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STATUS OF WATER QUALITY IN COAL MINING AREAS OF MEGHALAYA, INDIA

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Abstract: *The coal is one of the extensively utilized minerals in Meghalaya. Though coal deposit in the state is found all along the southern fringe of Shillong plateau, Jaintial Hills District is a major producer of coal. Coal extraction is done by primitive mining method commonly known as 'rat-hole' mining. Most of the mining activities are small scale ventures controlled by individuals who own the land. Mining operation, undoubtedly has brought wealth and employment opportunity in the area, but simultaneously has led to extensive environmental degradation and disruption of traditional values in the society. The water bodies of the area are the greatest victims of the coal mining. Pollution of the water is evident by the colouration of water which in most of the rivers and streams in the mining area varies from brownish to reddish orange. Low pH (between 2-3), high electrical conductivity, high concentration of ions of sulphate and iron and toxic heavy metals, low dissolved oxygen (DO) and high BOD are some of the physico-chemical and biological parameters which characterize the degradation of water quality. Contamination of Acid Mine Drainage (AMD) originating from mines and spoils, leaching of heavy metals, organic enrichment and silting by coal and sand particles are major causes of degradation of water quality in the area.*

Keywords: *Coal mining; water quality; aquatic life; acid mine drainage.*

Introduction

Meghalaya, one of the seven north-eastern states of India possesses rich deposits of various minerals including coal. 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. Jaintial Hills District is a major producer of coal. Sutnga, Lakadong, Musiang-Lamare, Khliehriat, Ioksi, Ladrymbai, Rymbai, Bapung, Jarain, Shkentalang, Lumshnong and Sakynphor are the areas of extensive coal mining in the District. Coal extraction is done by primitive mining method commonly known as 'rat-hole' mining. Most of the mining activities are small scale ventures controlled by individuals who own the land. Mining operation, undoubtedly has brought wealth and employment opportunity in the area, but simultaneously has led to extensive environmental degradation and disruption of traditional values in the society. Environmental problems associated with mining have been felt severely because of the region's fragile ecosystems and rich biological and cultural diversity. 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 (Das Gupta and Tiwari, 2000; Swer and Singh, 2004). Besides, a vast area has become physically disfigured due to haphazard dumping of overburden, caving in of the ground and subsidence of land.

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The water bodies of the area are the greatest victims of the coal mining. The problems of water quality degradation and its adverse impacts on availability of potable and irrigation water, soil quality and agricultural productivity, and biodiversity in the area have been attracting increasing attention of people. Here, we discuss the status of water quality of rivers and streams in the coal mining areas of Jaintia Hills Districts of Meghalaya. The article also summarizes some of the associated problems including adverse impacts on aquatic biota of the area. A few environmental management strategies that can be useful in mitigation of the environmental problems and rehabilitation of degraded ecosystems of the area have also been suggested.

Coal mining in Meghalaya

The Jaintia Hills, one of the seven districts of Meghalaya occupies the eastern part of the state. It covers an area of 3819 Km^2 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. The coal, in the area is found imbedded in sedimentary rocks, sandstones and shale of the Eocene age. The three coal seams vary from 30 to 212 cm in thickness (Guha Roy, 1992). 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 District 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 pits ranging from 5 to 100 m^2 are dug vertically into the ground to reach the coal seam. Thereafter, horizontal tunnels are made into the seam 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 and dumped on nearby un-mined area, from where it is carried to the larger dumping places near highways for its trade and transportation. The entire process of mining is done manually employing small implements. Most of the mining activities are small scale ventures controlled by individuals who own the land.

Environmental problems 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 in Jaintia Hills 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.

Deterioration of water quality

Study revealed that a large number of rivers and streams drain the undulating landscape of the Jaintia Hills. 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. The water is badly affected by contamination of Acid Mines Drainage (AMD) originating from mines and spoils, leaching of heavy metals, organic enrichment and silting by coal and sand particles. Pollution of the water is evident by the colour of the water which in most of the rivers and streams in the mining area varies from brownish to reddish orange. Low pH (between 2-3), high conductivity, high concentration of sulphates, iron and toxic heavy metals, low dissolved oxygen (DO) and high BOD are some of the physico-chemical and biological parameters which characterize the degradation of water quality. The extent of degradation of water quality is discussed below:

Colour:

The colour of the water in mining area generally varies from brownish to reddish orange. Siltation of coal particles, sand, soil etc. and contamination of AMD and formation of iron hydroxide are some of the major causes of change in water colour.

Formation of iron hydroxides [(Fe $(OH)_3$] is mainly responsible for orange or red colour of water in the mining areas. Iron hydroxide is a yellowish insoluble material commonly formed in water bodies of the coalfields. It is this material that stains streams and responsible for red to orange color of water. When elevated levels of iron are introduced into natural waters, the iron is oxidized and hydrolyzed, thereby forming precipitate of iron hydroxides. On the other hand, the water colour of Myntdu River which has been considered as control being located away from the mining area has been found clear with bluish tint.

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. This indicates serious condition of the water bodies of the area that hardly can support any aquatic life such as fish, amphibians and insects. Contamination of Acid mine drainage (AMD) leads to acidity or low pH of the affected water bodies. Acidic water is a matter of primary concern since it can directly be injurious to aquatic organisms. It also facilitates leaching of toxic metals into the water that could be hazardous to aquatic life, directly or can disturb the habitat after precipitation.

High concentration of metals:

Layers of rock and earth above the coal removed during mining commonly contain traces of iron, manganese, and aluminum and can also contain other heavy metals. These metals can be dissolved from mining sites through the action of acid runoff or can be washed into streams as sediment. Most of the water bodies in the coal mining area of Jaintia Hills have been found containing high concentration of various metals. Many metals, though common, can be toxic to fish and other aquatic organisms when present in high dissolved concentrations. Dissolved iron and iron precipitate, for example, can kill the aquatic biota that fish feed on, thus reducing the overall fish population.

Silt and suspended solids:

A significant threat to water quality and aquatic organisms comes from eroding soils at abandoned mining sites and deposition of unwanted material in the water bodies as silt. Silting of clay, sand, gravels and fine coal particles is a common feature in most rivers and streams of the mining area. Solids such as fine particles of coal, sand, mud and other mineral particles have been found deposited at the bottom of the water bodies. Besides, water was also found turbid and coloured due to suspended precipitates of iron hydroxides. Silt, fine sand, mud, coal dust and similar materials form a covering over the bottom and disrupt the benthic habitat. In addition they reduce the availability of oxygen and light for aquatic life.

Dissolved oxygen (DO):

Dissolve oxygen is essential for sustaining higher life forms in water. 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. Water of the unpolluted rivers and streams in Meghalaya contains usually very low concentration of sulphates as found in water of River *Myntdu* (3.66 mg/L). As pyrite wastes are chemically broken down, sulfate ions are produced in runoff water. Sulfates combine with water molecules and form sulfuric acid or can attach to calcium atoms to form gypsum sludge. Sulfuric acid is mainly responsible for acidity of the contaminated water. Elevated sulfate levels have also been found in AMD contaminated rivers and streams of Jaintia Hills.

Electrical conductivity (EC):

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 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

Causes of deterioration of water quality

Acid Mine Drainage:

The primary cause of degradation of water quality and the declining trend of biodiversity in the water bodies of the mining area is attributed mainly to the Acid Mine Drainage (AMD), which makes water highly acidic and rich in heavy metal concentration (Pentreath, 1994). 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. Mine drainage is generated when pyrite reacts with air and water to produce sulphuric acid and dissolved iron. During the process of pyrite oxidation, dissolved Fe^{2+}, SO_4^{2-} and H^+, followed by the further oxidation of the Fe^{2+} to Fe^{3+} are formed. Some or all of this iron can precipitate to cause turbidity of water (in the form of the red, orange, or yellowish colour), and sedimentation at the bottom of streams. The acid runoff or AMD aggravates the problem further by dissolving heavy metals such as aluminum, copper, lead, mercury etc. found in rocks and soil. As a result, the AMD contaminated surface water is not only acidic but also rich in different metals. The overall chemistry of AMD formation is summarized in reaction given below:

$$4\ FeS_2 + 15\ O_2 + 14\ H_2O = 4\ Fe(OH)_3\downarrow + 8\ H_2SO_4$$

Pyrite + Oxygen + Water = "Yellow precipitate"↓ + Sulphuric Acid

Silting:

Deposition of silt at the bottom of the rivers and streams is another important problem in coal mining areas. Solids such as fine particles of coal, sand, mud and other mineral particles were found deposited at the bottom of the water bodies. Besides, water was also found turbid and coloured due to suspended precipitates of iron hydroxides. Silt, fine sand, mud, coal dust and similar materials may be quite disruptive in streams as they destroy the benthic habitat and reduce availability of oxygen for benthic animals.

Organic enrichment:

Water bodies of the mining area appear to contain various types of organic matter which is evident by low Dissolved Oxygen (DO) and high Biochemical Oxygen Demand (BOD). High human population, lack of proper sanitation and a wide variety of anthropogenic activities associated with mining are responsible for different types of organic pollution in water bodies of the area. The organic matters are oxygen demanding hence leading to low DO and high BOD levels in water.

Impact on aquatic life

Aquatic communities of unaffected rivers and streams comprise of phytoplanktons, periphyton, macrophytes, zooplanktons, invertebrates and vertebrate species which play important role in normal functioning of the aquatic ecosystem. Any physical, chemical or biological change in water bodies affects one or all species and disturbs the normal functioning of the aquatic ecosystem. The benthic (bottom-dwelling) communities of rivers and streams consist of those organisms which grow in, on, or otherwise in association with various bottom substrates. Benthic 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 almost all insect orders, including a high diversity of insects classed in the taxonomic orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) commonly referred to as EPT taxa. Like many other potential pollutants, mine drainage causes a reduction in the diversity and total numbers, or abundance, of macroinvertebrates and changes in community structure. Water bodies affected by AMD possess a lower percentage of EPT taxa. Moderate AMD contamination eliminates the more sensitive species (Weed and Rutschky, 1971) whereas severely contaminated conditions are characterized by dominance of certain taxonomic representatives of pollution-tolerant organisms, such as aquatic worms (Tubificidae), midge larvae (Chironomidae), alderfly larvae (*Sialis*), fishfly larvae (*Nigronia*), crane fly larvae (*Tipula*), caddis fly larvae (*Ptilostomis*), and non-benthic insects like predaceous diving beetles (Dytiscidae) and water boatmen (Corixidae) etc.

(Rosemond et al., 1992). 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 caddis flies are tolerant of dilute acid mine drainage.

Fish, in natural habitat often depend for their food on small aquatic organisms including macroinvertebrates. As a consequence of depletion of aquatic invertebrates, the fishes do not get adequate supply of food and suffer indirectly from AMD contamination. AMD also has direct effect on fish by causing various physiological disturbances. The primary cause of fish death in acid waters is loss of sodium ions from the blood. Less availability of oxygen to the cells and tissues leads to anoxia and death as acid water increases the permeability of fish gills to water, adversely affecting the gill function (Brown and Sadler, 1989). Ionic imbalance in fish may begin at pH of 5.5 or higher, depending on the tolerance of the species. Severe anoxia occurs below pH 4.2 (Potts and McWilliams, 1989). Low pH that is not directly lethal may adversely affect fish growth rates and reproduction (Kimmel, 1983). It has been found that fish species are severely impacted below the pH 5.5. Water pH below 4.5 in most of the rivers in Jaintia Hills is most likely responsible for complete elimination of fish from the natural waters of the area.

Low pH, low DO, higher sulphate content and turbidity in water of coal mining areas are affecting the aquatic life. Study on benthic macroinvertebrates revealed presence of only a few tolerant species namely *Chironomus* larvae (Diptera), dragonfly larvae (Odonata) and water bugs (Hemiptera) in rivers and streams of the area. Analysis further revealed lower abundance and species diversity of macroinvertebrates. The presence of only a few tolerant species of benthic macroinvertebrates and the absence of most of the aquatic organisms particularly the sensitive species are most likely due to acidic water contaminated with AMD. Further, most of the rivers of the mining area lack commonly found aquatic organisms such as fish, frog and crustacean. On the other hand, studies done on river Myntdu, which is away from the coal mining area revealed relatively higher abundance and species diversity of macroinvertebrates. The species present in the river include many sensitive species such as stonefly nymph (Plecoptera), mayfly nymph (Ephemeroptera), caddisfly (Tricoptera) along with tolerant species listed above.

Another important source of water pollution is the organic enrichment by various anthropogenic activities leading to lower DO and higher BOD in water bodies of the area. This further makes the ambient unfit for survival of many aquatic organisms. 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 indicates diminishing life sustaining role of water in the area.

Remediation of the problem

Under prevailing grave conditions of general environment and water quality and aquatic life in rivers and streams of Jaintia Hills, there is an urgent need for initiating activities for ecorestoration of the affected areas. Here, we describe some measures to mitigate the environmental problems of the area including the improvement of water quality. Filling of 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 are some of the measures which can be helpful in ameliorating the environmental problems of the area.

Filling of abandoned mines:

Abandoned mines are continuous source of AMD, as the exposed rocks come in contact with water and air, and generate acidic seepage for long time to come. Abandoned unfilled mines cause subsistence of land mass and development of cracks that promote percolation of surface water, erosion of topsoil and generation of AMD. Hence, it is very important to fill the mines with the same overburden material that was removed during the process of mining. Additional rocks, sand and soil can also be used to fill the mines.

Extensive afforestation and revegetation of the mined areas:

Establishing vegetation on coal mined land is an important step in the process of ecorestoration. Vegetation helps in stabilizing the soil surface from erosion and controlling siltation. From the viewpoint of preventing acid mine drainage, vegetation is beneficial for reducing the amount of water and atmospheric oxygen entering the mine overburden. Some plants, particularly undergrowth helps in removal of dissolved metals and other toxic components from the water and soil. Hence, extensive afforestation of the mined areas with local and tolerant plant species will be of great help in ecorestoration of the degraded ecosystems.

Neutralization of acidity:

Various carbonate minerals such as limestone, calcite, dolomite etc. are found in nature in abundance. These materials produce alkalinity thus can reduce the effect of AMD in two ways. If alkaline water comes in contact with pyrite, the acid-generating reactions may be inhibited so that little or no AMD is formed. Alternatively, once AMD has formed, its interaction with alkaline materials may neutralize the acidity and promote the removal of Fe, Al and other metals from the water. Use of such alkaline materials in scientific manner may reduce the acidity of water and save agricultural fields and water bodies to some extent.

Conservation of topsoil:

Soil is essential for plant growth and agricultural productivity. Once lost, it takes decades in formation and regeneration. Hence, conservation of top soil is very important in the process of ecorestoration. Removal of topsoil prior to mining and its replacement as the final cover following coal mining is most beneficial method for assuring quick establishment of vegetation and ecorestoration. In addition to the benefits of topsoiling for improving vegetation and restoring pre-mining soil productivity, topsoil also helps in retention of water for plant growth. Further, topsoil limits the infiltration of water into the ground. It has been found that a final cover of topsoil on a mine backfill significantly reduces the infiltration rate of water. Limited infiltration of water means less production of AMD.

Management of AMD and Surface Water:

Proper management of AMD and surface water in mining areas can be of great use in mitigation of water pollution and related environmental problems. Channeling of AMD and its prevention from contamination of agricultural fields and water resources can save agricultural land and water bodies from degradation. Use of proper water management techniques to prevent AMD on mining sites can also control erosion and sedimentation, and surface water infiltration.

Conclusion

Water, a precious natural resource is vital for life of all organisms on the earth. Clean water is critical to the health, economic and social well-being, and quality of life. Any undesirable change in water quality affects not only the human beings and their activities but also a variety of flora and fauna of the area. As a result, the same life sustaining water turns into a life threatening substance that affects living organisms at different levels.

The rivers and streams of the Jaintia Hills, Meghalaya are the greatest victims of the coal mining. Contamination of acid mine drainage (coloured acidic seepage originating from mines and spoils), leaching of heavy metals, organic enrichment and silting are some of the major causes of water pollution. Degradation of water quality in the area is evidenced by low pH (in the range of 3 - 5), high conductivity, high concentration of sulphates, iron and other toxic metals, low DO and high BOD. Mine drainage is affecting aquatic life from elimination of all but the few tolerant species.

As a result, the rivers and streams which had supported extremely rich biodiversity and traditional agriculture, and were sources of potable and irrigation water in the area, now carry polluted water. The level of pollution has reached to the extent that water has become unfit for human consumption and irrigation, and toxic to plants and animals. Consequently, the same rivers and streams that supported human life and activities, and rich biodiversity including many species of fish, amphibians, aquatic insects etc. have now lost their life sustaining role and become nearly devoid of aquatic life. Under prevailing grave conditions of water quality and aquatic life in rivers and streams of Jaintia Hills, there is an urgent need for initiating activities for ecorestoration of the affected areas. Filling of abandoned mines, extensive afforestation, neutralization of acidic seepage, conservation of top soil, scientific management of AMD and water resources etc. will go a long way in restoration of the lost environmental glory of the area.

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