Fundamentals of Food Process Engineering

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Lecture - 51
Leaching and Extraction

Hello everyone. Welcome to the online certification course Fundamentals of Food Process Engineering, ok. So, this is our 11th chapter and in this chapter we will discuss on Leaching and Extraction. As the topic of extraction is very vast topic, and it has a huge application in food processing industries, many processes are there that we use extraction basically it can be again divided into many different categories. In which the 2 phase that we mix for extraction of one particular solute or one particular component that may vary from different combination. For example, liquid and vapor, liquid and gas or may be solid and liquid, liquid and liquid so many combinations are there.

But since this NPTEL course that we have designed on fundamental aspects of food processing, there we have not included many mass transfer index mass transfer processes. For example, distillation adsorption so, those thing we have not actually included. And therefore, in the leaching and extraction, we will give you an idea superficially that what are the different kinds of methods are there, what are different kind of equipments are there, and the applications of this and little bit of calculation part or some numerical problem on that.

But we will not focus on to the very details of this extraction process, because for that you have to know the mass transfer process specially distillation in a very detail, and here that is not within the scope of our course. So, therefore, I will try to give you an overview of the leaching and extraction process.

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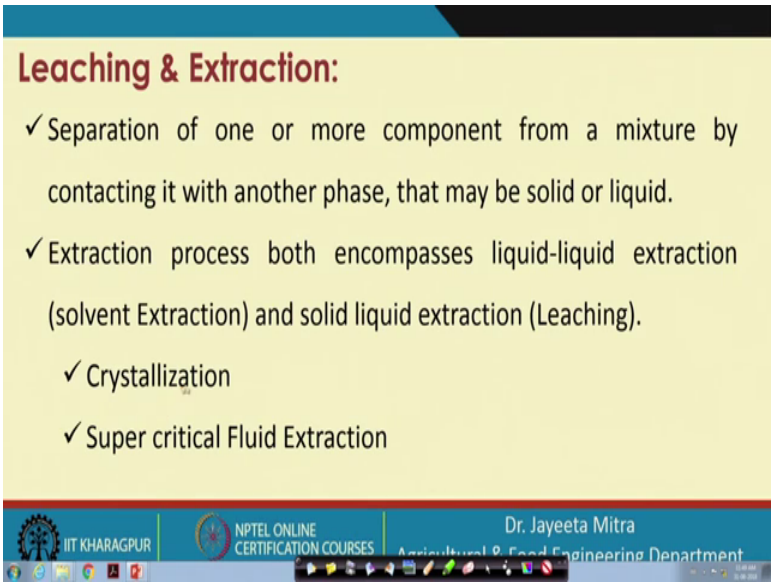

So, let us start with what is the leaching and extraction process is, as I mentioned that it is separation of one or more component from a mixture by contacting it that is the mixture with another phase that may be solid or liquid. So, the component that we want to separate that may be one component or may be a mixture, more than one component and then may be some you know some solid solute that we want to extract. So, extraction process both encompasses liquid liquid extraction that is called solvent extraction, and solid liquid extraction that is called leaching.

So I have already mentioned that we are not covering here distillation or adsorption all those techniques. Also there are one more separation method that is or you can say the extraction method; that is, special case which is crystallization and another is the super critical fluid extraction.

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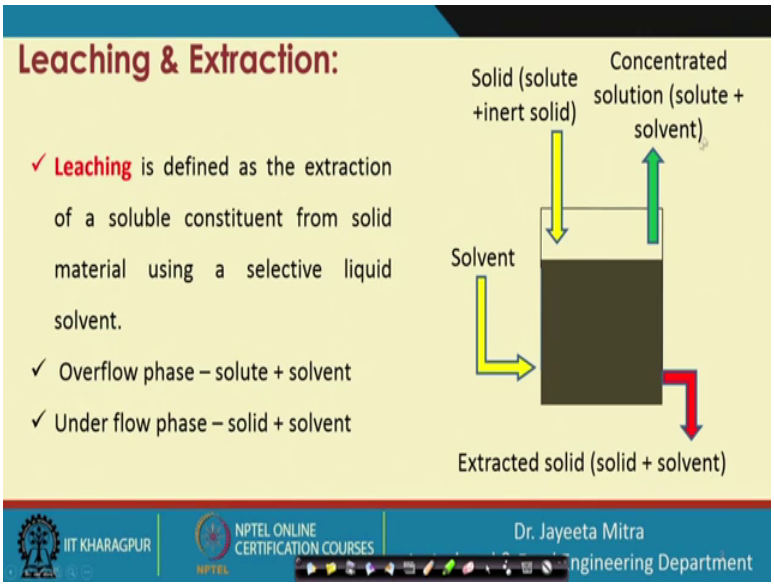

So, if you consider leaching so, the specific difference between the leaching and solvent extraction is that; in the leaching solid and liquid are coming into intimate contact so that some solute component from the solid will be you know dissolve in to the liquid component and will be getting separated. Whereas, in the extraction or specifically solvent extraction, 2 liquid phase are coming into contact, and then solute from one liquid will go to the other liquid, providing provided that the other the second liquid has higher affinity towards the particular solute component that we want to separate. So, in case of leaching it is defined as the extraction of soluble constituent from solid material using a selective liquid solvent.

So, what happens is that, we have a chamber or extraction chamber where we put the solid which is having the solute and also have the inert solid. The solute which we want to separate so, that has to be dissolved in the particular solvent ok. And there will be the inert solid, where the solute is now mixed and that we want to separate. So after this mixing what will happen? The concentrated solution, that is having the solvent and solute, why it is concentrated because, initially the solvent will not have any solute components. So, ideally this is 0 in the initial case or may be very low amount of that component if it at all exist, and when all the solute will come into the solvent so, solution become concentrated with that particular solute.

So, solute plus solvent will going out and the extracted solute; that means, solute has been taken out. So, that solute will be there, and some portion of the solvent will be getting mixed with the extracted solid so, that will also be there. So this is how the leaching process takes place. So, in this particular case, we can specifically name this 2 stream one that is the concentrated solution which is a combination of solute plus solvent and another is the extracted solid that is solid plus little amount of solvent; is termed as respectively over flow phase and under flow phase. Over flow which is the solute plus solvent and underflow that is the solid extracted solid plus solvent.

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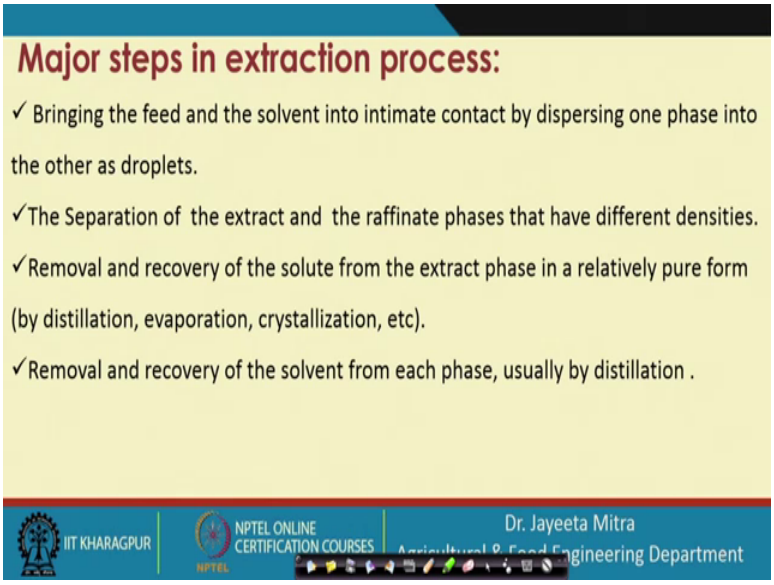

So if you look into the major steps in extraction process, you can categorize them into many segments. So, first is bringing the feed and the solvent into intimate contact by dispersing one phase into the other ok. So, the feet and the solvent you have to bring into intimate contact by dispersing one phase into the other as the droplets. So, the separation of the extract and the raffinate phase that how different density.

So, this particular thing is applicable when we talk about the liquid liquid separation, because in that case like for leaching we are we are mentioning as the over flow and under flow in case of liquid liquid extraction, we name them extract and raffinate. Extract that contains the solvent plus dissolve solute or the dissolve component that we want to separate, and raffinate is after extraction of the solute what liquid will remain

initial feed slurry or initial feed liquid will remain. So, that is called the raffinate phase, and they have different density.

So removal and recovery of the solute from the extract phase. Now when we have extracted so, the extract has now come from one phase to the other liquid phase. And relatively pure form, because initially it was in a mixture with some other liquid and now since the second liquid which is our solvent has higher affinity, that has taken that has you know all the solute concentration has come into the second liquid now in a pure form; so, that we need to separate from the liquid by distillation evaporation or crystallization.

Then comes the removal and recovery of the solvent from each phase usually by distillation. Each phase in the sense, when we perform liquid liquid extraction, then the liquid which is used as the as a solvent and which is having higher affinity to a particular solute component will extract that particular component into it and that will be coming out as an as an extract. And in the raffinate also some amount of the solvent will get mixed as it was happened in case of the leaching process.

So, from both the phase solvent has to be evaporated. From the first phase solvent or from the extract solvent needs to be evaporated, because we want to have pure form of the solute. So, we apply distillation or evaporation, crystallization and also that solvent has to be separated from the feed solution, because we want to have there also the initial material in pure form; now we want to extract the solvent out of that.

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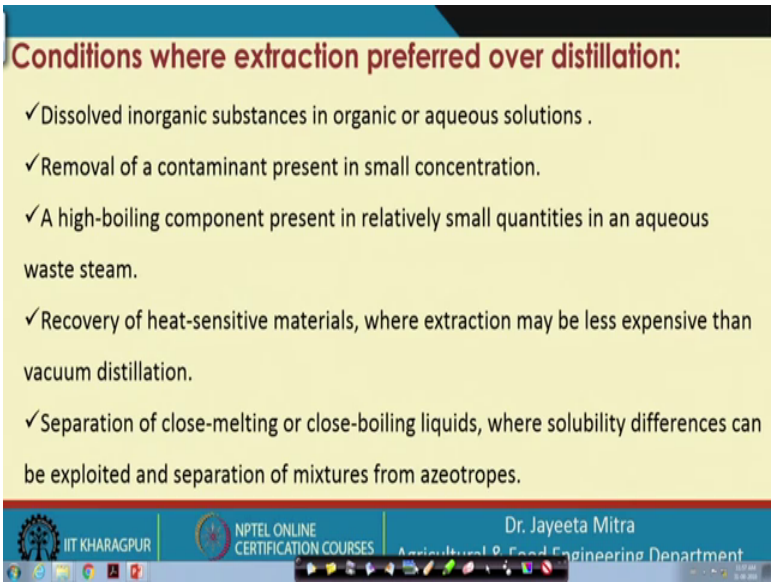

So, these are the thing now the obvious question will come that is the distillation or crystallization etcetera, we are doing what is the need of extraction process then, I mean what is the function of that. So, we can look for certain cases, where extraction is beneficial over the other existing method of separation. So, these are first one if there is dissolve inorganic substances in organic or aqueous solution. In that case, we need to apply the extraction process for separation of those components.

Second is removal of contaminant present in small concentration. If very small concentration of contaminant is present and we want to separate them by distillation or such kind of method. So, it will unnecessary increase your energy consumption right. So, then extraction is preferred, then high boiling component present in relatively small quantities in an aqueous waste steam.

So if high boiling component is present and very small amount. So, then extraction is beneficial over other methods of separation for example, distillation etcetera and recovery of heat sensitive material. So, for them we cannot apply high heat so, that the evaporation of one component will occur. So, in those case we definitely have to use the extraction process to separate them ok and because of because extraction is less expensive compared to the vacuum distillation. If you want to have distillation at lower temperature so, what we can do we can lower the vacuum level in the chamber, and then

we can have distillation at lower temperature. But compared to that extraction will be less expensive and beneficial in such cases for heat sensitive material separation.

Now separating of close melting or close boiling liquid; where solubility differences can be exploited and separation of mixture from azeotropes. For this cases, we definitely have to use the extraction process, because if they are close melting or close boiling liquid, distillation cannot be used to separate them they are always will be some mixture of the vapor because the they cannot be separated well by distillation. So, all such cases we need to use the extraction method, ok. So, maybe it is as depending on the case may be it is the liquid liquid extraction or some time we have to use the solid liquid extraction that is called leaching.

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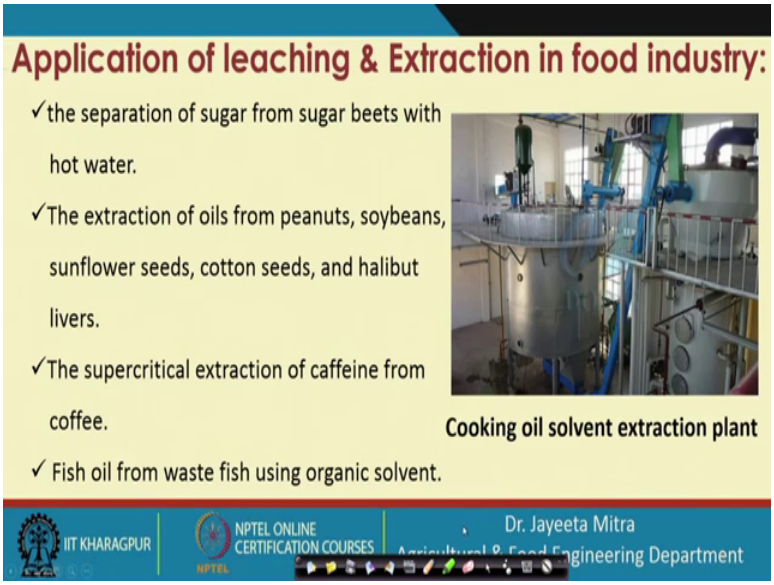

Now we will see the application of leaching and extraction in food industry. So, the separation of sugar from sugar beets with hot water this is very common, operation of extraction and not very expensive method hot water can easily dissolve the sugar from the sugar beet if the cells are disrupted and it is getting mixed with the water in a proper form. So, it is very easily can be extracted, then the extraction of oil from peanut soya beans, sun flower seeds, cotton seeds and halibut liver etcetera.

So, this separation this separation of components oil components can be done from by the extraction method and the super critical extraction of caffeine from coffee. So, super critical extraction we will discuss that that is another very efficient extraction method,

and caffeine from coffee is extracted by that method. Fish oil from the waste fish using organic solvent. So, organic solvent is used to extract the fish oil from the waste fish and all this are some by the extraction. So, these are very common application in the food industry.

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So, everyday life you use one of very common application of this leaching, which is when you use any tea whether it is black tea or green tea bag in your morning tea. So, what we do? We take a bag and there is there is granulated green tea leaf is there. We dip it into the hot water and then we get the tea. So, this is actually leaching of the polyfenals into the hot water ok. So, this is mechanism of leaching very simple and easy experiment of leaching process.

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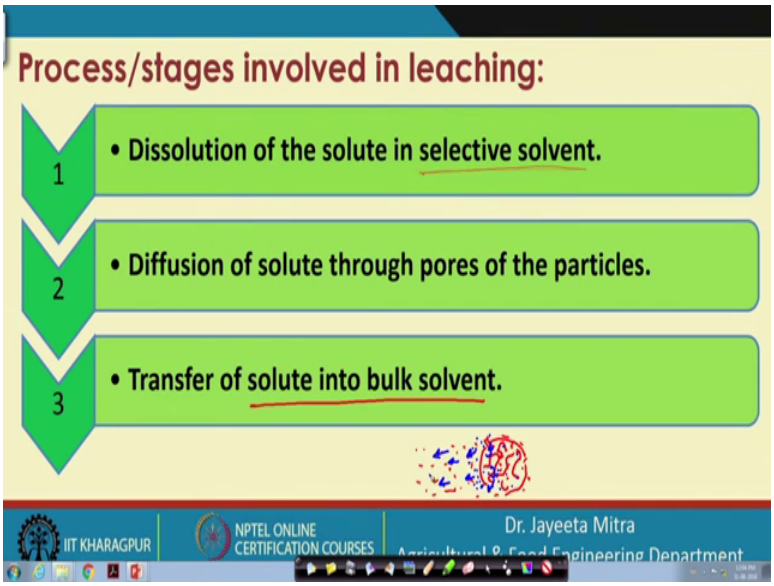

So, if we specifically see leaching methods so, in that these are the steps that we normally observe, once we make the once we bring the product bring the solid material, from which we want to extract the particular compound or particular solute. So, when that comes into contact with the solvent, solvent has to mix with that material very well and has to penetrate or percolate through it properly through the solid material solid phase properly.

So that the dissolution of the solute in this in the selective solvent will be there we use the term selective solvent, because not all the solute will have affinity in all the material. So, for that we have to select we have to select the solvent efficiently so that it will it will have some affinity higher affinity towards that particular solute.

Now once the dissolution occur, once the dissolution of the solute on the solvent has been occurred, after that what will be the next step the next step will be diffusion of solute through pores of the particle. Because there will be the particle and the liquid has to enter into the pores of the solid miscella or the solid particles. So, that the in the solute which is in the very inner core of the material will come out will dissolve into the solvent, and they will diffuse through the those pores and come out to the surface.

Now once they come out to the surface the next is transfer of the solute into the bulk solvent, ok. So, once we have suppose we have the material, we have the miscella ok, we have the miscella and there are you know pores through which the liquid when the liquid

is coming into direct contact with that. So, liquid has to first enter into the pores, then the solute which are in some you know some pockets of the of the material some inner core of the material. So, they will first dissolute they will then diffuse to the surface and they will then get mixed with the bulk liquid.

Once they get mix with the bulk liquid so the concentration is higher in the affinity of the solid particle whereas, if the liquid liquid is flowing. So, it has to then diffuse the material has to then diffuse to the bulk liquid. It will transfer to the bulk solvent. So, this is the whole process how the leaching takes place in a actual condition ok.

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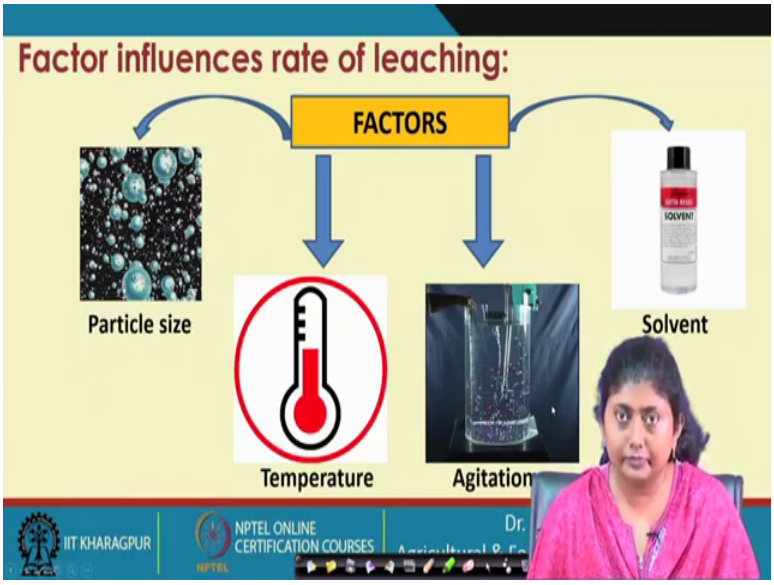

So, therefore, what may be the factors that can influence your leaching process. So, one thing is very sure that you have to bring the material the solid material with very good contact of the solute that of the solvent that you are using right. So, if the surface area of the material is increased so, then only it can happened that the product will come in very good contact of the solvent.

So therefore, we have to have very fine particles ok. So, that the surface to volume ratio is enhanced ok, many times what we do we use the granulated material to increase the extraction efficiency. So, for that particle size will be the first parameter or important parameter. So, based on the particle size your extraction rate may vary. Because the solvent has to reach at the very inner core of the material or it has to be in contact with the all solute components so, that it can be extracted.

Next is the solvent selection of solvent is very important, because if you have choice of 2 3 solvent, and they are in the relative order of affinity towards a particular solute. So, you have to select the higher affinity solvent the that solvent which is having higher affinity towards the particular solute component that you want to extract from the mixture.

So, selection of the solvent even you have to see the nature of the nature of the solvent that based on your material that you want to extract if it is the flavour compound you have to select the solvent accordingly if it is water soluble you have to select the solvent has the water. So, all this factor depend on selection of the solvent. Now temperature; how does temperature help in extraction? So, if we increase the temperature in case of an extraction process so, the temperature of the solvent is increased, and it becomes it is mobility increases and it is viscosity decreases. So, of because we know for liquid when you increase the temperature; so, it is viscosity decreases, and then it will have more mobility and it will have more extraction rate.

Now agitation, that is suppose there are the miscella is there, the particles are there in which the solvent is coming into contact with them and extraction is taking place. Now all the process of discussion and dissolution and then bulk transfer is very slow, unless you provide mechanical agitation to it. So, if agitation is being given in a system so, definitely extraction will be very fast. Because then the portion of the material which is normally exposed to the solvent will be enhanced by this agitation. So, all the area which where which where not in intimate contact with the solvent will also come with within the you know within the reach of the solvent and the extraction will be better.

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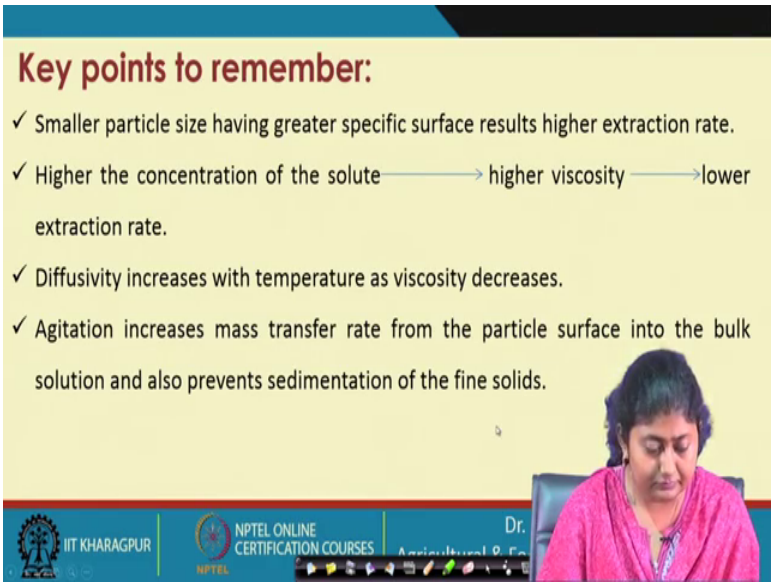

So this we have already discussed that the smaller particle having higher greater affinity greater extraction, concentration higher the concentration of the solute higher the viscosity lower will be the extraction rate that is very important. And diffusivity increases with temperature as viscosity decreases and agitation increases so, mass transfer will increase.

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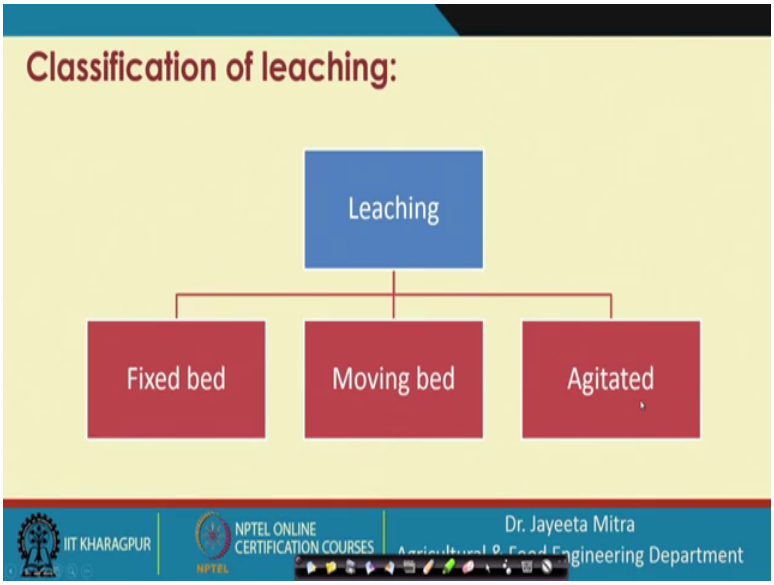

Now, coming to the classification of leaching so, leaching can be broadly categorized as either fixed bed leaching, moving bed leaching or agitated. So, fixed bed leaching; that

means, the bed of the particle is fixed through which the solvent is passing, and within this pass 1 pass or 2 pass like that the material the solute will be extracted.

Now the moving bed is that the material that has to be leached the component has to be leach from a solid, so that material is moving in many sections through which the solvent flow is occurring ok. And during this process the leaching or extraction of a particulate solute component is takes this. And the third one is agitated one; in which we provide some kind of mechanical agitation for better separation.

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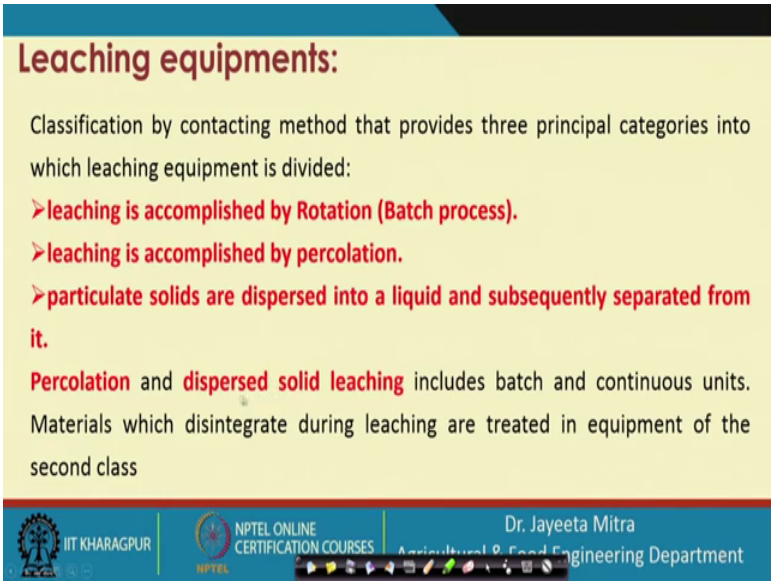

So, classification by contacting method, that is by contacting of the solute with the particular solvent. That provides 3 principle categories into which the leaching equipment is divided. So, first is the leaching is accomplished by rotation which is the batch process, then it may be accomplish by percolation, and particulate solute are dispersed into a liquid and subsequently separated from it ok.

So, that means, either by rotation which is a batch process or by percolation and dispersion. These are the methods percolation and dispersion disperse solid leaching includes batch and continuous unit. So, both the units batch and continuous can be observed for either percolation, dominated leaching or dispersed solid leaching. Materials which disintegrate during leaching are treated in equipment of the second class that is of the percolation leaching.

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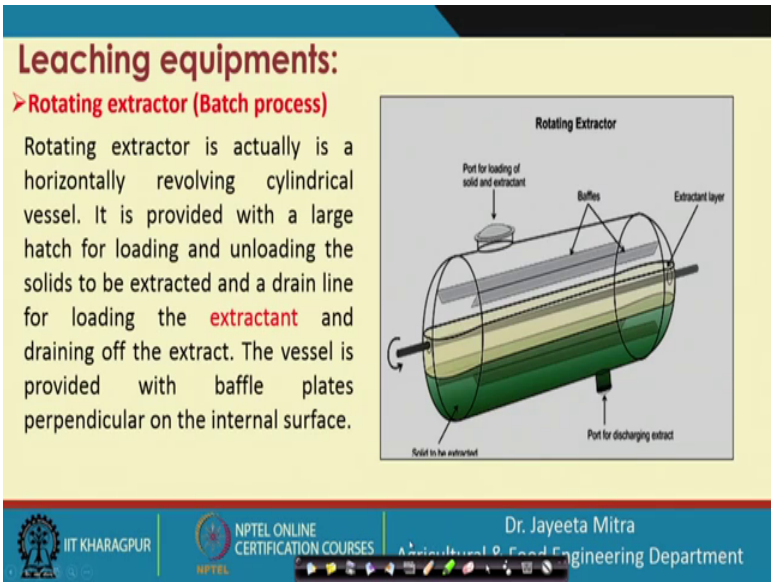

Now, the rotating instructor or the batch process, what happens here? So, this extracted is actually a horizontal as we can see, as we can see this is a horizontal horizontally revolving cylinder is there horizontally re revolving vessel cylindrical vessel. It is provided with a large batch for loading and unloading ok. So, the port for the loading of the solid so, from here we can load it ok, and there is a port for the discharging of the extract. So, extract discharge is also given here, and solid to be extracted that that is kept here. And there are extract extracted layers are given different extracted layers are given and also the baffles are provided ok.

So it is provided with a large hatch for loading and unloading the solid to be extracted and a drain line this is a drain line for loading the extractant and drain of the extract ok. So, this vessel is provided with the baffle plates perpendicular on the internal surfaces.

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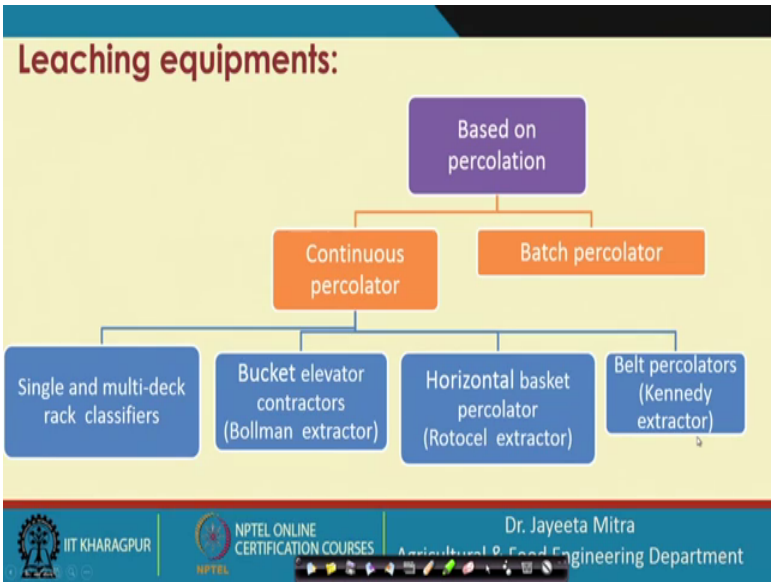

Now, based on the percolation again we can divide them into continuous percolator batch percolator, and continuous can be also divided into single and multi-deck rack classifiers. Bucket elevator contractor that is called the Bollman extractor, horizontal basket percolator that is called Rotocel extractor, and belt peculator that is called the Kennedy extractor.

So, percolator and dispersion actually on the percolation what we do is, the solvent is percolated through the material solid material and eventually comes to the next section, and if there are more number of stages they will go to all through all the stages, and finally we are getting the extracted product. Whereas, in the dispersion the solid particles and the solvent they are in the proper disperse form.

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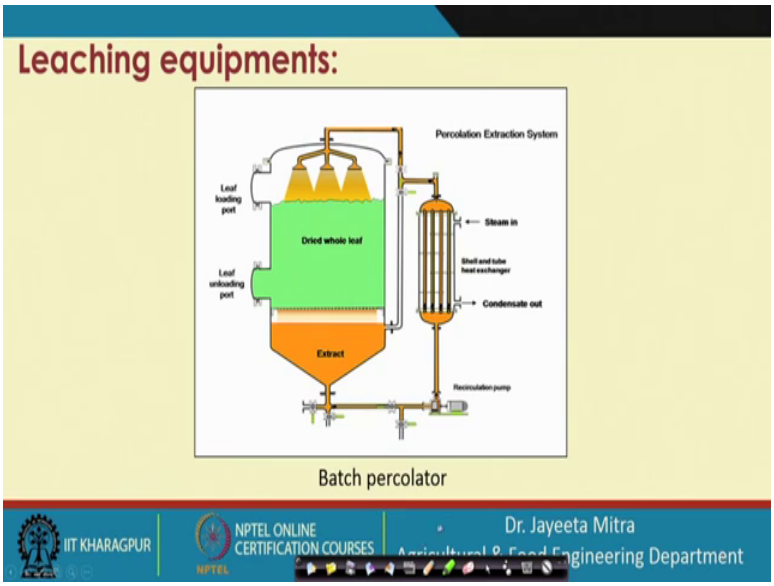

So, the batch percolator if you see this is a batch percolator. So, here there is loading section there is a loading port, and there is an unloading port ok. So, material is loaded from here and unloaded from here. We have a percolation extraction system where the spray of the solvent is from the top, and while passing through while percolating through the bed of the particle, the extraction is being done and then it is extracted at the bottom.

So, it may be re circulated some time as with the requirement because of if we feel that with one pass all the solute extraction has not completed. So, it may be again rerun and in that process we need to increase the temperature also by heat exchanger utilizing steam because we know that, if the viscosity decreases or the temperature increases for the solvent it can extract more right. So, this is the mechanism of the batch percolator.

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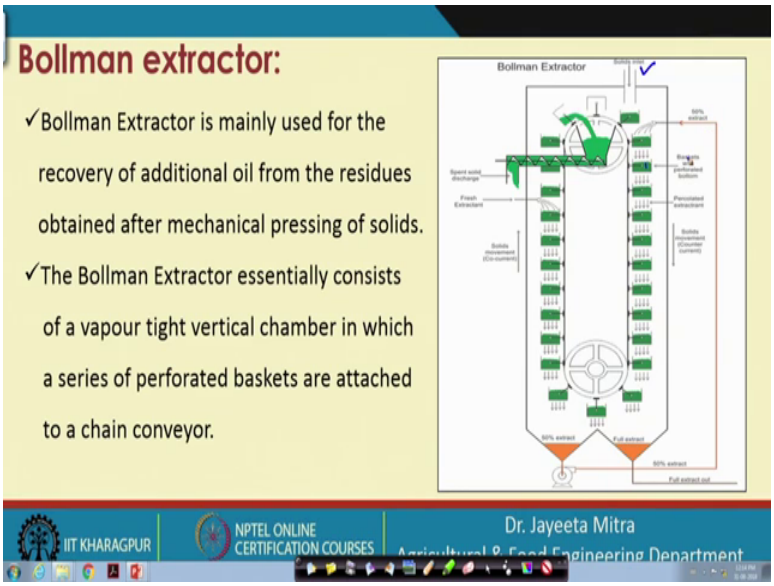

Next one is the Bollman extractor. What happens in the Bollman extractor is that so, there is the this is the diagram of the Bollman extractor, solid inlet is from this section. So, all the solids are coming into the buckets, there is the a close chamber of air tight chamber of the buckets. And the solid is coming for in the bucket in major quantity of the solid, and extract the 50 percent extract that we are collecting from this left arm extraction from the left arm that; that is being spread on the on the top of the solids that are coming into the fresh solid, where the solid components is there in a full concentration.

So, as these buckets are coming down they will the solvent will percolate through them, and the extract will collect at the bottom. Similarly, these buckets are eventually comes from left to right following the path of this bucket elevator, and as it move again upward the fresh extracted or fresh solvent are spread on them. So, the 50 percent extract is collected from the residual solute that, were there and then again it is circulated. So, this process is continuous and all the buckets are enquired at the top of this system, in Bollman extractor and by a screw mechanism that are taken away.

So this is actually the whole systems, and all this vertical chambers they have they have series of perforated baskets. So, this are all series of purported baskets in a chain conveyor. So, that all the liquid all the solvent will be percolated through them.

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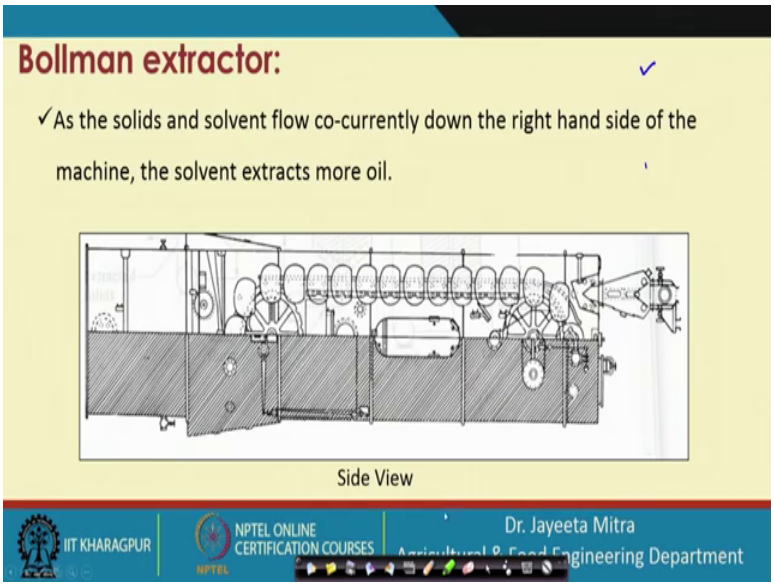

So, there are different geometry this is the side view of Bollman extractor. The mechanism is same as we have explained.

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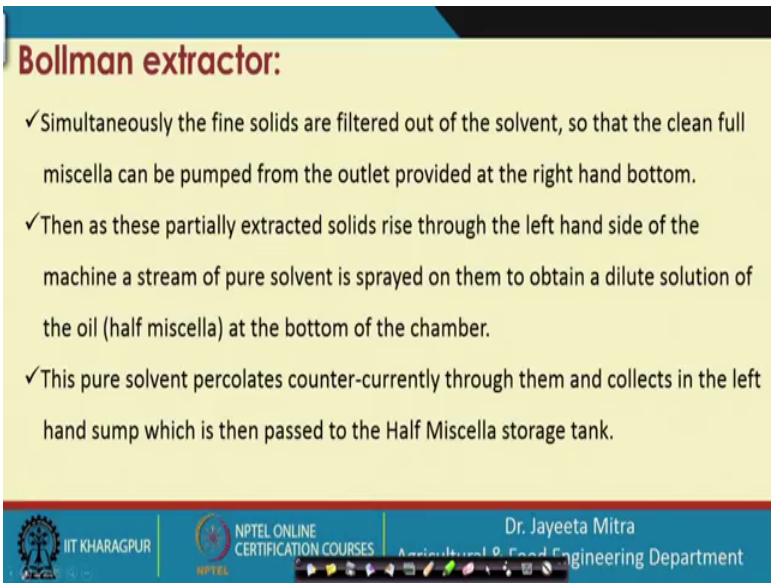

And simultaneously the fine solid are filtered out of the solvent. So, that the clean full miscella can be come from the outlet provided at the right hand bottom, and then as this partially extracted solid rise to the left hand side as we have seen, as we have seen in the figure. So, the same thing it has been mentioned that from the from this arm it is again going and spreading to the other arm and then again it is coming. So, the full extract we

can collect it we can collect in this section in this section we can collect the full extract. So, this is all about the Bollman extractor, this is the side view of that. And this already we have discussed.

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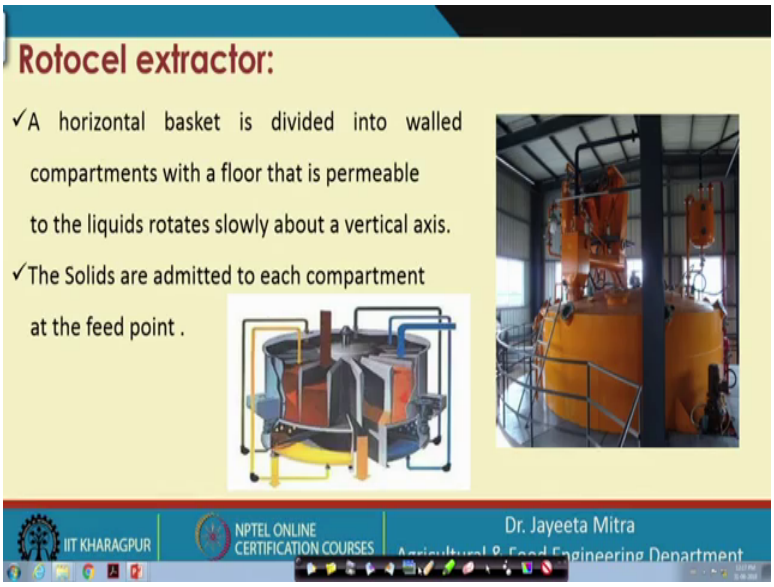

Next is the Rotocel extractor. Rotocel extractor this is horizontal basket, and that is divided into a walled compartment. We can see there are many compartment there are compartments. So, walled compartment is there with the floor that is permeable to the liquid rotate slowly about the vertical access. So, this is rotating about slowly about a vertical access, and that is permeable to the liquids that rotates slowly about a vertical axis. So, the liquid is coming liquid is coming on this small compartments, and the solid are admitted to each compartment at the feed point. So, there is a feed point where all the liquids all the solids are entered.

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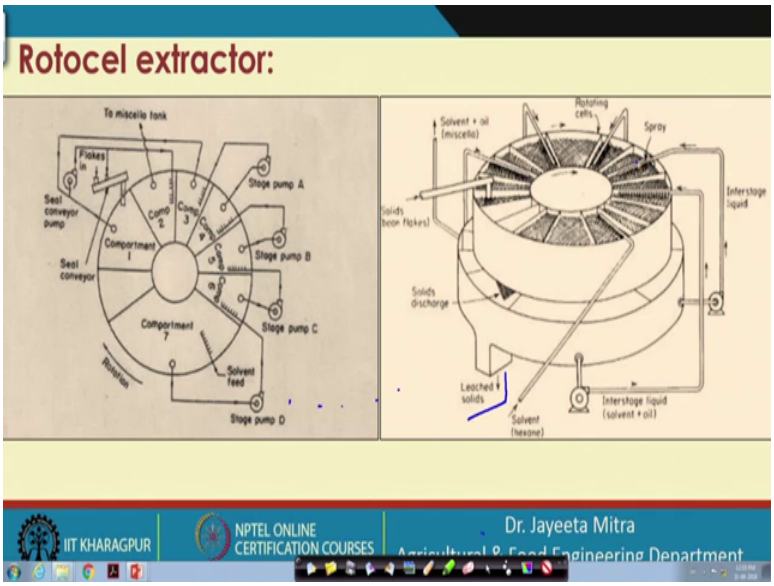

So, this is again the schematic view of Rotocel extractor we can see there is component 1, 2, 3, 4, 5, 6 and 7, I am solving feed at every from the top section everywhere the solvent feed is entering into and there are pumped to flow the material from one stage to the other. After one stage of extraction it is being thrown to the next one. So, like that an at the end of the process from the bottom the leach solid is being collected, ok.

So, the leach solid is collected from the bottom. And solvent is entered into this session, and this the solvent plus oil that is coming that again put into one chamber, again the (Refer Time: 31:57) is coming from the percolation that is again sent to the other and this process is going on continuously, and while this liquid is coming over the over the compartment, they the spray of solvent is being done. So, that it can percolate and go into the bottom and finally, the leach solid will be collected.

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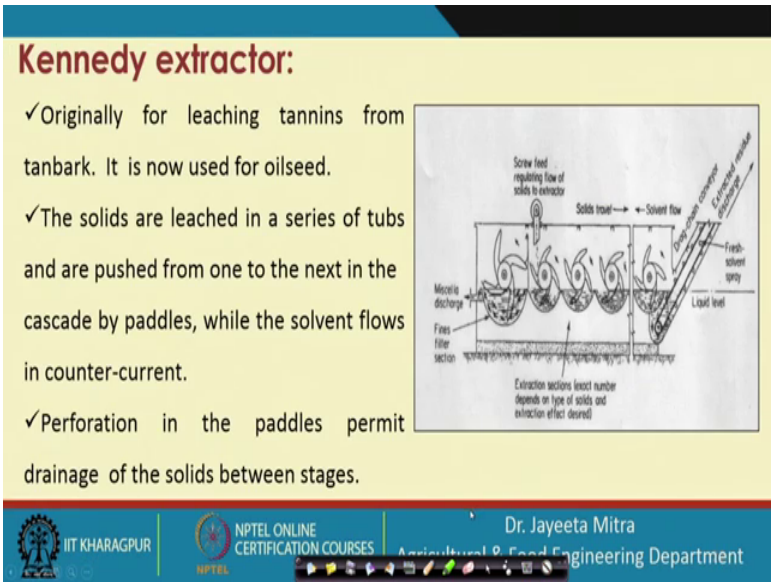

Then next is the Kennedy extractor. So, this is originally for leaching tannins from the tanbark, and it is now used for the oilseed extraction. The solid are leached in a series of tubs we can observe here that there are series of tubs are there. And these are pushed from one to the other next in a cascade by paddle. So, here are paddle so, that miscella discharged by this paddles to the next to next tubes consecutively. And while the solvent flows in the counter current fashion.

So, this solvent is coming from the other side so, as the slurry is moving from the left to right the solvent is coming from the right to left. Perforation in the peddles permit drainage of the solid between stages. So, there is the perforation and because of that the drainage of the solid between the stages is profound.

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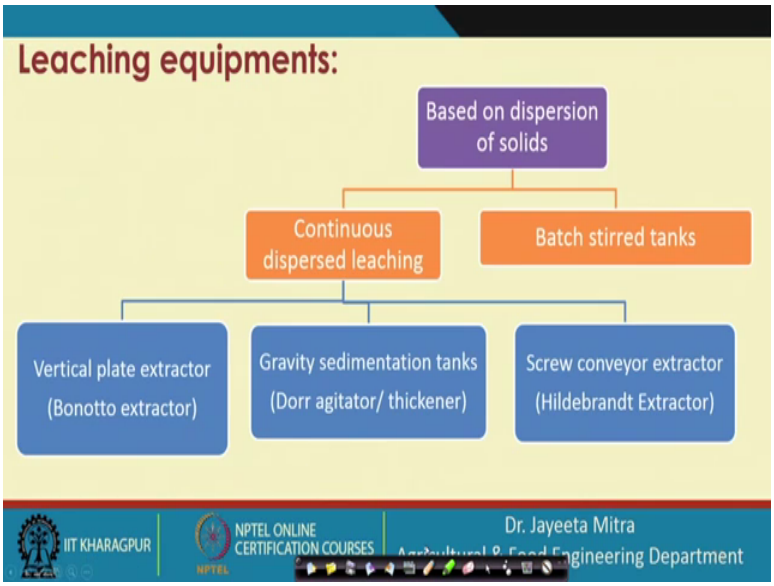

Now, another classification we can develop based on the dispersion of solid that is continuous disperse leaching and batched stirred tanks continuous disperse leaching again can be classified as vertical plate extractor that is called Bonotto extractor. Gravity sedimentation tank that is called Dorr thickener or agitator and the last one is the screw conveyor extractor that is called Hildebrandt extractor.

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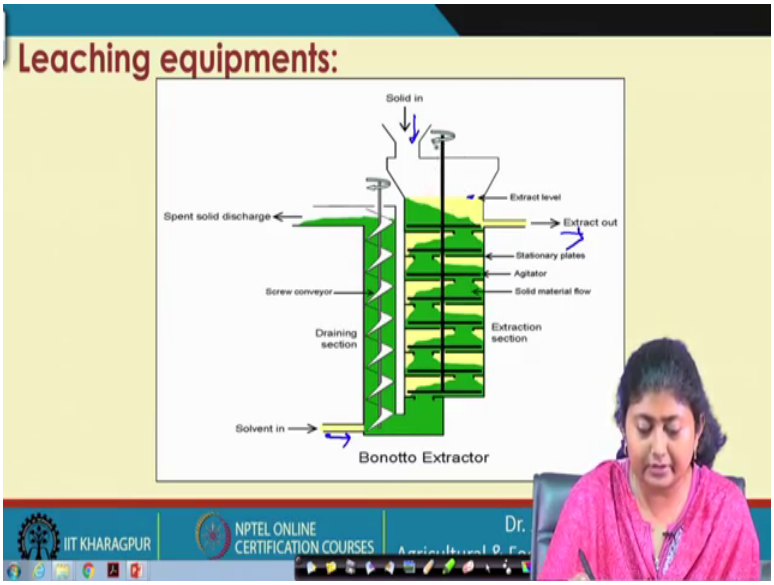

So, this is called the Bonotto extractor. What happened here is that, the solid comes in from the top and there is an extract level is there up to that it will be filled. So, there is

some agitator will be constantly will agitate and make the flow of the solid from the upper section to the lower section. This bottom section is called the extraction session. And the top section that is called the stationary plates, then there is agitator, and the solid material flow that is constantly from the top to the bottom.

Extraction section is also given, the solvent which is in from the bottom will be sprayed to the through the material and will going from the top section. So, instead will be out from this section where the solvent in from this section, ok. So, while the solvent will take away all the solute from the component the leached out solid that will come in this section and drain in the draining section.

And there is a screw that will take out all the solid and will discharge all the solid to the outer section. And this is rotational movement will be given that they is a shaft by which it is if the whole assembly is rotated so, that the proper agitation can be given for better extraction efficiency.

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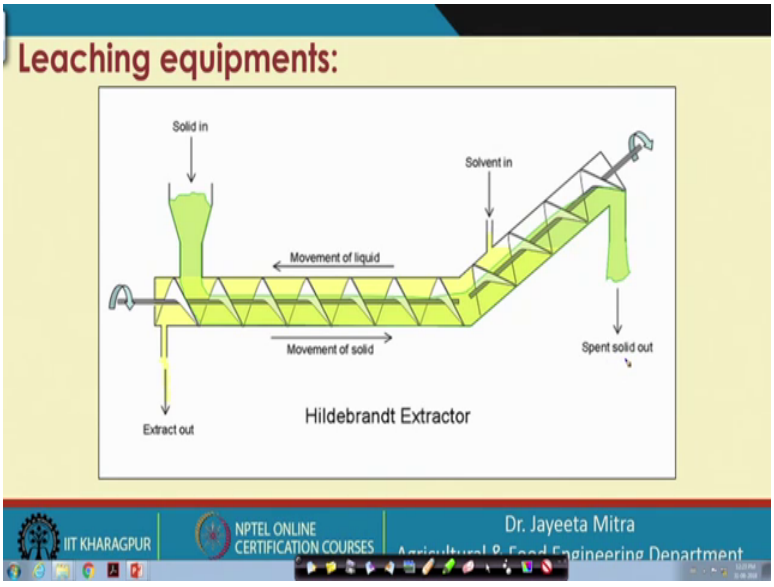

Then there is Hildebrandt extractor, here also the flow is almost counter current flow takes place. So, solid in from the left hopper and then the solid is taken away by the screw conveyor to the other section to the right section and the solvent comes in here. And this solvent is getting mix while it is moving towards the towards the left. So, the liquid is moving towards the left and then at the end the extract is taken away and movement of solid will goes on like this. And spent solid out from the top spend solid;

that means, all the solute has been extracted from that and this spent solid is come out from the top section.

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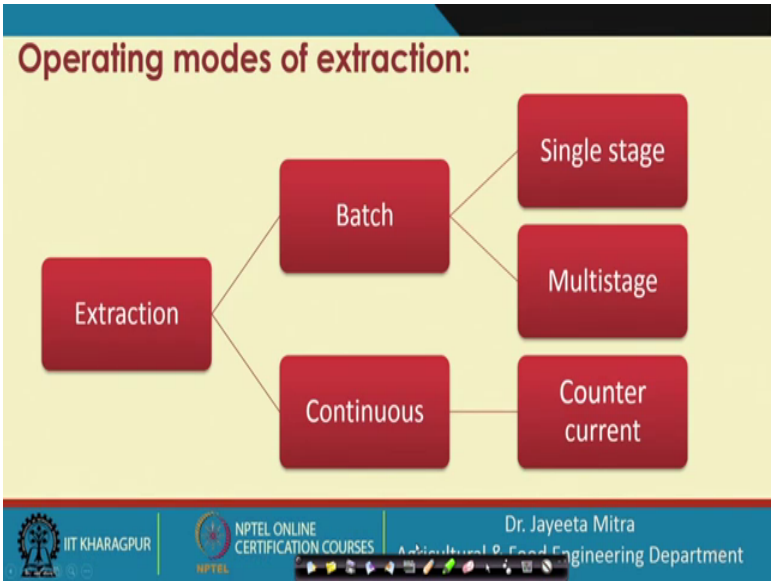

Another operating mode we can think of out that is the extraction of other batch or in continuous mode, in batch that is single stage multi stage and counter current stage.

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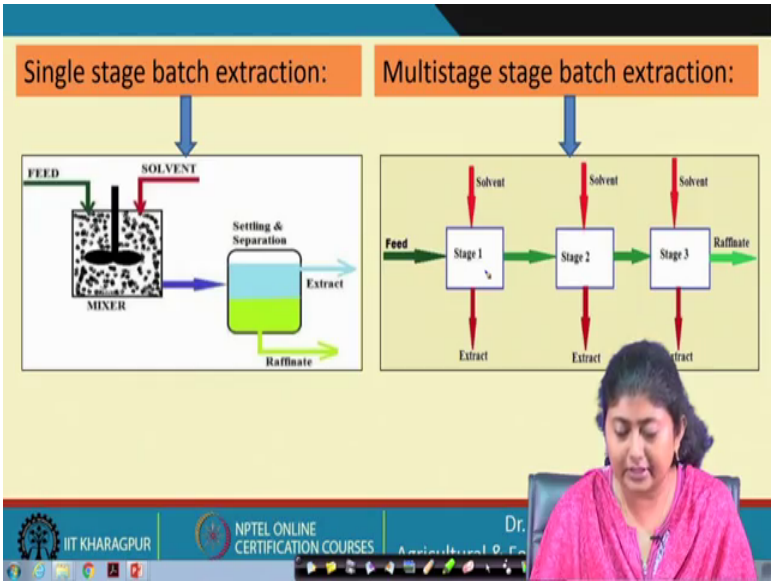

So, in the single stage batch as we have in the very beginning of this class this, this chapter we mentioned that in the feed and solvent comes into chamber comes into at the mixture chamber. There is proper mixing by paddles or agitators. And then settling and

separation will be occur in another section; where the extract that have the solvent and the solute component will go away. And this is also called also called the over flow in case of leaching process.

And there is there will be one that is having the slurry from which the solute has been extracted. So, in the terms of that solute you can call it dilute one this is raffinate this is called raffinate for you know liquid liquid extraction, and this is called the under flow where the solid. And little bit of solvent is present so, that is called the so that is called the under flow in case of the leaching process.

Now multi stage batch extraction is what in the multi stage batch extraction actually there are many stages. Stage 1, 2, 3 like that, and in every stage solvent freshly entered; however, the feed is moving from stage 1 to stage 2 stage 3 and so on. So, in every stage some amount of liquid component some amount of the solute component will be separated by this solvent and they will go to the extract.

So eventually all the extract have some amount of the solute, and at the last when the all solute component will be extracted then the feed will converted to the raffinate. So, this is the multi stage batch extraction. We again call it multi stage, but batch because this solvent is not re circulated the solvent is entered freshly at each chamber.

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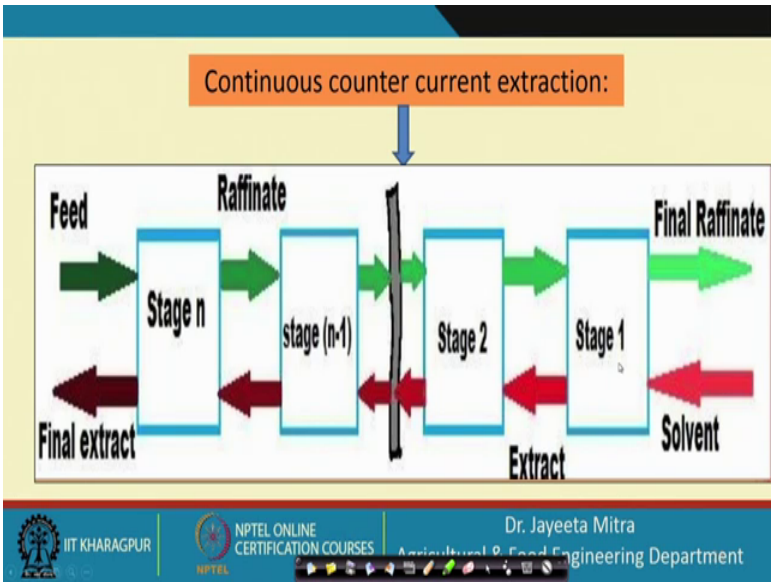

So, last thing is that continuous counter current extraction. In that there are many stages suppose up to stage 1 to stage n is there, and flow is taking place in a counter current fashion right. So, feed is entered from one side and going as a raffinate, and solvent is entered from the other side and going as a final extract. So, this is continues and counter current system. So, stage 1 to stage n minus 1 to stage 2 and one has we move solute is extracted from the feed and getting added to the extract or the added to the solvent. So, the extract of the first stage is entered in to the stage 2 and this process continuous.

So here we will stop. So, here we will in this particular class we have discussed, the different kinds of the leaching and extraction equipments, and little bit application of that, and the basic process of leaching and extraction.

Thank you.