

SUSTAINABLE MINING AND GEOINFORMATION

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Week – 05

Lecture 24: Mining and Its Environmental Impacts-II

Welcome students to lecture 24 of the NPTEL course on 'Sustainable Mining and Geoinformation'. Last class, we discussed the different phases of mining.

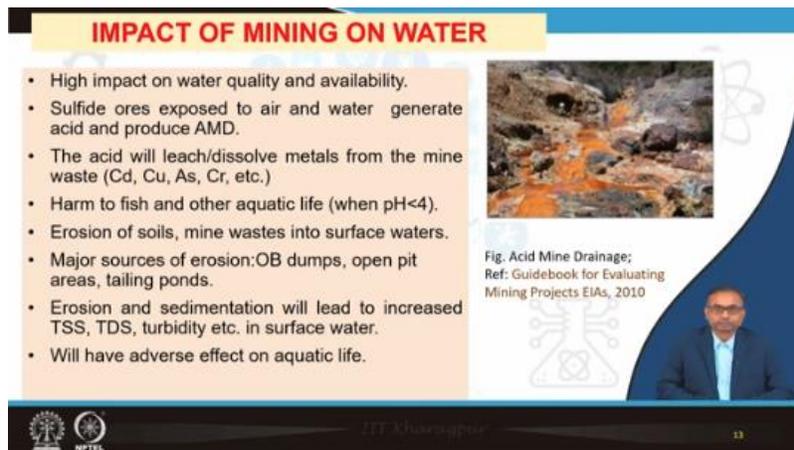


CONCEPTS COVERED

- Type and stages of mining
- Environmental Impacts caused due to mining;
- Impacts to the physical environment
- Impacts to the biological environment
- Impacts to the social and economic environment

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Today, we will discuss the different impacts of mining on the environment: the physical environment, biological environment, and social environment.



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 $\text{pH} < 4$).
- 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

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First, we will start with the impact on the physical environment, and in the physical environment, the water environment is very important for the mining industry because it

has a significant impact on the water environment. Particularly, the mining industry impacts water quality and also affects water availability. In some mines, especially those involving sulfide ores, like copper mines, lead and zinc mines, and even coal mines—since coal contains a lot of pyrite— these kinds of mines, when sulfide ores or sulfide present in the host rock is exposed to air and water, produce acid. We call this acid mine drainage or acid rock drainage (AMD or ARD). This acid drainage mixes with water bodies and makes the water acidic. Acidic water has a higher capacity to dissolve metals. The waste rock from the mine overburden or the tailings, as we discussed last class, contains heavy metals such as cadmium, copper, arsenic, chromium, etc. This acidic water easily dissolves these metals, which then enter the water, and in many cases, their concentration exceeds acceptable limits. Higher concentrations of metals as well as the pH—since acidic water can have a pH of less than 4 or even less than 3—are harmful to fish and other aquatic animals and plants. Moreover, mining also causes significant soil erosion from exposed workings, waste dumps, and tailing ponds. Sediments are carried away from these places. Whether through wind erosion or runoff (water erosion), these sediments find their way into water bodies, particularly surface water, increasing total suspended solids, total dissolved solids, and turbidity.

WATER POLLUTION DUE TO TAILING PONDS

- Ground waste mixed with water discharged as a slurry in tailings ponds.
- Impact of tailing ponds on water quality could be severe.
- Leaching of toxic metals and chemicals will pollute both surface water and ground water.
- Bottom of tailing ponds should be provided with impermeable liners.
- Tailings may contain toxic metals: As, Pb, Cd, Ni, C=N etc.
- In storm event, risk of failure of tailing dams dyke causing environmental disaster (contamination of soil, water bodies)

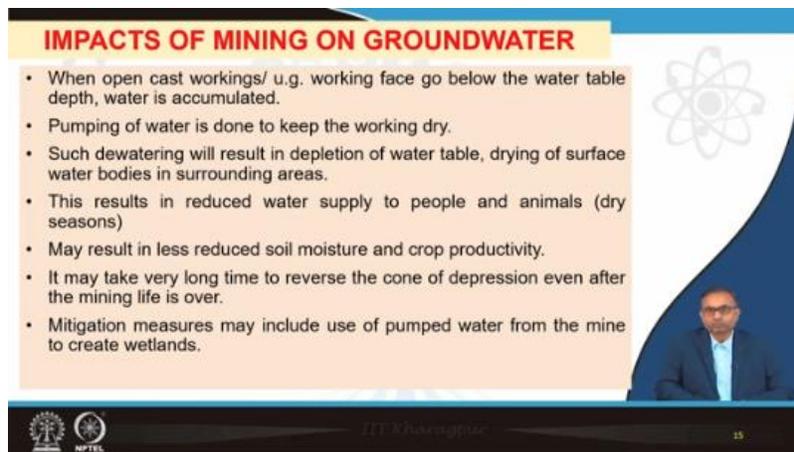
Key Challenge:

- To keep surface/ groundwater fit for human consumption?
- Whether surface / groundwater in the project area will support aquatic species and wildlife ?

Fig. Erosion from OB dumps leading to turbidity in surface water bodies.
Ref: Guidebook for Evaluating Mining Projects EIAs, 2010

All of this adversely affects water quality. Specifically, regarding tailing ponds, this waste material is pulverized in the beneficiation plant, mixed with water to form a slurry, and transported to what is known as a tailing pond. The impact of tailing ponds on water bodies is particularly severe during the rainy season when runoff spills over from the pond, carrying toxic metals like arsenic, lead, cadmium, and other heavy metals present in the tailings. So, they are dissolved in the water, and they go and mix with the water through leaching also. They will go to the ground water also. So, they will contaminate both surface water and ground water, but more the surface water. In some of the mines,

like copper mines gold mines, we are using cyanide. The cyanide solutions are used for extraction of the metal. So, this is very harmful hazardous chemicals which can mix with the water bodies and it will present serious environmental challenges because the treatment will be very, very expensive. Now, particularly in the case of tailing pond in a storm event, there is also a chance that the tailing pond dike, there may be failures. We have seen in many cases the dike has failed. So, when there is a dike failure, huge quantity of tailings are coming to the surrounding area, agricultural fields. Along with the tailings, water containing a lot of heavy metals. are also coming to the soil and thus, the soil will also be contaminated. So now key challenge in case of the water pollution is that how to keep surface water and groundwater fit for human consumption in the mining area and whether the surface water or the groundwater in the mining area will be able to support aquatic species and wildlife? Because of this pollution issues, heavy metal issues, acidity pH issues, whether it will be appropriate or whether the quality will be proper for the wildlife?



IMPACTS OF MINING ON GROUNDWATER

- When open cast workings/ u.g. working face go below the water table depth, water is accumulated.
- Pumping of water is done to keep the working dry.
- Such dewatering will result in depletion of water table, drying of surface water bodies in surrounding areas.
- This results in reduced water supply to people and animals (dry seasons)
- May result in less reduced soil moisture and crop productivity.
- It may take very long time to reverse the cone of depression even after the mining life is over.
- Mitigation measures may include use of pumped water from the mine to create wetlands.

The slide features a blue header with the title in red and white. A list of seven bullet points is on the left. On the right, there is a stylized atomic symbol and a small inset photo of a man in a suit. The bottom of the slide has logos for IIT Bombay and NPTEL, and the number 15.

That is a serious concern. Like surface water also, the mining activity has impact on the groundwater, particularly when the open cast working or the underground working faces, working areas go below the water table. A lot of water will be accumulated in the working and for mining, we require a dry working area. So, what we will do?

We will use the pumps and do the dewatering. We do dewatering from the underground mine or in the open cast mine, more so in the open cast mining. So, as you know, this groundwater table is a contiguous surface. And you are extracting the water, pumping out the water. So, continuous pumping out of the water will result in the depletion of the water table in the surrounding area and result in what is known as a cone of depression. So in the surrounding area also, the groundwater table level will come down in the

surrounding villages, in the wells, if there are some surface water bodies. So, this water table goes down and your water bodies, ground water bodies or even ponds, they become dry. So, it will have lot of problems particularly from the availability of the water to the nearby villages. Also, it will result in the reduced soil moisture, since the water table comes down. So, soil moisture will be coming down and it will also have effect on the productivity of the crop. After the mining is over, dewatering will stop. But you realize that it will take very long time to reverse the cone of depression and to re-establish the groundwater table what it was before the mining. So, this is a permanent, a long term effect. Now, mitigation measures may include use of pumped water from the mine to create wetlands.

IMPACT OF MINING ON AIR QUALITY

Air borne emissions from mines during different phases of mining.
Particulate matter and Gaseous pollutant.

- Mobile sources (HEMM)
- Stationary sources (OB dumps, tailing ponds, crushers, beneficiation/ smelter plants)
- Fugitive emissions (Blasting, haul roads, loading, unloading,)
- Gaseous emissions from combustion of fuels in HEMM, explosions, etc.
- Primary pollutants can lead to secondary pollution (smog etc.)
- Air pollution may have adverse health effect on humans, animals and plants.

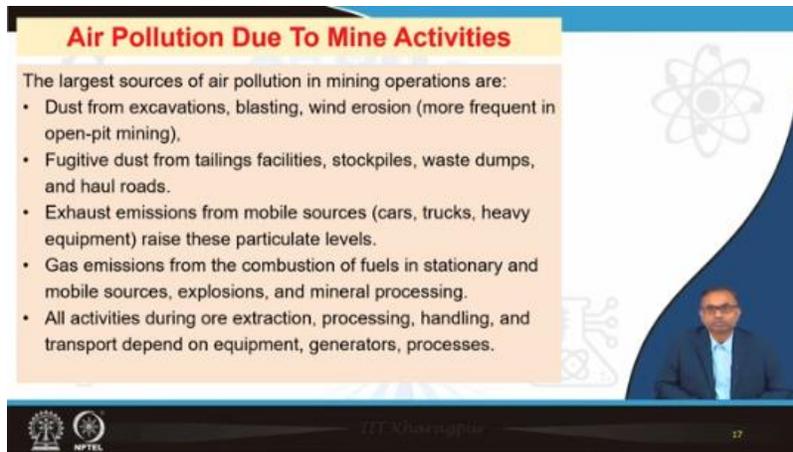
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So, there are lot of measures you have to take so as to reduce the impact on the groundwater. Now, water was the main thing. Next important environmental attribute is air quality. We all know that in the mining, we are using lot of heavy earth moving machineries, lot of other vehicles, there are grinding machines, crushers, primary crushers, secondary crushers. In the beneficiation plant, we have the different crushing plants. So, from these plants, also from heavy earth moving machineries They are emitting the particulate matter, that is the dust particles as well as they emit the gaseous emission. So, particularly this particulate matter emissions from point sources, then fugitive sources like blasting, haul roads. Then loading and unloading points, lot of particulate matters are generated and they become airborne. Gaseous emissions from the combustion of fossil fuels in heavy earth-moving machinery, as well as blasting, release many gaseous pollutants. These emissions, along with particulate matter, degrade the air quality. In mining areas, the overall air quality may be very poor in some cases. This air pollution adversely affects the health of humans, animals, and plants.

Air Pollution Due To Mine Activities

The largest sources of air pollution in mining operations are:

- Dust from excavations, blasting, wind erosion (more frequent in open-pit mining),
- Fugitive dust from tailings facilities, stockpiles, waste dumps, and haul roads.
- Exhaust emissions from mobile sources (cars, trucks, heavy equipment) raise these particulate levels.
- Gas emissions from the combustion of fuels in stationary and mobile sources, explosions, and mineral processing.
- All activities during ore extraction, processing, handling, and transport depend on equipment, generators, processes.



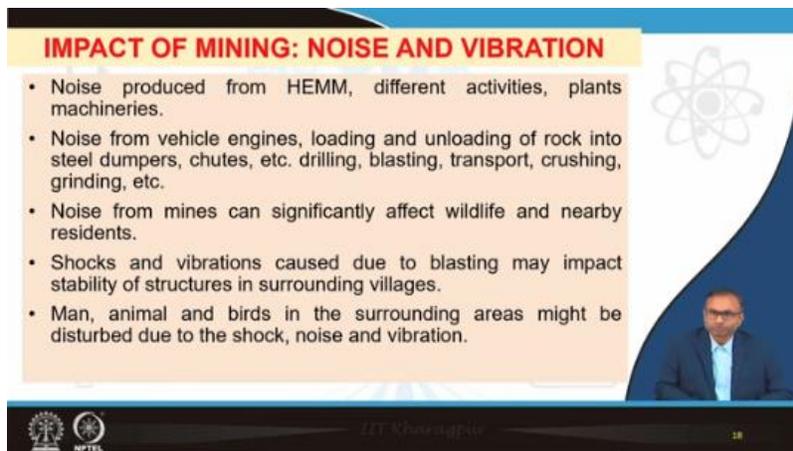
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As we discuss air pollution, the largest sources in mining operations are dust from excavation, blasting, and wind erosion. Many exposed areas lack vegetation. Strong wind currents make soil sediment airborne, causing dust pollution. Fugitive dust comes from tailings facilities, ponds, stockpiles, waste dumps, and haul roads. Exhaust gases from heavy earth-moving machinery (HEMM) and numerous vehicles, such as cars, trucks, and dumpers, contribute to pollution in mining areas. Plants and machinery in beneficiation plants also emit pollutants. All these factors result in poor air quality in mining areas.

IMPACT OF MINING: NOISE AND VIBRATION

- Noise produced from HEMM, different activities, plants machineries.
- Noise from vehicle engines, loading and unloading of rock into steel dumpers, chutes, etc. drilling, blasting, transport, crushing, grinding, etc.
- Noise from mines can significantly affect wildlife and nearby residents.
- Shocks and vibrations caused due to blasting may impact stability of structures in surrounding villages.
- Man, animal and birds in the surrounding areas might be disturbed due to the shock, noise and vibration.



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Noise is another aspect of air pollution in mining. Heavy earth-moving machinery, crushing, and grinding operations generate significant noise. Many operating machines produce noise, particularly from vehicle engines, loading and unloading rocks into steel dumpers, and chutes. Drilling, blasting, transportation, crushing, and grinding operations produce excessive noise, significantly affecting wildlife and nearby villages. Mining also causes ground vibrations, especially during blasting. These vibrations impact humans, animals, and birds in surrounding areas.

IMPACTS OF MINING ON WILDLIFE

- Wildlife: Plants and animals that are not domesticated.
- Habitat loss (removal of top soil and vegetation cover, displacement of fauna because of noise and vibration, emission)
- Some impacts are confined to mine site, some are far reaching.
- Some impacts are short term and some long term.
- Game animals, birds, and predators, leave these areas.
- Sedentary animals, like invertebrates, reptiles, burrowing rodents, and small mammals, may also be severely affected.
- Lakes/ponds/streams may be affected affecting aquatic species.
- Food supplies for predators are reduced by the disappearance of these land and water species.

Next is the biotic environment, particularly wildlife—plants and animals that cannot be domesticated. Open-cast mining begins with vegetation removal. This leads to deforestation. Forests are habitats for flora and fauna, so mining causes habitat loss. Habitat loss and vegetation removal have short-term and long-term impacts, particularly on animals, birds, and predators. Animals lose their habitats and may leave. Sedentary species, like invertebrates, reptiles, burrowing rodents, and mammals, are severely affected. Aquatic habitats like lakes, ponds, and streams are also impacted. Mining contaminates water quality, altering pH, TSS, and TDS levels. These changes affect aquatic plants, animals, and species.

IMPACT OF MINING ON WILDLIFE

- Surface mining destroys aquatic habitat.
- Sediment contamination of streams, lakes in open cast mining areas. Changes the physical and chemical water quality parameters of aquatic bodies.
- Habitat fragmentation: When large areas of land are broken into smaller patches makes it difficult for local species to move from one to other.
- Isolation may lead to decline of species.

Surface mining destroys the aquatic habitat, causes sediment contamination of streams and lakes in the open-cast mining areas, changes the physical and chemical water quality parameters, and because of that, many fish species and other aquatic species are affected. Now, in open-cast mining, in many cases, there is habitat fragmentation. You know, we have a continuous stretch of area, for example, a forest, and you have taken certain areas in between for your mining activity. So, the continuity or the wholeness of the area may

be affected. You know, there are some animal corridors. Or other areas where these animals travel. So, if you have taken some area in between, it will lead to habitat fragmentation. When large areas of land are broken into smaller patches, it makes it difficult for the local species to move from one part of the area to another. This restricts their freedom and will have an impact on them. So, this isolation will lead to the isolation of these species because they cannot freely travel, and it will lead to the decline of these species in that area.

IMPACT OF MINING ON SOIL AND LAND

- Mining contaminates soils of the surrounding areas.
- Soil contamination due to windblown dusts containing toxic metals etc.
- Soil contamination due to spillage of chemicals and hazardous materials.
- Toxicity of dust depends on metals present in the ore, associate minerals etc.
- Improper top soil preservation (opencast mines) destroys the soil flora, fauna and organic matter.
- Mining activity alters the physical, chemical and biological properties of the soil.
- Physical properties such as texture, structure, bulk density, porosity, hydraulic conductivity etc. gets altered due to interaction with HEMM.

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Now, another aspect of mining is its effect on soil or land. Mining activity may contaminate the soils of the surrounding area. The soil contamination may happen because of windblown dust containing toxic metals and heavy metals. So, when these dust particles fall on the soil, the soil is also contaminated. Sometimes, there is spillage or discharge of hazardous chemicals, oil, and grease. So, all these things will contaminate the soil. So, for mining activity in open-cast areas, we also remove the topsoil, and unless we preserve the topsoil scientifically, there will be loss or damage to the topsoil because topsoil is an ecosystem that contains soil particles. But it also contains a lot of biotic environments, flora, and fauna. Unless you preserve it properly, this flora and fauna, or the microorganisms and insects, will die. So, the loss of organic matter in the preserved topsoil is a very critical issue. When we do the mining or keep the waste material. As overburden in the overburden heap or the tailing pond, all these activities will lead to alteration of the physical, chemical, and biological properties of the soil. Physical properties such as texture, structure, bulk density, porosity, and hydraulic conductivity will change.

SOIL DEGRADATION

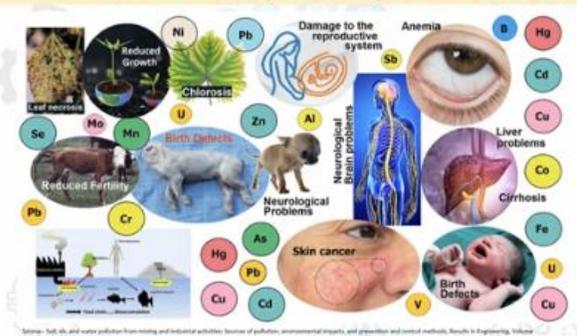
1. Physical Properties
 - physical properties of soil, including Bulk Density and texture, are affected by mining
2. Chemical Properties
 - Soil chemical properties including pH, EC, C and N concentrations, and C:N ratio are influenced by mining
3. Biological Properties



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Because we are using a lot of heavy earth-moving machinery. There is a lot of compaction and scarification. All these things will change the physical properties like bulk density, porosity, hydraulic conductivity, and also the chemical properties like pH. Electrical conductivity, the nutrient content like carbon and nitrogen, all these things will be changed because the soil is changing, and organic matter is changing like that. Biological properties change because your flora and fauna change, so that will also change. Now, overall, we have discussed that there is a change in the air quality, change in the water quality, change in the soil quality, and if you take all this together, the degradation of the air, water, and soil, so what is the.

IMPACT OF AIR, WATER, SOIL DEGRADATION



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So, in this slide, you can see the effects on the animals, on the plants, and on the humans, leading, in extreme cases, to several diseases in the plants, animals, and humans. And this actually creates serious environmental challenges for the ecosystem. By taking suitable environmental management measures and remedial measures, we have to ensure that this degradation is minimized or managed scientifically so that these effects are controlled.

SOCIAL IMPACT OF MINING

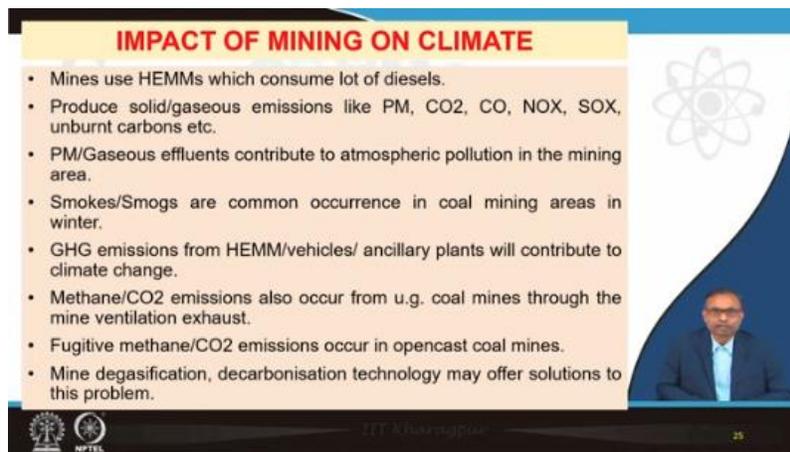
- Social impacts of mining are complex, both positive and negative.
- Mining creates wealth, jobs, and infrastructures, viz. roads, schools, hospitals, markets, communication services in remote and backward areas.
- It may cause considerable social disruption.
- Unless benefit shared with local communities, may lead to social tension and conflict.
- Human displacement and resettlement.
- Impacts of migration on native society.
- Lost access to natural resources like hills, water bodies etc.
- Impacts on livelihoods and public health.
- Impacts to cultural and aesthetic resources.
- Socio-economic impact

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Now, apart from the impacts on the physical and biological environment, there is also an impact on the socio-economic environment or social impact, if I may say so. Social impacts of mining are complex, both positive and negative. We know mining creates jobs, creates wealth, infrastructures like roads, schools, hospitals, markets, communication services, particularly in the remote and backward areas where this mineral deposit and mines are located. But along with these positive impacts or benefit, it may cause considerable social disruption or negative impacts. So now, unless the economic benefits of the mining project is shared with the local communities, it may lead to social tension and conflict. Because to start the mining project, particularly open cast mining project, there are displacement or the resettlement and rehabilitation will be done. Some people will be displaced. So, unless we make good compensation for the people, project affected people and provide a proper resettlement plan, there may be social disruption, tension and conflict. Now, because of the mining, people, particularly skilled people from other places, they come and they mix with the native people. So, when there is demographic migration, there are lot of social issues; demographic issues also arises. And the mining company, they should have a mechanism how to deal with these kind of demographic issues.

Because of the mining, because of the migration of other community to the mining area, now the local people, they will have less access to natural resources like water bodies, like hills, like agricultural lands. And it will have an impact on the livelihood and the public health. Particularly, when there is investment by the mining company, and if the purchasing power of the local people do not increase and market value increases because of the coming investment, so they will not be able to sustain their economic life. It will lead to some social tension. And also, it has been seen that there will be cultural impact, there will be aesthetic impact, and overall, there will be socio-economic impact which

may be some will be positive, some will be negative. So, what are these impacts? These have to be studied in a scientific manner.



IMPACT OF MINING ON CLIMATE

- Mines use HEMMs which consume lot of diesels.
- Produce solid/gaseous emissions like PM, CO₂, CO, NO_x, SO_x, unburnt carbons etc.
- PM/Gaseous effluents contribute to atmospheric pollution in the mining area.
- Smokes/Smogs are common occurrence in coal mining areas in winter.
- GHG emissions from HEMM/vehicles/ ancillary plants will contribute to climate change.
- Methane/CO₂ emissions also occur from u.g. coal mines through the mine ventilation exhaust.
- Fugitive methane/CO₂ emissions occur in opencast coal mines.
- Mine degasification, decarbonisation technology may offer solutions to this problem.

The slide features a blue and white background with a stylized atom symbol in the upper right. A video inset in the bottom right shows a man in a suit speaking. The bottom left corner contains logos for IIT Madras and NPTEL, and the number 25 is visible in the bottom right corner.

Now we are talking about the climate change. Climate change is a major and the most important atmospheric climate change issues. The mining activity will also have impact on the climate. It may contribute to the climate change because these heavy earth moving machineries that are using lot of hydrocarbon, lot of diesel, so they will be emitting the particulate matter, carbon dioxide, carbon monoxide, NO_x, SO_x, unburnt carbon and many greenhouse gases and these greenhouse gases and the other kind of pollutants, they will contribute to the atmospheric pollution in the mining area. Smoke and smogs are very common in the coal mining areas particularly in the winter season. Particularly, if you see the coal mines, the underground coal mines, from coal mines we are emitting lot of CO₂ and the methane which are greenhouse gases. From open cast coal mines, we are also emitting the fugitive methane, which will contribute to the greenhouse gas emissions from the mining. Solutions are available like: mine degasification, decarbonization technologies. They are available, and the mining company they can employ these technologies to reduce the greenhouse gas emission to the atmosphere.

VISUAL IMPACTS

- Mining operations (u.g. and O.C.) may present displeasing appearance and scenic features.
- Known as the visual disruption or visual impacts.

Sources of visual impacts :-

- Surface excavation
- Waste disposal (unvegetated OB dumps, tailing ponds)
- Plants and Buildings
- Disposal of abandoned tyres, machineries etc.
- Air, water pollutants, degraded soils.

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Now, lastly, in terms of impact, we call what is called the visual impact or aesthetic pollution. So, if you have visited a mining area, whether it is the underground or the open cast, normally it presents a displeasing appearance and scenic features. So, because of this, what we call it is a visual disruption or visual impact, or we also call it aesthetic pollution. Now, the sources of the aesthetic pollution, you know, the surface excavation is there without vegetation cover. We have waste disposal, unvegetated overburdened dumps, and tailing ponds. These present not-so-pleasing scenarios. We also have abandoned plants and buildings, disposal of abandoned tires, abandoned machinery, etc. Air pollution, water pollution, degraded soil, etc. All these taken together and coupled with a lack of vegetation present a very displeasing scenario. This is known as visual intrusion or aesthetic pollution.

Factors influencing the environmental impact

1. The size of the operation
2. Geographical and location factor
 - ❖ Population density
 - ❖ Topography
 - ❖ Climate
 - ❖ Economic, social and cultural factor
3. Method of mining: U.G./ Opencast
4. Type of the mineral and mineral characteristics: Coal/metal etc.

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Now, overall, we have discussed the different types of pollution due to the mining industry. So, this is the last slide: What are the factors influencing the environmental impact? How much impact there will be on the environment—whether physical, biological, or social—depends on the size of the operation. The larger the mine, the larger

the impact. The smaller the mine, the smaller the impact. It also depends on the geographical location and location factor. For example, if it is in a remote area, the impact may be less. If it is close to a city or town, the impact may be perceived as greater. Population density matters: if it is a less populated area, the impact on people may be less. But if it is a highly populated area, the impact will be greater.

There will be greater sociopolitical resistance from the people. Complaints will be more frequent. It also depends on the topography—whether it is a hilltop deposit, a flat area, or a valley. Particularly, air and water pollution will depend on that. Then, climate, economic, social, and cultural factors. The impact of mining also depends on the method of mining—whether it is open-cast mining or underground mining. Open-cast mines may be large projects, so they will have a higher impact. Underground mines will have a lesser impact. Lastly, the type of mineral mined matters—whether it is a coal mine, a metalliferous mine, or a limestone mine. Depending on the mineral, the environmental problems will differ. Now, we have come to the end of this class. I will summarize what we have discussed today.

The slide features a yellow header with the word "SUMMARY" in red. Below the header, a light orange box contains the text: "This lecture session has covered the different aspects of environmental pollution caused to physical, biological and social environment due to mining operation." Underneath this, a section titled "Key topics covered:" lists two bullet points: "Phases of mining" and "Impact on air, water, soil, wildlife, society, aesthetics, etc." The slide is decorated with faint icons of a gear, a molecular structure, and a chemical flask. In the bottom right corner, there is a small video feed of a man in a suit. The footer includes the NPTEL logo and the number "28".

Today, we started discussing the different environmental impacts on water, air, soil, noise and vibration, and the social impacts. We have covered all these topics today. Key topics covered in the last two lectures: the different phases of mining and the impact of mining on air, water, soil, wildlife, society, and aesthetics. These are the two lectures I have discussed. I introduced mining—what it is and its impact on different sectors or aspects of the environment.

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.



I hope these lectures have been informative and educative for you. We will discuss another topic in the next class. Thank you for your patient hearing. Thank you very much.