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WATER QUALITY, AVAILABILITY AND AQUATIC LIFE AFFECTED BY COAL MINING IN ECOLOGICALLY SENSITIVE AREAS OF MEGHALAYA

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INTRODUCTION

Meghalaya is one of the seven states of the north-eastern region of India. Lying between 25° 1'N and 26° 1'N latitudes and 90° E and 92° E longitudes, the state occupies an area of about 22, 429 Km². It is bounded in the north and east by the state of Assam and on the south and west by Bangladesh (Figure- 1). Most of the area of Meghalaya is hilly and records the world's highest rainfall along the Mawsynram-Cherrapunjee belt. The state possesses luxuriant ecological conditions for growth of a large number of species of plants, animals and microorganisms. The vegetation is interesting having a mixture of Asiatic and Indian peninsular elements representing tropical evergreen, tropical semi-evergreen, subtropical broad leaved hill forest, tropical moist deciduous, grasslands & savannas, temperate and sub tropical pine forest types. The flora is extremely rich in terms of species diversity and abundance including a number of endemic and rare species. Different types of landscapes, forest types and ecosystems present in the state harbour equally rich faunal diversity including many endemic and endangered species of vertebrates and invertebrates.

Geologically the state of Meghalaya is characterized by Archaean genesis complex. As a result, the state is rich in mineral resources such as coal, limestone, sillimanite, uranium etc. The coal deposits in the state occur along the southern fringe of Shillong plateau distributed in Khasi Hills, Garo Hills and Jaintia Hills. The coal is one of the extensively utilized minerals in the state with an estimated reserve of 619 million tones (Directorate of Mineral Resources, 1974), the largest reserve amongst the coal bearing states of the northeast India.

During recent past the ecology of the state has been seriously threatened by large scale environmental degradation caused by extensive deforestation, overexploitation of natural resources and other anthropogenic activities coupled with unprecedented rise in human population. Unscientific coal mining in many areas of the state viz. Jaintia Hills, Khasi Hills and Garo Hills has further aggravated the environmental problems. Acute scarcity of potable and irrigation water, pollution of air, water and soil, soil erosion, reduced soil fertility and loss of biodiversity are some of the manifestations of coal mining (Das Gupta et.al., 2002; Swer and Singh, 2003). Recently, we have initiated a study on biomonitoring of water quality in Jaintia Hills, Meghalaya and collected data pertaining to various physico-chemical and biological parameters of water quality in relation to benthic macroinvertebrate fauna. Here, we discuss some of our observations on coal mining in relation to water quality deterioration, availability of potable and irrigation water and associated problems including adverse impacts on aquatic biota. The article also summarises some environmental management initiatives that can be useful in mitigation of the environmental problems and rehabilitation of degraded ecosystems of the area.

Coal Mining In Jaintia Hills

The Jaintia Hills, one of the seven districts of Meghalaya occupies the eastern part of the state. It covers an area of 3819 Km² which is 17.03% of the total geographical area of the state. The Jaintia Hills District of Meghalaya is a major coal producing area with an estimated coal reserve of about 40 million tonnes. Sutnga, Lakadong, Musiang-Lamare, Khliehriat, Ioksi, Ladrymbai, Rymbai, Byrwai, Chyrmang, Bapung, Jarain, Shkentalang, Lumshnong, Sakynphor etc. are the main coal bearing areas of the District. Areas under coal mining in Jaintia Hills District are shown in Figure 2. The three coal seams found imbedded in sedimentary rocks, sandstones and shale of the Eocene age vary from 30 to 212 cm in thickness. The main characteristics of the coal found in Jaintia Hills are its low ash content, high volatile matter, high calorific value and comparatively high sulphur content. The coal is mostly sub-bituminous in character. The physical properties characterize the coal of Jaintia Hills as hard, lumpy bright and jointed except for the coal in Jarain which is both soft and hard in nature. Composition of the coal revealed by chemical analysis indicates moisture content between 0.4% to 9.2%, ash content between 1.3% to 24.7%, and sulphur content between 2.7% to 5.0%. The calorific value ranges from 5,694 to 8230 kilo calories/Kilogram (Directorate of Mineral Resources, 1985).

Coal extraction in Jaintia Hills is done by primitive mining method commonly known as 'rat-hole' mining. In this method the land is, first cleared by cutting and removing the ground vegetation and then pit ranging from 5 to 100 m² is dug into the ground to reach the coal seam. Thereafter, tunnels are made into the seam sideways for extraction of coal, which is brought into the pit by using a conical basket or a wheel barrow. The coal is taken out of the pit manually and dumped on nearby un-mined area, from where it is carried to the larger dumping places near highways for its trade and transportation. Most of the mining activities are small scale ventures controlled by individuals who own the land. The post-mining environmental management activities are yet to be started to restore the degraded ecology of the area.

Environmental Consequences Of Coal Mining

The extraction of coal creates a variety of impacts on the environment before, during and after the mining operations. The extent and nature of impacts can range from minimal to significant depending on a range of factors associated with ongoing mining processes as well as post mining management of the affected landscapes. The sensitivity of the local environment also determines the magnitude of the problem. Usually, an ecologically fragile environment has been found highly vulnerable, attracting long term ecological impacts.

Mining operation undoubtedly has brought wealth and employment opportunities in the area, but simultaneously has led to extensive environmental degradation. Large scale denudation of forest cover, scarcity of water, pollution of air, water and soil and degradation of agricultural lands are some of the conspicuous environmental implications of coal mining. Besides, caving in of the ground and subsidence of land and haphazard dumping of coal and overburden have deteriorated the aesthetic beauty of the landscape.

Degradation of water quality

Our study in Jaintia Hills of Meghalaya revealed that the rivers, streams and springs of the area that supported rich biodiversity and traditional agriculture, and served the sources of potable and irrigation water, are the greatest victims of the coal mining. The surface water is badly affected by contamination of Acid Mines Drainage (AMD) originating from mines and spoils, leaching of metals from soil and rocks, organic enrichment, silting etc. Low pH (between 3 - 5), high conductivity, high concentration of sulphates, iron and toxic metals, low dissolved oxygen (DO) and high BOD are some of the features of water that indicate extensive degradation of water quality in the area.

Studies done in Jaintia Hills suggest that unscientific coal mining is the primary cause of environmental degradation including deterioration of water quality and consequently its availability in the area. The influx of acidic water oozing out from mines or acid mine drainage (AMD) into the rivers and streams of the area is mainly responsible for degradation of water quality and aquatic habitat. The AMD contamination of water bodies has not only made water unfit for desired uses but also resulted into an environment devoid of most aquatic life. AMD contamination has adversely affected various uses of water including agricultural (irrigation and livestock) and domestic water supplies along with large scale degradation of cultivable land.

The severity and extent of degradation is not homogenous all along the coal mining area rather differ in space and time depending upon climatic conditions and season, extent of mining and other local factors including the quantity and quality of the acidic drainage, buffering capacity of the receiving stream and micro-hydrological conditions. Water bodies of the area have also been severely impacted by leaching of heavy metals, organic enrichment, turbidity and silting.

Indicators Of Water Quality

Physico-chemical indicators

A large number of rivers, streams and springs drain the undulating landscape of the Jaintia Hills. They support rich aquatic biodiversity, traditional agriculture and fisheries, and water supply needs of the local people. The major rivers and streams of Jaintia Hills are *Myntdu, Prang, Lukha, Lubha, Mynriang,* Umtarang, *Kopli* and its tributories such as *Mynriang, Umiurem* and *Myntang.* Some other streams in coal mining areas are kmai-um, Rawaka, *Thwai Kungor, Brilakam and* Mynsar. Most of these rivers and streams flow towards south-east into the flood plains of Bangladesh. However, a few also flow towards northern side into the Brahmaputra valley (Figure 3).

Water pollution in the coal mining areas of Jaintia Hills is evidenced by the brownish or reddish colour, low pH, low DO, high BOD and elevated levels of sulphate and dissolved metals. The results of physico-chemical analysis of water samples of some rivers (both affected and unaffected by coal mining) of Jaintia Hills are described below and summarized in Table 1.

Colour

The colour of the water in rivers and streams of mining area generally varies from brownish to reddish orange. Siltation and suspended paricles of coal, sand, soil etc. and contamination of AMD are some of the major causes of change in water colour. These problems are more pronounced in winter season (November to February) on account of intensive coal mining coupled with reduced water flow due to less rain fall. On the other hand, the water colour of Myntdu River which has been considered as control was found clear with bluish tint.

Acid Mine Drainage (AMD) is the greatest environmental problems of coal mining and main source of water pollution in the mining area (Kelly, 1988). It is formed by a series of complex geochemical and microbial reactions that occur when water comes in contact with pyrite (iron sulfide) found in coal and exposed rocks of overburden. Iron sulfide in presence of water, oxygen and bacteria forms sulphuric acid and iron hydroxide, which together with water are referred to as AMD. During the process of pyrite oxidation, dissolved Fe^{2+}, SO_4^{2-} and H^+, followed by further oxidation of the Fe^{2+} to Fe^{3+} are formed (Murad et al., 1994; Bigham et al., 1996). As elevated levels of iron are introduced into natural waters, some or all of this dissolved iron on oxidation and hydrolysis can form precipitate of iron hydroxide [$(Fe(OH)_3]$, which is mainly responsible for characteristics orange or red colour of water in coal mining areas. It is this material that stains streams, causes turbidity of water (in the form of the red, orange, or yellowish colour), and sedimentation at the bottom of the streams.

pH

The water in coal mining areas has been found highly acidic. The pH of streams and rivers varies between 2.31 to 4.01. However, pH of the Myntdu River was found to be 6.67.

Due to presence of H^+ ions and sulphuric acid, the AMD is highly acidic and contains high concentration of dissolved metals and trace elements such as aluminum, calcium, lead, barium, cadmium etc. The AMD discharge, when contaminates water bodies lowers the pH. Low pH conditions in the water accelerate weathering and the dissolution of silicate and other rock minerals, thereby causing the release of elements such as aluminum and manganese into the water.

Siltation

Solids such as fine particles of coal, sand, mud and other mineral particles were found deposited at the bottom of the water bodies. Deposition of iron hydroxide precipitates at the bottom of water bodies was also found in the area. Silt, fine sand, mud, coal dust and similar materials are known to be disruptive to aquatic organisms as they destroy the benthic habitat and reduce the availability of oxygen to benthic animals.

Dissolved oxygen

The Dissolved Oxygen (DO) in water is essential to sustain and maintain higher forms of life in water bodies. It is an important parameter to assess water quality. Dissolved oxygen was found to be low in water bodies of coal mining areas, the lowest being 4.24 mg/L in river Rawaka and stream Metyngka of Rymbai. However, DO in water of river Myntdu was found 10.2 mg/L.

Sulphate

The waters of the mining areas have been found containing sulphate concentration between 78 to 168 mg/L. The high concentration of sulphates is mainly due to presence of iron sulphide in coal and rocks and its reaction with water and oxygen. On the other hand, water of the unpolluted rivers and streams in Meghalaya contains usually very low concentration of sulphates as has been found in water of River Myntdu (i.e. 3.66 mg/L).

Conductivity

Conductivity is the measure of the capacity of a solution to conduct electric current. It is a rapid measure of the total dissolved solids present in water in ionic form. In this study, the conductivity was found highest in stream Metyngka of Rymbai with 2.7 mMHOS and least in the control river Myntdu with 0.1 mMHOs. High conductivity of water in coal mining area may be attributed to elevated levels of dissolved compounds and various metals.

Organic Pollution

High human population (due to presence of labourers, transporters and traders) and lack of proper sanitation are responsible for different types of organic pollution in the water bodies of the mining areas. High organic pollution load leads to low Dissolved Oxygen (DO) and high Biochemical Oxygen Demand (BOD) in water. Analysis of water samples revealed relatively higher BOD values in mining affected rivers and streams of Jaintia Hills compared to that of riverMyntdu.

Biological indicators

Biological indicators or bioindicators are the organisms or communities which respond to pollutant load and show specific changes in vital functions, accumulate pollutants or manifest alterations in species composition, diversity and abundance. They have been commonly used to characterize current status and to track or predict significant change in the water quality as their study reveals biological, chemical or physical attributes of the ambience. Biological indicators have been found both accurate and sensitive measures in assessment of the health of water bodies (Rosemond et al., 1992; Singh, 2003).

Benthic macroinvertebrates (bottom-dwelling invertebrates large enough to be seen with the naked eye) reflect definite pattern of change in the response to pollution, and thus have been widely used in biomonitoring of water quality. Benthic community affected by pollution show remarkable changes in their species composition and abundance or absence of certain species. For instance, benthic community impaired by pollution is manifested by the absence of many pollution sensitive species belonging to taxonomic orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) commonly referred to as EPT taxa, but dominance by certain pollution tolerant groups such as Chironomids (midge larvae) and Oligochaetes (aquatic worms).

Recently, we have undertaken a study on Biomonitoring of water quality in coal mining areas of Jaintia Hills using benthic macroinvertebrates. The study revealed presence of only a few tolerant species namely *Chironomus* larvae, dragonfly larvae, water bugs, worms etc. in low abundance and species diversity. However, studies done on river away from the coal mining area (i.e. upstream of River Myntdu) show relatively higher abundance and species diversity of macroinvertebrates, including many pollution sensitive species. The presence of only a few tolerant species of macroinvertebrates in low abundance, and absence of other commonly found aquatic organisms such as fish, frog and crustaceans in rivers and streams of the mining area indicate serious impact of coal mining on aquatic life (Table 2).

Scarcity Of Domestic Water Supply

People of the rural area of Jaintia Hills are mainly dependent on natural sources such as springs and streams for their domestic water supply. During recent years the area is facing acute shortage of domestic water supply due to coal mining. Most of the water bodies barring a few springs of the area have been severely polluted. As a result, the water has become unfit for domestic use and irrigation. Further, due to presence of large number of mine pits (both active and abandoned), subsistence of ground and development of cracks and crevices, the surface water readily percolates into the ground. As a result, many perennial springs and streams which served as life lines for the people are either completely vanishing from the area or turning seasonal. Polluted water is also responsible for degradation of agricultural fields leading to low crop yield abandonment of farming.

Amelioration Of Environmental Problems

There is an urgent need for undertaking measures for ecorestoration of the mining affected areas. Activities such as filling of abandoned mine pits, channeling of acidic seepage for checking AMD contamination of water bodies and crop fields, extensive afforestation, neutralization of acidity, conservation of topsoil etc. coupled with scientific management of mining operation can be helpful in ameliorating the environmental problems of the area. These activities can be undertaken with active participation of the local people, who have realized the seriousness of the problem, and are willing to initiate ecorestoration work in the area. Some individual and community initiatives have already been started in the form of channeling of acidic seepage to prevent contamination of agricultural land, restriction of mining near water sources, tree plantation etc. These initiatives may be miniscule considering the magnitude of the problem, but can be considered an important step in the process of ecorestoration of mining affected areas of Jaintia Hills. There is need for scientists, government departments and policy makers to join hands together and evolve working model for the area so that integrated approach can be adopted to mitigate the problem and restore healthy environment for generations to come.

CONCLUSION

During past a couple of decades the coal bearing areas of Jaintia Hills, Meghalaya are under extensive mining. The present modus operandi for coal extraction is unscientific and aggravating the ecological and environmental problems. Most of the water bodies of the area are highly polluted and gradually becoming devoid of aquatic life. The area is also facing acute shortage of domestic water supply. There is an overall decline in agricultural productivity due to contamination of land and soil with coal particles. seepage of acid mines drainage and scarcity of water. Hence. mining operation has proved detrimental to the water bodies, in particular and the fragile ecosystems of the area, in general. There is an urgent need for ecorestoration of the area in order to ensure availability of clean water, restoration of traditional agriculture, conservation of biodiversity and ultimately sustainable development.

Table- 1. Physico-chemical properties of the water of some rivers of Jaintia Hills, Meghalaya

Sl. No.	Rivers/ Streams	Surrounding Location	Colour of water	pH	DO (mg/L)	Sulphate content (mg/L)	Conductivity (mMHOS)	Remarks
1.	Waikhyrwi, Sutnga	Coal mining area	Brownish	3.96	5.94	78.69	Data not avilable	Polluted
2.	Rawaka, Rymbai	Coal mining area	Reddish brown	2.31	4.24	166.5	1.35	Highly polluted
3.	Kmai-um, Rymbai	Coal mining area	Reddish brown	2.66	5.84	144.0	0.74	Highly polluted
4.	Metyngka, Rymbai	Coal mining area	Reddish brown	2.42	4.24	168.0	2.70	Highly polluted
5.	Um-Mynkseh, Ladrymbai	Coal mining area	Brownish orange	3.52	5.04	118.7	0.67	Polluted
6.	Thwai-Kungor, Bapung	Coal mining area	Brownish	4.01	5.68	82.87	0.18	Polluted
7.	Umkyrpong, Khliehriat	Coal mining area	Light Orange	3.67	4.4	161.3	0.37	Polluted
8.	Myntdu, Jowai	Non mining area	Bluish	6.67	10.2	3.66	0.10	Clean

Table-2 Occurrence of macroinvertebrates in rivers and streams of Jaintia Hills.

Benthic macro invertebrates	RIVERS/STREAMS							
	Myntdu (Control)	Waikhyrwi (Sutnga)	Rawaka (Rymbai)	Kmai-Um (Rymbai)	Metyngka (Rymbai)	Um-Mynkseh (Lad Rymbai)	Thwai Kongor (Bapung)	Um Krypong (Khliehriat)
Plecoptera (stonyefly nymph)	P	A	A	A	A	A	A	A
Epheroptera (mayfly nymph)	P	A	A	A	A	A	A	A
Tricoptera (Caddis fly larvae)	P	A	A	A	A	A	A	A
Odanata (Dragon fly)	P	P	A	A	A	P	A	A
Hemiptera (Water bugs)	P	P	A	A	A	P	A	A
Diptera (Chironomus larvae)	P	P	A	A	A	P	A	A
Crustacea	P	A	A	A	A	A	A	A
Other aquatic organisms (fishes, frogs, & tadpoles)	P	A	A	A	A	A	A	A

P - Present; A - Absent

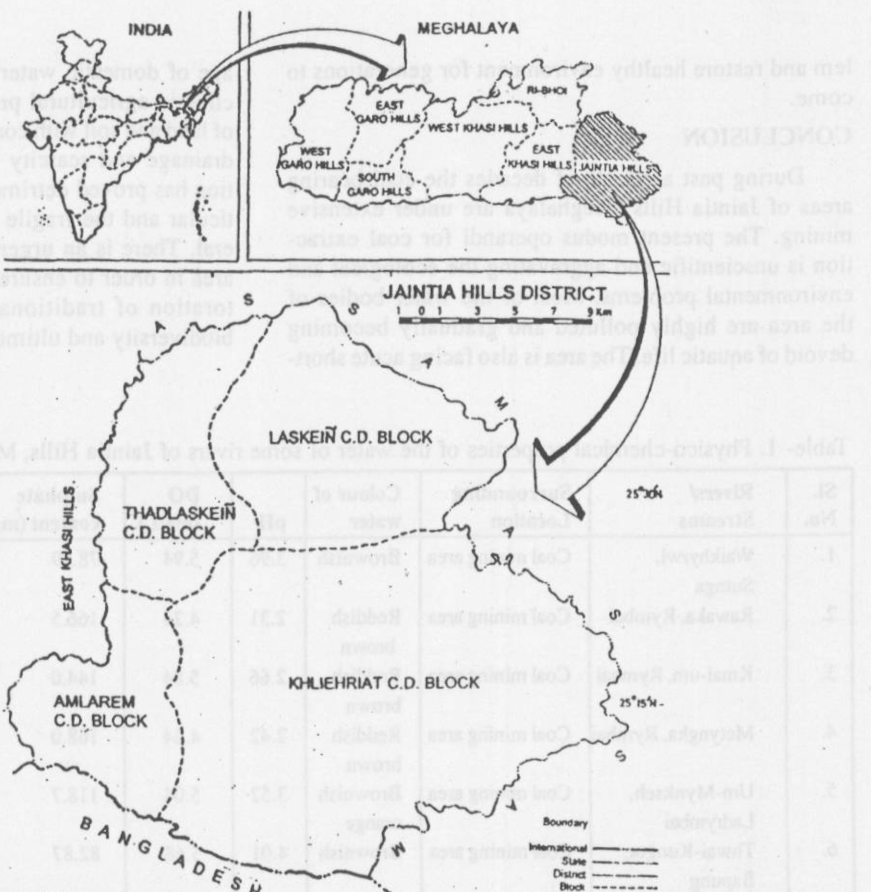

Fig. 1.Location Map of Jaintia Hills District.

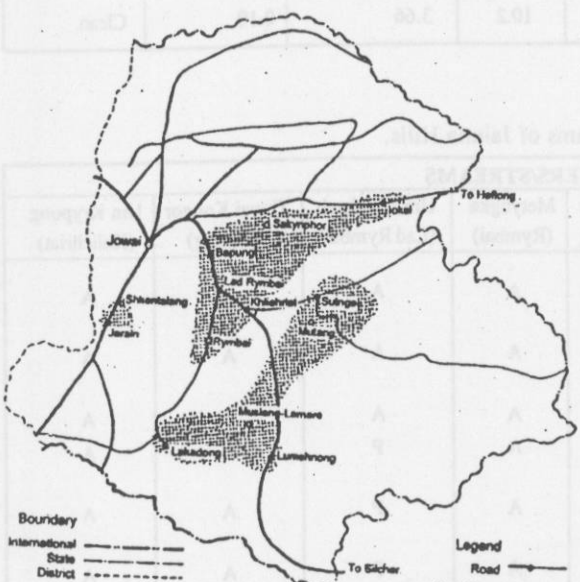

Fig. 2. Coal mining areas of Jaintia Hills.

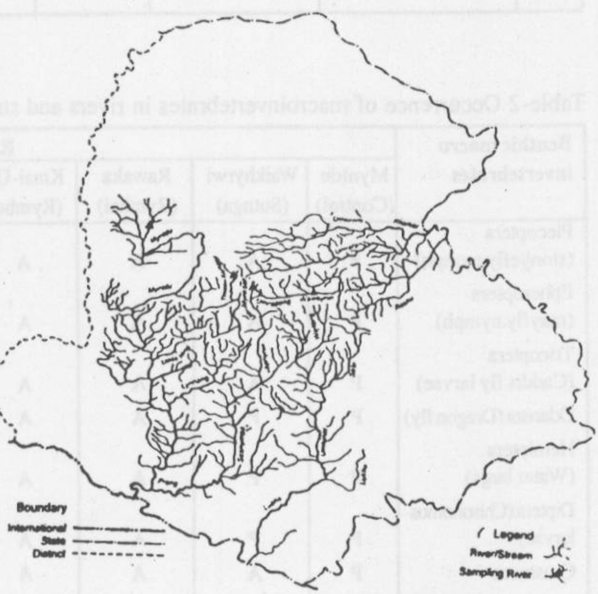

Fig. 3. Rivers/streams of coal mining areas along with Myntdu river (control)

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