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ACID MINE DRAINAGE CONTROL IN AN OPENCAST COAL MINE

by

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INTRODUCTION

Ecological disruption due to acid mine drainage is one of the most persistent pollution problems in some of the Indian coalfields, particularly in the lower Gondwana coal of Barakar formation, and Tertiary coal of Assam. The problem no doubt is mostly confined to a localized zone at the source, but may extend to distances if the acid mine water is allowed to get discharged into the main water stream. The coal mines that face a serious pollution problem due to acid mine drainage in India are Baragolai (ECL); Churcha, West Chirimiri, Ambora and Rkhikol (WCL); Gorbi (NCL) and Lakarka (BCCL).

The exact mechanism of acid mine drainage formation is not fully understood, but it is believed to be formed due to circulation of water through the oxidised sulphide minerals associated with coal-overburden and coal. The potential of a coal seam to produce acid mine drainage is governed by a number of factors. Among them the important one are, the sulphur content in coal seams and associated strata; hydrology and geology of the area. When acidic water is discharged into a nearby surface stream of a pond it causes deleterious effects on water quality, and therefore makes it unsuitable for the use of animals, plants, mankind and aquatic life (Killey, 1988; Kimel, 1988; Williams, 1988).

To overcome acid mine drainage problems in a coal mining complex a number of processes have been suggested by researchers (Hoey, 1971; Heunisch, 1985; Harvey, 1981; and Betson, 1987; Kimel, 1988). These are neutralisation by lime or limestone; avoidance of water filtration into acid producing minerals; submergence of acid forming minerals into stagnant water; sealing off acid producing area, and overburden, and the use of acid tolerance plants such as algae, cattails, etc. However, the unfortunate part is that they all lack universal acceptance in the mining field, either due to unsuitability of their adoption in a given field situation, or, because of cost limitations. To control acid mine drainage in a field situation, some workers have recommended the diversion of acid mine water

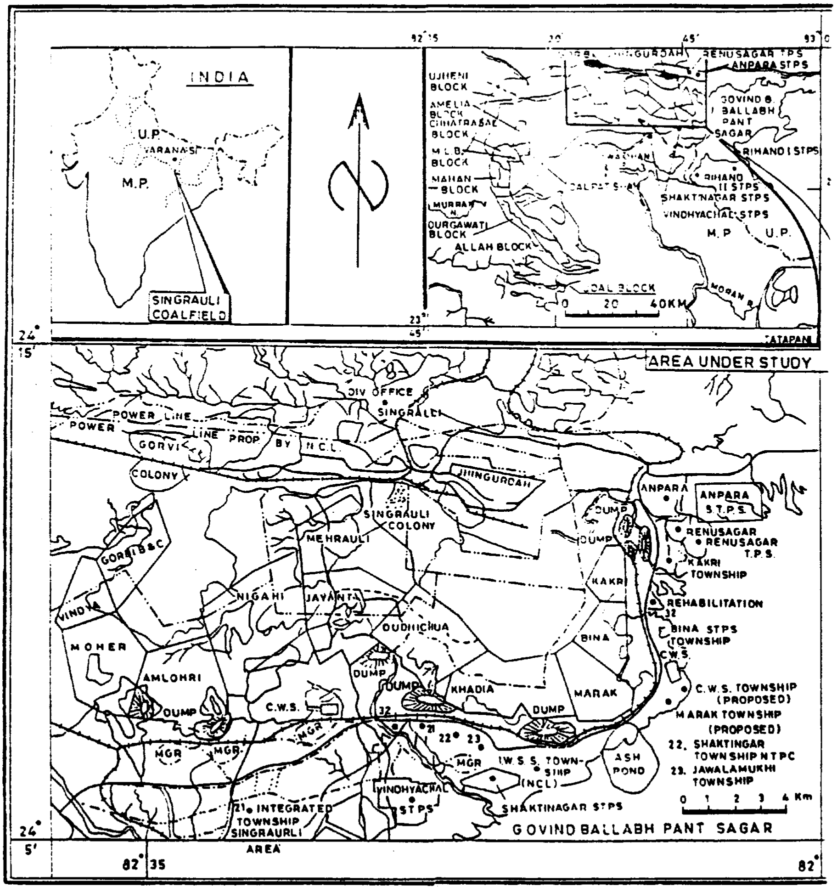

Figure 1 Location Map of the Site of Investigation

through such type of overburden rock materials which are alkaline in character (Dhar et al, 1987; Jamal, 1989; Dhar, 1990).

In this paper an attempt has been made, to study the feasibility of this technique as a means of controlling the acid mine drainage problem in one of the opencast coal mining project at Singrauli Coalfield, of the Northern Coalfields Limited, where pH of the water was found to be extremely low (Dhar et al, 1986).

CASE STUDIES

Brief Description of the Area

This study was made at the Gorbi mine of Singrauli, one of the largest coal mining complexes of the world. The topography of the area is highly plateau terrain and is located in the drainage area of the Son and Rihand rivers. The north flowing streams in the Mohar scrap area join the Bijul river, which is a tributory of the Son and the south flowing steams mostly join the Kanchan, a tributory of the Rihand. River Son join directly into the Rihand reservoir or join the perennial stream, Baliya nalla. Among the north flowing streams the most important is the Mehrauli nalla, which maintain a perennial flow. Most of the other nallas in the plateau area such as Turra, Murwani, etc. are seasonal. In the Amelia area, the main drainage comprises Parawar and Bandha nallas with semi-perennial flows.

The coal field is divided into 11 mining projects, viz. Kakari, Bina, Marrak, Khadia, Dhudhichua, Jayant, Nigahi, Amlohri, Mohar Block B, Gorbi and Jayant projects (Fig. 1). At present coal production is confined only in the five blocks namely Bina, Jhingurdah, Jayant, Gorbi and Dhudhichua, while the rest of the blocks are in the various stages of development. The local nalla used for disposing off acidic mine water of the Gorbi sump, covers roughly 1.5 km through Barakar sandstone rock, and about 3 km through Archean rock before it finally gets discharged into the Bijul stream. Figure 2 shows the geological formation and drainage pattern in and around the various mines of Singrauli Coalfield.

Water Quality

The sampling sites for water quality monitoring in and around the Singrauli coalfield area is shown in Figure 3. Table 1 summarises the physico-chemical analysis of water samples. From this table it is evident that the effluent of Gorbi mine is highly acidic in nature and is fully loaded with the total suspended solids (TSS) and total dissolved solids (TDS). Among the dissolved solids, iron and sulphate concentrations are high. The concentrations of hazardous metals such as chromium, lead, copper and zinc are also found to be above the tolerance limit. This acidic effluent is discharged into Bijul stream whose water quality in the upstream side is of potable nature. Due to disposal of acidic mine effluent the quality of the bijul water in the downstream side has changed to a considerable extent. Whereas in case of Jhingurdah mining project, the Chatka nalla, a tributory of Bijul receives the mine effluent. The water of this nalla on the upstream side is suitable for bathing and drinking purposes but because of the presence of various undesirable constituents above permissible limit, the downstream of Chatka nalla has deteriorated to a significant level. The clear water changes into blackish due to high concentration of oil, grease, suspended particulate matter and high acidity.

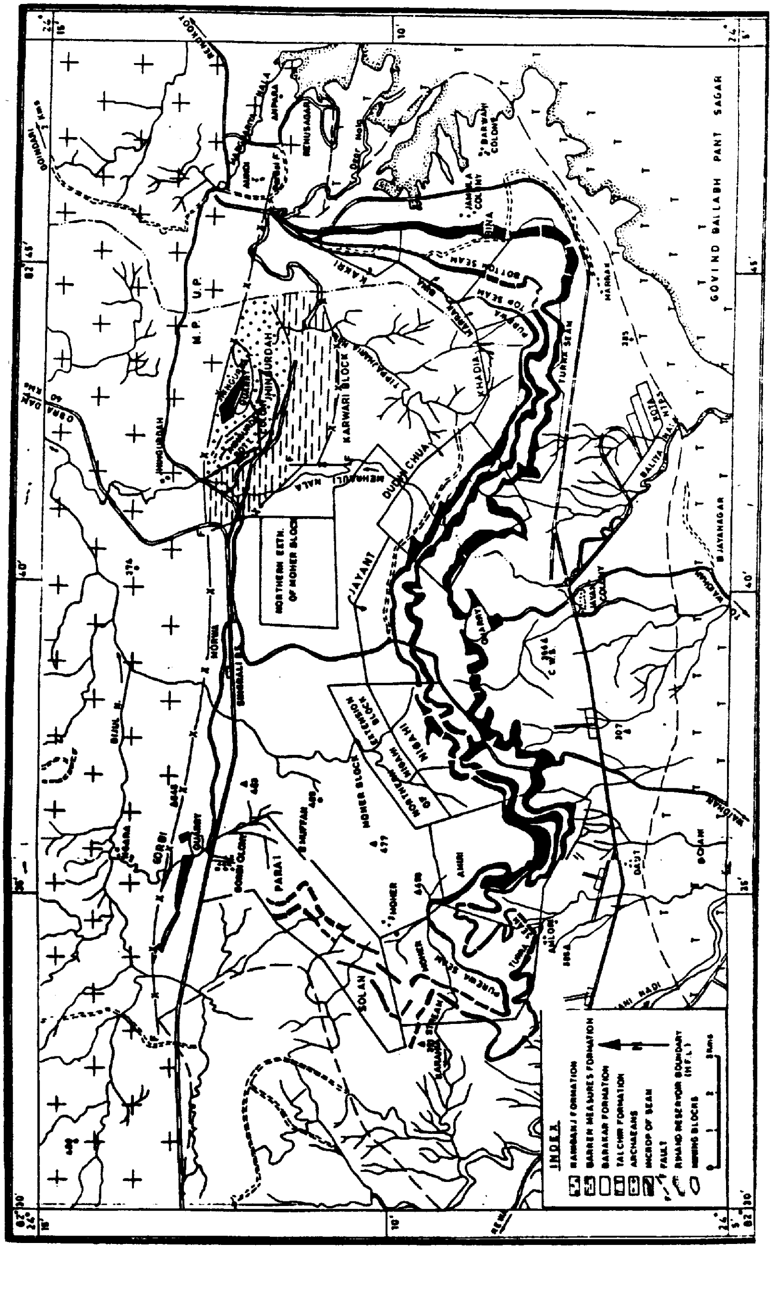

Figure 2 Geological Map of Moher Sub-basin of Singrauli Coal field, Singrauli (M.P.)

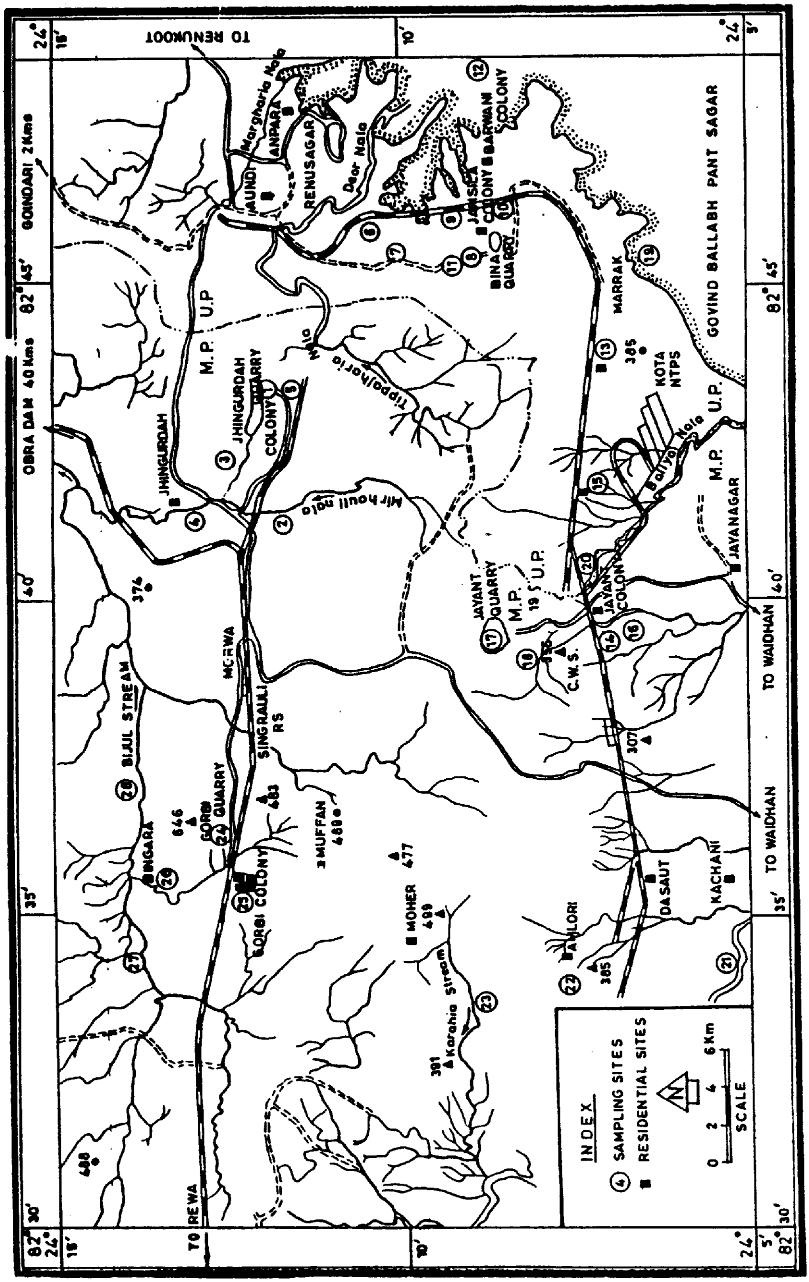

Figure 3 Map Showing Water Sampling Sites in and Around Singrauli Coalfield, Singrauli (M.P.)

TABLE 1 - PHYSICO-CHEMICAL WATER CHARACTERISTICS OF MINE WATER OF VARIOUS LOCATIONS

Parameters		Average Concentration							
		Bina sump water	Jayant sump water	Jhingurdah sump water	Gorbi sump water	Ash pond water	Turra U/S water	Bijul U/S water	Bijul D/S water
Temperature	(ºC)	31.30	28.90	30.06	27.25	32.03	29.90	27.80	27.85
pH value		8.70	7.41	5.19	2.66	9.51	7.76	8.75	6.12
Colour		Blackish	Blackish	Yellowish	Yellowish red	Greyish white	Clear	Clear	Greenish
TSS	mg/l	58.95	43.00	130.80	87.97	27.00	70.40	10.30	421.47
TDS	mg/l	380.00	415.00	1340.00	2420.00	190.00	143.30	363.30	602.50
BOD @ 20ºC	mg/l	1.90	2.70	2.03	6.05	3.10	2.20	2.46	2.59
COD	mg/l	68.00	81.50	386.00	290.00	53.30	11.00	24.66	45.50
Oil and Grease	mg/l	15.60	14.90	18.43	28.80	BDL	BDL	BDL	3.45
Bicarbonate	mg/l	137.80	131.33	216.22	73.76	140.16	38.40	180.51	72.46
Carbonate	mg/l	2.30	1.60	2.66	0.29	BDL	BDL	1.66	1.80
Chloride	mg/l	30.50	33.00	35.66	31.25	17.00	7.66	24.66	26.75
Fluoride	mg/l	0.16	0.20	0.11	0.35	0.35	0.11	0.086	0.1625
Nitrate	mg/l	0.10	BDL	0.06	0.30	0.01	0.06	0.016	0.035
Nitrite	mg/l	BDL	0.03	0.26	0.32	0.02	0.18	0.11	0.05
Phosphate	mg/l	BDL	BDL	0.06	14.20	0.33	0.60	BDL	BDL
Silicate	mg/l	6.05	4.40	8.80	12.97	8.83	5.20	17.13	16.60
Sulphate	mg/l	32.00	140.00	512.60	1789.50	25.00	23.60	16.00	513.75
Boron	mg/l	0.50	0.13	0.16	0.31	1.39	0.17	0.13	0.097
Calcium	mg/l	53.28	71.59	98.16	89.01	63.18	18.04	52.60	52.78
Chromium	mg/l	BDL	BDL	0.74	1.27	BDL	BDL	BDL	0.502
Copper	mg/l	BDL	BDL	0.15	0.62	BDL	BDL	BDL	BDL
Iron	mg/l	3.21	3.41	84.04	235.30	3.96	1.244	1.374	23.100
Lead	mg/l	0.08	0.09	0.24	1.21	0.98	0.049	0.12	0.157
Magnesium	mg/l	13.85	21.15	43.12	21.02	14.81	1.50	10.55	12.44
Potassium	mg/l	2.50	2.25	3.00	3.37	3.50	7.50	1.66	1.875
Sodium	mg/l	24.50	15.50	24.66	26.50	17.33	1.441	15.33	16.375

TABLE 2 - MINERAL CONSTITUENTS OF BARAKAR SANDSTONE

Sample No.	Types of sandstone	Quartz + Chert	Feldspar	Mica	Heavy Minerals Non-opaque	Heavy Minerals Opaque	Matrix/ Cement
NGS-176	Coarse grained white sandstone	53.2	8.1	4.1	0.1	0.9	33.6
NGS-176	Fine grained white sandstone	66.9	7.8	1.8	0.3	0.6	22.6
NGS-190	Coarse grained white sandstone	54.7	4.8	3.1	0.1	0.8	36.5
NGS-196	Fine grained white sandstone	60.9	7.2	1.4	0.3	0.1	28.1
NGS-201	Coarse grained white sandstone	54.9	6.4	3.6	0.3	0.4	34.4
NGS-202	Fine grained white sandstone	54.9	6.6	1.2	0.2	2.1	26.9
NGS-151	Coarse grained yellow sandstone	48.3	3.8	9.3	0.3	0.8	37.5
NGS-153	Coarse grained yellow sandstone	51.4	5.2	5.0	0.1	1.2	37.1
NGS-155	Coarse grained yellow sandstone	54.1	3.1	5.4	0.4	0.4	36.6
NGS-158	Fine grained yellow sandstone	56.3	2.9	3.0	0.6	0.7	36.5
NGS-171	Fine grained yellow sandstone	49.3	2.3	3.2	0.2	0.8	44.2
NGS-271	Fine grained reddish brown sandstone	51.0	0.2	1.1	0.7	3.2	43.8
NGS-288	Fine grained reddish brown sandstone	49.6	1.2	1.0	0.8	4.8	42.6
NGS-294	Fine grained reddish brown sandstone	53.4	1.6	0.9	0.9	5.3	37.9
NGS-303	Fine grained reddish brown sandstone	45.8	2.1	1.2	0.8	4.0	46.1
NGS-309	Fine grained reddish brown sandstone	49.2	1.1	1.0	0.2	3.4	45.1
NGS-314	Fine grained reddish brown sandstone	51.2	2.0	1.3	1.1	3.1	41.3

TABLE 3 GEOCHEMICAL CHARACTERISTICS OF COAL OVERBURDEN

Sample No.	Type of overburden	Oxide percentages									
		SiO_2	Al_2O_3	CaO	MgO	M_nO	K_2O	Na_2O	T_iO_2	Total Iron (Fe_2O_3+FeO)	Ignition Loss (water)
NGS-151	Yellow sandstone	68.20	10.41	2.45	4.62	0.016	2.39	1.26	0.88	1.73	3.84
NGS-153	Yellow sandstone	70.61	8.26	1.08	2.83	0.018	2.35	1.04	0.64	2.84	4.20
NGS-156	Yellow sandstone	64.18	11.51	1.26	2.39	0.27	2.08	0.89	0.78	2.31	3.80
NGS-158	Yellow sandstone	71.44	10.72	1.35	2.46	0.075	2.87	0.92	0.56	0.65	4.12
NGS-161	Yellow sandstone	70.42	9.94	2.08	2.22	0.034	1.81	1.41	0.49	1.64	4.18
NGS-271	Reddish brown sandstone	64.12	14.45	1.86	1.64	0.089	1.62	0.82	0.84	8.75	2.16
NGS-284	Reddish brown sandstone	65.14	13.64	2.08	3.82	0.034	1.84	0.64	0.92	11.26	2.24
NGS-285	Reddish brown sandstone	67.84	12.21	1.74	2.94	0.084	1.52	0.92	0.82	10.41	2.81
NGS-287	Reddish brown sandstone	62.11	16.45	2.12	2.66	0.054	1.63	0.66	0.96	5.73	1.96
NGS-288	Reddish brown sandstone	63.68	13.22	2.10	2.04	0.060	1.54	0.67	1.13	6.29	2.18
NGS-201	White sandstone	79.64	6.41	1.07	2.84	0.007	0.84	0.81	0.84	0.66	3.46
NGS-203	White sandstone	73.84	8.92	2.33	6.31	0.008	0.93	0.82	0.52	1.10	3.81
NGS-204	White sandstone	75.28	8.44	2.84	3.47	0.017	1.24	0.84	0.80	0.89	2.88
NGS-207	White sandstone	74.92	4.76	1.81	3.68	0.016	1.81	1.40	0.52	0.86	3.32
NGS-210	White sandstone	72.64	12.89	1.27	2.19	0.002	2.04	0.94	0.40	0.39	2.19
NGS-212	White sandstone	73.23	8.90	3.08	5.17	0.039	2.16	0.78	0.24	0.95	2.24
NGS-214	White sandstone	76.72	6.44	2.87	3.61	0.072	3.50	0.62	0.38	0.83	2.69
NGS-216	White sandstone	78.01	7.89	1.42	3.11	0.041	2.86	0.48	1.04	0.88	2.23
NGS-218	White sandstone	74.18	6.46	1.97	2.77	0.027	2.48	1.21	0.92	1.06	3.12

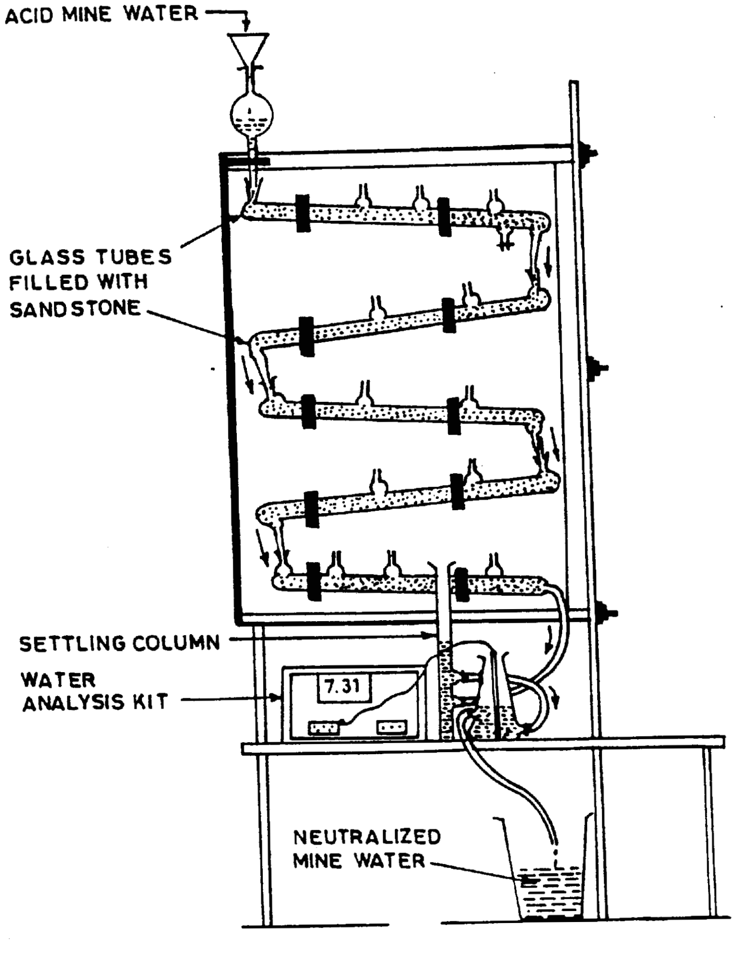

Figure 4 Schematic Diagram of Acid Neutralisation Model

TABLE 4 DESCRIPTIVE STATISTICS OF THE IMPORTANT TOXIC METALS IN COAL OVERBURDEN

Sample No.	Types of overburden	Trace Metal Concentration in ppm						
		Lead (Pb)	Zinc (Zn)	Copper (Cu)	Nickel (Ni)	Cobalt (Co)	Chromium (Cr)	Cadmium (Cd)
NGS-151	Yellow sandstone	14	10	10	10	10	7	1
NGS-153	Yellow sandstone	40	125	20	29	20	8	1
NGS-156	Yellow sandstone	26	74	71	55	26	4	1
NGS-158	Yellow sandstone	78	85	155	51	29	5	1
NGS-161	Yellow sandstone	16	29	10	35	17	6	1
NGS-271	Reddish brown sandstone	39	18	16	10	10	11	1
NGS-284	Reddish brown sandstone	220	87	105	25	24	10	1
NGS-285	Reddish brown sandstone	29	62	25	215	190	14	1
NGS-287	Reddish brown sandstone	22	46	14	25	24	5	1
NGS-288	Reddish brown sandstone	14	10	10	10	10	23	1
NGS-201	White sandstone	22	46	14	25	24	7	1
NGS-203	White sandstone	28	47	71	11	10	9	1
NGS-204	White sandstone	36	72	29	17	10	4	1
NGS-207	White sandstone	18	19	10	12	10	23	1
NGS-210	White sandstone	25	100	34	56	10	8	1
NGS-212	White sandstone	25	300	61	125	75	7	1
NGS-214	White sandstone	18	19	10	140	245	6	1
NGS-218	White sandstone	18	19	10	140	245	11	1

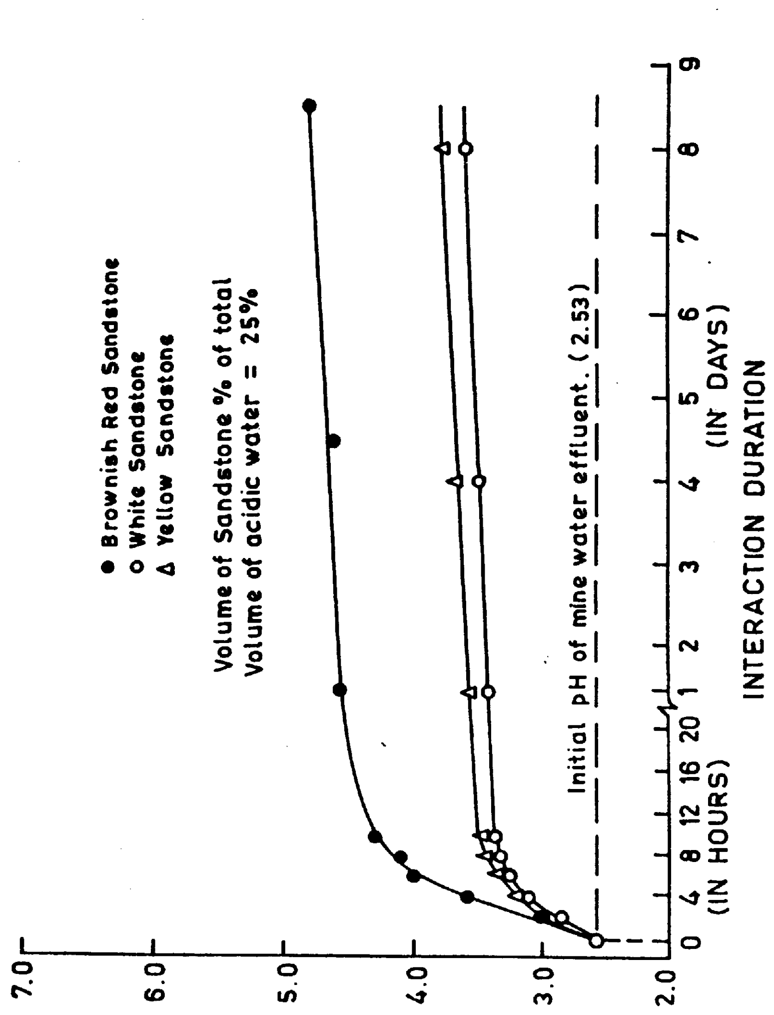

Figure 5 Neutralisation Capacity of Overburden Associated With Coal

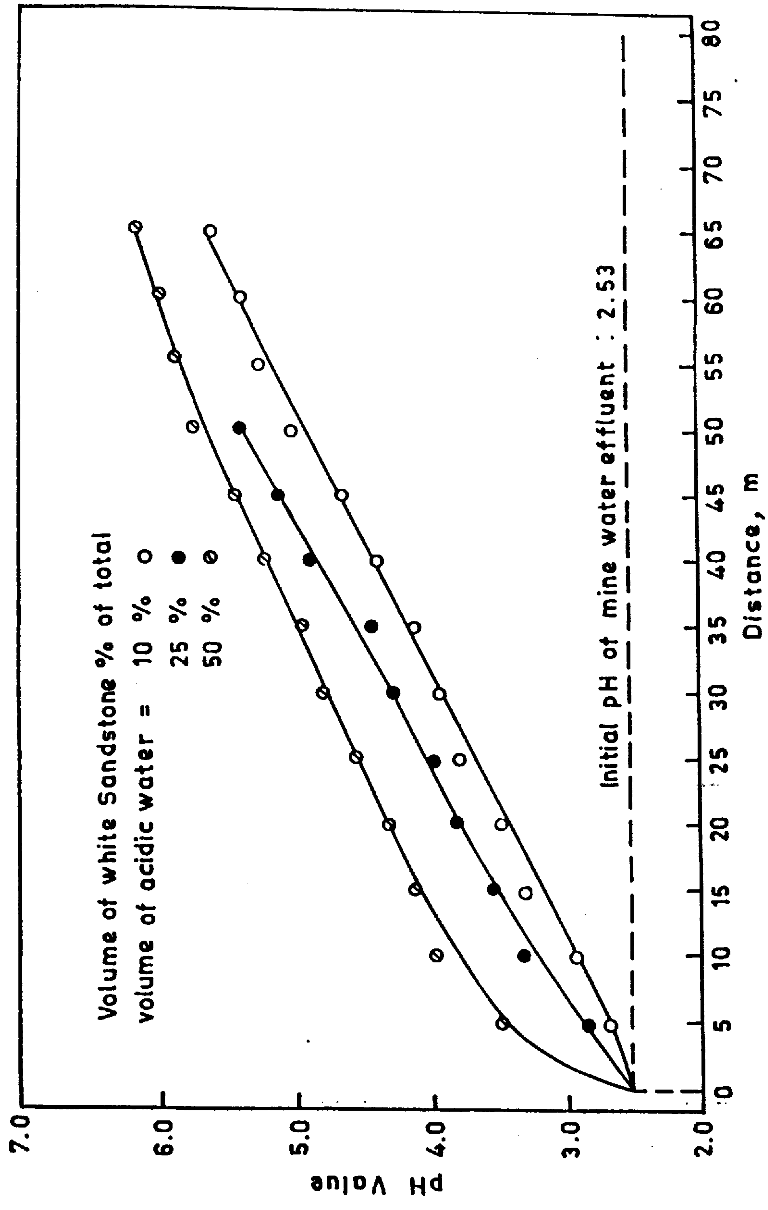

Figure 6 Effect of White Sandstone on Acid Neutralisation in Mine Water

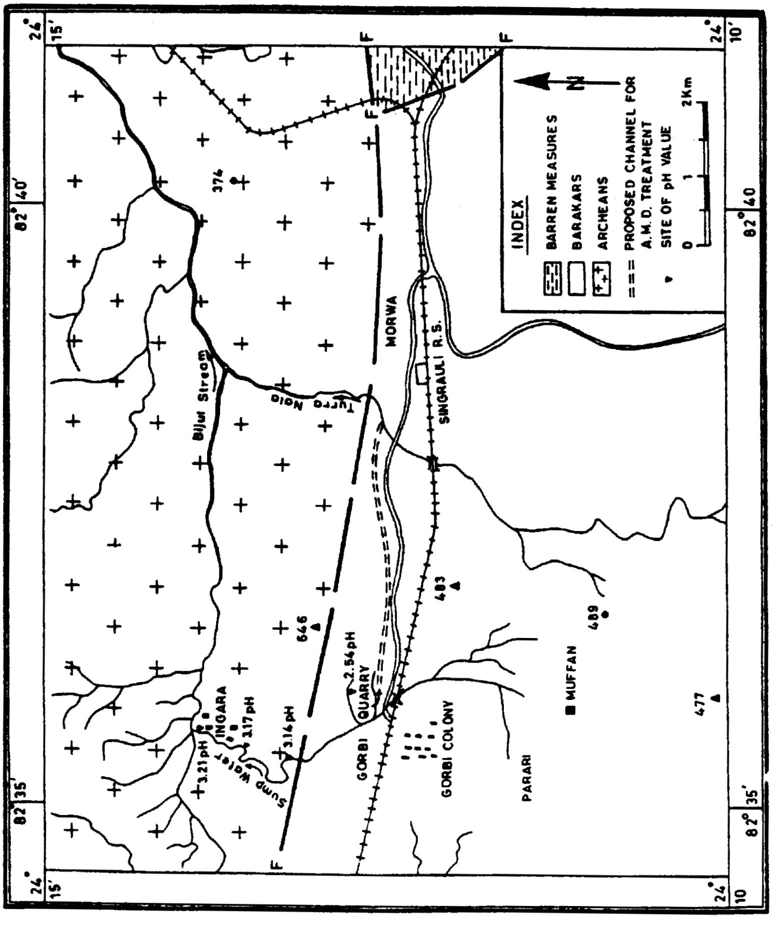

Figure 7 Map showing Geological Formation Drainage Pattern and Proposed Channel for Acid Mine Drainage Treatment, Gorbi Opencast Coal Project.

In the field study it was observed, that when the sump water of Jhingurdah mine flows down to a distance of approximately 1km in the Jhingurdah nalla through coal-overburden, water gets almost neutralised i.e. its pH has raised from 5.5 to 7.44. Water of Jhingurday nalla then mixes with the water of Mehrauli nalla, the pH of which is about 8.7. This, thus causes a complete neutralisation of Jhingurdah mine water before it gets finally discharged into Bijul stream. Similar observation was also noted with the sump water of Gorbi mine. The pH of this water increases from 2.5 to 3.14 when it flows for a distance of 1.5km in the nalla which is in the Barakar rock formation. pH in this case shows only a slight increase from 3.14 to 3.21 even after flowing for a distance of over 3km in the nalla through Archean rock formation. This highly acidic water finally gets disposed off into Bijul river. Thus, polluting the water of the local nalla and Bijul stream. Its impact is felt up to an extent of 1 to 1.5km beyond where it meets the Bijul stream, the point of confluence.

Neutralising Capacity of Overburden Rockmass

To study the neutralising capacity of the coal-overburden rockmass, minerological study was conducted on the rock samples collected from various sites in the Barakar rock formations; (Table 2). The rocks show a marked variation in the physical appearance such as white sandstone, yellow sandstone, brownish red sandstone. The white sandstone is characterised by white and yellowish white colour consisting mostly of quartz, along with few mica and feldspar tints. Yellow sandstone is reddish yellow to brownish yellow in colour due to rich iron content and is also harder and fine grained in comparison to white sandstone, consists of large grains of feldspars (mostly albite and microcline), quartz and mica. The reddish brown sandstone is not very common and found in localised patches. It also has high iron content. The mineral constituents and important oxides are summarised in Table 2 and 3 which show that the overburden rock formation has alkaline character perhaps because of the presence of weathered feldspar, alkali and alkaline metal oxides. This alkaline constituent of the rockmass is mainly responsible for raising the pH of the acidic mine water when once it flows in the nalla through Barakar rock formation. Neutralising capacity of the coal-overburden based on R-pH concept (Dhar, et al, 1987) also shows that the Barakar sandstone rocks are in the basic range and can be used as a neutraliser for acidic mine water. Table 4 also reveals that trace metal concentrations in these rocks are not much and thus if used for neutralisation purposes may not significantly affect the water quality. On the other hand, the rock of Archean formation is less reactive in nature due to its fine grained hard and compact nature. To confirm further the field observation, water-rock interaction study was conducted in the laboratory on the Barakar rock samples which showed alkaline characteristics (Figure 4). The experiments were conducted; one under static condition, simulating the condition of large settling tank where suitable rock formation which has good neutralizing potential in a particular coalfield (Figure 5 and 6). Thus, in case of Gorbi acidic mine water, the concept of diverting the existing water flow route through a new nalla passing through Barakar sandstone formation to somewhat longer distance before it is finally discharged into Bijul stream, may be a solution to control pollution of this water stream. Figure 7 shows a proposed channel plan for disposing off acidic water of Gorbi mine. Interestingly, the water in the Turra nalla (into which the acidic water is proposed to be discharge) has a pH value in alkaline range (Table 1), and therefore will further help in neutralising the acidic water if not properly neutralised during its coarse of flow through the proposed channel through Barakar sandstone.

The villagers living near this nalla also have strong objection against the discharge of acidic mine water in the nalla. The proposed approach of diversion of acidic mine water thus seems to be not only an answer to the objection of the local population, but will also satisfy the statutory requirement of disposing off acid mine effluent water within the recommended limits into the inland water bodies, in order to avoid its pollution. The method is simple and cost effective and thus need to be given a field trial on a larger scale. The authors understand from the Regional Office of the CMPDI, Singrauli, that a pilot study to test the proposed technique has been taken up.

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