	1.22
Sample 4	2.5	2110	2956	1930	385	58	49	4066	0.5	1.20
Sample 5	2.3	2480	3030	1490	192	50	58	2600	0.2	1.56
Sample 6	5.9	88	1156	590	100	328	104	1190	0.16	0.80
Baragolai										
Sample 1	8.40	--	607	415	22	250	112	750	0.15	0.60
Sample 2	3.98	190	984	900	60	222	96	1200	0.21	0.96
Sample 3	4.45	144	1010	790	120	126	59	874	0.14	0.90
Sample 4	4.1	160	529	595	56	288	78	1180	0.32	1.10
Tipong										
Sample 1	3.87	210	611	570	39	98	68	814	0.24	1.10
Sample 2	8.15	--	500	605	16	504	110	780	0.16	0.70
Sample 3	4.1	100	984	890	45	400	112	936	0.22	1.50

1. Samples are light yellow-yellow-yellow raddish in appearance.
2. Mean values are given in Table.

Table 4 Trace Metals Analysis of Acidic Mine Water Samples

Parameter (mg/1)	Ledo (Tirap) 66				Mine water samples			Jeypore	
	1	2	3	4	5	6	7	8	9
pH	2.7	2.7	2.5	3.1	1.9	2.8	2.45	2.3	2.5
As	1.6	0.4	-	-	0.4	0.4	-	1.0	0.6
Cd	1.2	-	0.9	4.8	-	-	0.3	4.0	1.6
Cr	6.6	0.8	10.00	6.5	11	1.0	0.8	4.6	8.5
Cu	0.4	0.7	0.7	-	-	0.6	0.9	-	0.3
Hg	0.3	-	-	-	0.5	-	-	0.2	0.9
Pb	1.1	0.7	1.6	0.9	0.5	1.2	1.0	0.9	0.9
Zn	2.5	1.0	2.4	3.0	1.2	4.6	0.8	1.5	0.8
Mn	2.4	17.0	12.0	8.2	8.2	8.2	1.6	1.2	3.4
Al	2.0	1.9	49	3.6	10.5	44	29	56	13
Ni	3.0	3.6	3.1	3.5	3.1	4.0	N.D.	4.5	6.0

Table 5 Classification of Mine Waters

Underground Minewaters

(A)	(B)
Neutral to Alkaline Minewaters (pH = 7.0 and above)	Acidic Minewaters (pH = 2.0 to 7.0)

(A-1)	(A-2)	(A-3)
Soft alkaline (pH = 7.5 to 8.5)	Hard alkaline (pH = 7.0 to 8.5)	Highly saline (pH = 6.0 to 8.0)

(B-1)	(B-2)
Soft, slightly acidic water (pH = 5.0 to 7.0)	Hard, highly acidic water (pH = 2.0 to 4.5)

Table 6 Characteristics of Alkaline Mine Waters

Water Quality Factors		Category of the Alkaline Minewaters		
		A-2	A-2	A-3
(a)	pH	7.5-8.5	7.0-8.5	6.0-8.0
(b)	Alkalinity (Mg/1 $CaCO_3$	200-700	100-500	10-30
(c)	Hardness Mg/1 $CaCO_3$	50-150	200-1500	1000
(d)	T. Dissolved solids mg/1	300-700	500-1500	1500-2500
Element or Iron Content				
(e)	Calcium mg/1	10-50	50-200	100-150
(f)	Magnesium mg/1	10-30	40-180	80-100
(g)	Total Iron mg/1	0-2	0-5	0-5
(h)	Sulphate mg/1	10-100	100-800	1000 and above

Trace Elements

Either completely absent or present in quantities less than 0.1 mg/litre

Table 7 Characteristics of Acidic Mine Waters

Water Quality Factors	Category of Acid Minewaters	
	B-1	B-2
(a) pH	5.0-7.00	2.0-4.5
(b) Acidity mg/1 H_2SO_4	25-150	100-2500
(c) Hardness mg/1 $CaCO_3$	200-500	500-3500
(d) Total dissolved solids mg/1	400-800	1000-4000
Element or Ion Content		
(e) Calcium mg/1	20-80	100-250
(f) Magnesium mg/1	10-70	50-100
(g) Ferric iron mg/1	0-20	10-250
(h) Ferrous iron mg/1	20-50	20-200
(i) Total sulphate mg/1	200-600	100 and above
(j) Chloride mg/1	20-50	20-100
Trace Elements		
Al, Cu, Zn, Hg, Ni U, Cr, Sb, etc.	Present in quantities of 0 5 mg/1 depending upon other conditions	