

Water Pollution in Coal Mining Areas of Jaintia Hills, Meghalaya and its Impact on Benthic Macroinvertebrates

Sumarlin Swer and O.P. Singh

Introduction

Meghalaya, one of the seven states of north-eastern region of India is rich in mineral resources such as coal, limestone, sillimanite, uranium etc. Coal is one of the most exploited minerals in the state with an estimated reserve of 619 million tonnes (Directorate of Mineral Resources, 1974). The Tertiary coal deposits of Meghalaya, belonging to Eocene age are found mostly on the southern slopes of the State. The coal seams vary between 0.3 meters and 2.12 meters in thickness. Coal mining is carried mostly in Khasi Hills, Garo Hills and Jaintia Hills district of Meghalaya. The District-wise estimated coal reserve is given below:

Table 1: District-wise estimated coal reserve in Meghalaya

<i>Sl. No.</i>	<i>District</i>	<i>Estimated Coal Reserve (million tonnes)</i>
1.	East Khasi Hills	91.1
2.	West Khasi Hills	98.1
3.	Jaintia Hills	39.3
4.	Garo Hills	390.5
	Total	619

Though Jaintia Hills District has the lowest estimated coal reserve, it ranks first among the coal producing districts of the state with the annual production of 2935.9 metric tonnes during 1999–2000. The major coal bearing areas of the District are Sutnga, Lakadong, Musiang-Lamare, Khliehriat, Ioksi, Ladrymbai, Rymbai, Bapung, Jarain, Shkentalang, Lumshnong and Sakynphor.

Mostly the coal of Jaintia Hills is of hard, lumpy bright and jointed type except the coal in Jarain which is both soft and hard in nature. The coal of Jaintia Hills is characterized by its sub-bituminous nature, low ash content, high volatile matter, high calorific value and comparatively high sulphur content. Analysis of the coal indicates that the moisture content varies from 0.4% to 9.2%, the ash content from 1.3% to 18.1% and sulphur content ranges from 2.7% to 5.0%. The calorific value ranges from 5,694 to 8,320 kilo calories/Kilogram (Directorate of Mineral Resources, 1985).

The extraction of coal in Jaintia Hills is carried out by the primitive method commonly known as "Rat-hole" method of mining. In this method coal is extracted by digging pits ranging from 5 to 100 m² either from the surface of the coal bearing location or rat-holes from the sides of a hill to reach the coal seams. The coal from the pit is brought out by using conical baskets or wheel barrow. Though this method may be the most economical and suitable to the local populace who own the mines, it is proving to be environmentally degrading. Deforestation, soil erosion, surface run-off, caving in of the ground and pollution of land, air and water are some of the prominent environmental problems associated with coal mining in the area (Das Gupta *et al.* 2002). Of these, surface water pollution is of primary concern because it supports various human activities and rich diversity of both aquatic and terrestrial organisms. The concern for water pollution in the area increases further considering the fact that the area is ecologically sensitive and rich in biodiversity and shares international border.

Jaintia Hills has a large number of rivers and streams that drain the undulating landscape of the district. Most of these rivers and streams flow towards south-east into the flood

plains of Bangladesh. However, a few also flow towards northern side draining into the Brahmaputra valley. Some of the major rivers and streams in Jaintia Hills District are rivers Myntdu, Lubha, Lukha, Prang, Kupli, Mynriang, Umiurem, Myntang etc. Of these rivers Myntdu, Lubha, Lukha and Prang flow towards the Bangladesh plain whereas rivers Kupli, Mynriang, Umiurem and Myntang flow towards Brahmaputra valley in Assam. In addition, there are several other rivers and streams in coal mining areas. These water bodies in the area serve as important sources for drinking water, irrigation and support a rich array of floral and faunal diversity. Unfortunately, rampant coal mining has adversely affected the quality of water of most rivers. Acid mine drainage originating from mines and coal spoils, leaching of heavy metals and organic enrichment by various anthropogenic activities are the main sources of water pollution which has serious implications on aquatic life, agricultural activity and availability of potable and irrigation water in the area. In the present article, various aspects of water pollution caused by AMD originating from coal mines in Jaintia Hills, Meghalaya have been discussed.

Methods

Sampling and analysis

Seven rivers/streams namely River Waikhyrwi, River Rawaka, River Kmai-um, Stream Metyngka, Um-Mynkseh, River Thwai Kungor and Um-Kyrpong located in and around coal mining areas were sampled for various physico-chemical parameters and benthic macroinvertebrates. Upstream of river Myntdu which is located far from coal mining areas was taken as reference or control river. Standard methods as described in APHA (1998) were followed for sampling of water and its analysis.

A fine meshed net was used to collect three samples of benthic macroinvertebrates at each sampling site, from different substrate such as cobble, gravel, sand-silt etc. Collected macroinvertebrates were preserved with 4% formaldehyde

for identification and laboratory analysis. Identification of benthic macroinvertebrates was done using literature suggested by Pennak (1978).

Observations

Water quality in coal mining areas of Jaintia Hills

The colour of rivers and streams of coal mining areas was observed to be brownish to reddish orange. River Waikhyrwi of Sutnga and Thwai-Kungor of Bapung exhibited brownish colour while that of rivers Rawaka, Kmai-um and stream Metyngka were reddish brown. On the other hand, the colour of Ummynkseh and Umkyrpong was brownish orange and light orange respectively. The formation of iron hydroxide (discussed later) due to acid mine drainage is the main cause for the change in water colour. However river Myntdu, the control river was found to have bluish tint.

pH

The pH depicting hydrogen ion concentration of water in coal mining areas was found to be low. The lowest pH value in the range of 2.31 and 2.42 was found in river Rawaka and stream Metyngka respectively of Rymbai. The pH of various rivers of the area is given in Table 2. Observation shows that most water bodies of the area carry acidic water especially the ones in Rymbai. The low pH can be directly linked to the Acid Mine Drainage originating from mines and spoils which seep into the water bodies. It was observed that many open shafts and rat hole mines are present near the rivers/streams and these are continuously affected the water quality. On the other hand, a pH of 6.67 was however recorded in river Myntdu.

Dissolved oxygen

Dissolved oxygen is an important parameter to assess water quality. It is essential to support and maintain the survival of aquatic organisms in water bodies. Dissolved oxygen was found comparatively low in rivers and streams of coal mining areas falling within the range of 4–5 mg/l, whereas in the

control river it was found to be 10.2 mg/l. Low dissolved oxygen level further indicates the degradation of water quality in the water bodies of the mining area.

Sulphate

Sulphate content was found to be 3.66 mg/l in river Myntdu, whereas the same was found significantly high in various rivers of coal mining areas with maximum value of 168 mg/l in stream Metyngka of Rymbai. The iron sulphide present in coal and other rocks on oxidation releases sulphate ions and is the main source of high concentration of sulphate in water bodies of the mining area.

The analysis of physico-chemical properties of water in Jaintia Hills shows that water bodies of mining areas are highly acidic in nature; possess low dissolved oxygen, high sulphate and trace element content. Observations of physico-chemical analysis are summarized in Table 2.

Table 2: Physico-chemical properties of water samples of some rivers/streams of mining areas and of river Myntdu, which has been considered as control

<i>Rivers/ streams (Location)</i>	<i>Colour of water</i>	<i>pH</i>	<i>Dissolve Oxygen (mg/l)</i>	<i>Sulphate (mg/l)</i>
Waikhyrwi (Sutnga)	Brownish	3.96	5.94	78.69
Rawaka (Rymbai)	Reddish brown	2.31	4.24	166.5
Kmai-um (Rymbai)	Reddish brown	2.66	5.84	144.0
Metyngka (Rymbai)	Reddish brown	2.42	4.24	168.0
Umynkseh (Ladrymbai)	Brownish orange	3.52	5.04	118.7
Thwai-Kungor (Bapung)	Brownish	4.01	5.68	82.87
Umkyrpong (Khliehriat)	Light orange	3.67	4.4	161.3
Myntdu (Jowai)	Bluish	6.67	10.2	3.66

Benthic macroinvertebrates in water bodies of Jaintia Hills

Benthic macroinvertebrates are bottom dwelling organisms, visible by naked eyes that inhabit bottom substrates of aquatic ecosystems for at least part of their life cycle. Among the benthic macroinvertebrates, stonefly nymph, mayfly nymph,

caddis fly larvae belonging to Order Plecoptera, Ephemeroptera, and Tricoptera respectively are known to be sensitive species and used in biomonitoring studies. Besides these, Megaloptera, clams, aquatic beetles are also sensitive to pollution. The presence of these sensitive macroinvertebrates would indicate the cleanliness of the water. Dragon fly and damsel nymphs belonging to order Odonata are known to be moderately tolerant to some pollution. On the other hand, Chironomus larvae, Tubificids and other oligochaetes are known to be tolerant species and their presence in abundance would indicate pollution of the water (Rosenberg and Resh, 1993).

Owing to its many advantages over physical and chemical analysis, biomonitoring has been widely adopted as the key method in assessment and monitoring of water quality. Biomonitoring is the systematic use of living organisms and their biological responses to evaluate changes in the environment. Unlike physical and chemical data, biological monitoring determines not only the present status of any water body but also of the past, since living organisms integrate and register pollution over a long period of time. Biomonitoring can detect subtle disruptions and intermittent pollution, thus gives an early warning about the state of health of the water body.

During present study, collection and analysis of macroinvertebrates in river Myntdu (considered as control being located away from the mining area and not polluted by coal mining) revealed presence of stonyefly nymph (Plecoptera), may fly nymph (Ephemeroptera), caddis fly larvae (Tricoptera), dragon fly (Odonata), water bugs (Hemiptera), Chironomus larvae (Diptera) and Crustaceans in the upstream water of river Myntdu. Whereas, study undertaken on rivers located in mining area and polluted by coal mining (rivers such as Waikhyrwi (Sutnga), Rawaka (Rymbai), Kmai-Um (Rymbai), Metyngka (Rymbai), Um-Mynkseh (Lad Rymbai), Thwai Kongor (Bapung), and Um Krypong (Khliehriat)) showed presence of only a few tolerant species in low species diversity and abundance (Table 3).

Table 3: Benthic macroinvertebrates in water bodies of mining areas and river Myntdu

Benthic Macro-invertebrates (Presence or Absence)	Rivers/Streams							
	Mynt-du Jowai	Waik-hyrwi (Sutn-ga)	Rawala (Rym-bai)	Kmai-Um (Rym-bai)	Metyn-gka (Rym-bai)	Um-Mynk-seh (Lad Rym-bai)	Thwai Kon-gor (Bap-ung)	Um Kry-pong (Khlie-hriat)
Plecoptera (stonyefly nymph)	P	A	A	A	A	A	A	A
Ephemeroptera (may fly nymph)	P	A	A	A	A	A	A	A
Tricoptera (Caddis fly larvae)	P	A	A	A	A	A	A	A
Odonata (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, and tadpoles)	P	A	A	A	A	A	A	A

P: Present; A: Absent

Among the benthic macroinvertebrates, Plecoptera, Ephemeroptera and Tricoptera known to be sensitive to acidic water and can survive in waters with plenty of dissolved oxygen were absent in water bodies of coal mining areas as these water bodies are acidic and have low dissolved oxygen. These sensitive species were however present in River Myntdu.

Dragon fly nymph belonging to family Gomphidae and Aeshnidae were found in river Um Mynkseh and Waikhyrwi of Sutnga but in low abundance. Water bugs belonging to order Hemiptera were also found in water bodies of the mining area but in low abundance. Chironomus larvae known to be one of the most tolerant species were found abundantly in rivers/streams of mining areas. Crustaceans belonging to Family Atydae were found in the control river but absent in rivers/streams of mining areas. Other aquatic organisms like fishes, tadpoles and frogs known as highly sensitive to acid water were totally absent in the water bodies of mining area but were present in River Myntdu.

Discussion

The rivers, streams and springs, which had supported rich biodiversity and traditional agriculture, and served the purpose of drinking and irrigation in the Jaintia Hills are badly affected by contamination of Acid Mine Drainage (AMD) originating from mines and spoils, leaching of heavy metals and organic enrichment. The effect of AMD on local streams varies with the size of the stream and the total pollution load put on the stream. The silting of stream and river beds by coal particles, sand and rock pieces are destroying the natural benthic habitats. Consequently, the rivers and streams of the area showed low pH, high conductivity, high concentration of sulphates, iron and many toxic heavy metals, low Dissolved Oxygen (DO) and high BOD. All these parameters characterize the degradation of water quality and diminish the life supporting function of the water. As a result, there is a drastic depletion of aquatic life, particularly of aquatic animals in the area.

AMD is the greatest environmental problem of the mining sector. The AMD is generated both by active and abandoned mines and is a serious liability, especially to our water bodies. It has the potential for long-term, devastating impacts on water and land and their flora and fauna. The iron disulfide or pyrite (FeS_2) is the principal sulfur-bearing minerals in bituminous coal (Hawkins, 1984).

The AMD is formed when pyrite is exposed and reacts with air and water to form sulphuric acid and dissolved iron. Some or all of this iron can precipitate to form the red, orange, or yellow sediments in the bottom of streams containing mine drainage. The acid runoff further dissolves heavy metals such as copper, lead, mercury into ground or surface water. The rate and degree by which acid mine drainage proceed can be increased by the action of bacteria.

Environmental impact of AMD

Mine drainage is a complex of elements that interact to cause a variety of effects on aquatic life that are difficult to separate into individual components. Toxicity is dependent on discharge volume, pH, total acidity, and concentration of dissolved metals. The pH is the most critical component, since the lower the pH, the more severe the potential effects of mine drainage on aquatic life. The overall effect of mine drainage is also dependent on the flow (dilution rate), pH, and alkalinity or buffering capacity of the receiving stream. The higher the concentration of bicarbonate and carbonate ions in the receiving stream, the higher the buffering capacity and the greater the protection of aquatic life from adverse effects of acid mine drainage (Kimmel, 1983). Alkaline mine drainage with low concentrations of metals may have little discernible effect on receiving streams. Acid mine drainage with elevated metals concentrations discharging into headwater streams or lightly buffered streams can have a devastating effect on the aquatic life. Secondary effects such as increased carbon dioxide tensions, oxygen reduction by the oxidation of metals, increased osmotic pressure from high concentrations of mineral salts, and synergistic effects of metal ions also contribute to toxicity. In addition to chemical effects of mine drainage, physical effects such as increased turbidity from soil erosion, accumulation of coal fines, and smothering of the stream substrate from precipitated metal compounds may also occur (Parsons, 1968; Warner, 1971).

Impact of AMD on macroinvertebrates

Benthic (bottom-dwelling) macroinvertebrates are often used as indicators of water quality because of their limited mobility, relatively long residence times, and varying degrees of sensitivity to pollutants. Unaffected streams generally have a variety of species with representatives of all insect orders, including a high diversity of insects classed in the taxonomic orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT taxa). Like many other potential pollutants, mine drainage can cause a reduction in the diversity and total numbers, or abundance, of macroinvertebrates and changes in community structure, such as a lower percentage of EPT taxa. Moderate pollution eliminates the more sensitive species. Severely degraded conditions are characterized by dominance of certain taxonomic representatives of pollution-tolerant organisms, such as earthworms (Tubificidae), midge larvae (Chironomidae), alderfly larvae (*Sialis*), fishfly larvae (*Nigronia*), crane fly larvae (*Tipula*), caddisfly larvae (*Ptilostomis*), and non-benthic insects like predaceous diving beetles (Dytiscidae) and water boatmen (Corixidae) (Nichols and Bulow, 1973; Roback and Richardson, 1969; Parsons, 1968). While these tolerant organisms may also be present in unpolluted streams, they dominate in impacted stream sections. Mayflies are generally sensitive to acid mine drainage, however, some stoneflies and caddisflies are tolerant of dilute acid mine drainage.

In fact, most organisms have a well defined range of pH tolerance. If the pH falls below the tolerance range, death will occur due to respiratory or osmoregulatory failure (Kimmel, 1983). Low pH causes a disturbance of the balance of sodium and chloride ions in the blood of aquatic animals. At low pH, hydrogen ions may be taken into cells and sodium ions expelled (Morris *et al.* 1989). Mayflies are one of the most sensitive groups of aquatic insects to low pH; stoneflies and caddisflies are generally less sensitive to low pH. Mayflies and stoneflies that normally live in neutral water experience a greater loss of sodium in their blood when exposed to low pH

than do acid-tolerant species of stoneflies, such as *Leuctra* and *Amphinemura*, whose sodium uptake is only slightly reduced by low pH (Sutcliffe and Hildrew, 1989).

Acid waters typically have fewer species and a lower abundance and biomass of macroinvertebrates than near-neutral pH waters. Attempts have been made to specifically identify limiting factors, and two factors investigated are interruption of the food chain and direct effects of low pH levels on aquatic life. The macroinvertebrates are often grouped by their feeding habits, and assemblages of invertebrates in acidified waters appear to be related to food availability. The fauna of low pH streams is usually composed of shredders (organisms that eat leaves that fall into the stream), collectors (organisms that filter or gather particles of organic matter from the water), and predators. Low pH tends to eliminate species that feed on algae (scrapers or grazers). Low pH may inhibit growth of bacteria which help break down of leaves to make them more easily digestible and which also serve as a food source. These observations led early investigators to theorize that low pH levels reduced the food sources for invertebrates, thereby indirectly reducing their numbers. This is partially true; however, more recent studies have shown that direct effects of low pH on aquatic life are more critical than indirect effects on food sources (Rosemond *et al.* 1992).

As discussed, AMD is the greatest environmental problem of the mining sector. It is generated both by active and abandoned mines and has potential for long-term, devastating impacts on rivers, streams and aquatic life. With existing technology, AMD is virtually impossible to stop, once the reactions begin. Hence, the first and best line of defense against AMD is to prevent the potentially acid generating material from mixing with air and water. Besides, filling of mine pits, channeling of seepage water for checking AMD contamination of water bodies and crop fields, afforestation with native species, undertaking effective soil conservation and water resources management programmes are some of the measures that can mitigate the problem and go long way in restoration of the degraded ecology of the area.

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