

SUSTAINABLE MINING AND GEOINFORMATION

Prof. Basanta Kumar Prusty

Department of Mining Engineering

Indian Institute of Technology Kharagpur

Week – 05

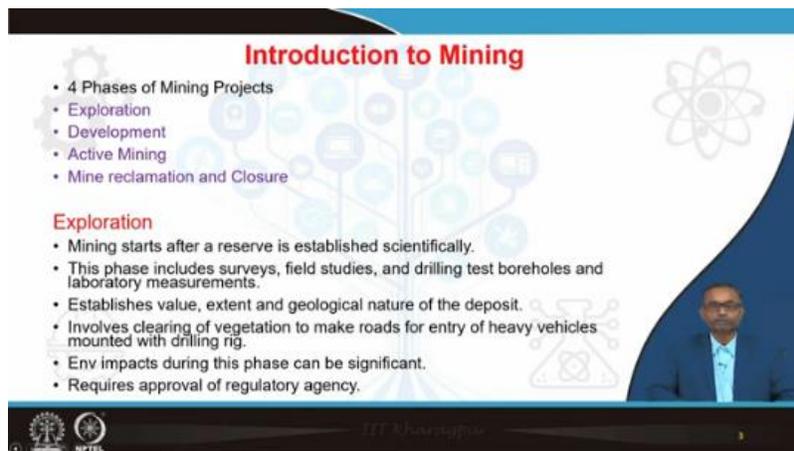
Lecture 23: Mining and Its Environmental Impacts-I

Welcome students to this week's class. So, the NPTEL course on Sustainable Mining and Geoinformation. My colleague Professor Behera has already introduced the topic of geo information and discussed in detail, so the second part of our NPTEL course is about sustainable mining. Today, I will introduce the mining industry and will also talk about what are the environmental impact of mining industry. First, I will introduce the topic of mining to all the students. Since the students are from various disciplines and I am hoping that there are also some students who are from the background of mining engineering, but there are also students from other backgrounds. So, for all of you I will be introducing the topic of the mining. In today's class we will talk about type and stages of mining then environmental impacts caused due to mining industry particularly impact to the physical environment, impact on biological environment and impact on the social and economic environment.



So, those who are not from the mining background, so for them, it is very important that when we talk about the mining, there are four phases of the mining industry. First one is exploration. Before you open a mine, we have to first identify where the mineral deposit is located and whether the mineral deposit is commercially viable. So that is done in the first

phase of the mining which is known as the exploration. So the exploration is done in the exploration phase. Mining starts after a reserve is established scientifically and this phase will include the exploratory survey, field studies, drilling of test boreholes, collection of samples and testing of those samples in the laboratory. So, after the establishing the grade and we calculate the reserve then we establish the value, the extent of the reserve and geological nature of these deposits. These are very very important before we Invest in a mining and before we start in a mining project. Because as you may appreciate that, mining is a very very capital intensive industry. So, we cannot invest so much of capital unless we are particularly sure about the commercial viability.



The image shows a presentation slide titled "Introduction to Mining". The slide is divided into two main sections. The first section, "4 Phases of Mining Projects", lists: Exploration, Development, Active Mining, and Mine reclamation and Closure. The second section, "Exploration", lists: Mining starts after a reserve is established scientifically; This phase includes surveys, field studies, and drilling test boreholes and laboratory measurements; Establishes value, extent and geological nature of the deposit; Involves clearing of vegetation to make roads for entry of heavy vehicles mounted with drilling rig; Env impacts during this phase can be significant; and Requires approval of regulatory agency. The slide features a blue and white color scheme with a background of abstract circular patterns and a small inset photo of a man in a suit. Logos for IIT Bombay and NPTEL are visible at the bottom left.

So, in the exploratory phase it involves clearing of vegetation to make roads for entry of heavy vehicles. As you know, that most of the mineral deposits are occurring in a forest area. So that means there is forest cover and below the forest cover you have the mineral deposit. So, when we go for the exploration, it will essentially involve clearing up some of the vegetation to make inroads, make roads for entry of heavy vehicles mounted with a drilling rig because you will go there for drilling so that we will collect rock samples and those samples will be tested in the laboratory. So, we have to establish roadways and through the roadways, these drilling rigs can go and we all know that when we make the roads and the heavy vehicles will ply so there will be environmental impact particularly in the forest area. This exploration also will require approval of regulatory agency including environmental clearance from concerned ministry that is, state government forest department as well as the in some cases central government forest department. So, that was the first phase exploratory phase and the second phase is that when your exploration is over and you have identified the deposit and you have found it commercially viable then we go for the development of the mine.

Development Phase:

- Construction of access road- for heavy equipment, supplies to the mine site, and to evacuate ores.
- Site preparation and clearing: to prepare land for office, colony, workshop etc.

Active Mining Phase:

- **Open-pit mining:** A method of mining in which layers of rocks, overburden and ores are removed by cutting machines or by drilling and blasting.
- Before, the area is cleared of vegetation and top soil is removed and stored.
- The fragmented overburden/ore is transported by shovel-dumper combination.

The second phase is known as the development phase and in this development phase, we are mainly constructing access roads to the mining site so that the heavy equipment which will be used for extraction of the ore deposit, heavy earth moving machinery can be taken to the site of the mining. Roadways are also necessary so that, you know, the essential supplies can be taken to the mine site. Also, when during the mining, you will be extracting the ores, those also have to be evacuated. So, for all these, we require roads and roadways we have to construct in the development phase. Second thing is that the site preparation and clearing because you have to open a mine. You have to prepare the base site where you can construct offices, you can construct colonies, you can construct various facilities within the mine. Let us say workshop you require. If you are using drilling and blasting, explosive for storage of explosives, magazines you have to construct. You have to construct the sites for the electric transformers and all that.

So, all the site preparation will be done during the development phase. Once the development phase is over, then the third phase comes. which is known as active mining phase. This is the mine mining industry that we are talking about this is the actual mining active mining phase. Here, I would like to tell you that this mining it can be two three types but primarily, there are two types of mines that we have seen or we practice. One is the open pit mining and the other is the underground method of mining. So, both these methods they are different, unique and their preparation, their environmental impacts are very different. So, we will be discussing in the active mining phase particularly if we are going for a open pit mining. As you know, this open pit mining, it is a method of mining in which layers of rocks and overburden and ores are removed either by drilling and blasting or by cutting machines. Particularly, the overburden rocks are generally removed by drilling and blasting. Once we remove the overburden rock layer, which is above the ore deposit, then we are able to reach the ore deposit and then we can extract the ore and depending upon

what kind of ore, depending on the strength properties, either it is extracted by the drilling and blasting or in some cases it will be extracted by the cutting machines like surface miners and other things. Now, before you start the open pit mining, we have to clear the vegetation. Because, as I told you that the mineral deposit, in most of the cases, it is lying below the vegetation. So, you have to clear the vegetation, and once the vegetation is cleared so there is a layer of topsoil so now topsoil. is a precious resource, so we have to remove the topsoil and we have to store it scientifically at a secured location because this topsoil will be requiring afterwards for our reclamation when the mining activity is over.

So now once the vegetation and topsoil is removed so you are removing the overburden layer by let us say we are doing drilling and blasting and by shovel and dumper combination we transport the overburden particularly the overburden we transport we are replacing it in a site in a mine area but the ore we will transport the ore out of the mine. It can go to the beneficiation plant or it can go to the end user site. For example, coal mine, it can go to the power plants through different means of transportation like railway or trucks or whatever it is. So, this was about the open pit method of mining. We have the second method of mining, which is known as underground mining. Particularly, when the deposits are at a shallow depth, less than 200- 250 meter, we can use the open pit mining method. But when the ore deposit or the coal deposit is at a higher depth, we are talking about 300- 400 meter, more than 400 meter, then this open pit method of mining may not be techno-economically feasible, then we have to go for the underground method of mining. In underground method of mining the ore body is accessed through a shaft or through inclines. Now from the shafts or from the inclines a series of tunnels or roadways are driven to reach the ore deposit.

Active Mining Phase

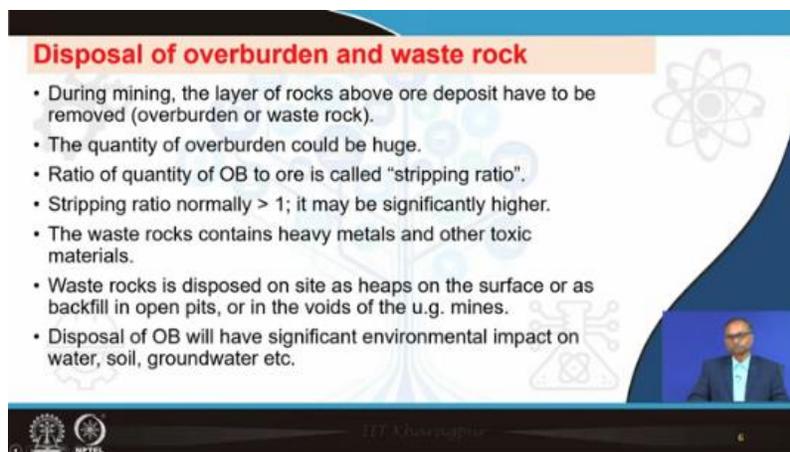
Underground Mining:

- In u.g. mines, ore body is accessed through shaft/ incline.
- From the inclines/shafts a series of tunnels (horizontal) are driven to extract the ore deposit.
- In case of coal mines, bord and pillar or longwall methods are used to extract coals.
- In case of metalliferous deposits, "stoping" or "block caving" methods are employed to extract ores.
- Underground mining has lesser environmental impacts compared to open cast method.
- However, it is often more costly and may have greater safety risks.

Logos: IIT Bombay, NPTEL

Now in case of coal mines, generally board and pillar method of mining or long wall method of mining are used to extract coal. In case of metalliferous deposits, we are using

what is known as the stoping method or block caving method to extract the ores. The underground method of mining has lesser surface footprint and it has lesser environmental impact compared to open cast method or open pit methods. However, the underground method of mining is often more costly and there are greater safety risks associated with the underground method of mining. So, both for open pit method of mining as well as the underground method of mines, particularly for open pit method of mining, the overburden that we have displaced they have to be disposed in an environmentally sound way. In open mining, the layers of the rocks above ore deposit have to be removed. This is called the overburden or waste rock and the quantity of the overburden rock could be huge we use a ratio called stripping ratio which is the basically the volume of overburden removed per ton of ore produced so the unit is meter cube of OB per ton of ore or metre cube of OB per ton of coal that is known as stripping ratio. Normally, this stripping ratio will be greater than 1, but for some deposits or when the depth of the deposit becomes more, the stripping ratio may be significantly higher. It can go up to 6, 7, 8 like that.



Disposal of overburden and waste rock

- During mining, the layer of rocks above ore deposit have to be removed (overburden or waste rock).
- The quantity of overburden could be huge.
- Ratio of quantity of OB to ore is called "stripping ratio".
- Stripping ratio normally > 1 ; it may be significantly higher.
- The waste rocks contains heavy metals and other toxic materials.
- Waste rocks is disposed on site as heaps on the surface or as backfill in open pits, or in the voids of the u.g. mines.
- Disposal of OB will have significant environmental impact on water, soil, groundwater etc.

The slide features a blue and white color scheme with a stylized atom icon on the right and a small video inset of a man in a suit speaking in the bottom right corner. Logos for IIT Bombay and NPTEL are visible in the bottom left corner.

So, that means for ton of ore or we have to remove more volume of overburden. So higher the stripping ratio, we have to remove the higher volume of the stripping ratio, higher volume of the overburden. So, this overburden that we are removing, we will be storing it as a heap, overburden heap within the mining area and these are source of environmental problems because this overburden material or rocks contains heavy metals as well as other toxic materials. So, these waste rocks, they are disposed on site as heaps on the surface or as black fill in the open pits or in the voids of the underground mines. Disposal of overburden will have significant environmental impact on the water bodies, particularly surface water bodies, on the soil and also on the groundwater. Now, we are still in the active mining phase and in the active mining phase, we have to do the extraction of the ore and the transportation of the ore. So, OB and ore body is fragmented by drilling and blasting

and by cutting machines. Machines such as surface miners for open cast mining or continuous miner in the underground mining they are used for cutting the coal or the ore and the fragmented ore is transported out of the mine using heavy earth moving machinery HEMM or using the machines such as shovel and dumper combination, we transport the ore body or the coal out of the mine.

Extraction of ore and transportation

- OB and Orebody is fragmented by drilling & blasting or by cutting machines.
- Machines: surface miner, continuous miners
- The fragmented ores is transported out of the mine using heavy equipment and machinery (shovel-dumper).
- Equipment viz. loaders, haulers, dumpers are used to transport the ores to processing (beneficiation) plants using haul roads.
- HEMM are used to handle OB rocks in the mine (OB dumps)

The slide features a blue and white color scheme with decorative icons of a hard hat, a shovel, and a dumper. A small video inset in the bottom right corner shows a man in a suit speaking. Logos for IIT Bombay and NPTEL are visible in the bottom left corner.

Equipment which are used for transportation and extraction of the ore and the transportation includes loaders, haulers, dumpers. They are used to transport the ore to the nearest processing plant. Normally a processing plant will be situated near the mine premises. This is called a beneficiation plant. So, using haul roads, on the haul roads using these equipment, we will be transporting these ores or coal to the processing plant or coal washery. These heavy earth moving machineries or dumpers they are also used to handle OB rocks in a mine. Next activity is that once the ore body is taken to the processing plant, which is located in the mine premises, we call it a beneficiation plant. So, why it is necessary? Because metal content in a ore may be very small. For example, to give you example, copper percentage in the ore like chalcopyrite, it may be lower than 2%, may be, 1 percent, 0.5 percent like that. The ores containing this small percentage of metal cannot be transported for a long distance to the smelting because our copper smelter will be located at several hundred kilometers of away for example let us say we have the Hindustan Copper Limited mines at Rajasthan. But they don't operate a smelter there.

Beneficiation

- Metal content in ore may be very small (Cu in chalcopyrite < 2%)
- The ore is ground and metals are separated from gangue minerals in a beneficiation plant.
- Milling produces fine particles and allows for efficient extraction of metals.
- However, it also helps in release of contaminants from the tailings.
- Tailings are waste materials residue after separation of enriched ores.
- Beneficiations include physical and chemical separation techniques.
- Separation techniques: Gravity concentration, magnetic separation, electrostatic separation, floatation, solvent extraction, electrolysis, leaching, precipitation.
- Wastes from the above processes: tailings, heap leach materials (gold and silver), and dump leach materials (for copper).

The slide features a blue and white color scheme with a stylized atomic symbol in the background. A small video inset in the bottom right corner shows a man in a suit speaking. Logos for IIT Bombay and NPTEL are visible in the bottom left corner.

I think their smelter is now in Madhya Pradesh. So, what they will do? They will do the beneficiation in the beneficiation plant, which is located in the proximity of the mine. And there they will be doing some enrichment, removing some of this waste material, gangue minerals and the enriched ore containing higher content of metal will be transported to the smelter. So, for enriching the ore, what you do? The beneficiation, the ore is milled or ground and metals are separated from gangue minerals in a beneficiation plant. Milling produces fine particles and allows for efficient extraction of metals. However, when we do the grinding and milling and the particle size becomes small, now this also accelerates the release of contaminants from the tailings, this fine material, fine size grounded material. Now, when you separate the metal part and the waste part, this waste part is known as tailings. So, these tailings will be disposed nearby in a site that is called as tailing pond, which is nearby the mine may be several kilometers away. Since these tailings are very fine in size, now there are many toxic metals that is present. It will be very easy for these metals to be now mobile and they can, by the process of leaching, mix with the water. So, tailings are waste materials, residue after the separation of the enriched ore and how we are doing the beneficiation? Beneficiation includes physical and chemical separation technique.

The different separation techniques that are normally used are gravity concentration, magnetic separation, electrostatic separation, floatation, solvent extraction, leaching, precipitation, etc. Now waste from these separation processes we call them as tailings and these tailings are you know either you are disposing them in the tailing pond or you are disposing them in as a paste material in the underground mining. Another method of beneficiation is leaching where what we are doing a solution containing cyanide is used for beneficiation of some of the ores. For example, gold, silver and copper. So, we make a heap of these finely ground ores and use the cyanide solution. So, these solutions they will

dissolve the metal content and these solutions impregnated with the metals will be collected for further processing. But there is one serious environmental problem when these cyanide solutions part of them they can go and mix with the ground water. So that creates a serious environmental challenge.

Leaching for Beneficiation

- A solution containing cyanide is used for beneficiation of gold, silver, and copper ores.
- Cyanide needs special attention because of its serious environmental and public safety impacts.
- Leaching: Finely ground ore is deposited in large pile ('leach pile') on top of an impermeable pad, and a solution containing cyanide is sprayed on top of the pile.
- The cyanide solution dissolves the desired metals and the 'pregnant' solution containing the metal is collected from the bottom of the pile using a system of pipes.

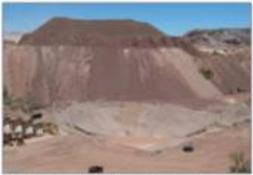


Fig. Heap leach, Bighorn gold mine, CA.
Ref: Guidebook for Evaluating Mining Projects EIAs, 2010



So, in the figure, you can see a heap leach in the pit in a gold mine, this is taken from a the reference is given: Guide book for evaluating mine projects - EIAs 2010 book. So, this is the leaching for beneficiation and once the beneficiation is over, we produce the tailings and the tailings which are basically the residues of ore that remain after the desired metal is separated and these are fine in size. So, high volume of tailings are generated from the beneficiation plant and these tailings will contain lot of toxic metals. Heavy metals are there. Heavy metals are present in the mineral and in the associated minerals. Because they are finely ground, now they are easily mobile. So, they can mix in the soil, mix in the water, groundwater, and they present a big environmental challenge. There are two methods of tailing disposal. One is wet tailing in the water, tailing pond and another is the dry tailing disposal in the underground mines as a paste backfill.

Tailings Disposal

- Tailings- residue of ore that remains after milling and desired metals extracted.
- High-volume of tailings are generated.
- Disposal of tailings containing toxic wastes is a key environmental challenge.
- Aim to prevent mobilization and release of toxic constituents of tailings into the environment.
- Wet tailings disposal
- Dry tailings disposal (paste backfill in u.g. mines)



Fig. Wet disposal of tailings;
Ref: Guidebook for Evaluating Mining Projects EIAs, 2010



So, the figure you can see it is a wet disposal of tailing where the tailings mixed with water as in slurry form. It is collected from the beneficiation plant and through pipeline it will be taken to the tailing pond, which is several kilometers away from the beneficiation plant. Last phase, fourth phase is known as mine reclamation and closure.

Mine reclamation and closure

- After active mining is over, mine facilities and site are reclaimed and closed.
- Impact during after-mining closure phase may be significant and may persist for decades.
- Goal of mine reclamation and closure is to return the site to condition close to pre-mining condition.

Derelict land

- Revegetation
- Restoration
- Reclamation

The slide features a blue header, a white background with faint icons of a tree, a gear, and a molecular structure, and a small video inset of a man in a suit in the bottom right corner. Logos for IIT Bombay and IIT Madras are visible in the bottom left corner.

So, when the mining activity is completed, that means, let us say the reserve is complete, it is no more possible to extract commercially, so then mine we have to close in a scientific manner, in an environmentally sound manner. So, after active mining is over mine facilities and sites are reclaimed and closed. The environmental impact of the mining will continue even after the active mining is over. Active mining is over does not suggest that the environmental impact comes to an end. Environmental impact will continue for decades and in some cases for centuries also. Particularly, the impact on the water, impact on the groundwater, impact on the soil, it will continue for very long time and it will require certain physical, chemical, biological treatment for the restoration or for the reclamation of the site, reclamation of the water body and like that. So, as we know that particularly open pit mining, open cast mining will be responsible for degrading the land and we produce some derelict land. Derelict land means, land which cannot be used without treatment. So, it will require certain treatment then some commercial productive use of the land will be possible. So, in the case of open cast mining, we are producing derelict land and there are three concepts that are used. When we say reclamation, there are three concepts we think of. One is the revegetation, second is restoration and third is reclamation. So, revegetation, we go for the plantation on the degraded soil and we establish a forest cover. And because when the forest cover is established, gradually lot of the environmental problems, whether it is soil, it is biological problems, this wildlife and whether it is the water, gradually they are taken care of. Second is the restoration. Restoration means that we have to bring back the condition of the mining area to the pre-mining condition, particularly bringing back the

soil condition, bringing back the biodiversity, bringing back the natural drainage. So that is restoration. This is practically may not be possible, but this is a theoretical concept. And third is the reclamation. Since restoration is practically, it is a theoretical concept and it is not practically possible. So instead of going back to pre-mining land use, we try to achieve whatever is best in the present socio-economic condition. We try to find some economic land use and also, we try to, using the technology, we try to solve all the environmental impact. So, that is known as the reclamation. So, we have discussed all the different stages of the mining. Now we will talk about the environmental impact associated with the mining. So, as you know, there are the different stages of the mining and in those stages, what are the different impact? Now, overall, when we are doing the mining what are the environmental impact associated with the mining? So, environmental impact associated with mining are diverse in nature that means there are some impact which are long term, there are some impact which are short term, there are certain impact which are easily quantifiable and there are some impact which can only be assessed only subjectively.

Environmental Impacts Associated with Mining

Environmental impacts associated with mining are diverse.

- Some problems are easily quantifiable;
- Some problems can be assessed only subjectively.
- Longterm and Short term environmental pollution

Some problems associated with Mining are:

- Water pollution
- Air Pollution
- Impact on wildlife
- Soil contamination and Land Degradation
- Social Impact
- Visual intrusion

The slide features a blue and white background with a stylized tree graphic. A small video inset in the bottom right shows a man in a suit speaking. Logos for IIT Madras and NPTEL are visible in the bottom left corner, and the number 12 is in the bottom right corner.

So, it is a complex scenario to quantify the environmental impact due to mining. But some of the obvious environmental problems that are occurring in a mining that we can very easily understand is that the pollution of the water bodies, pollution of the air, air pollution, impact on the forest and the wildlife, the contamination of the soil and the degradation of the land then the visual intrusion or the aesthetic pollution and now it is becoming more important that the impact of a mining on the society. So, if you can see that the impact on the environment one is, what are the impact on the physical environment like air, water and soil and land. Impact on the biological environment that is the flora and fauna and the wildlife and then the impact on the social environment or socio-economic environment. So, most important and most obvious is the impact of mining on water.

IMPACT OF MINING ON WATER

- High impact on water quality and availability.
- Sulfide ores exposed to air and water generate acid and produce AMD.
- The acid will leach/dissolve metals from the mine waste (Cd, Cu, As, Cr, etc.)
- Harm to fish and other aquatic life (when pH<4).
- Erosion of soils, mine wastes into surface waters.
- Major sources of erosion: OB dumps, open pit areas, tailing ponds.
- Erosion and sedimentation will lead to increased TSS, TDS, turbidity etc. in surface water.
- Will have adverse effect on aquatic life.



Fig. Acid Mine Drainage;
Ref: Guidebook for Evaluating
Mining Projects EIAs, 2010



Dr. Khairulghani

13

Now, this environmental impact I think we are coming to an end of this class and maybe we will discuss it in the next class. So, now I will summarize, whatever I have covered in this class. In today's class, we have discussed what are the different phases of the mining. Particularly, we have discussed four phases of the mining. And in these four phases of the mining what are the different environmental impact that could occur? We have discussed the different impacts that could happen.

REFERENCES

1. Guidebook for Evaluating Mining Project EIAs (2010), Environmental Law Alliance Worldwide.
2. Mohsen Moghimi Dehkordi, Zahra Pournuroz Nodeh, Kamran Soleimani Dehkordi, Hossein salmanvandi, Reza Rasouli Khorjestan, Mohammad Ghaffarzadeh, Soil, air, and water pollution from mining and industrial activities: Sources of pollution, environmental impacts, and prevention and control methods, Results in Engineering, Volume 23,2024, 102729, ISSN 2590-1230.
3. Down, G.C. (1977), Environmental Impacts of Mining, Applied Science Publishers Ltd.



Dr. Khairulghani

14

I hope my first lecture was very informative and useful for you and we will continue this lecture. Next class, we will talk about the different pollutions and impact environmental impact associated with mining industry. So, for today, thank you very much.