MINERAL ECONOMICS AND BUSINESS

Prof. Bibhuti Bhusan Mandal

Department of Mining Engineering

IIT Kharagpur

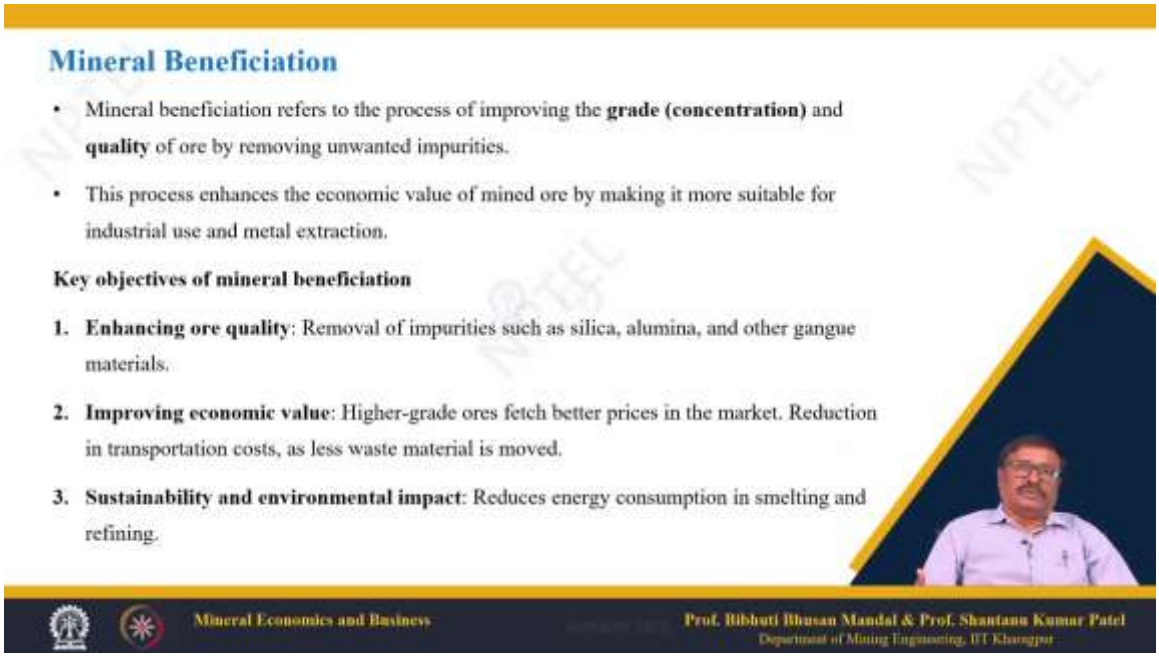
Week 4

Lecture 20 : Beneficiation Cost, Environmental Impact and Cost

Welcome everybody. In this ah lecture we will be talking about the cost of beneficiation process that means, the processing of ore and overall in environmental impact and the cost for ah mitigation. These two topics will be discussed. And the concepts that we will cover in this lecture are the beneficiation cost, certain case studies to understand the different components of the beneficiation cost. different stages of mineral beneficiation and their cost breakups, environmental impacts of mining operations and then the factors that affect the capital expenditure in environmental management because there is a mitigation cost involved.

And also the factors that affect the operational expenditure operating expenditure in environmental management that is both the CAPEX and OPEX. And the strategies for reducing environmental cost will be as is added as a suggestion in the end of this lecture.

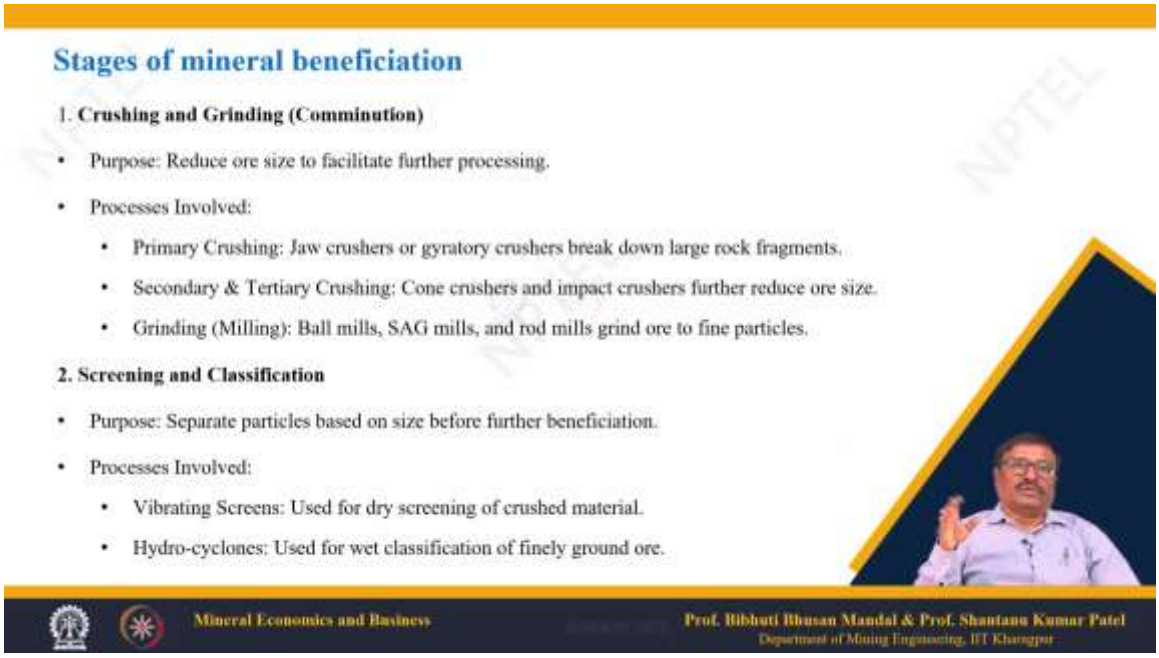
As you are aware that the mineral beneficiation follows the production for the purpose of ah of improving the grade or we concentrate the value mineral of the ore. and the quality of ore by removing unwanted impurities from the ore that is produced from a mine. But in coal also we do coal washing and different processes are involved to improve the commercial viability of the mineral or coal that we are processing.



The process will definitely enhance the economic value by making it more suitable for industrial use and metal extraction as the case may be. So, what are the key objectives of this mineral beneficiation process? We enhance the ore quality by removing the impurities like like silica, alumina or other gangue minerals. We improve the economic value because higher grade ore will face better prices unnecessary dilution with low grade will definitely reduce the price. And the sustainability and environmental impact because of reduced energy consumption in smelting and refining.

When we send the high-grade concentrate, we use less energy to extract the metal from the concentrate instead of processing the entire thing in the final stage. So, how do we start? Say we produce the ore from a mine. Big boulders or large rocks are there, but the entire thing is not crushed into smaller particles in the mines. So, the first thing is that we need to reduce the ore size to facilitate further processing, which we call size reduction or, in general, comminution. The comminution process is a stage-by-stage reduction in

size, not just from big to very small. There are different processes involved. For example, in primary crushing, jaw crushers or gyratory crushers are used to break down large rock fragments into smaller ones.

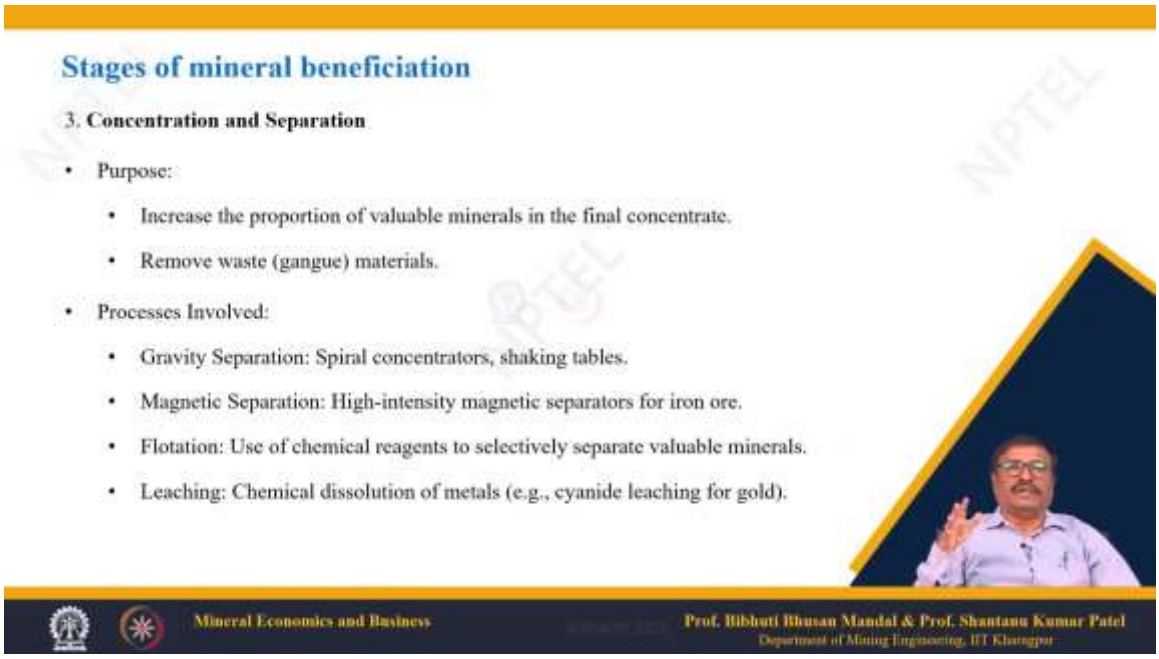


Then, secondary and tertiary crushing stages further reduce the size to make it suitable for feeding into the grinding mill. The grinding mill processes the small pieces of rock into fine particles. The idea is to reach the liberation size, where the valuable minerals are almost physically separated from the gangue minerals. So that they can be processed to remove the waste effectively, and we can collect the valuable minerals from there. Now, at every stage of crushing, as you see, we are reducing the size.

So, there is a target size. If we use a screen, we can classify the oversize and undersize. The undersize goes to the further process, and the oversize— That means sizes above the desired size will go back to the previous stage and be crushed or ground again to bring them down to the right size. Now, the processes include using vibrating screens for classification or hydrocyclones for wet classification of finely ground ores.

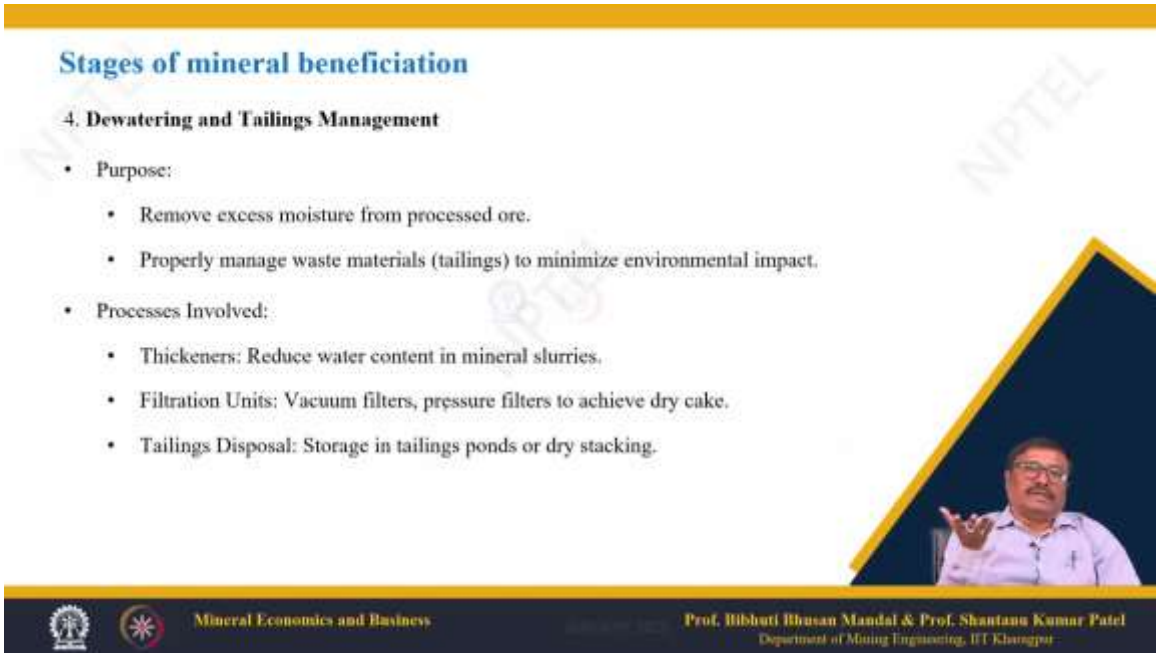
Then we come once we reach that very fine ah the particles where the value minerals can be now separated, then it goes to the concentration process. So, either we can use ah gravity separation or say spiral concentrators, shaking tables these are examples of

gravity separation. And for magnetic separation we have high intensity magnetic separators for iron ore. In flotation, we use the chemical reagents for selectively separate separating the valuable minerals. The valuable minerals will say float and the other part sink as the process is designed.



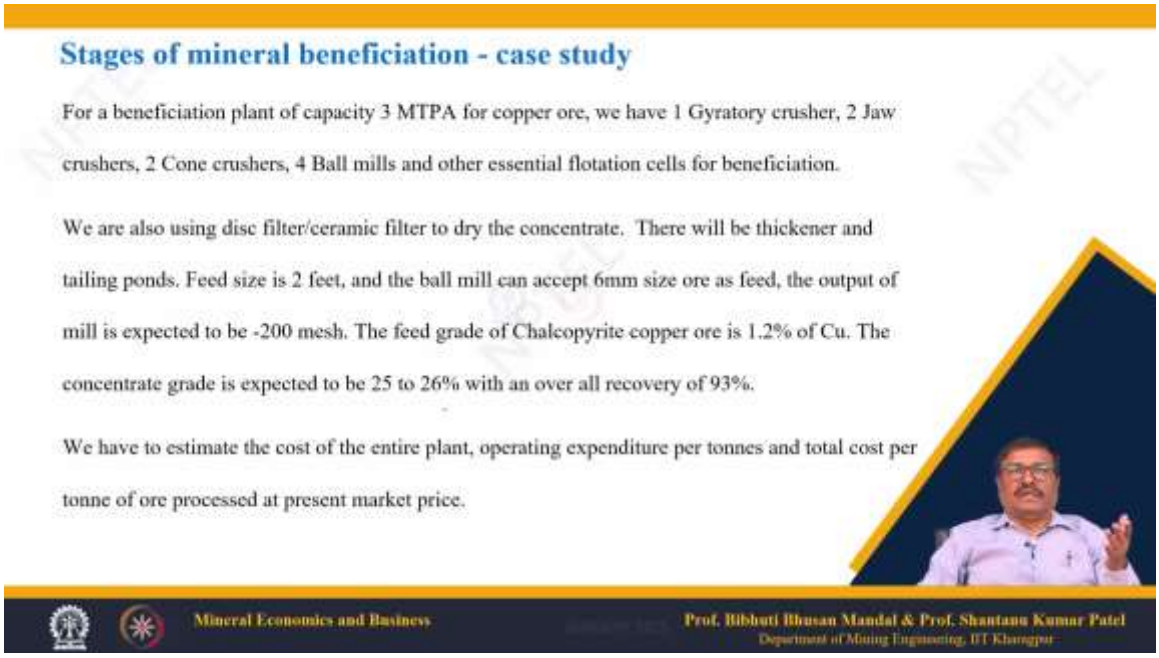
In leaching the chemical dissolution of metals. is done say for example, cyanide leaching for gold. So, if you use the chemical then the our the the value mineral will be leached that means, will be liquefied as another and then it will come out, then we can process to take out the gold. So, the in copper mining also we use the leaching process. ah in certain cases.

Now, ah after that when you take out the ah value mineral or or rather the concentrated part, then there will be certain waste material we call them tailings. So, tailings will be reject as waste reject as waste and the enriched ore is called the concentrate concentrate. The concentrate will have lot of moisture or water you need. So, what we do that first we need to thicken this thing that means, we feed to a thickener in which the the ah the water will be going up because the the material try to settle down at the bottom of the tank and the water will be above that slurry.



So, what will do we collect the slurry from the bottom of the thickeners. And this is further processed in filtration unit. The purpose of using the filtration unit like the vacuum filters or pressure filters is to achieve dry cake that means, we try to remove the moisture as much as possible. Then we then we we we stack it for further transport and metallurgical process. And the tailing part what we do that this is the waste material fine, but in many cases or most of the cases we try to use this tailing material for the purpose of filling back filling in underground mine specially or otherwise the excess material whatever is not utilized by back filling will have to be ah stored in a tailing dam is called tailing pond or you can use dry stacking which is nowadays has become very popular.

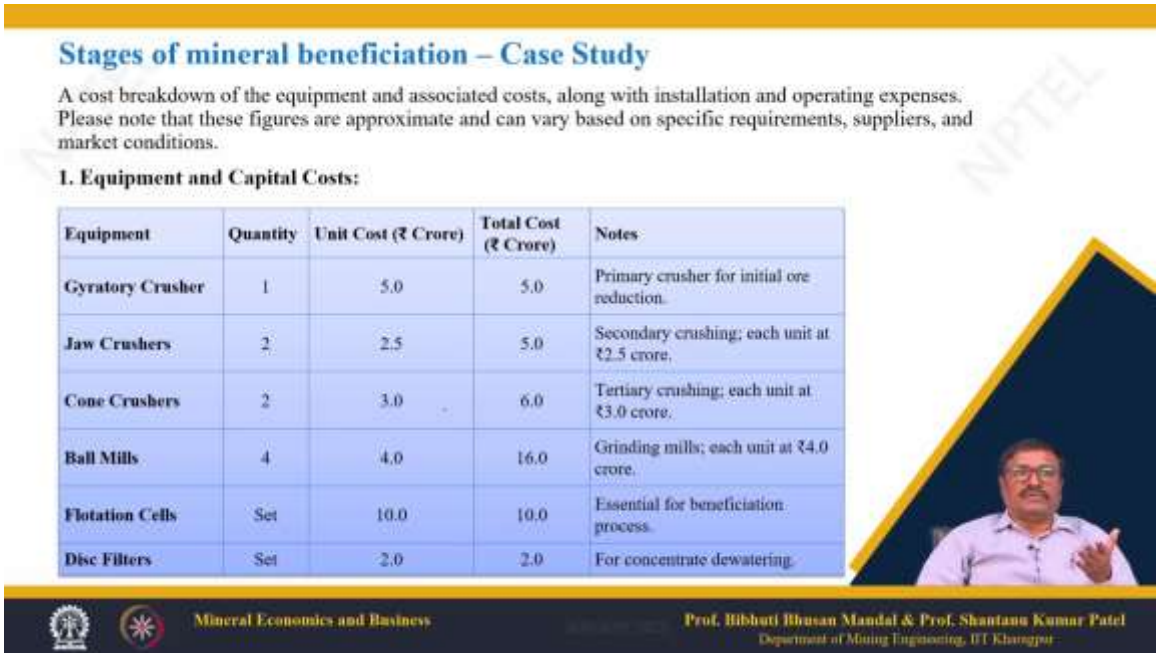
Let us take a case study and the cost involved in this process. For a beneficiation plant of capacity which can handle 3 million tonnes per annum for copper ore, we can use one gyratory crusher to handle this ore as a primary crusher followed by two jaw crusher. then 2 cone crushers, then we can use 4 ball mills in line and other essential flotation cells for beneficiation. Now, here we are using the gyratory crushers as primary. So, from there at that place we are feeding the ROM runoff mine and then it is gradually getting ah reduced in size unless and until through the ball mills we get the fine particles the fine particles.



After that as I said before that we use the disk filter or ceramic filter for drying the concentrate that means, reducing the moisture content from the concentrate. So, there will be thickener for further process on the tailing pond where we dump the tailing store it properly. In this case the feed size is 2 feet around ah that is ROM size rocks and the ball mill can accept 6 millimeter size ore as feed. The output of the mill is expected to be around minus 200 mesh and the feed grade of the chalcopyrite is a 1.2 percent copper. So, the concentrate grade is expected to be 25 to 26 percent that means, from 1.2 percent to enriched 26 percent and overall recovery will be 93 percent in the total beneficiation plant.

Now, this is a specific case ah case study where we have taken it from ah certain ah sources and we are just trying to understand the the cost involved in the installation and running this kind of beneficiation plant. So, we need to estimate the cost just because in DPR when you prepare a detailed project report the beneficiation has to be thoroughly detailed and the cost involved is required for estimating the capital cost or operating expenditure of the plant. So, in this case a cost breakdown of the equipment and associated cost along with the installation and operating expenses are shown here. These are approximately it can vary also depending on specific requirement suppliers or even the market conditions the cost might change over time, but at present we have these

figures for you to understand what could be the cost involved. We have said we will be using gyratory crusher 1 crusher which will cost us around 5 crores and jaw crusher we will use 2.

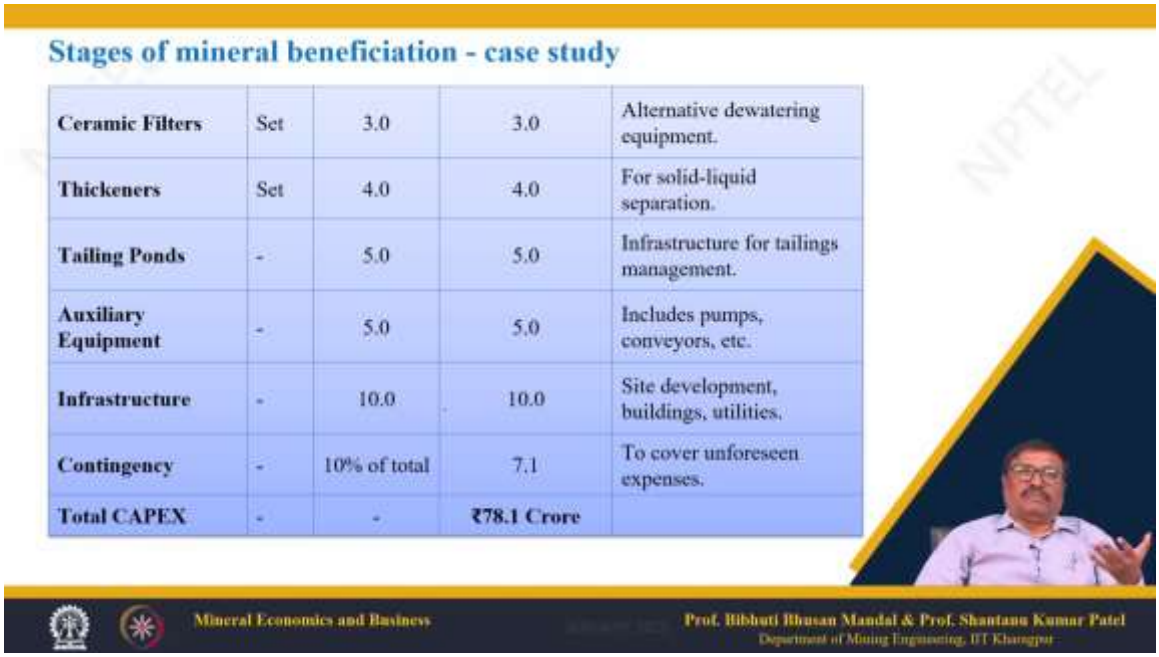


So, that also will cost us 2.5 crores each cone crusher 2. So, we have 3 crores each and that will cost us 6.0 ah crores. Ball mills we need 4 as I said. So, here we are we have designed 4 ball mills one may be idle 3 may be running. So, in case of breakdown we can run the other one like that we have designed here.

These are design assumptions there could be variations depending on the person who is designing it. So, say 16 crores will be there then the flotation cells about 10 crore in line. And then these filters we are using here which will be costing us a 2.0 crores this is for the purpose concentrate to taking out the moisture from the concentrate. Similarly, we can use ah ceramic filters which will cost us around 3.0 ah this your ah crores and thickeners ah for removing the water big in the beginning ah.

So, the 4 crores will be spending for that for solid liquid separation natural and the settled material will be sent to the the the the the disc filters or ceramic filters. Now, the tailing ponds is will be costing us around 5 crores that is in the beginning it may be much much more than this depending on the size and the geographical condition or the terrain how

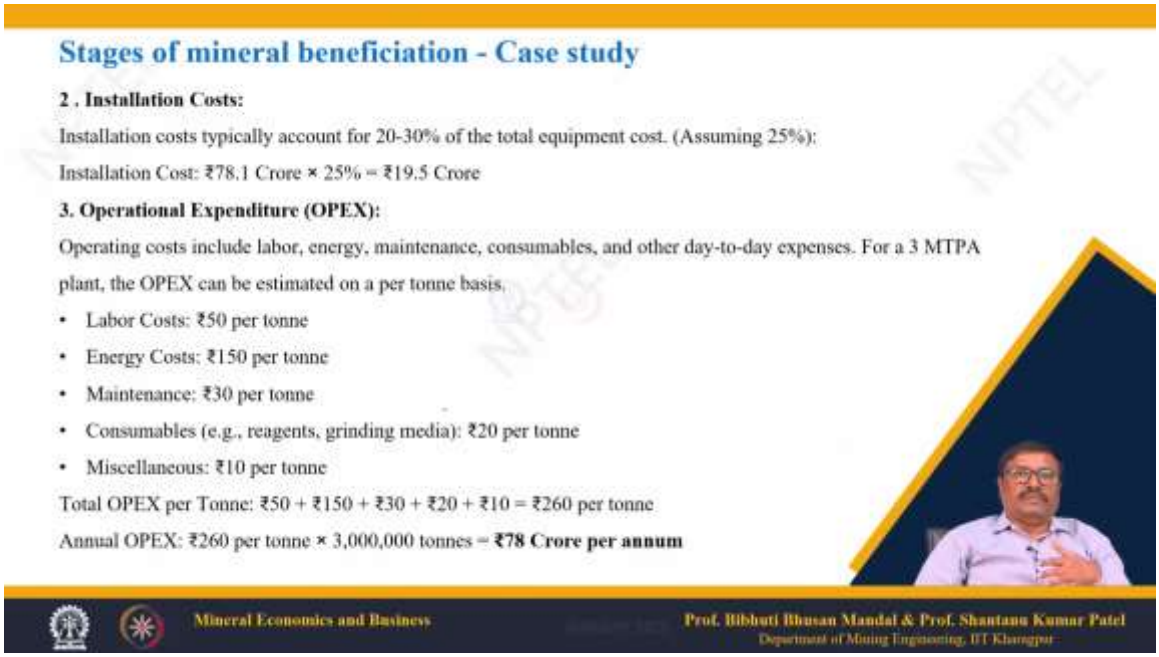
much you want to you require to invest for making the embankment which could be big investment in the beginning. And auxiliary equipment as I said in pump, conveyor these and these all these things will cost us another say 5 crores. Infrastructure, the plant structure all these the ah shades and the structures there will be requiring at least around 10 10 crores for site development, building, utilities. Contingency is just taken as a lump sum 10 percent of the entire cost.



This is to ah cover the air force So, total capital expenditure will be here around 78.1 crores, 78 crores this is the figure coming now. As an example, so installation cost typically account for around 20 to 30 percent of the total equipment cost assuming 25 percent it is coming as 19.5 crores for the installation purpose. Now, the operational expenditure once you have installed then we are thinking about the operational expenditure for processing 3 million ton per annum. So, all the labour cost, energy, maintenance, consumables, chemicals all these things will be required.

So, labour cost we are taking rupees 50 per ton, energy rupees 150 like that. So, it is coming total operational expenditure is coming around 260 rupees per ton this is quite reasonable. And annual operational expenditure rupees 260 per ton and for the total total ton is if you have 3 million tons then it is coming 78 crore per annum for the entire

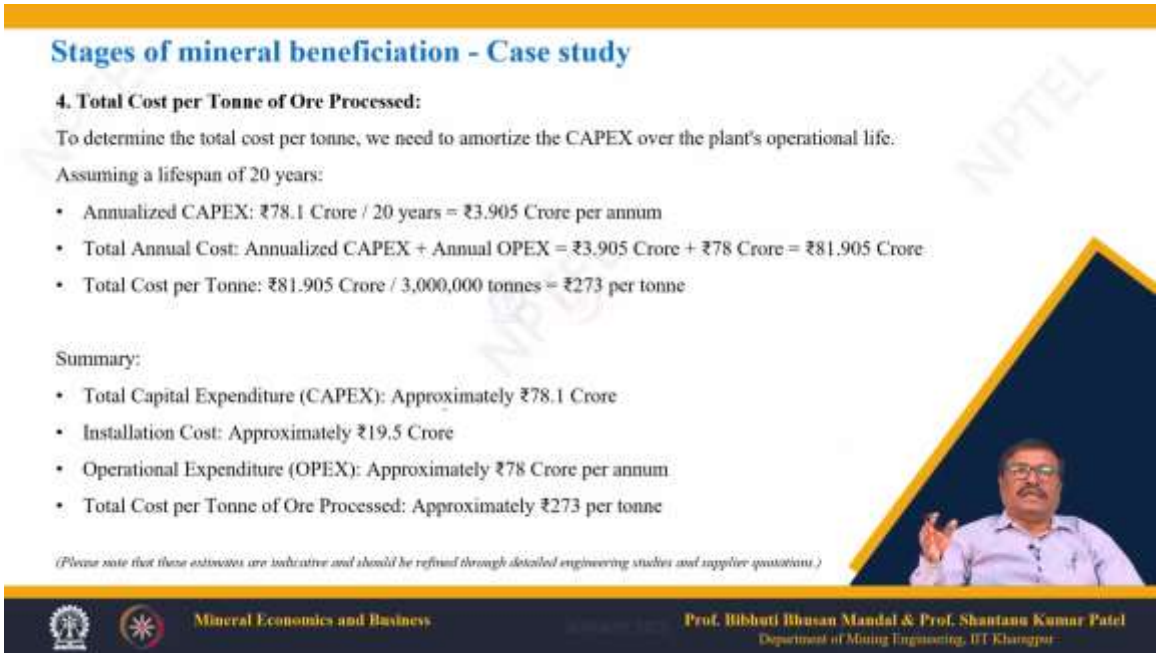
operational expenditure. Now, now let us have the let us combine the capex and OPEX part.



So, if you are amortizing this capex that means, if you are dividing the capital expenditure over the life of the mine which is estimated to be 20 years life span. Then annually we will be spending around 4 crores per annum means, we will be dividing this as if we are spending the same amount of money over a period of 20 years. Remember that we are not using the time value of money concept in this particular exercise that will be separately taught. And there this figures will change because over the 20 years the time value concept when it is applied then this figures will change.

But, let us have at this present as if the it remains constant assuming that. So, the total annual cost annualized capex and annualized opex will be the rupees 3.9 or 4 crore plus 78 which comes roughly as 82 crores. So, total cost per ton will be coming to rupees 273 per ton. There are reports where the cost is slightly higher or depending on the efficiency of machines or the quality or the design of the plant, the modern plant the cost could be less. But remember that now the switching over from one system to another system is sometimes not always the new machines are not always compatible with the old machines.

But there are certain things like in place of disk filter you can use this ceramic filter. So, that will make it more efficient. So, like to summarily what we can say that the total capital expenditure is about 78 crores and installation cost is 19.5 crores. So, operational expenditure is 78 crore per annum and the cost per ton of ore processed will be 273 rupees per ton. So, that we can find out from the.



So, it is a case study that gives you an idea of what could be the the cost per annum for the purpose of installing a copper ore beneficiation plant and that will process 3 million ton per annum. So, giving the example of say the mining process or beneficiation process, we are coming to an important part of the ah mining operations that is the environmental impact of the the the mining. So, as as we have repeatedly we have ah encountered this ah the problems ah that is created due to the industrialization. In mining definitely we call we are we are likely to cause air pollution and dust emission due to blasting drilling and material handling. There will be greenhouse gas emissions also from the diesel powered equipment, there will be release of particulate matters and toxic gas even from the blasting also all these things.

For mitigation measures we need to have dust separation, here the cost is coming that how we are mitigating the environmental impact. So, dust separation using the water spraying or chemical binders and we are switching to say electric or hybrid mining

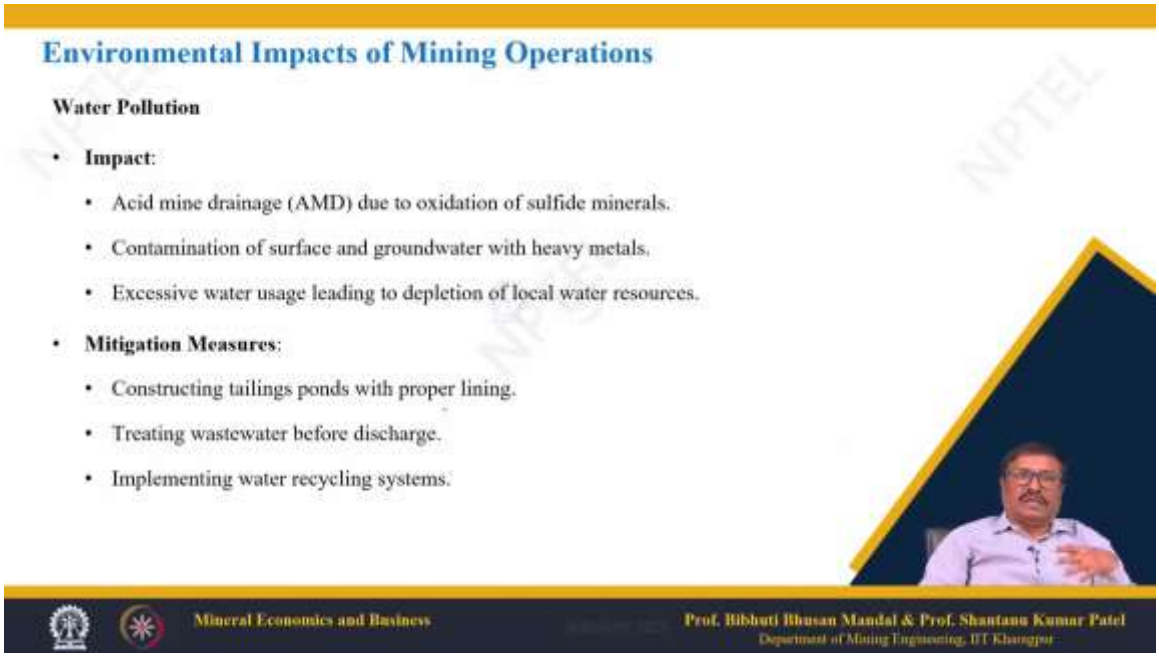
equipment. So, that can be that will reduce the diesel emissions and your installing air pollution control system back filter or scrubbers that will reduce the your impact environmental impact. So, these are important mitigation measures. In water pollution the acid mine drainage is very well known due to the oxidation of sulphide minerals and the contamination of surface and ground water is also with heavy metals.

Excessive water usage leading to the depletion of local water resources that is another issue. Now, the mitigation measures are for the water pollution. We have to construct the tailing ponds with proper lining so that the water does not come out and then contaminate the water bodies around or the agricultural land around. We have to treat the waste water before we discharge so that it does not cause any harm and we implement the water recycling system so that the water cost is reduced and the water can be the conservation of the water and we can reuse this for the industrial purpose by recycling the water that is distressed from the plant or the mine.

Mining also causes land degradation, habitat destruction, soil erosion, or subsidence in the case of, say, caving operations or underground mining operations. In coal mining, there is also subsidence. In caving operations, it is intentional—we know that there will be subsidence on the surface; it will cave in. So, what are the mitigation measures connected with this? So, we have to go for land reclamation and afforestation. We have to plant trees again where we have caused deforestation.

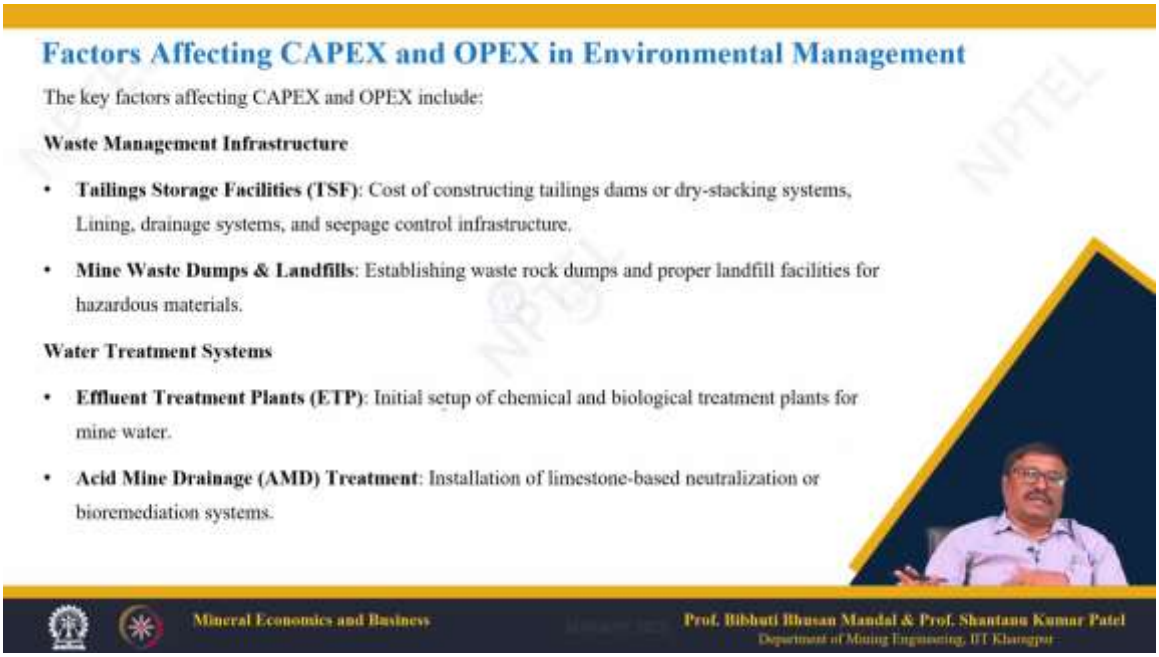
We have to backfill the open voids created in open pits. And, for the stability of the overburdened dams or the backfilling wherever we are doing it, we try to stabilize them using, for example, geotextiles to prevent all these things—though they will incur costs. We are now going to discuss certain things that are necessarily produced in mining operations. Other than dust and water pollution, we also have noise pollution and vibrations. So, the impact comes from drilling, blasting, and ore transportation—there will be huge noise continuously throughout the operating life.

During blasting, we also cause a lot of vibration, which will affect nearby communities and wildlife. The sudden shock will scare wildlife away from their natural habitats. What are the mitigation measures that we can take? We can implement controlled blasting techniques so that the noise is less and the vibration is also reduced. We can put up noise barriers to ensure the noise is absorbed before it is transmitted further away. We also have the problem of biodiversity loss due to the destruction or disruption of ecosystems or wildlife habitats.



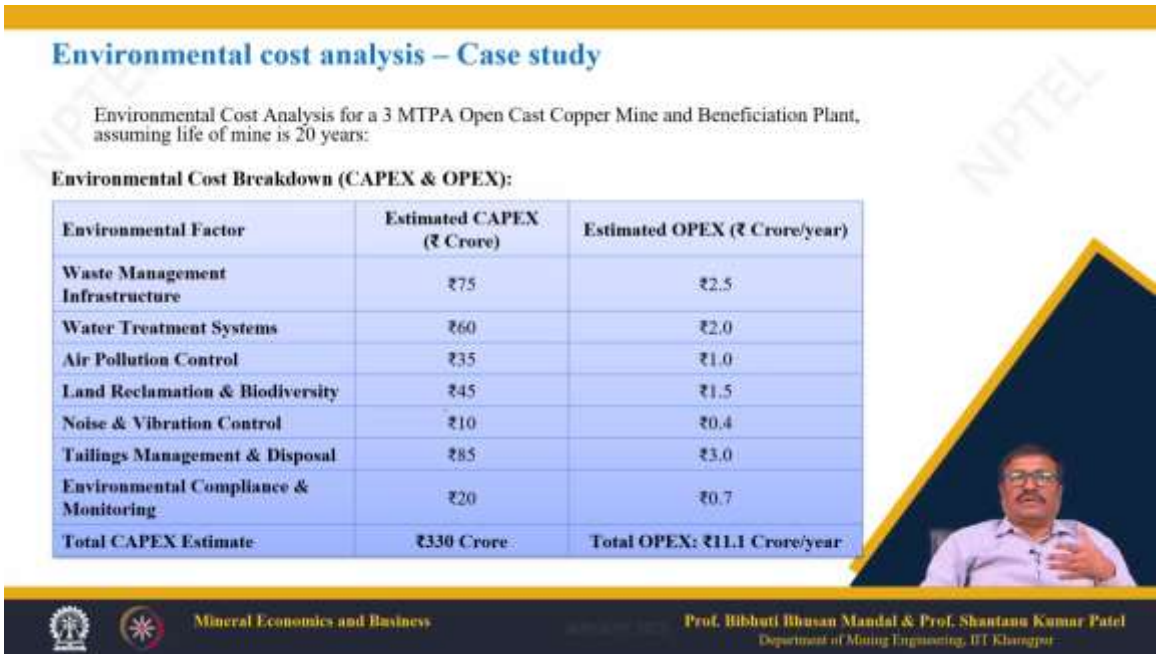
So, there will be fragmentation of the forest because you are making roads through the forest, dividing it. So, the continuity is gone. So, what are the mitigation measures that we can take? We can establish biodiversity offset programs by creating wildlife corridors. So, that we can support efforts to maintain the ecological balance.

Now, what are the factors that affect the capital and operating expenditure for environmental management systems? This environmental management system is nothing but those systems implemented and operated to mitigate adverse environmental impacts. For example, tailing storage facilities, mine waste dumps, landfills, and in water treatment, we have effluent treatment plants, which we call ETPs, along with the initial setup of chemical and biological treatment plants for mine water. Additionally, acid mine drainage water treatment installations and limestone-based neutralization are used to neutralize pH acidity, along with bioremediation systems. All this will incur costs in plant installation and system operation throughout the mine's life.



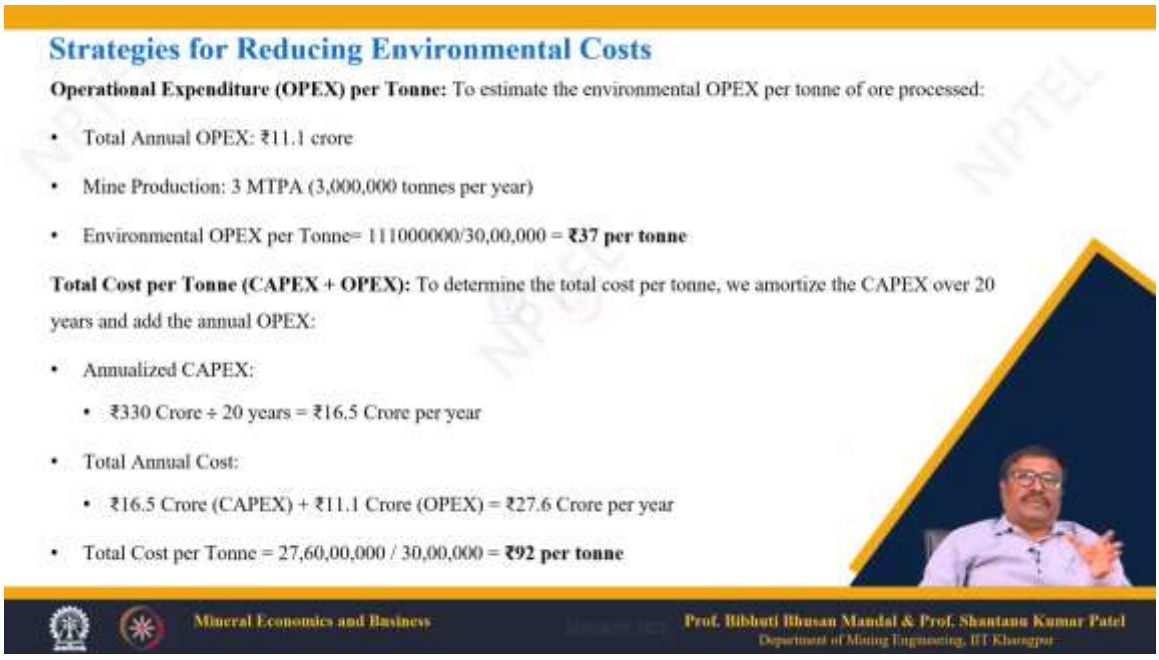
Even after the mine is closed, arrangements must still be made. So, whether it's tailings or backfill, whatever we dump or leave behind should not cause any environmental harm in the future, which we must ensure before leaving the site. In air pollution control, we must install dust separation systems and emission control systems, and for land reclamation and biodiversity conservation, we need to follow mine closure planning, which involves mine closure costs. So, in progressive rehabilitation and implementation of the progressive mine closure plan, we must ensure that allocated funds are properly utilized to maintain uniform progress.

That means, in tune with the progress is mining, we should not lag behind in that. So, the cost will be throughout the life of the mine you have to go on spending and when the mine is closed all your actions should have been completed by then by that time. So, the also we have talked about the biodiversity protection measure like the wildlife corridors, the afforestation all these things. For noise and vibration control the control blasting technique. So, we need to spend in scientific studies and we have we must use proper efficient ah blasting softwares blast design softwares and low implosive impact materials to control the blast noise and vibration.



Now we will take a case study where about 3 million ton ah per annum open cast copper mine and a beneficiation plant assuming the life of a ah of the mine is 20 years. So, the the environmental cost we have taken this this this figures from certain consultants. And what they said is that the waste management infrastructure will cost you around 75 crores and the operating expenditure of the waste management infrastructure will be reduced 2.5 crores per year. Similarly, we have figures for water treatment system 2 crores per year, air pollution control 1 crore per year, land reclamation and biodiversity about 1.5 crore per year, noise and vibration control we have around 40 lakhs. Tailing dam management system and disposal costly is 3 crores per year.

Environmental compliance and monitoring we have some 70 ah lakhs here. So, total estimated value for the the CAPEX is ah on the in the middle column we have the capital expenditure for installation, establishment of the facilities that will cost us around 330 crores over which can be utilized for the ah for 20 years. and the operating expenditure will be around 11.1 crore per year. Now, if you transform this or use this figure and then distribute this figures per ton then we can arrive at a conclusion that per ton of ore processed or produced how much are the environmental cost incurred or what you have to spend. So, for environmental OPEX per ton of ore processed



We can take the annual operating expenditure as 11.1 crore, as we have shown in the previous slide. We know the production is 3 million tons. So, dividing that, it comes to around 37 rupees per ton. When we are combining the CAPEX and OPEX, The annualized CAPEX is distributed over 20 years, which will come to around 16.5 crore per year. Here, 16.5 crore per year for the capital expenditure, and the total annual cost will be 16.5 crore plus 11.1 crore, which is 27.6 crore per year. So, when you divide again by the 3 million tons per annum production, it comes to around 92 rupees per ton.

This is slightly on the higher side in this case because our estimation is absolutely quite conservative. We will be installing most of the things following all the rules, regulations, and standard practices or advanced practices. Usually, depending on the scale of

operation and implementation, it varies between 30 to 80. So, it is very close to the realistic figures. So, it is about 92 rupees here, 90 rupees per ton of ore that we have produced from the mine. So, what are the strategies that we can follow for reducing the environmental cost? Other than the cost figures, we should plan right from the beginning before installation on what we can do to reduce the cost and also to understand what alternatives we have for better mine management in regard to environmental mitigation.

We can switch over or partially switch over to renewable energy like solar and wind energy. The integration of these with the traditional reliance on coal or nuclear power will give us certain advantages. We can also produce because, in mining, there are places where we can see, even in India, that mining companies have installed huge solar areas with solar panels. So, they are not only supplying to their own needs, they are also feeding into the national grid. So, that is a very good advantage.

We see we say that we are in remote areas, we are doing mining, but how to utilize those remote areas or the places where this is not used at all. So, there you can install solar or wind energy and then contribute to the production of renewable energy. We can go for automation in waste management, like a driven monitoring system to optimize waste disposal. Nowadays, many techniques have come. So, we can design things properly. So, that you need less space and less risky waste disposal.

So, that during rainfall or other cases, the tailing dam does not break and then does not cause environmental havoc or catastrophic damage. You can switch over also to dry processing technology wherever possible, so that you reduce water consumption and trailing disposal costs. Also, we can go for capturing carbon dioxide emissions from mining operations, which can prevent penalties and also carbon taxes. This will also reduce the carbon footprint, which means the carbon tax liabilities and environmental penalties. So, these are during the design itself, before the plant or before the project is implemented, we can think of implementing these alternatives right from the beginning.

So, what happens is that you not only reduce the environmental cost, you adopt the state of the art, and definitely you help in managing the environmental cost, and you can effectively reduce the environmental cost, which is also environmentally friendly. With this, we come to the end of this discussion on cost reduction, and we also give certain importance, as I said before, to progressive reclamation and water cycling systems, conservation of water. And, I must also mention fuel efficiency by using certain sensors. There are many companies which are using the latest technologies through IoT-enabled operations. So, also the automation compliance monitoring means that certain sensors will always say beforehand what things are going to happen. So, the emission levels can

be easily monitored from a remote location. This will help in reducing the environmental cost.

And, the ethical part also means that we must reduce the environmental harm. So, not only the cost, but we will be doing these things for the benefit of society and the habitats around the mining areas. We have taken most of the references that you are seeing here. Also, the Ministry of Mines website provides a lot of information from very renowned contractors. or consultants—multinational, I mean, international consultants—from there also we have taken the figures. So, you can go through these pages once again, and on your own interest, you can design or ask for a design of a certain hypothetical project and understand what could be the relevant figures for that project.

This is a good process of learning. So, thank you for being with us. Thank you very much. See you again.