



Stages in the life of a mine and their environmental impacts

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Abstract

Mining industry provides economic boost to a nation and is an indispensable activity. It generates employment and help to builds infrastructure which provides an impetus for the improvement of standard of living of the people. Mining adversely impacts the ecology and biodiversity by altering air, water and soil in and around the mine site and it is ironical that this activity cannot be carried out without any negative impact on the environment. The paper seeks to identify the adverse environmental impacts associated with individual stages of the mining activity. Since mining activity is intrinsically harmful, therefore there is need to develop and implement practical ways to protect the environment.

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Introduction

Mining is defined as a process of extracting minerals and valuable minerals from Earth's surface and the seas. In India, the practice of mining dates back to the year 1774 when the East India Company had granted permission for coal mining in West Bengal. Later, oil drilling began in India in the year 1866 and in 1880, gold mining was started in Karnataka. Before independence, the mining activity was done at a moderate scale and it was only after the India gained independence, it increased at a faster pace to meet the growing needs.

The ores recovered from the mining process provide several benefits including precious minerals and industrial materials for building infrastructure like homes, hospitals, highways, airports etc. This industry is one of the core sector industries which play a significant role in the economic development of a country and makes a country rich. India is the largest producer of sheet mica, the second largest producer of steel in the world and is at the seventh position in terms of bauxite reserves.

Due to the advantageous strategic location, India produces 95 minerals which contribute significantly to the economy. According to the data released by the Government, Indian mining industry is valued at around 2.8 lakh crore rupees. Recently, the Hon'ble Prime Minister of India, Mr. Narendra Modi has in June 2020 launched commercial coal mining which is considered a big step by the experts towards making India self-reliant in terms of the energy sector.

In addition to economic development, mining immensely benefits the local communities as the minerals which are extracted from mining activity are essential foundation of life and are continually used by the society. The mining industry generates employment, business, wealth and everything which a country needs for its development. According to the yearbook of Indian Bureau of Mines published in 2018, the Indian mining sector had employed around 4.77 lakh people in the financial year 2018. With the improved household income, the mine workers are

able to provide better health care and nutrition to their families ameliorating the overall standard of living. Not only at the individual level, but also at the community level, infrastructure including rail, roads and water is considerably brushed up owing to mining advancements. The giant mining industry in the State of Goa used to support about 3,00,000 people before being shut down by an order of the Supreme Court of India.

Mining: An Impediment in Environmental Pursuits

The list of benefits arising from the mining industry is long, but the fact that a just balance between 'mining activity' and 'sustainable development' is indispensable cannot be overlooked as well. Like all the other industries, mining activity adversely affects the environment. It affects the natural environment and leads to loss of natural resources.

It disturbs the natural habitat in and around the mine sites, lowers the water table, cause land degradation and makes it unstable. The supplies that are provided to the mine site, the roads which are accessed to ship the processed products and the activity of constructing roads to facilitate the inflow of heavy vehicles to the mine site have irreversible adverse impacts on the environment. As the mine sites are usually located in remote areas, the trees are cut down in order to make way for installation of equipments and transportation of mined materials. The mining activity not only disturbs the ecosystem and cause environmental degradation, but also takes away cultural heritage and many other things which are spiritually important to the people living in that area. The impact of mining industry on the environment has been particularly highlighted in the recent years after its effects are better understood by the general public.

Objectives of the Study

The main aim of the present study is to identify the adverse environmental impacts caused by different phases of a mining project like the exploration and development phase specifically on the water, air and soil. The present study also identifies the potential

threats posed by the waste generated during the mining activity. The study sets itself to achieve the objective of emphasizing the importance of attainment of sustainable development goals during all the stages of the mining operations. It also seeks to highlight the role of mining companies towards rehabilitation of the mined lands.

Inception of Sustainable Development in the mining regime

For the first time, the Stockholm Conference of 1972 opened eyes of the world community by raising the 'Environmental Issues' globally. This was followed by an International Round Table Conference on 'Mining and Environment', held in the year 1981 in Berlin. Later, in 1987, the Brundtland Report introduced a revolutionary concept of 'Sustainable Development'. The report defined a 'development' as 'sustainable' only if it is able to meet the present needs while ensuring that the future is able to meet its own needs. In 1992, 'Earth Summit' was organized in Rio De Janeiro, Brazil which was intensely devoted towards the concept of 'Environment and Development'.

In the present time, owing to the accelerated growth and development, 'Environmental Degradation' is recognized as a survival issue by the developing countries as well, which was earlier seen largely as a problem of the industrialized nations. Therefore, a need has arisen to maintain a balance between 'Development', 'Environment' and 'Mining'. This balance was also recognized as a theme of World Bank Conference, 1994 held at Washington DC and also at Round Table Conference on Artisanal Mining, 1995.

Sustainability is an essential pre-requisite of a mining activity. In the recent years it has been seen that the companies are improving their policy objectives aiming at maintaining economic viability along with their social and environmental responsibility. There have been several initiatives taken by some companies to ensure that the mining corporations meet the requirements of sustainable development. For instance, Mining Association of Canada has established a program in 2004 and participation in

this program is mandatory for all the members of Mining Association of Canada. The objective of this program is to meet the need of the society for minerals in a way which is socially economically and environmentally responsible. Regular assessments, performance reporting, consultations with the affected communities are some of the features of this program. In Australia, many sustainability projects have been undertaken to reduce the environmental impact caused due to mining operations. For instance, a solar plant is built at De Grussa Mine, located about 900 km north of Perth to meet the power needs so that there can be an increase in the renewable energy.

Judicial Perspective

The importance of integrating sustainable development in the mining regime has been particularly emphasized in the Indian context in the recent years. Owing to its inherent nature, mining operations affects the quality of water, air and soil adversely. It drastically modifies the landscape and dangerously affects biodiversity. Mining activity disrupts the flora and fauna and disturbs the ecological balance of an area to such an extent that many species across the world are on the brink of extinction. The Hon'ble Supreme Court of India has also passed some flagship judgments concerning environmental sustainability of the mining sector. One of such judgments is *Samaj Parivartana Samudaya & Ors. v. State of Karnataka & Ors.*, popularly known as Bellary iron ore mining case. This case highlighted the rampant iron ore mining in Karnataka that led to environmental devastation. The report filed by Karnataka's Lokayukta in 2008 alleged massive scale irregularities in the mining activity undertaken in Bellary. Mining was being done in the state without obtaining environmental clearance and outside the scope of law. Consequently, while noting that due to over exploitation of the mineral reserves considerable damage has been caused to the environment, the Hon'ble Apex Court imposed a ban on the mining operations in the year 2011. The Court observed that the essence of Article 21 of the Constitution of India and the precautionary principle

warrant suspension of these operations. In the year 2013, referring to Article 48A and 51A of the Constitution of India, the Court held that ecology and environment are national assets and they are subject to intergenerational equity. Similarly, in *Goa Foundation v. Union of India & Ors.*, to investigate the mining irregularities in the leases issued in the State of Goa, a commission under the Chairmanship of Justice M.B. Shah was appointed by the Central Government. The Hon'ble Supreme Court took serious note of the report filed by the Commission's and held that the mining department of the State of Goa and the State Pollution Control Board failed to perform their duties to control pollution and regulate mining. While acting as a guardian of our rights, the Court tried to strike a balance between environmental and ecology through the principle of sustainable development and intergenerational equity.

Individual Mine Stages and Environmental Impacts

A mining activity is broadly categorized into four stages i.e. Exploration stage, Development stage, Extraction Stage and Beneficiation Stage. The exploration stage begins with the compilation and examination of geological information, maps and information gathered by satellites and aircraft. It mainly involves the identification of the minerals followed by drilling at the target area and demarcation of the ore bodies. To ascertain the location and volume of mineral deposit available for extraction, many surveys, field studies are undertaken. The satellite-based devices like low flying aircrafts cause disturbance to the people inhabiting the area and drilling results in surface water and groundwater pollution. These exploratory activities sometimes include clearing of vegetation to allow ingress of heavy vehicles. Only after the project proponent finds sufficient evidence indicating existence of mineral ores, the mining activity progresses.

The next stage i.e. Development Stage includes preparation of the mine site and building of roads etc. The construction of access roads for the movement of heavy vehicles, huge machineries and heavy equipment to and fro the mine site generate dust and noise. Also, to clear the land, deforestation is mercilessly done

without any prior planning for rehabilitating the mined land. This majorly affects the wildlife and aquatic life in the area around the mine site.

After the site preparation is completed and the equipments are placed suitably, the actual process of extraction and concentration begins. Usually, the method of extraction involves the removal of waste rock, which is the hard layer of soil covering the metal ores. During extraction of ore, rocks are drilled and blasted and the final product is shipped to the market which considerably disturbs the surrounding environment. Blasting causes noise pollution and during the process harmful gases like sulfur dioxide are emitted in the atmosphere.

It also causes vibrations that affect the entire region and sometimes even lead to visible cracks on the buildings. To reach the ore, drilling is done resulting in generation of dust and fine ore particles. These particles are sometimes inhaled by the local inhabitants and mine workers leading to serious respiratory problems. Medical studies have proven that harmful exposure to different chemicals lead to bronchitis, cancer and various eye ailments.

The next step after blasting is milling in which the ore is separated from the waste. Milling is an important part of the beneficiation process which improves the value of an ore economically by separating the high-quality product and the waste material.

To carry out beneficiation, various methods such as floatation, gravity separation, magnetic separation, amalgamation and leaching are employed. Leaching is usually done when silver, copper and gold ores are to be extracted. In leaching, the solution is treated with chemical called cyanide. After the ore has been successfully extracted from the cyanide solution, the solution is left abandoned resulting in many environmental issues. Sometimes accidental spills occur resulting in their leakage in the natural environment thus creating imbalance in ecosystem. If this is not properly managed, then the effect on human life, wildlife, environment and natural resources is irreversible.

Sometimes after the mineral ore is extracted, the process of grinding is employed in which the extracted ore is grinded into any fine particles to obtain the good grade ore. The useful metallic ore is then shipped to its destination while huge waste deposits are dumped near the mine sites and ignored. The transportation of the final product outside the mine site also disturbs the environment. The quality ore is only a few percent of the total rock and therefore enormous waste is generated. These tailings are often discarded without any the treatment resulting in long-term impact on the environment. Dangerous chemicals continue seeping from the tailings and getting mixed in the atmosphere posing threat to the ecology and biodiversity.

Impact on Water

Water is a renewable natural resource required for basic things like washing, drinking, growing crops etc. Industries like mining industry and other construction and manufacturing industries consume large quantities of water. However, besides the increasing concern for the depletion of water, its contamination is a real problem affecting millions of people worldwide. In particular, mining activity severely affects the quality of water and makes it unfit for human consumption.

Water is used in large quantities throughout the mining process and water contamination occurs at nearly all the stages of this activity. During several mining processes, huge boulders are pushed towards the sides leading to dissolution of minerals like iron, cadmium, lead etc. in the water. This results in killing of several organisms and destruction of the aquatic life. In the process of milling itself, water is used in large quantities causing its potential contamination. However after the process is over, it is usually left abandoned. This untreated water comes in contact with environment and the results in environmental degradation.

Mining affects the quality of water in broadly four ways. The first and the most lethal way by which mining affects the water quality is through Acid Mine Drainage. It is a major source of water pollution in

and around the mine site. Typically, Acid Mine Drainage is generated in huge quantities during coal mining. Mining of coal leads to exposure of materials containing sulphide which reacts with oxygen resulting in formation of acid. This acid gets mixed with the water resources and impacts the rivers, streams and aquatic life. The constituents present in large quantities in the Acid Mine Drainage are aluminium, calcium and sulphate. In the areas which receive moderate to high rainfall, the situation is even worse. Rainfall triggers oxidation and the acid water gets mixed with the water bodies rapidly. This water when fetched to vegetation makes it toxic as well. Acid Mine Drainage affects the environment even after mine closure as it continues to leak from orphaned and abandoned mines also. The Tsolum River in Canada is an example of the toxic legacy mines have left behind. Once rich with life, this river now is not able to sustain its native 'salmon species' due to release of Acid Mine Drainage from now abandoned copper mine located adjacent to it.

Secondly when the heavy measures present in a mineral are exposed to the environment, they leach and get mixed with the water thereby disturbing its pH level. The lowering of the pH level of water, makes it highly acidic and corrosive. The dust generated during mine site preparation and excavation of ore also disturbs the aquatic life by penetrating into the nearby water bodies.

Thirdly, the chemicals which are used to extract the ore from a rock sometimes accidentally leak and spill in the water bodies making it highly contaminated. The aquatic life dependent on these water resources are not able to bear the toxicity and get eliminated.

Lastly, the construction of mine site, movement of heavy vehicles and the digging of pits disturb the entire vegetation and wildlife habitat in and around the mine site. This creates an imbalance in the physical, chemical and biological quality of an area. It is possible to treat the mine water by simple ways like treating it with materials like limestone and caustic soda which helps in settling of the dissolved metal in the water and

increasing its pH level. Other methods which can be used to treat water are filter systems, sedimentation ponds and passive water treatment methods using plants or soil to filter the contaminants.

Impact on Soil

Soil is an important constituent of a nation's agroecosystem and is an essential requirement for human and animal sustenance. It is a habitat for organisms, contributes to biodiversity and is a growing medium for vegetation. It supports the environmental and human health by providing the very basic and essential food, fuel and feed. However, industrial activities including the mining activity strips the soil of its surface features thereby completely distorting its organic and natural matter.

The initial steps of a mining activity require clearing of top soil which leads to devastation of agricultural lands and uncontrollable soil erosion. This loosened soil gets washed away and comes into contact with waterways, disturbing the plant life and aquatic life downstream. The removal of soil layers also destabilizes the land and destroys the soil properties. The waste rocks and tailings also contribute to sedimentation and soil pollution.

Sometimes, the mine water containing chemicals pass through the fields or seeps in the water table changing the soil structure and reducing its fertility. Researchers working in a UNESCO project in South Africa have found high levels of lead and copper in the agricultural soils around the mine sites.

Impact on Air

Air pollution occurs during all the stages of mining activity especially during exploration and development phase. The movement of heavy vehicles generates dust which contaminates the air. Activities like blasting and transportation of mineral deposits like lead, arsenic and cadmium exposes traces of these metals which after coming in contact with air leads to chemical reactions causing air pollution. The people inhabiting near the mine sites regularly inhale the air mixed with chemicals which causes serious

respiratory diseases and allergies in them. Dust emanating from the tailings facilities and waste dumps also increase the particulate matter in the air leading to air pollution.

Waste generation during all the stages

Mining activity generates huge waste which can be brought to use in things like building materials. However, a large amount of waste needs to be safely discarded to avoid any risk to the environment and human health. Sometimes chemical like cyanide are used in the processing stage and the waste generated from it, if left unattended, can be highly toxic and lead to environmental devastation. Usually cyanide is used in extraction of gold as it dissolves gold in an aqueous solution. However if the waste is not treated properly, then even a very little amount of cyanide can cause permanent damages to humans and animals. Waste is generated during all the stages of mining activity and it can be broadly classified into three heads i.e. the tailings, waste rock and mine water.

Waste rock is generated when ore is extracted from the rock. The amount of waste rock which needs to be removed to reach the ore mainly depends on the location of ore, the method which is used for mining and the constituents of the rock. Stripping ratio is a method used to estimate the volume of waste rock and the ore. For instance if stripping ratio is 2:1, that means the mine 1 tonne of ore, 2 tonnes of waste rock need to be mined. Since the composition of waste rock can be different, they need to be managed and treated separately. The highly toxic waste rocks contain cyanide, ammonia etc. which can cause harmful effects on the environment even if they are released in very small concentration.

Some waste rocks contain less toxic elements such as zinc or copper but they may cause considerable loss if they are present in higher concentrations. Furthermore phenomenon's like weathering pose a serious threat to the environment. Weathering occurs when air and water start to breakdown the rock. The larger chunks of rocks takes a long time to weather whereas the smaller chunks undergo this process quite quickly. Yet another parameter for separating

the waste rocks is dividing the potentially acid generating rocks from the non-acid generating rocks.

Tailings are generated when during the processing of ore, the valuable minerals are separated and all fine-grained slurry is left behind. Tailings are usually generated in large quantities. If the tailings are left unattended, then there are reasonable chances that toxins are generated and they affect human health and surrounding ecosystem. The grade of an ore decides the amount of tailings which will be generated during its mining. For instance, usually iron ores have higher grades, therefore less tailing are generated. On the other hand sulfide and gold ores are low grade, resulting in high tailings. Mostly the tailings are stored by conventional impoundment storage method where dams are built specially engineered to retain them to avoid their contact with the air and water. Similar to the weathering of waste rocks, when tailings come in contact with air, they weather too and in fact there weathering is on a higher side as their surface area is more than the surface area of a waste rock. The situation worsens when the tailings contain sulfide minerals as when they come in contact with the air, they oxidize.

To prevent this, the method of subaqueous deposition is employed in which the tailings containing sulfide minerals are kept under water. In the South African Gold Mining Industry, a method known as 'sub-aerial deposition' is employed in which tailings are not deposited under water but rather they are deposited in thin layers of water and these depositions are regularly rotated. The regular rotation ensures that the tailings get dry and reduced in density before the next layer of tailings is deposited.¹

Review of literature

There is a rich tapestry of professional and academic writing relevant to this study. The social and environmental issues with respect to mining in developing countries have been identified and discussed in the book *Mining and the Environment: From Ore to Metal* by Karlheinz Spitz and John

Trudinger.² In the book, *Environmental Impacts of Mining Activities: Emphasis of Mitigation and Remedial Measures*³ by Jose M. Azcue the environmental factors to be taken care of by the mining industry to attain the objectives of sustainable development and the treatment of mining effluents.

The environmental effects of mining operations has been extensively discussed by M. Sengupta in his book *Environmental Impacts of Mining: Monitoring, Restoration and Control*.⁴ The paper *Impact of Mining Activity on Water Resource: An Overview study*⁵ by Dalchand Jhariya, Rubia Khan, et. al. reviews the impact of acid mine drainage and the other significant impacts of the mining activity. In the Indian context the report of Sustainable Development Framework by ERM India Pvt. Ltd., titled as *Sustainable Development Framework for the mining sector in India- A report by the Ministry of Mines*⁶ is a complete guide and contains the principles and practice guidelines to be followed by the mining industry. The report highlights several important areas like sustainable mining and the approach which should be followed for its attainment.

The report expresses serious concern about the regulatory lapses resulting in ineffective management of environmental impacts caused due to the mining activity. These academic writings offers insight on the environmental issues with very limited information about the environmental challenges posed by individual mine operations. After a thorough study of several studies relevant to the present research, it is

² Karlheinz Spitz and John Trudinger, *Mining and the Environment: From Ore to Metal* (CRC Press Taylor & Francis Group, The Netherlands, 2008).

³ Jose M. Azcue, *Environmental Impacts of Mining Activities: Emphasis of Mitigation and Remedial Measures* (Springer-Verlag Berlin Heidelberg, Germany, 1999).

⁴ M. Sengupta, *Environmental Impacts of Mining: Monitoring, Restoration and Control* (Lewis Publishers, USA, 1993).

⁵ Dalchand Jhariya, Rubia Khan, et. al., "Impact of Mining Activity on Water Resource: An Overview study", *Conference Paper in National Seminar on Recent Practices & Innovations in Mining Industry* (2016).

⁶ ERM India Pvt. Ltd., "Sustainable Development Framework for the mining sector in India- A report by the Ministry of Mines" (Ministry of Mines, Government of India, 2011).

¹ D.E. Daniel (ed.), *Geotechnical Practice for Waste Disposal* (Springer Science Business Media, B.V., UK, 1993)

apparent that not much emphasis has been placed on the responsibility of the mining companies towards rehabilitation and reclamation of the mined lands.

Conclusion and suggestions

In the last few decades, Indian mining sector has grown tremendously without any corresponding and equivalent advancement aimed at attaining sustainable development. It will not be wrong to say that each individual stage of the mining operation cause irreversible damage to the environment. Even before the actual commencement of the mining operation, the mere preparation of the mine site and its related activities result in destruction of the natural biodiversity. Mere preparation of the mining operations involves variety of fuels, oils and aerosols which are potentially dangerous. These chemicals sometimes leak in the environment due to human error or failure of equipment. During the mining processes, all the stages impact the environment and cause air, water and noise pollution. Activities carried out at each individual stage affect the environment in its peculiar way by generating toxins causing irreversible damage to the ecology. Despite the problems have been known and recognized from a long time, no effective steps have been taken for improvement. The present study concludes that sustainable mining is possible only if before undertaking the mining activity, its potential environment and social impacts are thoroughly assessed and taken care of. Also, due weightage needs to be given to the concept of sustainability even in the after-mine-closure plan as well. This will ensure that the biodiversity on the site where the mining operation was completed be properly restored and brought back to its original form. In light of the above observations, the following recommendations are made to attain sustainable developmental goals and improve environmental and social performance of the mining companies.

1. To facilitate Sustainable Development Goals in India, an authority should be formed by the Parliament similar to the Office of Surface Mining Reclamation and Enforcement, US. The office in US ensures that the coal mines are operated in such a

manner that the local community and environment are protected as well as rehabilitation is undertaken to make the land beneficial for most mining use.

2. The mining companies should demonstrate proof of sufficient funds solely dedicated towards 'Environmental Management Costs' in their pre-mine plan and post-closure plan. These funds should be deposited in a 'Mine Rehabilitation Fund' and should be utilized in case mines are left orphaned or abandoned by their owners.

3. The mining companies should be provided adequate information, guidance and support by the government about the ways to ensure proper reclamation of land right from the managerial-level to the worker-level. If the senior management is focused to find sustainable solutions, everyone including people at the operator level would understand the importance of it.

4. A harmonious partnership between the mining companies and the respective governments is a contributory factor in maintaining focus on sustainability. The mining companies should be given the authority to hire environmental specialists for guidance and support qua reclamation of land.

5. The companies which seek to undertake mining activity must be put to strict proof to demonstrate the attempts made for reclamation. The workers should also be given basic level education towards their duty in protecting the mother earth.

6. Sound environmental management practices would ensure future sustainable development. Though this green initiative seems to be a little costly, but in the end reduction and recycling of waste helps the companies to gain a competitive edge.

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