

Land Degradation due to Mining in India and its Mitigation Measures

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Abstract—The impact of mining activities on pollution of air, water, land, soil quality, vegetation including forest ecosystems, and on human health and habitation has become a matter of serious concern. Any deterioration in the physical, chemical, and biological quality of the environment affects human health and flora and fauna. The health problem of miners arising out of on-site pollution due to dust, gases, noise, polluted water, etc. is receiving increasing attention. The magnitude and significance of impact on the environment depends upon the mineral being mined and mining practice, and the potential of the environment to absorb the negative impacts. Some of the negative impacts on the landscape and the human environment can effectively be permanent. While some segments of the minerals industries, governments and others are much more conscious of these issues, it has been observed that effective sector-wide management of these problems is neither universal nor adequate. The current paper presents a status report of the extent of land degradation caused by mining of some important minerals in India and discusses various practices that can be adopted to control them. It is suggested that the land reclamation should be a continuous process and should be carried out in a scientific manner.

Keywords- mining; land; stripping ratio; reclamation

I. INTRODUCTION

Mining activity exerts a long lasting impact on landscape, eco-system and socio-cultural-economic considerations. It is noteworthy to mention that the actual land mass available to man kind is just 30% of total global surface area. India's land area is about 2-3% of the global land area, where as it supports more than 16% of the global population. This important statistics reveals that the poor per capita land holding stands at 0.32 hectares, which calls for due attention to restoration/reclamation of land after mining in order to utilize the land for useful purpose.

Mining and its subsequent activities have been found to degrade the land to a significant extent. Overburden removal from the mine area results in a very significant loss of rain forest and the rich top soil. Overburden removal is normally done by the process of blasting or using excavators, which results in generation of large volume of waste (soil, debris and other material). This is useless for the industry and is normally just stored in big piles within the mine lease area, and sometimes, on public land. The bigger the scale of the mine, greater is the quantum of waste generated. Opencast mines are therefore more pollution intensive as

they generate much higher quantities of waste compared to the underground mines. Open-pit mines produce 8 to 10 times as much waste as underground mines [1].

II. LAND DEGRADATION

The ratio of overburden excavated to the amount of mineral removed is called the stripping ratio. For example a stripping ratio of 4:1 means that 4 tonnes of waste rock are removed to extract one tonne of ore. Lower the ratio, the more productive the mine. Stripping ratio varies with the area under mining. According to the data generated by the Indian Bureau of Mines, average stripping ratio for limestone mines in India is 1:1.05. For large-scale cement sector with captive mines, the average stripping ratio is only 1.05. This is quite good; however, the generation of overburden varies from mine to mine. It is as high as 1.363 tonnes per tonne of limestone in case of Madras Cement Limited: KSR Nagar Jayantipuram to 544 kgs per tonne of limestone in case of ACC's unit at Jamul [2]. For iron ore mines, the stripping ratio ranges around 2-2.5. This means that for every tonne of iron ore produced, double the quantity of waste is generated. In 2003-04 itself, iron ore mines of Steel Authority of India Ltd. (SAIL) generated 4.76 million tonnes of overburden and rejects from its 12 mines in the country [3].

The coal mines of Coal India Limited (CIL) removed about 500 million cubic meters (Mcum) of overburden (OB) to produce 260 MT of coal in 2003-04 at an average stripping ratio of 1.92 m³ of OB against per tonne of coal production [4]. As demand for coal increases to meet the country's energy requirement, the coal companies are digging deeper and deeper and even opting for lower grades of coal. The country is even planning for production from 300 m depths at stripping ratio of 1:15 for D and F grade quality of coal. If these mines were operational, it would mean that even if 1 million tonnes of coal were extracted, it would generate 15 million tonnes of waste material. This is huge quantity and in a country like India where land is at premium, it would be very difficult to find enough land to store this waste.

Bauxite ores in India are harder and have a higher stripping ratio when compared to the Australian counterpart. 20 Indian bauxite has a stripping ratio of around 1.2 as compared to only 0.13 in Australia [5].

Though most mining wastes, such as overburden, are inert solid materials, the industry also generates waste that is

toxic in nature. Some of these toxic are inherently present in the ore, for example, heavy metals such as mercury, arsenic, lead, zinc, cadmium, etc. These heavy metals leach out of the stored waste piles, contaminating the local environment. However, some toxic chemicals are also found in waste, as they are added intentionally during extraction and processing.

Impact of mining on land environment gets reflected in land-use pattern of the respective area because the more the land gets exposed to erosion by losing its green cover or by getting disturbed otherwise due to mining (excavation, overburden dumping etc.) and related activities, its water resources gets damaged, soils get contaminated, part or total of flora and fauna gets lost, air and water gets polluted and the more damages go on proceeding in accelerated rates and the cumulative effects push the land towards degradation. The process works through a cycle known as land degradation cycle.

The magnitude and significance of impact on environment due to mining varies from mineral to mineral and also on the potential of the surrounding environment to absorb the negative effects of mining, geographical disposition of mineral deposits and size of mining operations. A list of minerals has been prepared by Department of Environment, the mining of which is supposed to have serious impact on environment. These minerals include coal, iron ore, zinc, lead, copper, gold, pyrite, manganese, bauxite, chromite, dolomite, limestone, apatite and rock phosphate, fireclay, silica sand, kaolin, barytes. Mineral production generates enormous quantities of waste/ overburden and tailings / slimes which are indicated in table 1 in respect of some minerals. These details have been worked out with the help of actual production figures and the projections made in respect of overburden/waste and tailings/slimes [6, 7]. Though the Table 1 given below is not exhaustive, nevertheless it gives some idea about the quantities of mineral and waste material to be handled. Actual data are not available on the extent of land occupied by mining operations including waste disposal sites. It is however, estimated that about 13546 ha of land was affected in 2005-06.

The total area of mining lease with active mining operations is the minimum area which is being affected by waste generation. However, the actual off-site area affected by pollution and degradation by the accumulation of waste material will be far more than the area of the lease in which the operations are in progress. It is also possible that a

number of mines may exist in a close cluster adding to the adverse effects. Accumulation of tailings and red mud will add to the seriousness of the environmental adverse effects. In addition, there are a very large number of abandoned mines and mining sites for which detailed information is not available.

However, in most of the cases it has been observed that the damage due to mining activity has been reflected on decrease in green cover or water resource or both. Greenery bears a pivotal role in protecting the quality of all aspects of environment, also in many cases it is considered as a desired indicator of protector of environmental quality in the region. Regarding desired land use pattern, our National Forest Policy has fixed the national average forest cover at 33%. Though this realization generated long back, the country is still far behind the desired level in this matter. This fact indicates that there is still some drawback in the land-use management system. Strategies need to be developed including policy intervention, promoting research and stakeholder participation, and technological intervention to check land degradation.

III. LAND RECLAMATION METHODS

The National Academy of Sciences, America has defined three categories of remedial treatment:

Rehabilitation: The land is returned to a form and productivity in conformity with a prior land-use plan including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Reclamation: The site is hospitable to organisms that were originally present or others that approximate the original inhabitants.

Restoration: The condition of the site at the time of disturbance is replicated after the action.

According to these definitions, Rehabilitations usually permits the greatest flexibility in future land use and incurs the least cost. Reclamation infers that the pre- and post disturbance land uses are nearly the same. Restoration allows no land use flexibility and incurs the greatest cost. There are various perspectives regarding the most appropriate goals for land treatment. Generally, the industry favours rehabilitation, regulatory authorities favour reclamation, and many ecologists favour restoration. The central issue often is future land use

TABLE 1. Mineral Production, waste generation and land affected in 2005-06

Sl. No.	Mineral	Production (MT)	Overburden/waste (MT)	Estimated land affected (ha.)	Norms used (land in ha/MT of coal/ore)
1	Coal	407	1493	10175	25
2	Limestone	170.38	178.3	1704	10
3	Bauxite	12.34	7.5	123	10
4	Iron ore	154.4	143.9	1544	10
5	Others	9.44	18.61	-	-

requirements and whether returning to the pre disturbance use constitutes the best use of land.

Post mining site reclamation and restoration is the final and crucial stage, which requires proper planning. It must be clearly understood that the reclamation should not be confined necessarily towards the decommissioning phase of the project. Rather site reclamation should be progressive such that rate of restoration is more or less similar to the rate of mining.

The reclamation process consists of several key features that must be studied carefully for effective land restoration [8]:

Mapping, in order to delineate the areas of direct and indirect environmental degradation with the use of accurate and appropriate techniques, viz. scaled maps, remote sensing and aerial photographs etc.

Geological and geotechnical investigations for the strata that is likely to influence restoration. This includes the field and laboratory testing of soils and materials to investigate the parameters that are essential for sustainable restoration. For example the toxicity of the soil, stability of waste dumps need to be investigated before reclamation is carried out.

Meteorological and climatological investigation in order to collect standard data (temperature, amount of rainfall, humidity and wind patterns etc.) and to assess their influence on atmospheric and water pollution.

Hydrological conditions at a site include the quantity, quality, movement and storage of water above and below the surface. Hydrology is determined by upslope and onsite characteristics of climate, geology, topography, soil and vegetation. Climate provides the water input to the hydrologic system whereas the other parameters determine the movement of water into and across the surface.

Topographic conditions refer to the surface configuration of an area described as rugged, rolling, gentle or smooth. The topography surrounding the disturbed sites also influences reclamation plans and practices. The reconstructed surface must blend with the undisturbed landscape so that matter and energy fluxes smoothly travel through the reclaimed surface.

Soil condition including the soil's water holding capacity controlled by the combined factors of texture, aggregation, bulk density and over all depth directly

influences plant productivity, leaching potential and ground water replenishment.

Vegetative condition particularly the quality, quantity and diversity of vegetation at a site reflect the entire environment setting in addition to the past and present human activities. The plant community in an area may be native and introduced, sensitive and tolerant, common and endangered species.

IV. RECLAMATION PLANNING

The goals for reclamation can be viewed from theoretical and practical perspectives. Simply put, a reclamation project should aim to produce environmentally sound and stable conditions that ultimately integrate the disturbed area into the general ecosystem. Accordingly, a reclamation plan should address the topographic reconstruction, topsoil replacement or substitution, revegetation and site monitoring and maintenance.

Topographic Reconstruction

Most natural landscapes are composed of drainage basins which in turn consists of hill slopes and stream channels in an orderly arrangement for effectively conveying water and sediment. These gets disturbed during mining. The character of the post reclamation equilibrium differs from that of the pre-disturbance equilibrium because geologic and soil properties can not be replicated. Topographic design, therefore should be based upon expected properties following reclamation rather than pre-disturbance properties. Care is also to be taken to minimize erosion and runoff where ground cover is temporarily removed. Special flood-control and sediment-control measures are necessary to prevent damage. The importance of topographic reconstruction can not be neglected because the resulting landforms are the foundation upon which other reclamation practices are executed and eventual land uses take place.

Replacement of Topsoil and Soil Reconstruction

Revegetation of the reclaimed surfaces require a suitable growth medium. In most cases, top soils have the necessary physical, chemical and biological properties to sustain plant development, although the use of substitute

geologic materials is often inevitable. In general top soil layers are higher in organic matter, microbial activity, and nutrients than underlying subsoil or geologic material. Top soils contain significant seed bank that can be used to great advantage in revegetation. Stock piling and reuse of top soil almost always facilitates achievement of reclamation goals. When spoil or other coarse-textured materials are revegetated without top soil covers, moisture stress induced by compaction, high coarse-fragment contents, salts, and high surface heat is usually the primary factor limiting growth. Therefore as far as practicable the top soil should be stored at a suitable place with proper precautionary measures so that it could be utilized during reclamation process. Some of the best practices involved in the topsoil management are:

- Scrap the top soil prior to drilling and blasting
- Scrapped topsoil should be used immediately for plantation work; otherwise it should be stacked in a designated area.
- Stacked topsoil should be surrounded by proper embankments to prevent erosion.
- Stacked topsoil should be stabilized further by grasses and bush to protect from the wind.

Revegetation

Revegetation is a principal goal of reclamation and results in many desirable secondary water quality and aesthetic benefits. Revegetation goals are from simple erosion control to the full restoration of complex native communities. The approaches and protocols employed, therefore, are specific for region, site and land use. The development of a permanent vegetation cover should aim to establish a plant community that will maintain itself indefinitely without attention or artificial aid, and support native fauna. To extract better results, some ecological variables must be considered while selecting species for plantation. These are; their capacity to stabilize soil, soil organic matter and available soil nutrients, and under storey development. In the initial stages of revegetation quick growing grasses with short life cycle, legumes and forage crops are recommended. It will improve the nutrient and organic matter content in soil. Plantation of mixed species of economic importance should be done after 2-3 years of growing grasses. While selecting suitable species for plantation in mine area, the following considerations have to be taken into account:

- ✓ Planting pollutant tolerant species.
- ✓ Plants of fast growing with thick vegetation foliage
- ✓ Indigenous/exotic plants species with easy adaptability to the locality.
- ✓ Socio economic requirement of the people of the surrounding area.

The benefits of vegetation are of immense benefit to the local inhabitants. Some of these have been demonstrated in Figure 2 [9].

V. CARE AND MAINTENANCE AND MINE CLOSURE PLANNING

On the cessation of mining, a process of decommissioning with a follow up programme of reclamation/rehabilitation should start. This should include adoption of preventive measures against slope failure, managing toxicity of tailings or waste rock which may limit re-vegetation and preventing acid drainage from abundant pits, tailing etc. A participatory management for care and maintenance of the reclaimed area may ensure a process of benefit sharing specially from the forest, that are grown, as a major work component of reclamation plan.

VI. CONCLUSION

In principle, the areas or resources affected by mining should be returned to a safe and productive condition through rehabilitation, which may or may not involve a return to pre-mining conditions, and reclamation should be an ongoing activity throughout the life of the operation as well as after decommissioning. The mining industry, the government and the local people must work together to care for future generations. There is also a need for better planning of reclamation/restoration system to bring back the derelict land in short time for use. It takes time, money and certain degree of geological good fortune to transform disturbed mined land in to a park, forest, lakeside, farmland or further industrial development etc. Sometimes, land value and materials may not support the mining project for land reclamation since the cost of reclamation may be very high. Hence constant research and development efforts are required to find out newer and latest technologies and methodology to reclaim the land for better use since economic development must have respect for environmental integrity.

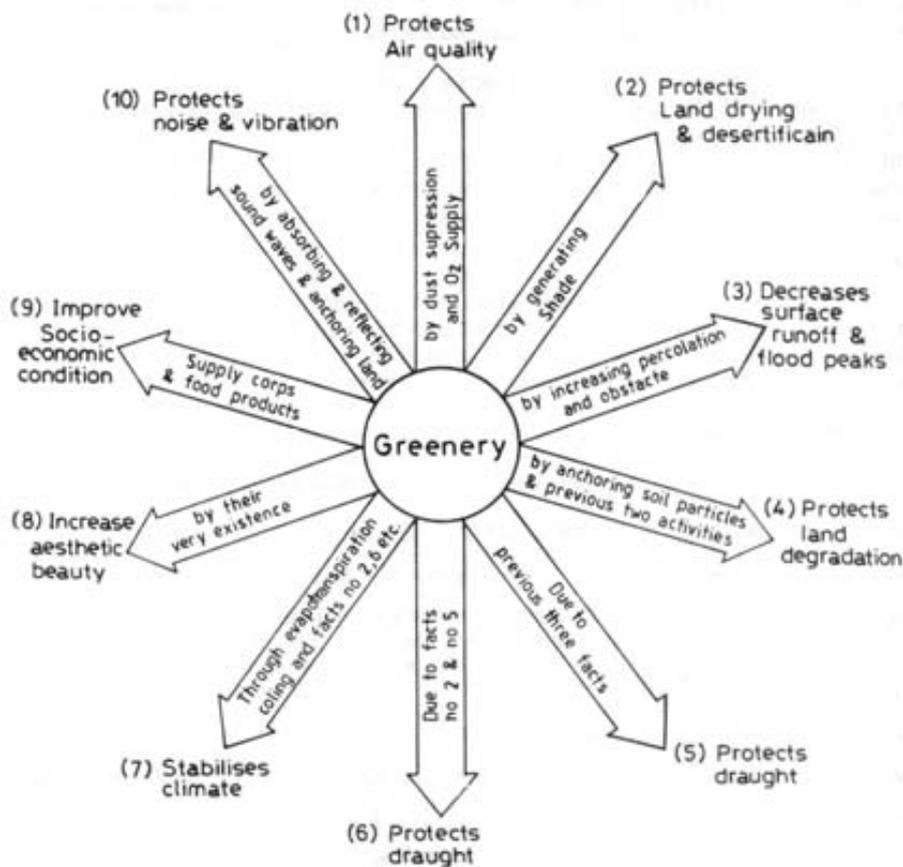


Figure 2: Role of greenery in protecting environment

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