Impact of Mining on Plant Diversity and Community Structure of Aquatic and Terrestrial Ecosystems of Jaintia Hills, Meghalaya

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I **Mr. S. Jeeva**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other university/institute.

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Chapter 1

General Introduction

Tropical forests are one of the major vegetation and the most diverse groups of terrestrial ecosystem of the globe. These forests are found in tropical and subtropical belts, and inhabit major populations of plant species, and act as reservoir of biodiversity (Valencia et al. 1994; Richards 1996; Whitmore 1998; Aiba and Kitayama 1999). The forests of Meghalaya are the best example of tropical and subtropical forests. Presently, these forests are facing threats because of anthropogenic disturbances. The degradation of ecosystems and destruction of habitats due to anthropogenic activities are the major causes of decline in global biodiversity. In view of the growing threat to biodiversity, it is important to see how natural communities and their structural attributes are affected by progressive erosion of biodiversity caused by anthropogenic disturbances (Mishra et al. 2004).

The investigation of anthropogenic impacts is central to studies of global environmental change and sustainable development (Fu et al. 1998; Gong et al. 2000; Wang and Gong 1998; Withers and Dil 1999; Shi et al. 2000). Apart from causing changes in the soil environment, land use and land cover changes are regarded as important components and primary cause of global environmental changes (Turner et al. 1995; Li 1996; Wang et al. 2004). Changes in land use leads to changes in land cover, which in turn directly affect terrestrial ecosystems and biogeochemical cycles, in particular those of carbon and nitrogen (Dunn et al. 1999; Fu et al. 1999; Withers and Dil 1999). Furthermore, such changes can leads to soil loss and degradation, including the migration of soil nutrients to surface waters (Guo et al. 2001) and shifting of the soil atmosphere carbon balance (Wang and Zhou 1999; Jin et al. 2001).

Ecosystem destruction by quarrying activities, such as coal mining and limestone extraction create significant impact and degradation problems because of soil depletion and alteration in the original topography. Removal of vegetation induces a very high risk of soil erosion in these areas (Clemente et al. 2004). All these will lead to accelerated erosion of biological diversity and creation of several other environmental problems (Singh et al. 2002). The situation is particularly alarming in tropical areas where loss of forest and degradation of land, that earlier supported forest, are being destroyed at unprecedented rates (Parrotta et al. 1997). As the utilization of natural resources continues and opportunities to restore ecosystems damaged by human activities become more common, restoration is playing an increasingly important role in environmental protection (Prach et al. 2001).

In recent years with the extensive use of minerals, domestic and international demands have increased. Moreover, with the economic development of mountain areas to eliminate poverty, rare-earth mining is developing rapidly (Pensa et al. 2004; Walker et al. 2004). Though extraction of minerals is essential for developmental activities, however, this has led to a series of environmental problems such as forest destruction, soil and water loss, and environmental pollution, which will result in reduced biodiversity (Xu and Liu 1999; Yang 1999). The terrestrial and aquatic ecosystems adjoining the mines become adversely contaminated leading to loss of biodiversity and depletion of other natural resources. All such environmental perturbations exert tremendous pressure on human health and socio-economic fabric of the society. These in turn, have multifaceted repercussion at local, regional and global level (Singh 2005).

The environmental impacts of mining operations commence with exploration activities, extend through extraction and processing of minerals, and may continue with post closure of the operation, where the nature and extent of impacts vary throughout the stages in mining operation. Large scale denudation of forest cover and depletion of biodiversity, scarcity of water, pollution of air, water and soil, and degradation of agricultural lands are some of the serious environmental implications of mining (Mishra et al. 2005). Besides, caving in of the ground, subsidence of land and haphazard dumping of minerals and overburden, deteriorate the aesthetic beauty of the landscape and leave scars on the face of the earth (Chaulya 2004).

The mineral extraction processes drastically alters the physical and biological nature of a mined area (Corbett et al. 1996). As a result of mining, significant areas of land are degraded and undesirable waste materials in the form of dumps and tailings replace existing ecosystems around the world (Kleiv and Sandvik 2000). Moreover, tailings are almost completely devoid of vegetation due to toxic level of heavy metals and other unfavorable edaphic conditions. The bare surfaces of tailings are susceptible to wind and water erosion and act as a continuous source of metal contamination to the surroundings (Shu et al. 2005; Tordoff et al. 2000). In addition, the common method of mining increases drainage and the physical and chemical erosion of the substrate, hindering natural germination and establishment of young plants, thus delaying recolonization (Sort and Alcaniz 1996). Degradation of aquatic ecosystems and receiving water bodies, often involving substantial reduction in water quality, can be among the most severe impacts of mining.

Water draining from mining areas are often seriously affected by run-off from operating and abandoned mine workings. Effluents typically consists of acid mine drainage (AMD), eroded material from mine tailing deposits and waste from ore processing operations (Salomons 1995). AMD is a result of complex and interactive suit of physical, chemical and biological processes operating within the waste material. The major factors controlling the rate of oxidation include:

- pH,
- acid neutralizing capacity,
- temperature,
- concentration and reactivity of redox species,
- oxygen availability,
- concentration of carbon dioxide,
- nutrient requirements,
- sulphide mineralogy and particle size,
- galvanic interactions,
- hydrogeology.

AMD is evolved from reduced sulfur materials that have been oxidized on exposure to water and oxygen, and a process often brought about through mining activities (Hallberg et al. 2005). In a large proportion of the literature, AMD is summarized by a chemical equation giving the reader the impression that it is a pure inorganic process. However, numerous publications have shown that in a sterilized sample of the waste material there is hardly any leaching of metals at all unless other oxidizing agents, other than bacteria, are present like ferric iron. The role of bacteria and chemical processes in the dissolution of sulphide minerals has been summarized by Singer and Stumm (1970) for oxidation of pyrite.

$$FeS_2(s) + {}^{7}/_{2}\,O_2 + H_2O \xrightarrow{\text{microbially}} Fe^{2+} + 2H^{+} + 2SO^{2}{}_{4}^{-}, \tag{1}$$

$$2Fe^{2+} + \tfrac{1}{2}\,O_2 + 2H^{+} \xrightarrow{\text{microbially}} 2Fe^{3+} + H_2O, \tag{2}$$

$$FeS_2(s) + 14Fe^{3+} + 8\,H_2O \xrightarrow{\text{Chemically}} 15Fe^{2+} + 2SO^{2}{}_{4}^{-} + 16H^{+}, \tag{3}$$

$$Fe^{3+} + 3H_2O \xrightarrow{\text{Chemically}} Fe(OH)_3(s) + 3H^{+}\,. \tag{4}$$

Attempts to demonstrate that microbial action duplicated by ferric iron alone have not been definitive, and have led to the suggestions that both direct and indirect bacterial action may be operating simultaneously (Ehrlich 1990). Apart from iron, other heavy metals are also released since many heavy metals are incorporated in pyrite (FeS_2), and other sulphides can also be leached accordingly. The most active bacteria involved in the leaching of sulphide minerals are *Thiobacillus thiooxidans*, *Leptospirillum ferrooxidans* and *Acidithiobacillus ferrooxidans* (Bosecker 1997; Kelly and Wood 2000).

The pyrite oxidation reactions produce sulfuric acid and ferric hydroxides and mobilize other trace metals depending on the surrounding mineralogy (Schmidt et al. 2002). These toxic acids and metals flow to surface waters, where the acid is eventually neutralized, causing metals to precipitate and coat streambeds with metal oxides, impairing the habitat and adversely affecting the water quality in rivers (Office of Surface Mining 1995). The biotic effects associated with AMD impact surface waters including acute impairment of aquatic life as a result of low pH and elevated levels of dissolved heavy metals (Henry et al. 1999; Kullberg et al. 1992; Schmidt et al. 2002).

The contamination of soil with trace elements is considered a serious localized problem related to mining activities. Heavy metal contamination from mining activities creates a wide spectrum of hazards under an equally wide spectrum of contexts. Gaseous, particulate, liquid and solid waste discharges into the environment from mines cause soil and water acidification, air, water, soil and plant contamination by trace elements, deterioration of soil biology and fertility, and soil erosion. The environmental concern in mining areas is primarily related to mechanical damage of the landscape, trace elemental pollution and acid mine drainage (Anju and Banerjee 2005).

Historically, mining is next to agriculture, the world's oldest and most important activity. Exploration, extraction and utilization of minerals are important for the economic growth. India is endowed with significant mineral resources distributed all over the country, including the seabeds. In India, the number of mines and the production of minerals have increased substantially (Singh and Vasistha 2004). The total number of mines has increased by 42 per cent and the production of coal, iron, copper, bauxite and limestone has increased by 4, 11, 33 and 16 times, respectively from 1957 - 1985 (Anon 1990). India has an estimated 85 billion tones of mineral reserves remaining to be exploited.

Meghalaya has rich deposits of coal and limestone. The coal deposits occur along the southern fringe of Shillong plateau over a length of 400 km (Coal India 1986). In the hills of Meghalaya, coal bearing sedimentary formation is sub-horizontal to gentle deep in nature. Coal and limestone are mainly found in Khasi Hills, Garo Hills and Jaintia Hills of the state. The total coal reserve of Meghalaya is about 560 million tones. However, limestone deposits are around 5,000 million tones (Mineral Resources 1998), among these 531 tones of limestone has been estimated from the western part of Jaintia Hills, Meghalaya (Ministry of Mines 2006). The total coal and limestone reserves in Jaintia hills have been estimated to be about 40 and 1,050 million tones, respectively. These reserves are mainly situated in Sutnga, Lakadong, Musiang – Lamare, Khliehriat, Ioksi, Ladrymbai, Rymbai, Bapung, Jarain, Shkentalang, Lumshnong and Sakynphor. Coal is embedded in sedimentary rocks, sandstone and shale of the Eocene age. These three types of coal seams vary from 30 to 212 cm in thickness (Guha Roy 1992).

Mining operations in Meghalaya is being done mainly with the most traditional and unscientific methods and have led to massive environmental degradation. It affects the land, water and community health, particularly when the ecological and occupational considerations are not given due importance. Extraction of coal in Jaintia hills is done by primitive mining method commonly known as ‘rat-hole’ mining. In this method, the land is initially cleared by cutting and removing the ground vegetation, and then pits ranging from 5 – 100 m^2 are dug vertically in the ground to reach the coal seam. Thereafter, horizontal tunnels are made into the seam for extraction of coal, which is brought back to the pit by using a conical basket or a wheelbarrow. The entire process of mining is done manually employing small implements. While digging the pits, the pieces of soil and rocks above the coal seams are thrown haphazardly outside the pit creating coal mine spoils that cause large-scale destruction to the surrounding agricultural cropland and vegetation, often beyond replenishment. The prevailing land ownership system encourages this kind of unscientific mining operation in the area (Lyngdoh et al. 1992; Das Gupta 1999; Swer and Singh 2005).

Jaintia Hills has a large number of ? and rivers and streams that drain the undulating landscape of the area and serve as important sources for drinking, irrigation and support a rich array of floral and faunal diversity. Unfortunately, rampant coal mining has adversely affected the quality of water of most water bodies. Acid mine drainage originating from mine 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.

An understanding of the environmental impact of mining on aquatic and terrestrial ecosystem is a prerequisite for effective management practices. Keeping the above facts in view, the present research work intends to study the impact of coal and limestone mining on aquatic and terrestrial ecosystems of Jaintia Hills, Meghalaya. To achieve the above goal, two objectives were framed: (a) to determine the water and soil characteristics affected by coal and limestone mining and (b) to study plant diversity and community characteristics in the mining areas.