Course on Industrial Biotechnology
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Lecture 49
Module 10
Metal Leaching

Welcome back to my course industrial biotechnology now now in the last lecture I try to tell you the production of high fructose corn syrup which is I told you mostly used by the in the western country. Now I am little bit coming to the special area that is called metal leaching how biotechnological application we have in the metal leaching and lot of industry they are using the metal leaching process for the recovery of metals and this metal leaching process basically that is applicable where ore contains very low percentage of metal because because as we know that when we use the ore high high concentration of metal then we go for chemical process, chemical process we go for chemical that is very that is well known but you know that when the ore contains very low amount of the metal then we go for this metal leaching process.

Leaching basically that signifies something you are liquefying so now question come how this leaching take place.

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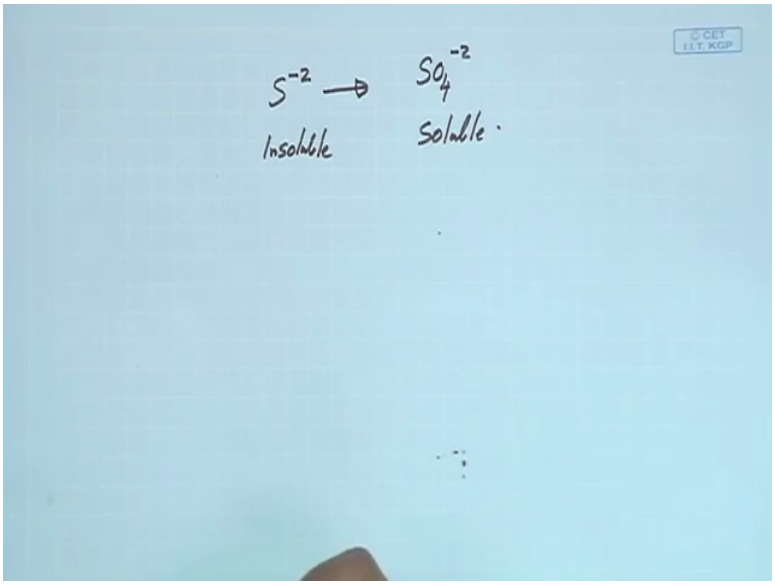

Now you know that when you talk about any kind ores that in metal ores particularly it is kind of iron sulphide you know iron iron sulphide is S minus 2 this is the sulphide you know

I will say this is the sulphide and and and this when it undergoes this leaching process this convert to sulphate. So when it convert to sulphate this is insoluble and this is soluble, so this is this is so the metal sulphide this is convert to metal sulphate this is how the solubilisation take place and this is called the metal leaching.

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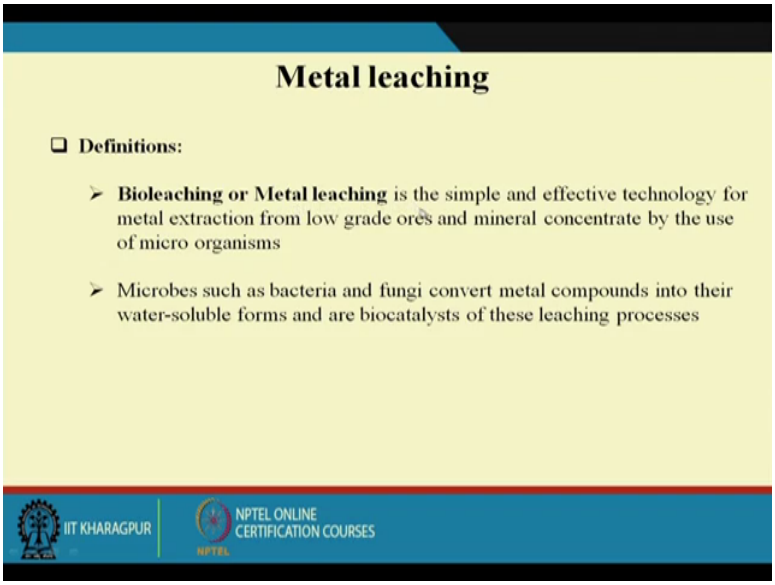

So the bioleaching or metal leaching is a simple and effective technology for metal extraction from low grade ore and minerals concentrate by the use of microorganism. So I shall I shall discuss very interesting that I can discuss that you know how this is taking place. The microbes such as bacteria and fungi convert the metal compounds into their water soluble form are biocatalysts of their leaching process.

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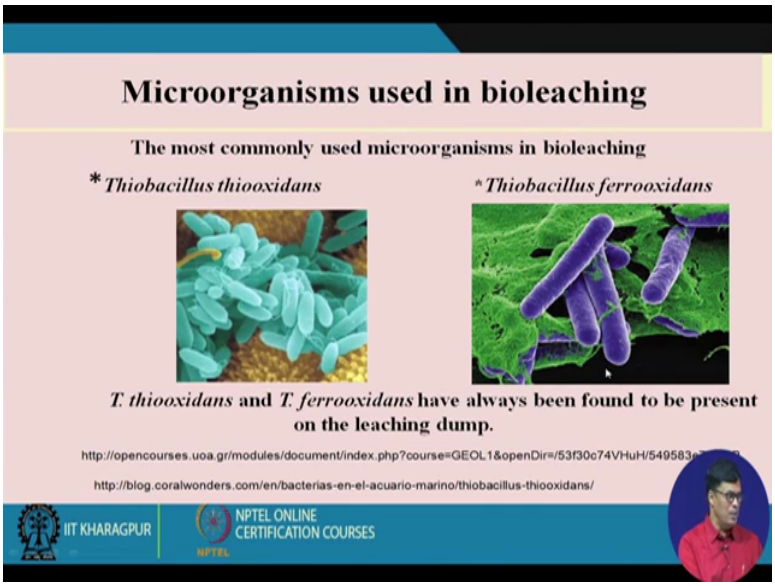

Now this is two organism very interesting that thiobacillus, thiooxidans and thiobacillus ferrooxidans this is a very commonly used microorganism for the bioleaching process because largely available in the metal dumb you know where your metal ore has been dump. If we isolate the organism from there we can find this two organism commonly present in this. They are largely used for solubilisation of sulphide.

So it looks like this you can the idea of kind of rod shape the thiobacillus thiooxidans that also kind of rod shape and thiobacillus ferrooxidans that also rod shape this is always found to be present in the leaching dump.

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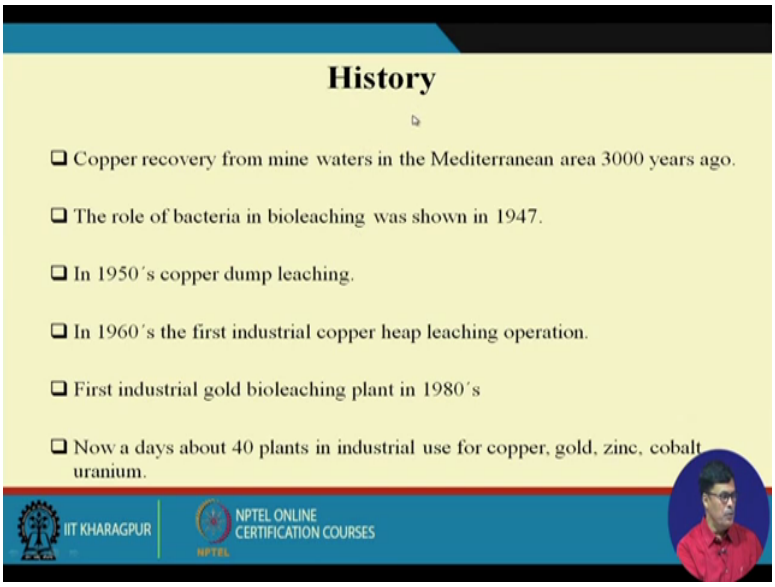

Now if you look at the history this is the copper recovery from mine water in the Mediterranean areas that take place 3000 years ago, so it is a very old process and the role of bacteria in bioleaching was shown in 1947, 1950s the copper dump leaching that that that have been carried out in 1960s the first industrial copper heap leaching operation also take place.

Now first industrial gold bioleaching plant was established in 1980 now-a-days 40 plants in industrial use copper, gold, zinc, cobalt and uranium. So this is there is lot of of industry they use these process for recovery of the metals and particularly when we talk about the high costly metals like you know for uranium and gold this is I shall show you that at the end that how and how the different process affect the economy of the process, economy of this metal recovery process.

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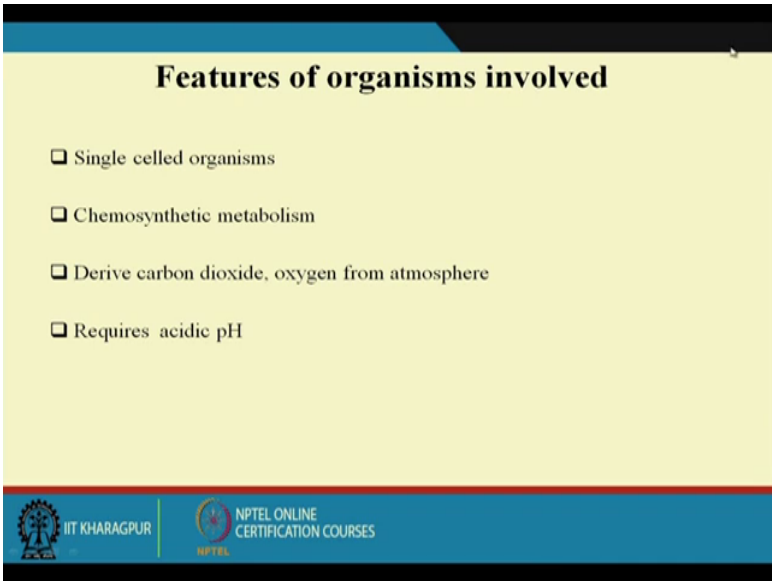

So the feature of the organism involved it is single cell organism and chemosynthetic metabolism that you have and derived from carbon-di-oxide, oxygen from the atmosphere and require acidic pH so acidic pH is mandatory they require in this for this organism.

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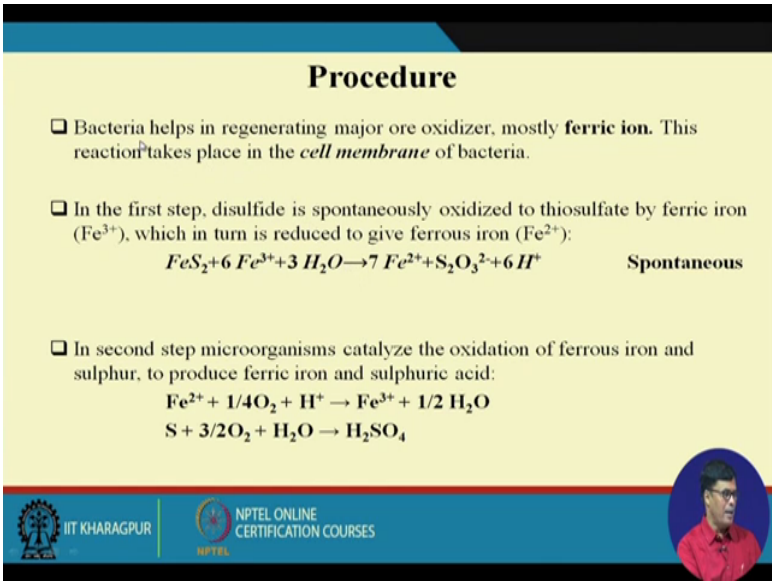

Now if you look at the bacteria helps in regenerating major ore oxidizer mostly the ferric ion. This reaction takes place in the cell membrane of the bacteria like you know I was talking about the ferric sulphide FeS2 and ferric ion then water it form the ferrous ion and this is the thiosulfate and 6 hydrogen ion and then this is the reaction this sulphur also this is ferrous ion is converted to ferric and this sulphur converted to H2SO4.

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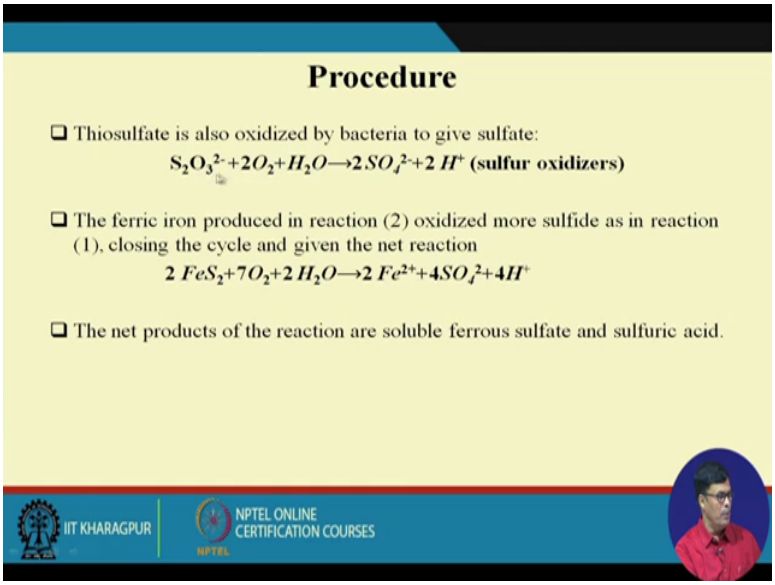

And this that thiosulfate in presence of oxygen it produces sulphate and here also direct reaction we can have this this how this sulphide is converted to sulphate. So when this I can I can I can give the example of the ore like chalcopyrite, pyrite this is largely available in the ore so this is sulphide ore and and when you treat with this organism and when bioleaching takes place it produces sulphate so it will come all the metals will come in the soluble form. Now if it comes in the soluble form then your recovery process will be very simple and by through the electroplating process or different process we can use for the recovery of the metals.

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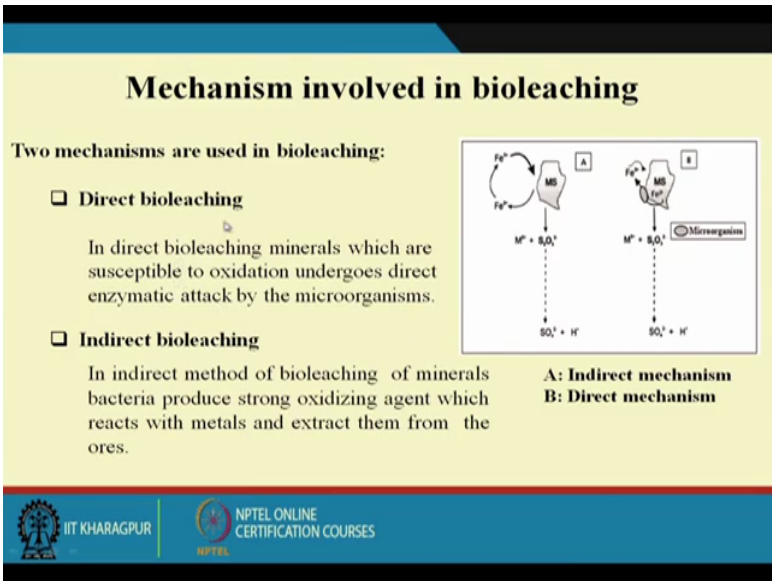

So we have two types of leaching bioleaching process one is direct bioleaching, another is indirect bioleaching. In the direct bioleaching the minerals which are susceptible to oxidation undergo direct enzymatic attack by the microorganism so this is directly metal that you know this here the microorganism directly attack the metal ion and it and it produce the converted to sulphide. Indirect means bioleaching the minerals bacteria produce strong oxidizing agent, it produce some kind of ferrous is converted to ferric and this ferric goes inside the cell and then help for the this solubilisation of the protein that you know in indirect method the bioleaching that of minerals bacteria produces strong oxidizing agent which react with metal and extract them from the ore.

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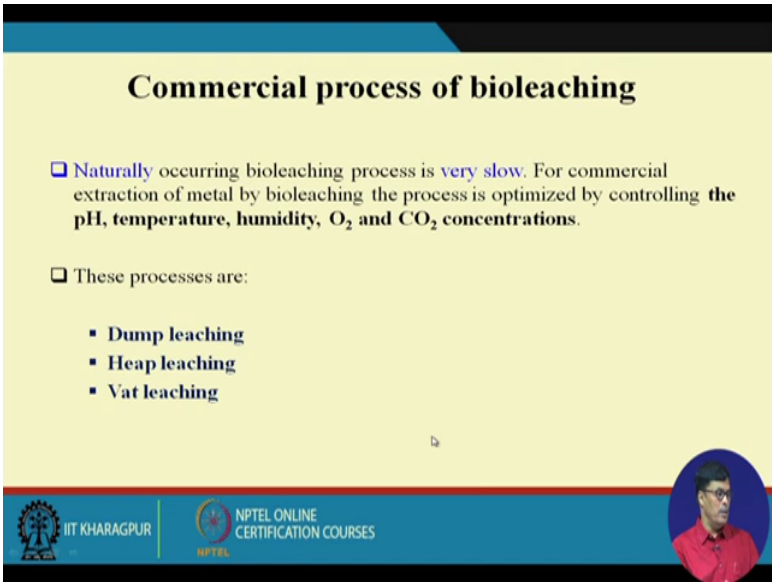

This is the natural occurring bioleaching process is very slow it is not very fast for commercial extraction of metal by bioleaching process is optimize by controlling the pH, temperature, humidity, oxygen and carbon-di-oxide concentration. So this is this is the usually the done in presence of oxygen and there are three types of leaching process we have one is called dump leaching, another is heap leaching and vat leaching.

Now if you look at the cost analysis of this three process are different that in case of dump leaching this is usually execute at the at the at the at the mine at the mine we have all the ore there we have some collection basin, we put we spray sprinkle the microorganisms then then we collect the this this soluble material recycle back to the system again and again until and unless most of the material have been solubilize.

So this is the low costly process the reason is that this is executed in the in the mine itself and heap leaching also usually done at the mine but it is it is done in a planned manner, so they have more more provision of aeration more provision of that organised manner. So monetary involvement in this heat leaching is comparatively high but vat leaching we usually take place in a control vessel where we can maintain the temperature pH and all these things so your rate of reaction and time of reaction obviously would be very high so this is the three things we have we have the dump leaching, we have heap leaching, we have vat leaching.

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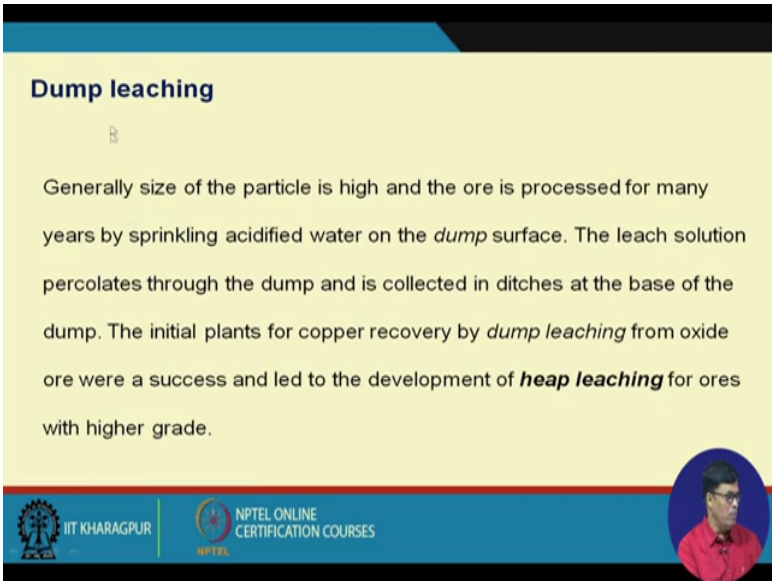

Now dump leaching generally generally size of generally size of particle is high and ore is processed for many years by sprinkling the acid water in the dump side dump side means I I want to means the mine the leach solution percolates through the dump and is collected in the ditches in at the base of the dump. The initial plant of copper recovery by dump leaching from oxide ore were a successful and lead to the development of heap leaching of ore for high for higher grades.

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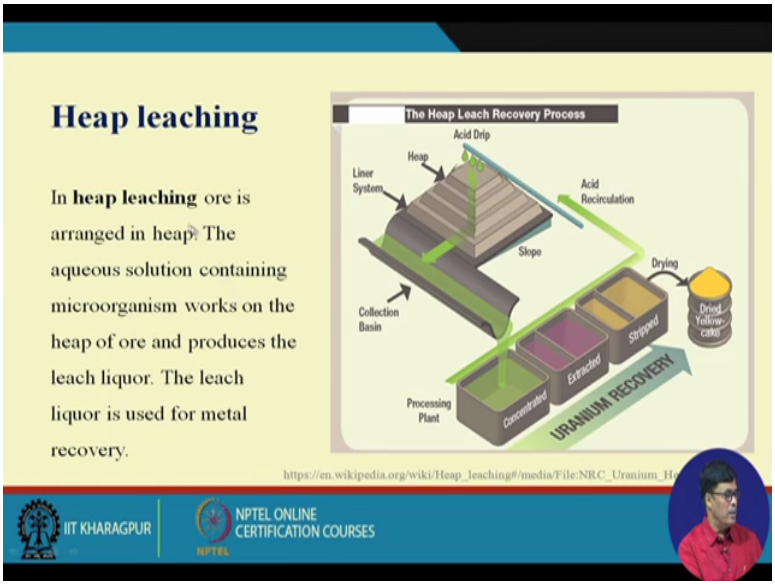

Now if you look at the heap leaching it is as I told you it is (())(10:24) organized manner we have we use that you know we can collect they have the provision for collecting the leach, the leaching material we can we can we can do the concentration here then the collection basin that we have and this is the processing plant we have from this we can recover the metals we consider this is the uranium recovery that is kind of a example that has been given here.

In heap leaching ore is arranged in heaps this is the heaps this is you can see in different layers formation is there the aqua solution containing the microorganism walks on the heap of the ores so we use this is the sprinkler we sprinkle the that the acid solution with the microorganism on the ore. So you know when it travels through this then sulphide will be converted sulphate and it is solubilize and liquid will comes out like this and produce the leach liquor. The leach liquor is used for metal recovery.

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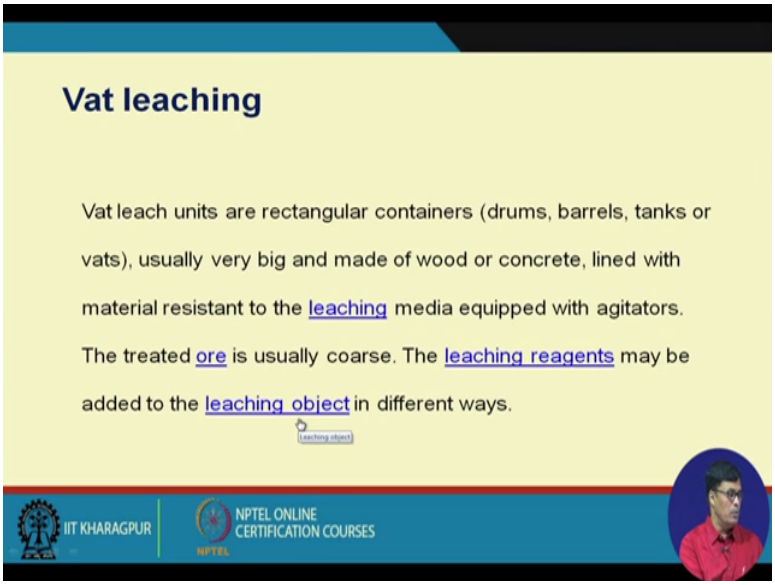

Now vat leaching as I told you vat leach unit is a rectangular container this is usually done in a controlled environment drum barrels tanks or vats usually very big and made of wood or concrete or lined with material resistance to the leaching media equipped with agitator. The treated ore is usually coarse and leaching reagent may be added to the leaching object in different ways so this is this is a costly process, the vat leaching is basically it is a costly process and here you can have the control environment and we already pointed out that microorganism they are very sensitive to the environment if you maintain the environmental conditions properly then your microorganism can work very fast so that is that plays very important role but this is competitively with dump and heap leaching this is competitively costly but recovery metal recovery will be very high in this process.

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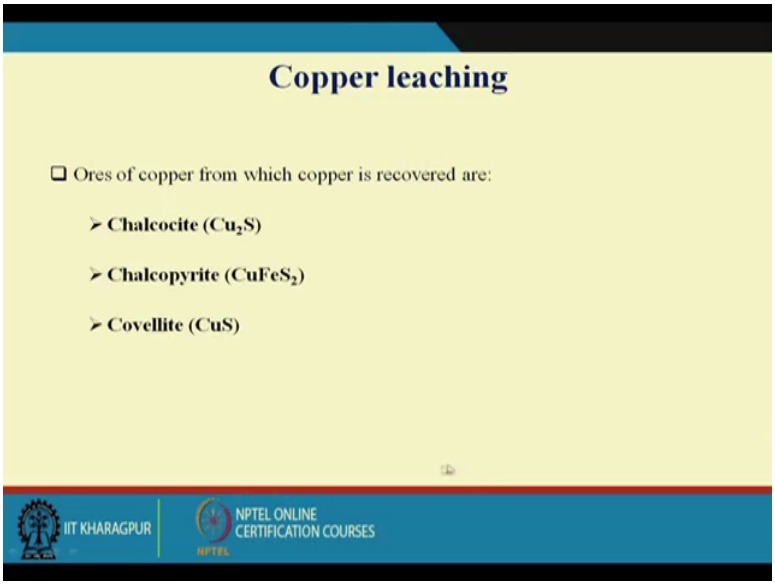

Now copper leaching we have different type of ores I told you that chalcocite, chalcopyrite and covellite that you know this is the typical copper ore that is available in the mines because in India this this copper leaching process largely used by the industry so so for the recovery of copper.

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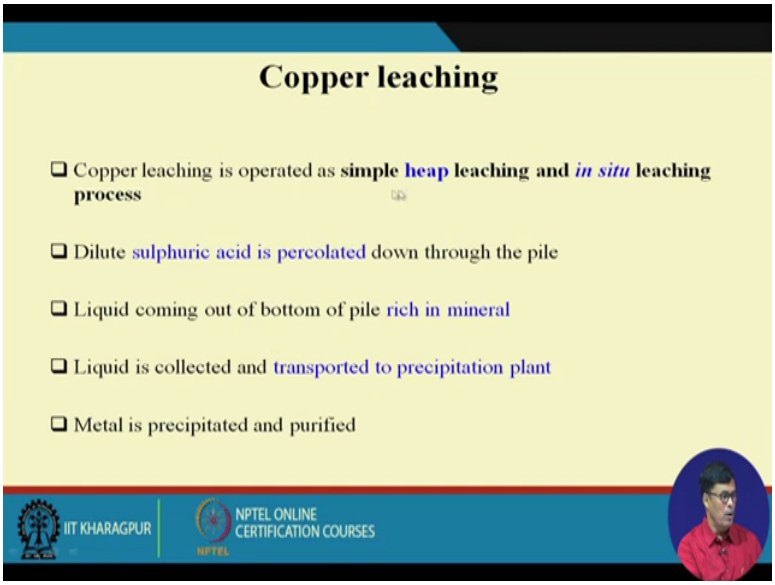

Now copper leaching operated simple heap leaching and in situ in situ leaching process, in situ means that this client is taking place at the at the mine itself and dilute sulphuric acid is percolated through the piles and liquid coming out from the bottom of the piles rich in minerals and liquid is collected and transported to precipitation to precipitation plants metal is precipitated and purified.

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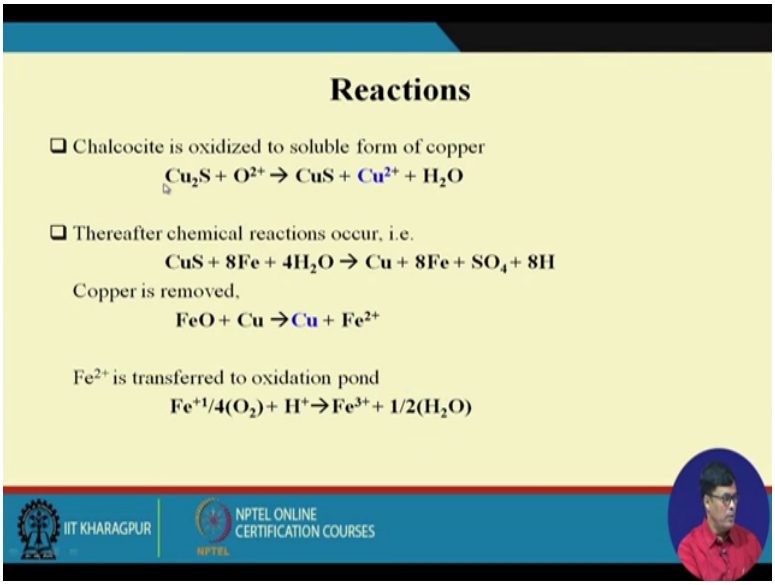

And this is the reactions that we have copper sulphide, that you know Cu2S is converted to CuS and CuS is converted to this copper and copper is removed like your final reaction is this ferrous oxide and copper copper and ferrous ion that we have and iron is transferred to the oxidized pond and convert into a ferric this is this is the reaction how it is take place.

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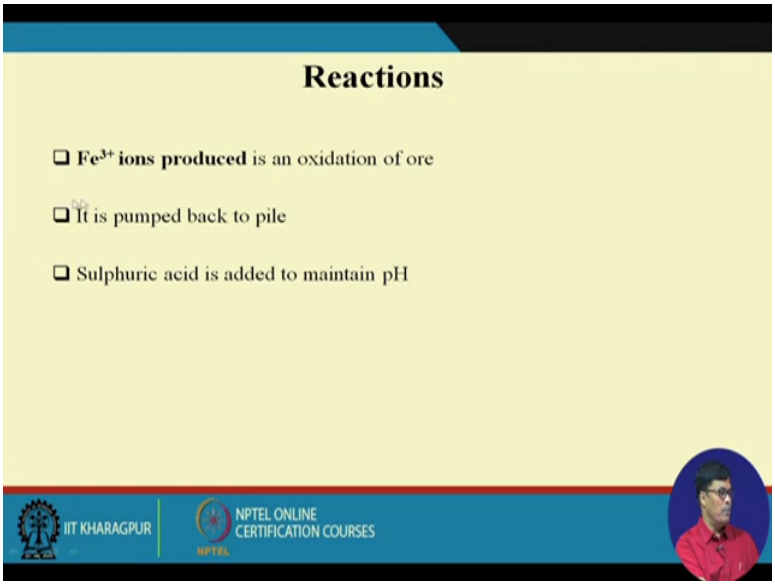

And ferric ion produces as the oxidation of ore and it is pumped back to the piles and sulphuric acid is added to maintain the pH.

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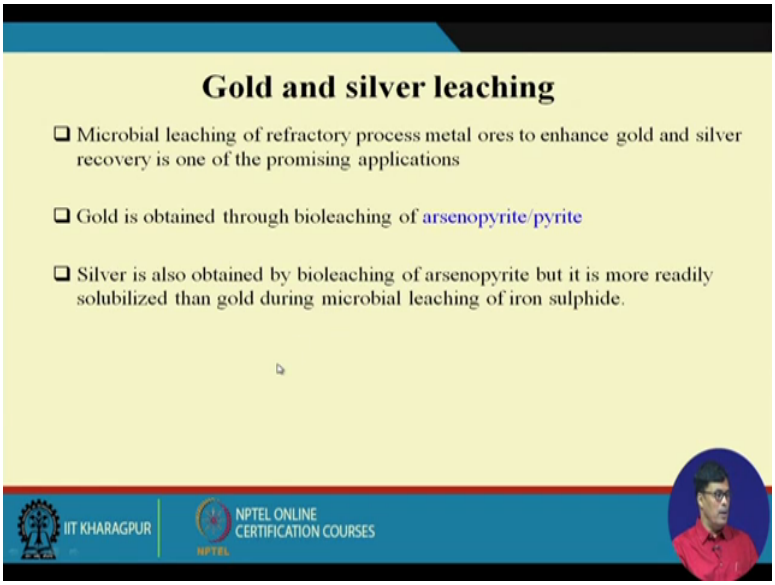

Now gold and silver leaching the microbial leaching of refractory process metal ores to enhance the gold and silver recovery is one of the promising applications. The gold is obtained through the bioleaching, the arsenopyrite or pyrite, silver is also obtained from bioleaching the arsenopyrite but it is most readily soluble than gold during the microbial leaching in iron sulphide.

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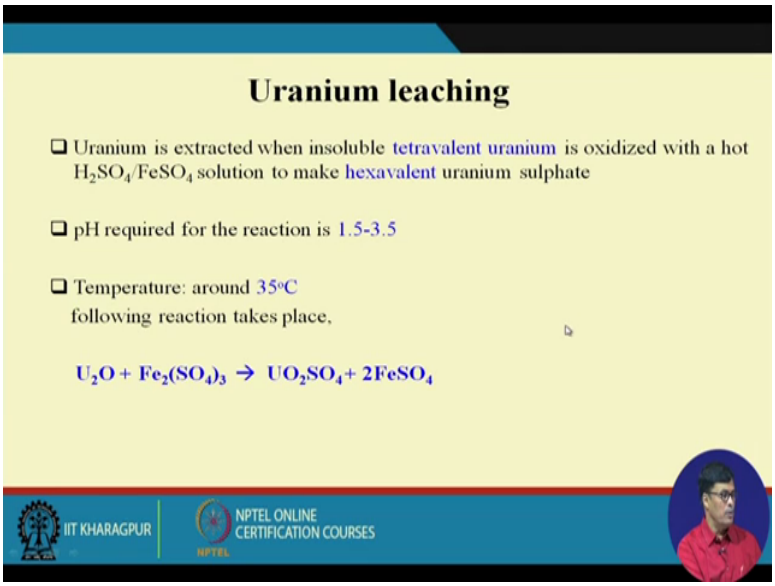

So uranium leaching uranium extracted when when in soluble tetravalent uranium is oxidized with hot sulphuric acid and ferrous sulphide solution makes a hexa hexavalent uranium sulphate. The pH required for this reaction is 1$5 to 3$5, temperature we maintain 35 degree

centigrade the reaction is like this, the uranium oxide they react with ferrous sulphate and this is ferric sulphate and then it produces the uranium sulphate this is in the soluble form.

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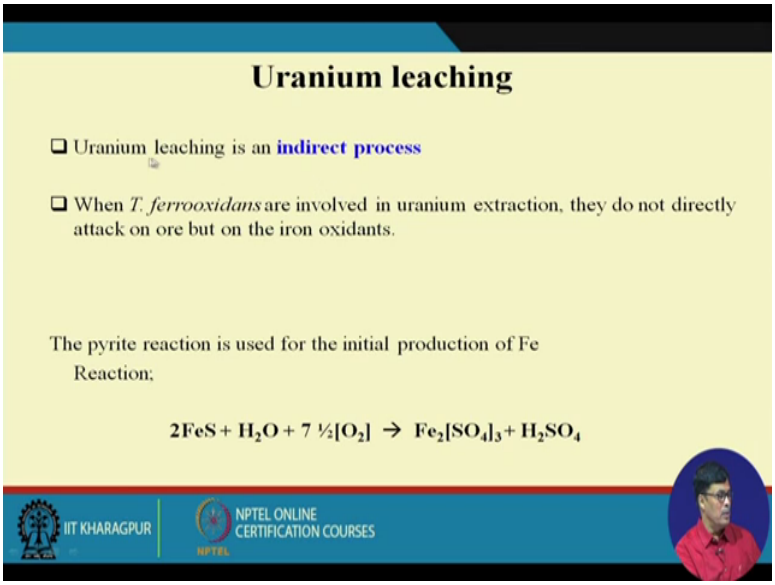

So uranium leaching is the indirect process where the T ferrooxidants that is involved for the uranium extraction and they do not directly attack the ore but iron oxidants. The pyrite reaction they initially produced iron this is the kind of reaction that we have how the sulphide convert to sulphate.

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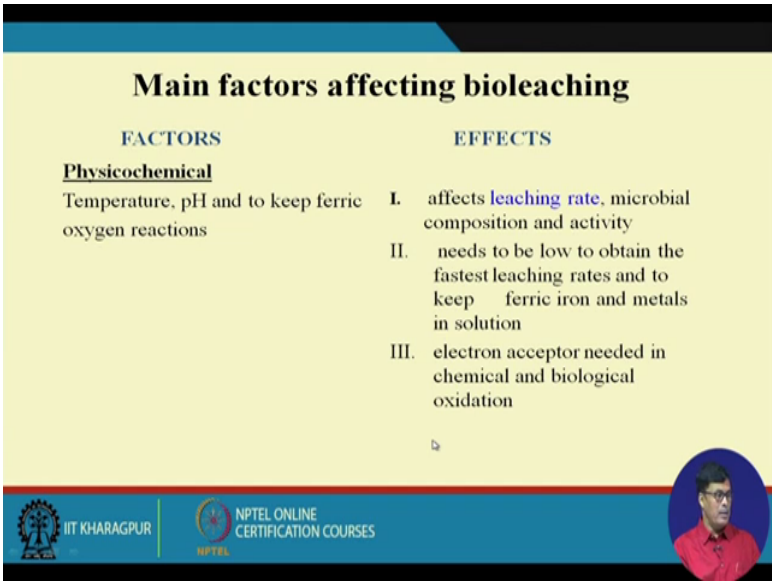

Now the main factors is that affect the bioleaching process your physiochemical is temperature, pH to keep the ferric oxygen reaction and affects is the affects the leaching rate

microbial composition and activity that so activity of the organism plays very important role needs to be low to obtain the fastening leaching rate to keep the ferric iron and metal in solution. Electron acceptor needed to be chemical and biological oxidation.

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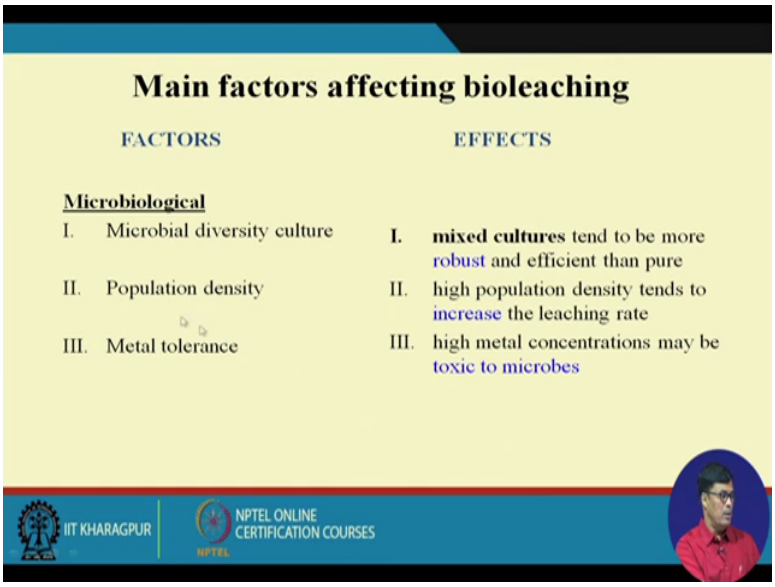

Now main factors of the microbiological things also very important, microbial diversity culture and population density and the metal tolerance that plays very important role. The mixed cultured tends to be more robust and effective than pure because because if if two three cultures present in the in the in the ore then what will happen that if one particular organism is inhibited or other organism my not be inhibited by the same concentration of the metal iron so it work.

So we always find that in case of metal leaching process it is quite effective, here I want to point out that particularly in case of I shall discuss about cheese making industry and the cheese making process one important step is the curd making. In the curd making process we have we have we require lactobacillus (())(17:23) that different types of organisms and this organisms they have the bacterial fuzz the contamination problem and due to this contamination problem what is happened if bacterial fuzz is very specific for a particular bacteria if it attack a bacteria that bacteria will be inactivated.

So that is why if we use the mix culture then always it is favour the curd formation is similar to here that always mix culture or microbial diversity culture all helps in the metal extraction process. Now population density high population density tends to increase the leaching process because this is the this is the organism they secrete the enzyme and that take part in

the reaction. Naturally the metal that have population density plays very important role, metal tolerance as I told that that concentration of metal as when when it is insoluble form then your organism will not be inhibited but as soon as metal coming in the soluble form the metal ion concentration increases that may give some kind of inhibition effect on the microorganism. So the metal tolerance also very important in this particular bioleaching process.

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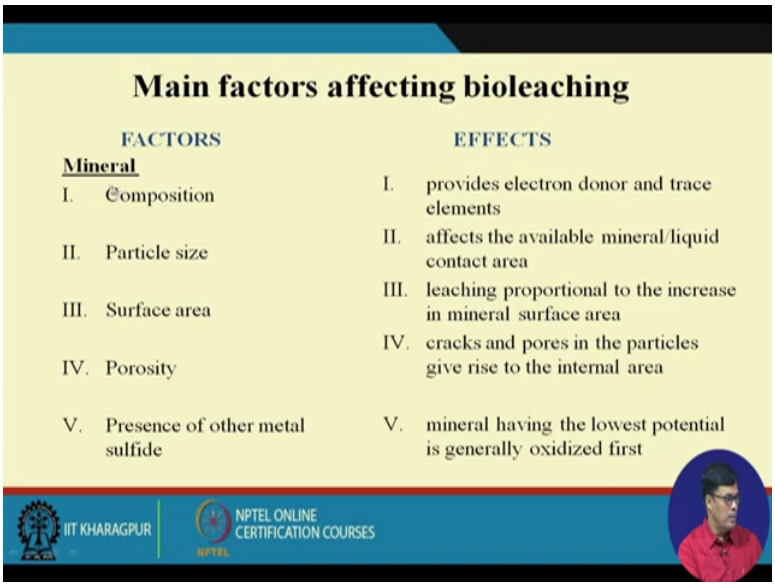

Now that other factors like minerals, composition, particle size, surface area, porosity and presence of other metal sulphide this is very important. Composition provides the electron donor and and trace elements. The particle size more particle size more surface available for contacting with the bacteria and more leaching will be more that the surface area, the particle size and surface area they are quite co-related with each other. Porosity cracks pores or particles give rise to the internal area that is also very important presence of other metals sulphate, sulphide that minerals having the lowest potential is generally oxidized fast.

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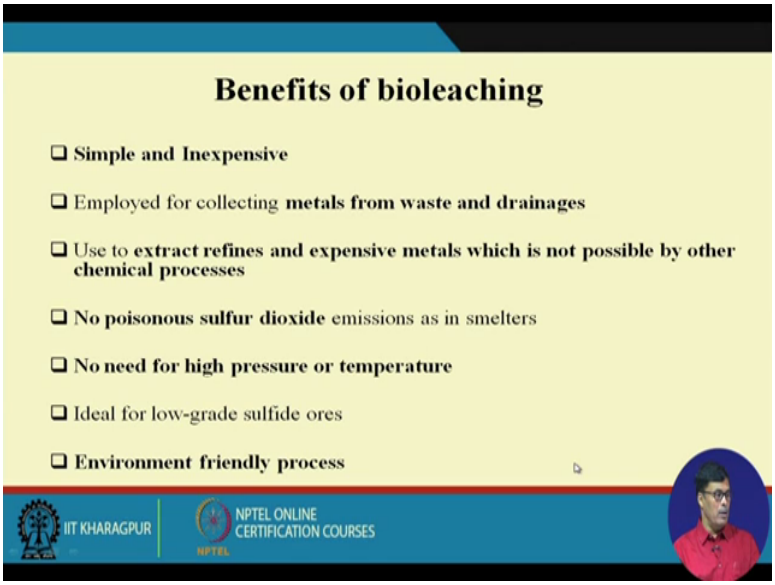

So benefit of bioleaching is the simple and expensive employed for collecting the metals from waste or drainage and use extract use the extract refines and expensive metals which is not possible by other chemical process. No poisonous sulphur-di-oxide emission takes place as in smelters, no need for high pressure and temperature. Ideal low grade solid ores can be used and environmentally friendly process.

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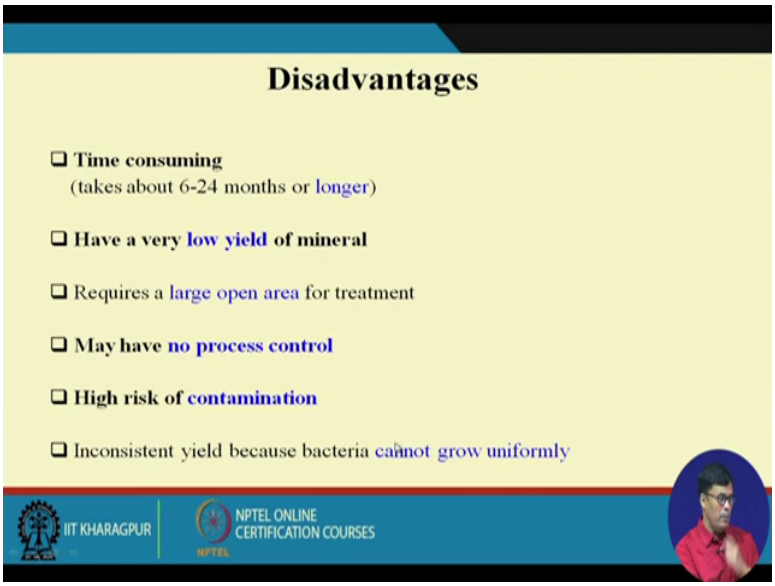

The disadvantage of this process is several it is the time consuming takes place 6 to 24 hours longer, have a very low yield of minerals and required large open area for treatment maybe no process control and high risk of contamination since it is a open open that if you look at

dump and heap leaching it is open process, contamination problem will be very high inconsistent yield because bacteria cannot grow uniformly.

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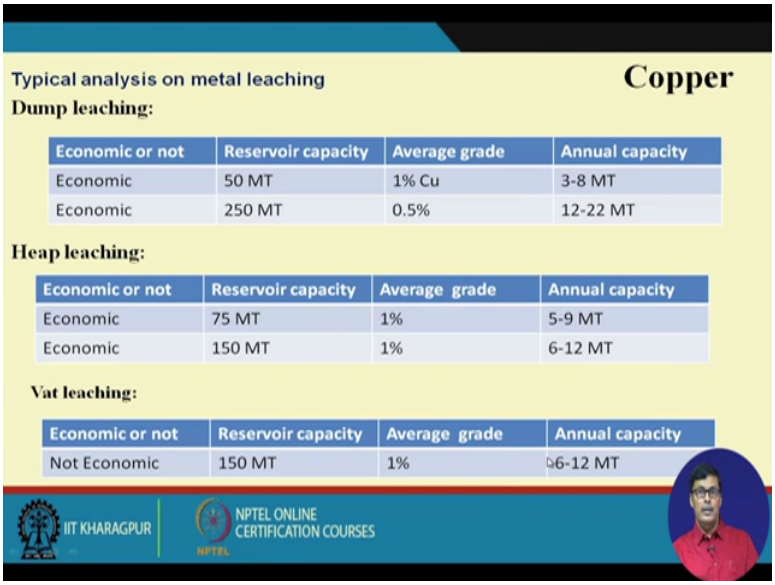

This is at the end I want to discuss that how this this process affects the you know that costing of the process that you know we have we have we have two examples with us with the copper copper recovery system and the gold recovery system, will make a comparative study with respect to dump leaching, heap leaching and and you have vat leaching. And I told you if you look at this process dump leaching operational cost will be very less, heap leaching will be comparatively little bit high and vat leaching will be very high so it is like this.

Now you when you do it here they did kind of economic analysis now if the reservoir capacity is 50 metric tonnes, it contains 1 percent copper at annual capacity of production with 3 to 8 metric tonnes they found it is economic. Now even if it is reservoir capacity is 250 metric tonnes the average grade is 0$5 percent copper then annual production is 12 to 22 metric tonnes then they found it economic.

Now here you see that the heap leaching also 75 metric tonnes and 150 metric tonnes 1 percent copper. They they even 5 to 9, 6 to 12 you find economic. But vat leaching with the same when you use the 150 and metric tonnes and 1 percent that copper and seize to 12 metric tonnes here but it is not economic. Why it is not economic because the operation operating cost cost of operation of the process vat leaching is comparatively high as compared to heap leaching and dump leaching.

So that is why this is not this is not economically feasible so that depend operational cost plays very important role in the metal leaching process.

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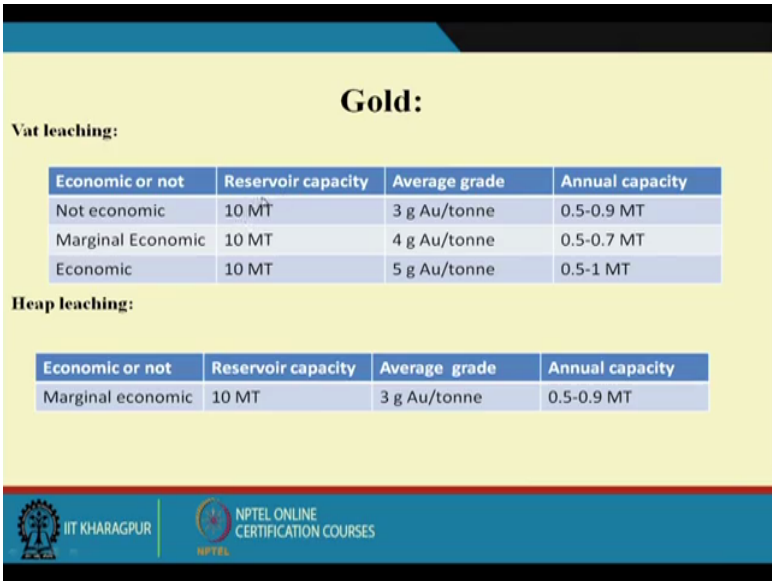

Now I have another example with a gold leaching process now we find that the reservoir capacity is 10 metric tonnes then we have average grade of that gold is 3 gram, gold per tonne and annual production is 0$5 to 0$9 metric tonnes, it find non-economic even in vat leaching it is not economic.

Then 10 metric tonnes if the concentration increases 4 grams gold per tonne it is 0$5 to 0$7 metric tonnes. It is find marginal economic but economic things will come when the goal concentration comes to 5 gram gold per tonnes and annual production is 0$5 to 1 metric tonnes then it finds that your vat leaching process is economic

Now if you come here in case of this this heap leaching process that even 10 metric tonnes and 3 gram that gold per tonnes is present there and annual production is 0$5 to 0$9 metric tonnes of gold we find it has the marginal economic. So so we we find that metal leaching process is quite interesting the reason is that that this is applicable when ore contains very low amount of our metal because this then metal recovery process through the chemical process is no good because it is very, this is usually take place at high temperature and high pressure so it is it is very costly process.

And that is why when your ore contains very low amount of metals then your your bioleaching process will be mostly effective and we find that two organism that is thiobacillus ferrooxidans this is the organism which is very effective for the leaching process

and where sulphide is basically converted to sulphate. Sulphide is the insoluble material that remains in the ore and this is converted to sulphate, when it is converted to sulphate the metals will come in the soluble form then you can precipitate out the metal and get the pure metal from that solution.

So the recovery process will be little bit easier only the problem is that when you go for this process we find this reaction is very very slow reaction and also concentration of metal ion in the solution also quite less so that is that is the only (())(25:15) we find there are 40 different industries we have throughout the years and they are largely operating and for this metal recovery process. So I think this is very useful this is a very good application of the biotechnology that biotechnological science for the recovery of some useful metal for the human benefit, thank you very much.