Food Oils and Fats: Chemistry and Technology

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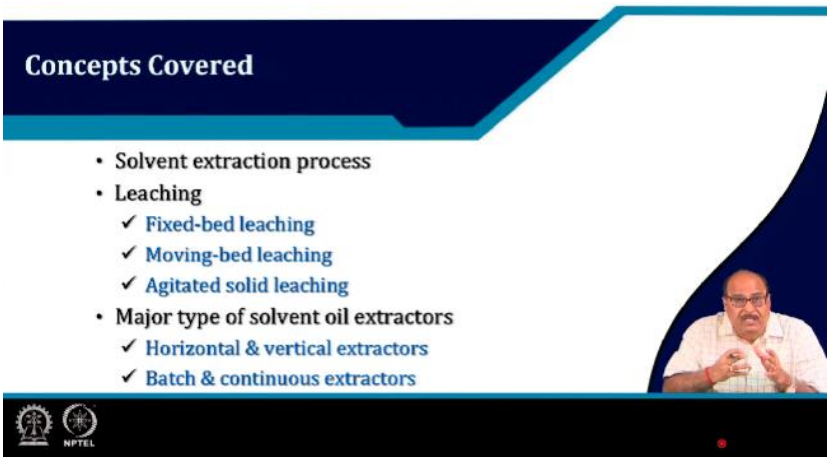
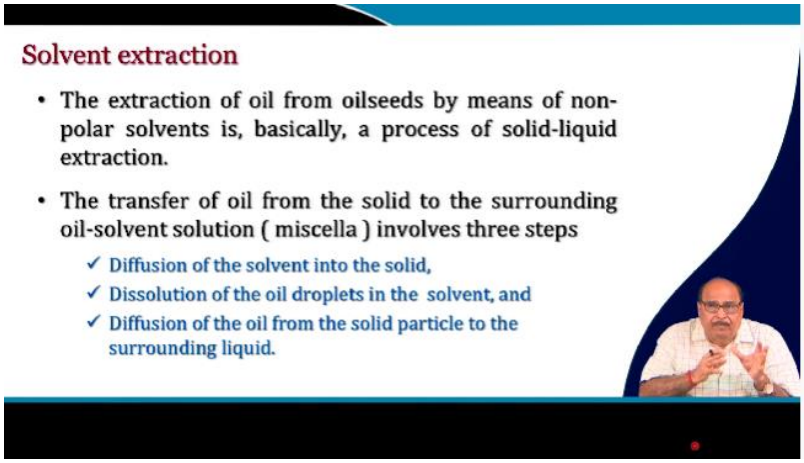
Module 05: Solvent Extraction of Edible Oils

Lecture 23: Solvent Extraction Technology & Equipment

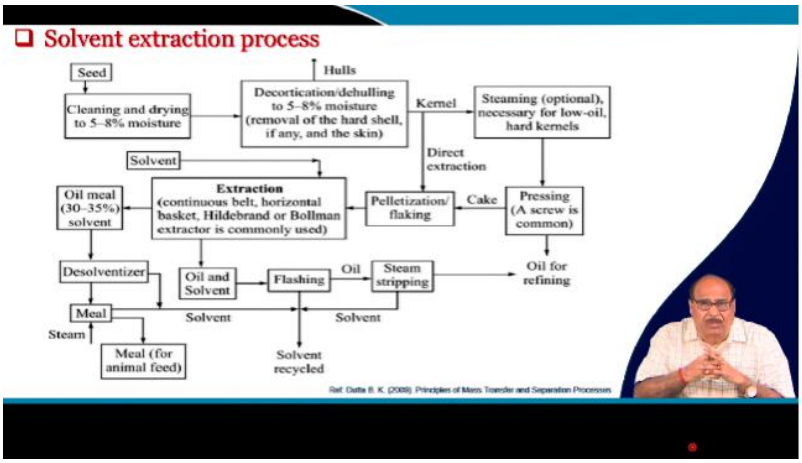
Hello everybody. Now, we are in lecture 23 of this course and in this in the next half an hour or so, we will discuss various aspects of solvent extraction technology and equipment.



The concepts which are covered in this lecture include solvent extraction process, leaching, different types of leaching like fixed bed leaching, moving bed leaching, agitated solid leaching and then major type of solvent extractors like horizontal and vertical extractors, batch and continuous extractors and so on.

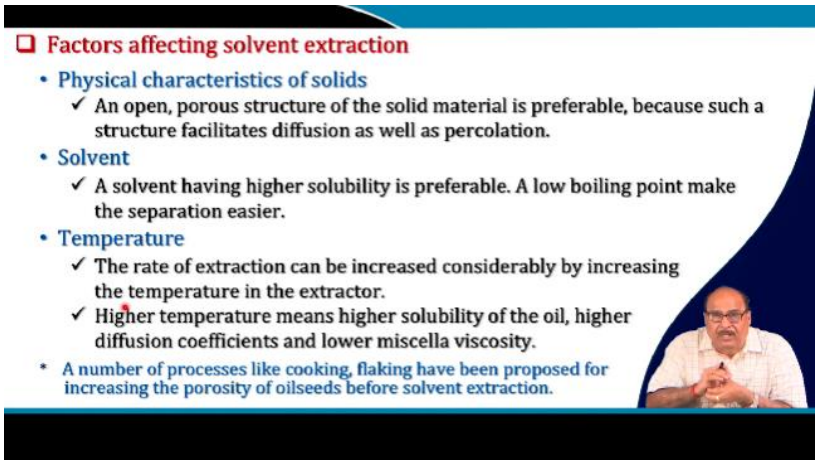


In the earlier lecture, we have seen the principle, mechanism and techniques. The extraction of oil from the oil seeds by means of a non-polar solvent and is basically a solid liquid extraction process.

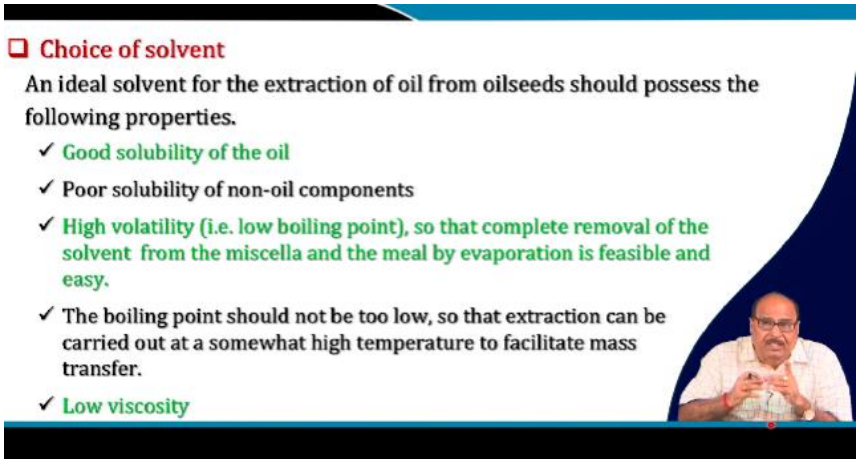


The extraction process is a normally taken after cleaning, drying etc. that is seed is taken up 5 to 8 percent moisture content. And then it is subjected to various pretreatment like decortication/dehulling, removal of hard cells if any and the skin. These kernels are steamed which depends upon the type of the seeds. It is optional process necessary for low oil containing hard kernels that is steaming becomes important and then it is pressed. A screw press is common and then you get oil for edible oil. So, this is system for pressing and when the hulls are obtained then these hull are send for solvent direct extraction then it is pelletized or flagged and then sent to the extraction chamber. Alternatively in the case of prepress solvent extraction process after pressing oil goes here and the cape is then pelletized and flagged and then it is sent to the extractor where it is brought into the contact between the prepared material flagged and pellets with the suitable solvent. So, it may be different types of extractor. The oil and solvent mixture that is the miscella which is flushed

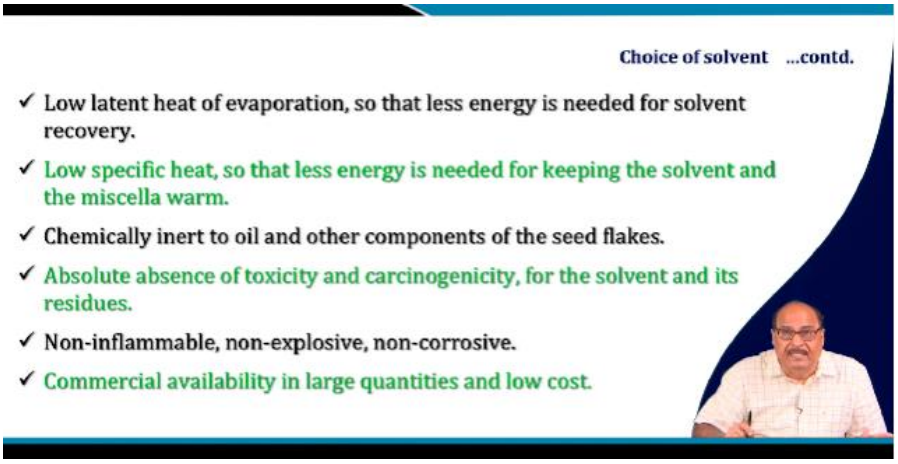
off that is the solvent is flushed off and finally, steam stripping and this solvent is further redirected for the extraction process and you get the oil. The other hand that is after you get the miscella and then separately you get the oil meal that is the residue remaining after the extraction and the meal also contains around 30 to 35 percent of the solvent. So, this also should be treated for making the meal because it is a good source particularly in some cases it has a good quality of proteins. So, this can be used for food purposes or various other purposes feed materials etc. So, this is solvent is removed by desolventizers, meal toasting etc. So, these are the three major operations here that is in the case of solvent extraction process one is the extraction of oil, then you get miscella, then desolventization of miscella and then that is desolventization of the meal, meal desolventization.



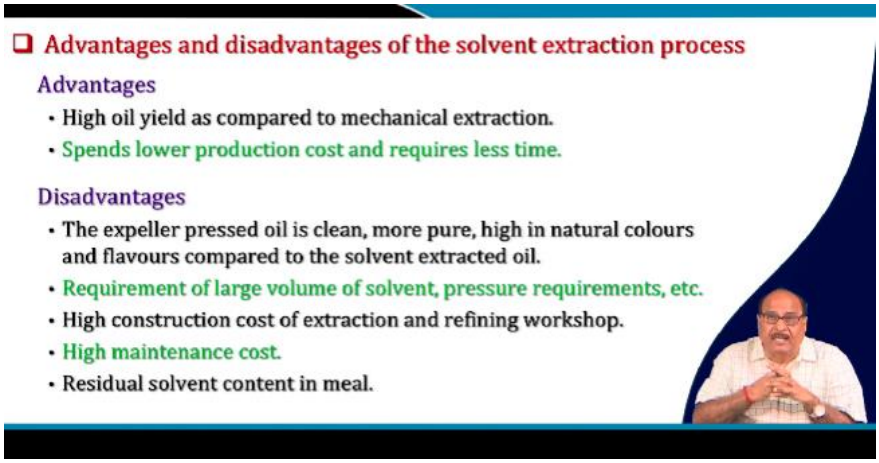
So, the factors which influence the solvent extraction process include the physical characteristics of solid that is an open porous structure of the solid material is preferable because such a structure facilitate diffusion as well as percolation. Then the solvent having higher solubility is preferable a low boiling point make the separation easier. The temperature is another factor, the rate of extraction can be increased considerably by increasing the temperature in the structure. In the earlier class, we discussed little bit about this, but however, high temperature makes higher solubility of the oil higher diffusion coefficient and lower miscella viscosity, but the very high temperature should be avoided. A number of processes like cooking, flaking have been proposed for increasing the porosity of the oil seed before solvent extraction.



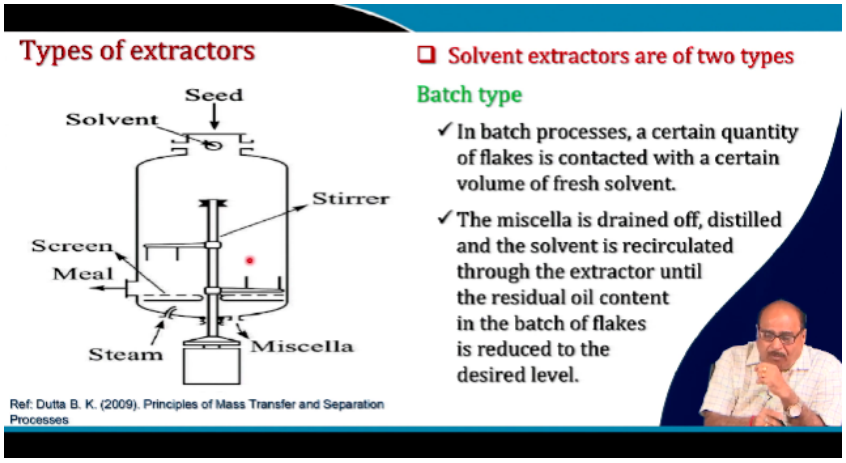
And choice of the solvent very important in the solvent extraction technology we should have a proper type of solvent that is an ideal solvent for extraction of oil from oil seed should possess the property like it should have good solubility of the oil, poor solubility of non-oil components, it should be highly volatile like it should have low boiling point. So, that the complete removal of the solvent from the miscella and the meal by evaporation is feasible and easy. The boiling point should not be too low. So, that extraction can be carried out at somewhat high temperature to facilitate mass transfer. The solvent should have low viscosity,



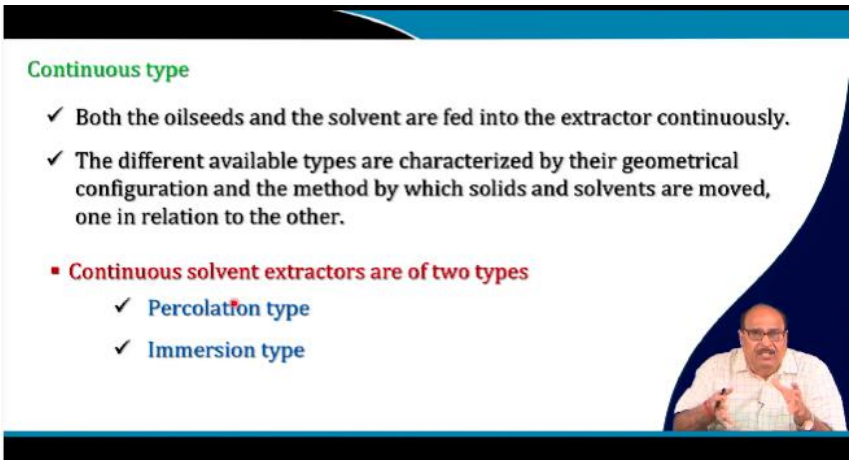
It should have low latent heat of evaporation. So, that less energy is needed for solvent recovery, it should have low specific heat. So, that less energy is needed for keeping the solvent and miscella warm. The solvent should be chemically inert to oil and other components of the seed flakes. It should be there should be absolute absence of toxicity and carcinogenicity for the solvent and its residue. It should be non-inflammable, non-explosive and non-corrosive and more importantly it should be commercially available in large quantities at low cost.



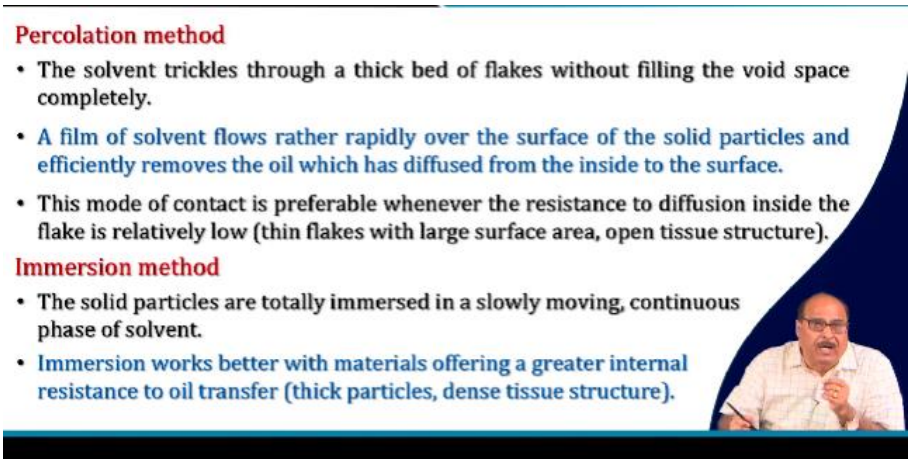
The advantages and disadvantages of the solvent extraction process number advantages include the high oil yield as compared to mechanical extraction and it spends lower production cost and requires less time. However, the solvent extraction process has certain disadvantages. The expeller pressed oil is clean, more pure, high in natural colors and flavors compared to the solvent extracted oils. Requirement of large volumes of solvent pressure requirement, etc. and the invariably result into the reduction or inferior in the quality of the oil as compared to those obtained from direct expelling or pressing. High construction cost of the extraction and refining workshop. It requires high maintenance cost and the presence of the residual solvent content in the meal.



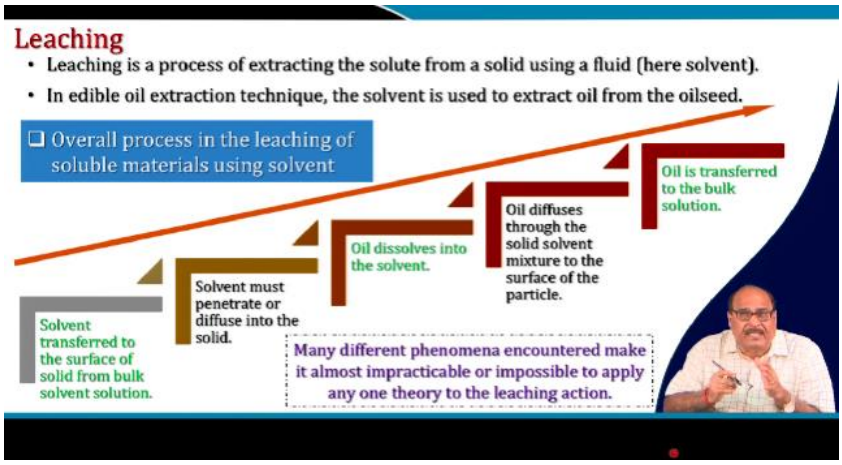
Solvent extractors are the heart of the solvent extraction processes equipment. They may be two types, batch type and continuous type. In the batch process, in this figure there is a certain quantity of flax is contacted with a certain volume of fresh solvent here. The miscella is drained off from the bottom of the solvent distilled and solvent is recirculated to the extractor until the residual oil content in the batch of flax is reduced to the desired level ok. The batch equipment has various arrangement or that is a seed is fed from the top and as well as solvent and in this there is a pillar that is one can stir is provided which gives intimate mixing of the solvent and the oil.



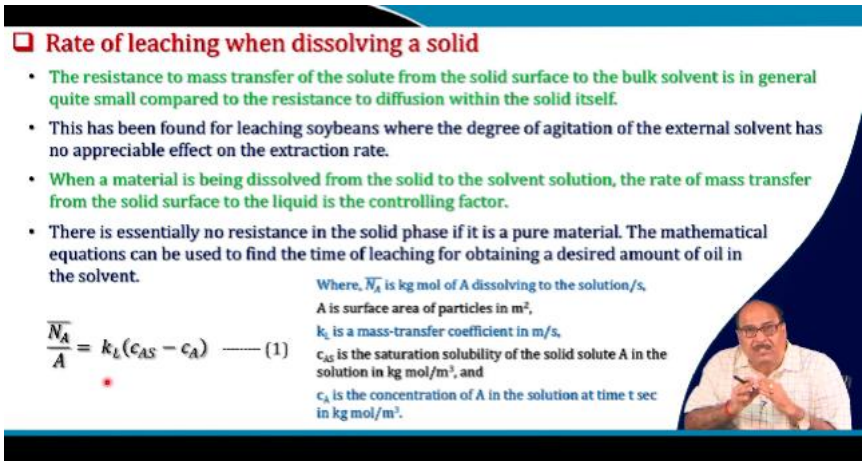
In the continuous type both the oil seeds and the solvent are fed into the extractor continuously. The different available types of the continuous extractors are characterized by their geometrical configuration and the method by which oil seeds and solvents are moved one in relation to the other. The continuous extractors are further two types one is the percolation type other is the immersion type and even now there are modern extractor which are a combination of both percolation as well as immersion types.



In the percolation method, solvent trickles through a thick bed of flax without filling the void space completely. A film of solvent flows rather rapidly over the surface of the solid particles and the efficiently removes the oil which has diffused from inside to the surface. This mode of contact is preferable whenever the resistance to diffusion inside the flax is relatively low particularly when the flax is thin as well as they have the large surface area, they have opened tissue structure and so on. In the immersion method, the solid particles are totally immersed in a slow moving continuous phase of solvent. Immersion works better with the materials offering a greater internal resistance to oil transfer like if the particles are thick they are dense tissue structures etc.



Leaching is a process of extracting the solute from the solid using the fluid. Here the fluid is the solvent. In edible oil extraction technique, the solvent is used to extract the oil from the oilseeds and the overall process of the leaching of the soluble material using solvent involves is described: number one, the solvent is transferred to the surface of the solid from bulk solvent solution then optimum conditions should be provided so that the solvent must penetrate or diffuse into the solid. Then oil dissolves into the solvent, oil diffuses through the solid solvent mixture to the surface of the particle and then finally, oil is transferred to the bulk solution and many different phenomena encountered make it almost impossible or impracticable to apply any one theory to the leaching action. Many a times, the combination of theories are applicable.

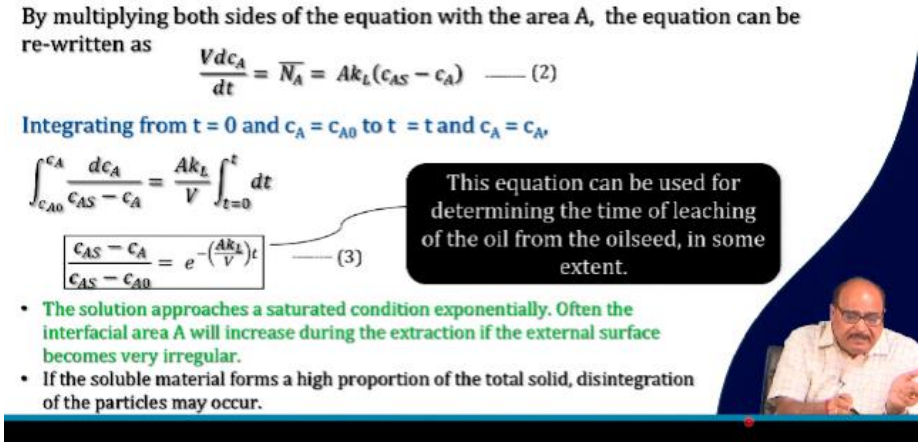


So, rate of leaching when dissolving a solid is very important. The resistance to mass transfer of the solute from the surface of the solid to the bulk solvent is in general quite small compared to the resistance to diffusion within the solid itself. This has been found for leaching soybeans where the degree of agitation to the external solvent has no appreciable effect on the extraction rate. When a material is being dissolved from the solid

to the solvent solution, the rate of mass transfer from the solid surface to the liquid is the controlling factor. And there is essentially no resistance in the solid phase if it is a pure material. There are various mathematical equations which can be used to find the time of leaching for obtaining a desired amount of oil in the solvent. And one such equation is represented by

$$\frac{\overline{N_A}}{A} = k_L(C_{As} - C_A)$$

where N A is the kg mole of A dissolving the to the solution per second. A is the surface area of particle in square meter, K L is the mass transfer coefficient in meter second, C A is the saturation solubility of the solute, A in the solution in kg mole per cubic meter and C A is the concentration of A in the solution at time T in kg mole per cubic meter.



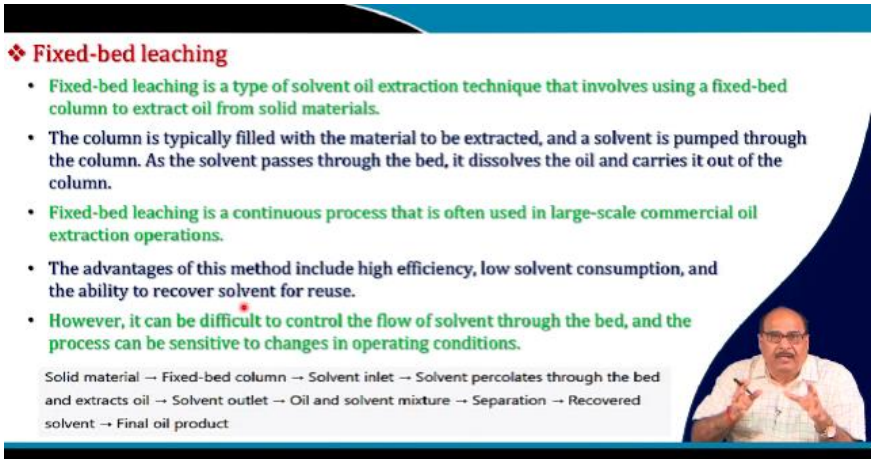
So, by multiplying both sides of this equation with the area A, the equation can be rewritten as

$$\frac{V\,dC_A}{dt} = \overline{N}_A = Ak_L(C_{As} - C_A)$$

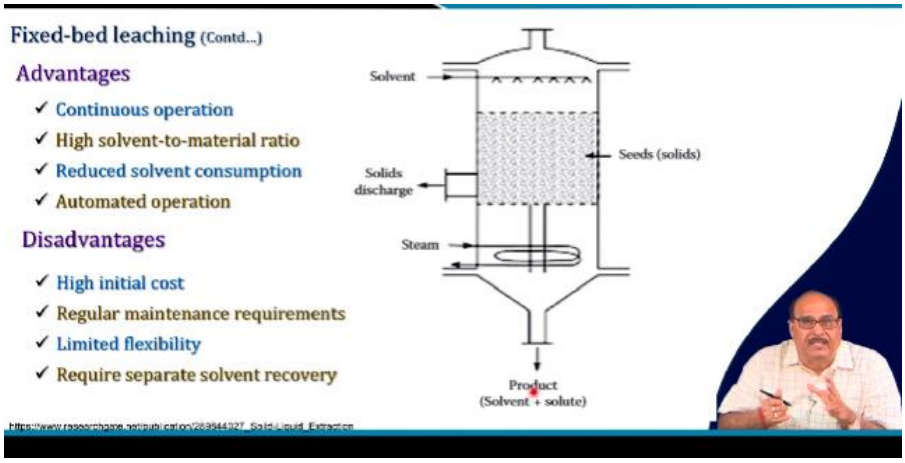
$$\int_{C_{A0}}^{C_A} \frac{dC_A}{C_{AS} - C_A} = \left(\frac{AKL}{v}\right)\int_{t=0}^{t} dt$$

$$\frac{C_{AS} - C_A}{C_{As-c_{A^0}}} = e^{-\left(\frac{AKL}{v}\right)}$$

This last equation can be used for determining the time of leaching of the oil from the oil seed in some extent. The solution approaches a saturated condition exponentially and often the interfacial area A will increase during the extraction if the external surface becomes very irregular. If the solution material forms a very high proportion of the total solids, disintegration of the particles may occur.

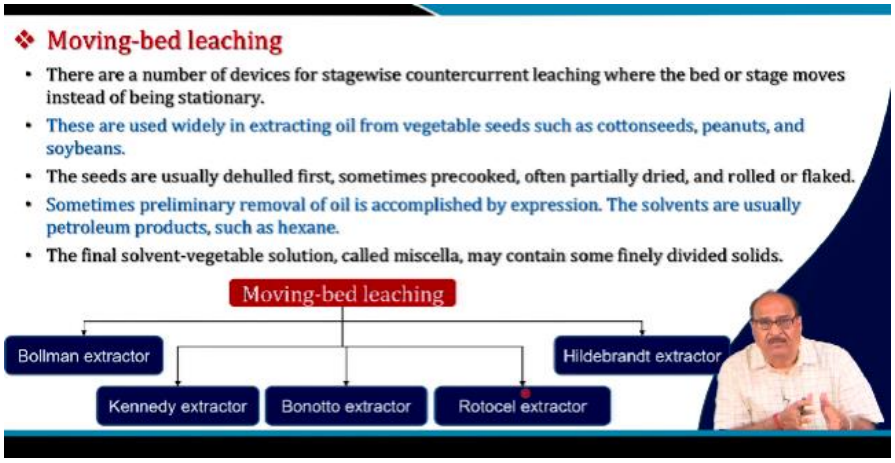


Fixed bed leaching is a type of solvent oil extraction technique that involves using a fixed bed column to extract oil from seed materials. The column is typically filled with the materials to be extracted and solvent is pumped through the column. As the solvent moves through the bed, it dissolves the oil and carries it out of the column. Fixed bed leaching is a continuous process that is often used in large scale commercial oil extraction processes. The advantage of this method includes the high efficiency, low solvent consumption and the ability to recover solvent for reuse. However, it can be difficult to control the flow of solvent through the bed and the process can be sensitive to changes in operating conditions. So, in the stepwise manner, this fixed bed leaching may be that is a solid material, then fixed bed columns into the solvent inlet, then solvent percolates through the bed and extract the oil, then it comes to the solvent outlet, oil and solvent mixtures are obtained, then separator recovered solvent is sent again back and finally get the final product that is the crude oil.

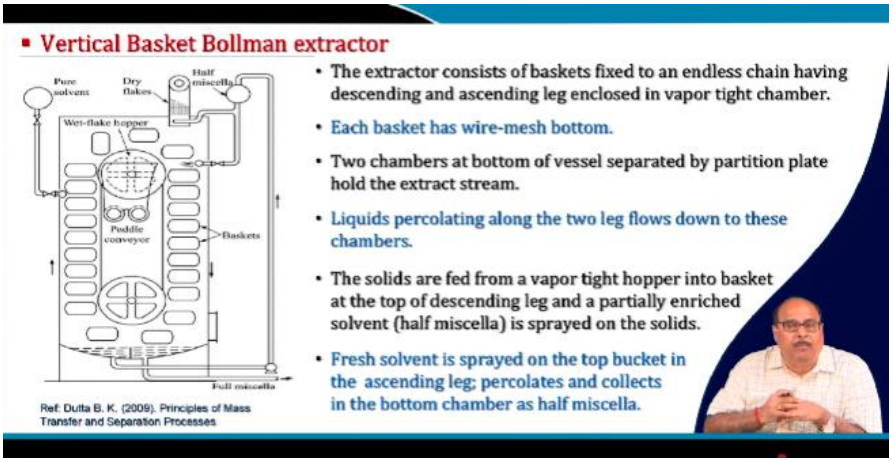


So, this is you can say the fixed bed leaching system here that is the here there is solid sheet solids are there and then it improves solvent is coming. So, it basically the it is the in this the solvent oils are getting dissolved into the solvent and finally, we get the miscella is recovered from the product. So, this system has both again like any system advantages and

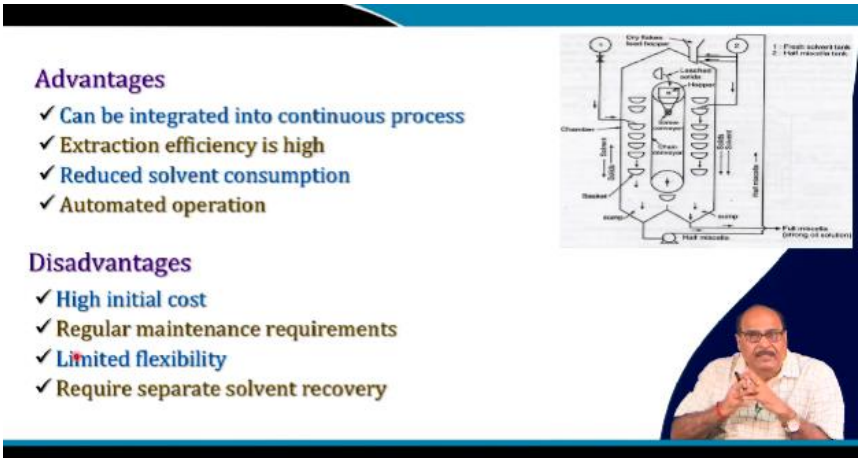
disadvantages. Advantages of the fixed bed leaching include it is a continuous operation, high solvent to material ratio, there is a reduced solvent consumption and it is an automated operation which can be made into continuous. However, the disadvantages include high initial cost, regular maintenance requirements, limited flexibility and it requires separate solvent recovery system.



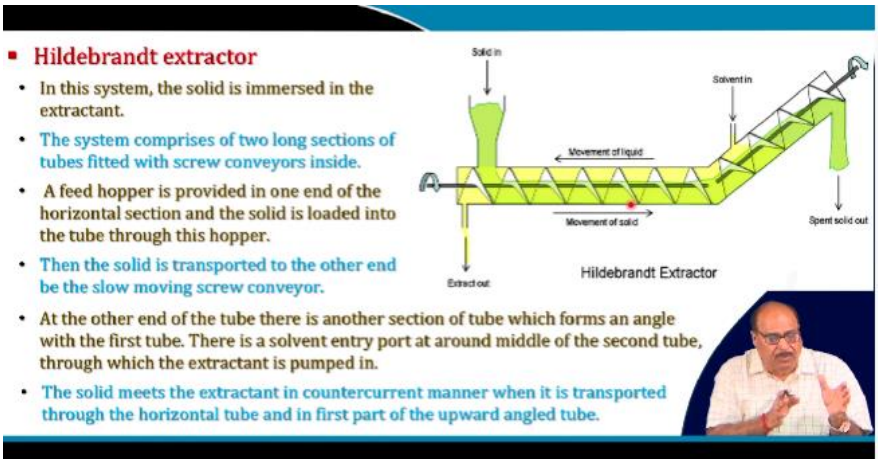
Then comes the moving bed leaching, there are a number of devices for stage wise counter current leaching where the bed or stage moves instead of being stationary. In the earlier case, bed was stationary, now it is moving and these are used widely in extracting oil from vegetable seeds such as cotton seed, peanuts, soybeans etc. The seeds are usually dehulled first sometime even pre cooked often partially dried and rolled or flagged and sometime this preliminary removal of oil is accomplished by expression in the case of prepress solvent extraction process. The solvents are usually petroleum products such as hexanes etce and the final solvent vegetable solution called miscella may contain some finely divided solids. So, moving bed leaching that is extractors which operate on the principle of moving bed leaching they are Bollman extractor, Hildebrandt extractors, Kennedy extractor, Bonotto extractor and Rotocel extractors.



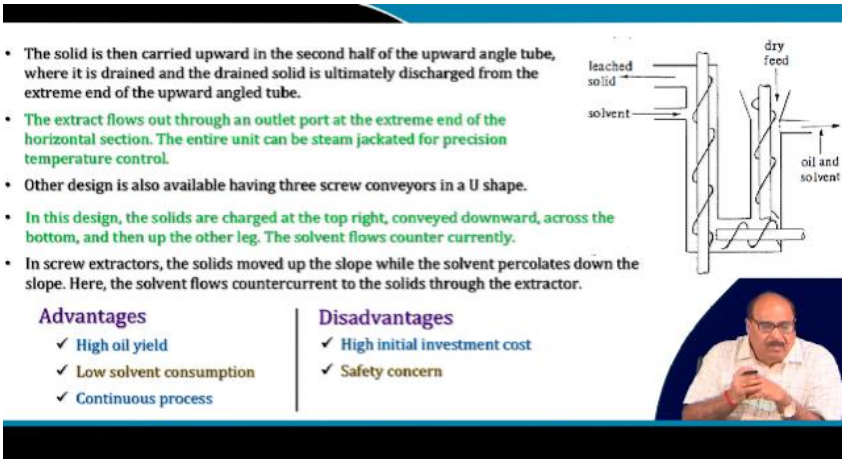
Vertical basket Bollman extractor consist of different various baskets which are fixed to an endless chain having descending and ascending leg enclosed in a vapor tight chamber. So, each basket has a wire mesh bottom. The chambers at the bottom of the vessel are separated by partition plate which hold the extract stream. Liquids percolating along the two legs flows down to these chambers. The solids are fed from a vapor tight hopper into the basket, at the top of the descending leg and a partially enriched solvent that is half miscella is sprayed on the solvent. This solvent is sprayed on the top bucket in the ascending leg and it percolates that and collects it in the bottom of the chamber as half miscella and finally, the full miscella is obtained and collected.



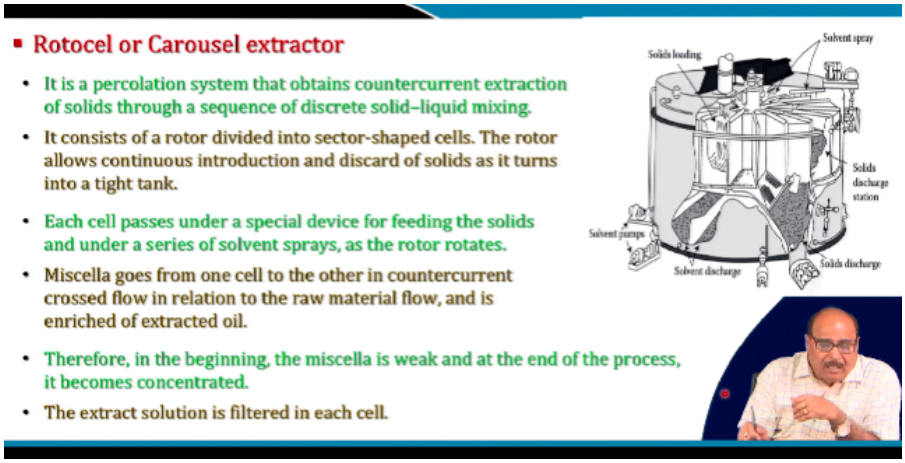
The advantage of this system include that it can be integrated into a continuous process extraction efficiency. In this system is high, there is a reduced solvent consumption and again it is automated operation. However, the disadvantages are the high initial cost, regular maintenance requirement, limited flexibility and also requires a separate solvent recovery system.



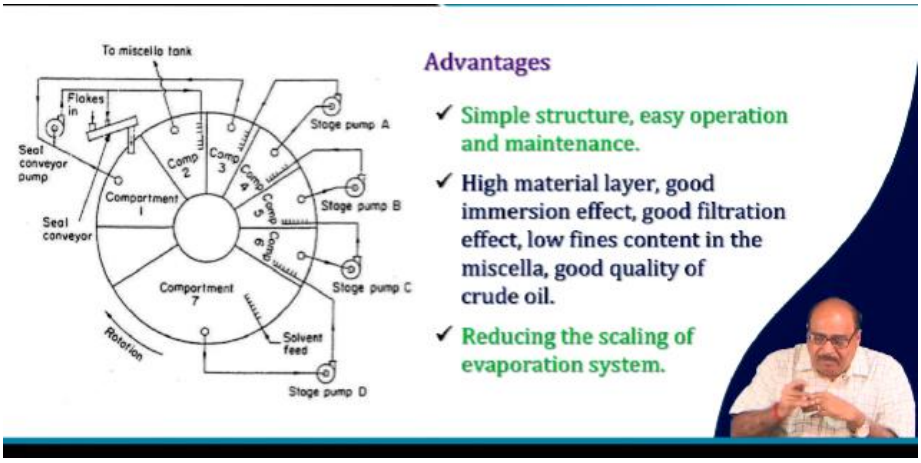
In the Hildebrandt extractor system, the solid is immersed in the extractant. The system comprises of two long sections of tubes fitted with the screw conveyors inside. A feed hopper is provided on the one side of the horizontal section and the solid is loaded into the tube using this hopper solid. Then the solid is transported to the other end of the slow-moving screw conveyor. At the other end of the tube there is a another section which is inclined which forms an angle with the first tube and there is a solvent recovery port in the almost in the middle of the second tube along with which the extractant or the solvent is pumped in. So, basically, there is a counter current movement where the solid material and the solvent move in the counter current way manner and it is transported through the horizontal tube in the first phase upward.



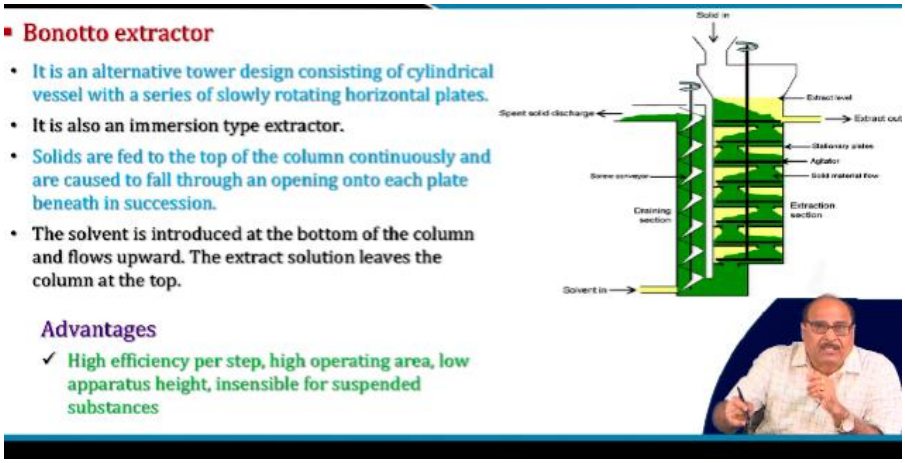
In the same immersion type Hildebrandt extractor, you can see here in the figure and this solid is carried out upward in the second half of the upward angle tube that is where it is drained and solid is ultimately discharged from the extreme end of the upward angle tube in the earlier case. The other design which is available here is the screw conveyors in a U shape. In U shape, the solids are charged at the top end in the one conveyor down across the bottom and then up in the other leg the solvent flows counter currently. In the screw extractors the solids move up in the slope while the solvent percolates down the slope here the solvent flows in counter corner to the solid through the extractor. So, the advantage of this method is high oil yield, low solvent consumption and continuous process and disadvantage is the high initial investment cost and it has some safety concern.



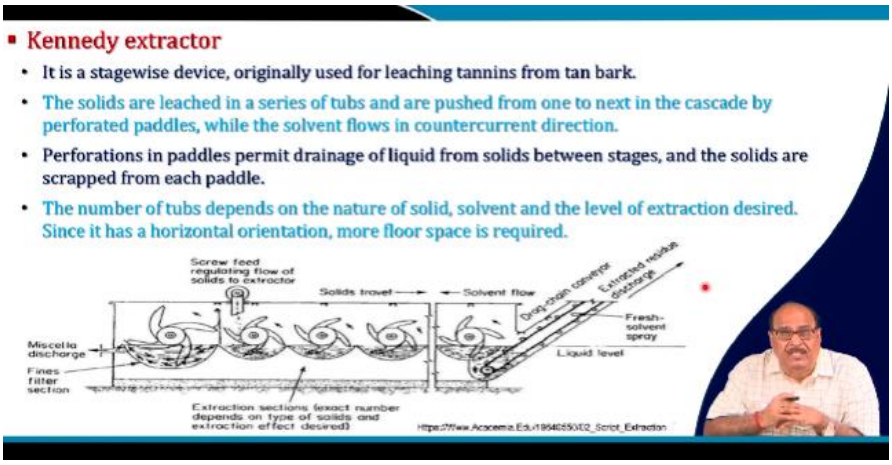
Then the other type of rotor extractor is rotocel or carousel extractor. It is a percolation system that obtains counter current extraction of solid through a sequence of discrete solid liquid mixing. It consists of a rotor divided into sector shaped cells. The rotor allows continuous introduction of direct discard of solid as it turns into a tight tank. Each cell passes under a special device for feeding the solid and under a series of solvent spray as the rotor rotates. Miscella goes from one end to other in a counter current cross flow in relation to the raw material flow and is enriched of the extracted oil. Therefore, in the beginning, the miscella is weak and the end of the process is sometimes concentrated. The extracted solution is filtered in each cell.



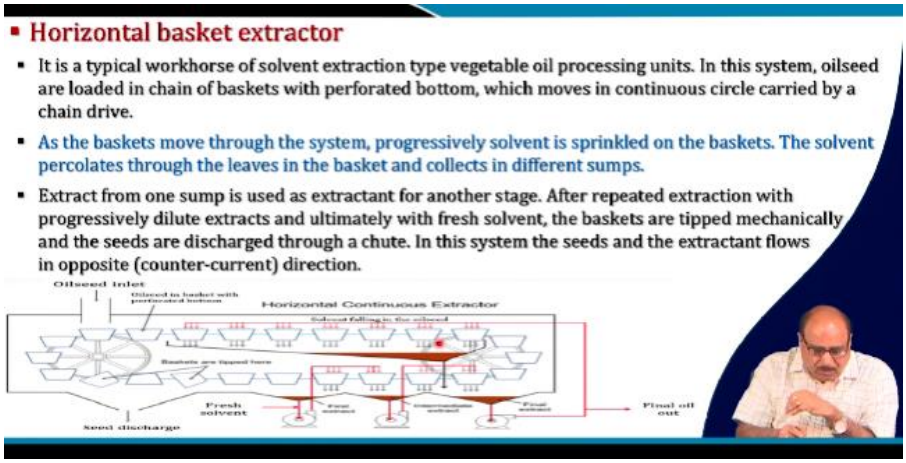
The advantage is it is simple structure, it has easy operation and maintenance, high material layer, good immersion effect, good filtration effect, low fines content in the miscella, very good quality of crude oil can be obtained and the reducing and scaling of the evaporation system is another advantage of this process.



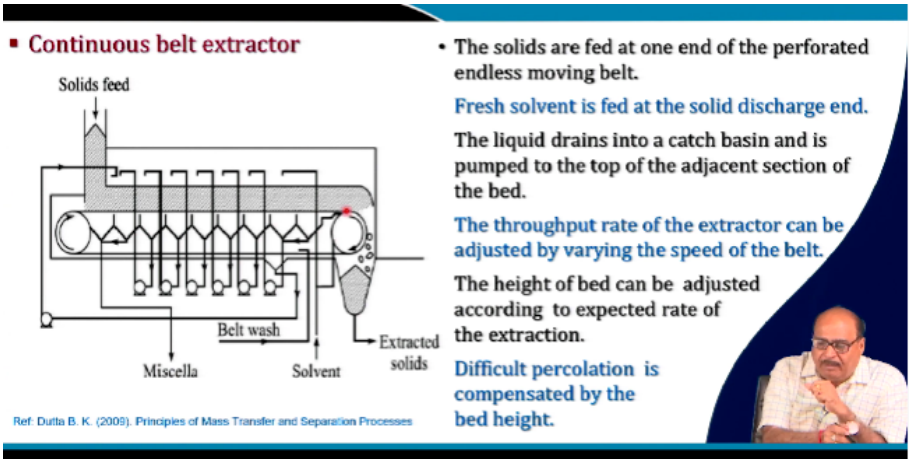
Then bonotto extractor as you can see here in the figure it is an alternative tower design consisting of cylindrical vessel with a series of slowly rotating horizontal plates. It is also an immersion type extractor. Solids are fed to the top of the column continuously you can see here in the figure continuously and are caused to fall through an opening into each plate beneath the in succession. This element is introduced at the bottom of the column and flows upward. This extracted solution leaves a column at the top and it has a high efficiency per step, high operating area, low apparatus cost and in joule for in sensible for suspended substances.



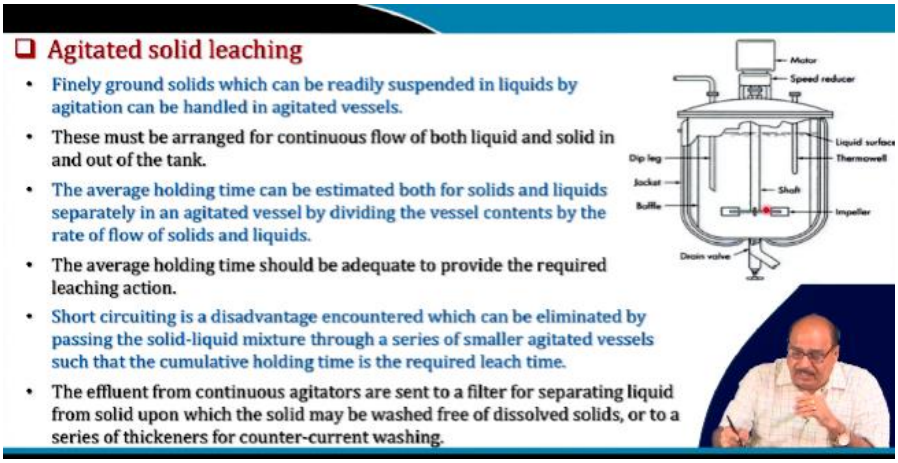
The Kennedy extractor is a stagewise device originally used for leaching tannins from the tan work. The solids are leached in a series of tubs and are pushed from one to the next in the cascade by perforated paddles while the solvent flows in counter current direction. Perforations in paddles permit drainage of liquid from solid between stages and the solids are scraped from each paddle. The number of tubs depends on the nature of the solid, solvent and the level of extraction desired. Since it has a horizontal orientation, more flow space is required that is the drawback.



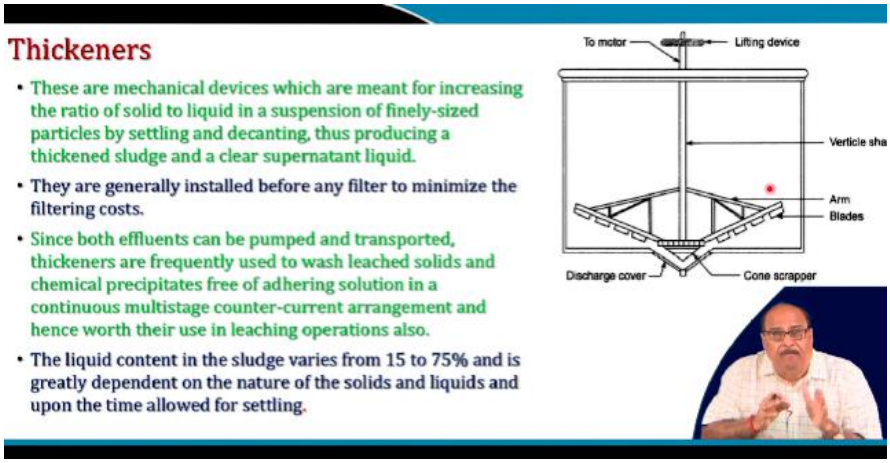
Then horizontal basket extractor this is an oil seed inlet there are different basket and in this basket the material moves and solvent is falling through oil seed etc. This is a typical work house of solvent extraction type vegetable oil processing unit. In this system, oil seeds are loaded in chains of basket with perforated bottoms which moves in continuous cycle carried by a chain drive. As the basket move through the system progressively solvent is sprinkled on the basket. This solvent percolates through the leaves of the basket and collects in different sums. So, the basket is stored from one sum is used as an extractant for another stage after repeated extraction with the progressively dilute extractants and ultimately with fresh solvent the baskets are tipped mechanically and the seeds are discharged through a tube. In this system the seeds and the extractant flow in opposite that is counter current direction as you can see here in the figure and finally, the oil comes.



Then continuous belt extractor you can see in the figure it is the solids are fed at one end of the perforated inlets moving belt fresh solvent is fed at the solid discharge end the solvent is fed from here. You can see the liquid drains into catch basin and is pumped to the top of the adjacent section in the bed. The thorough put rate of the extractor can be adjusted by varying the speed of the belt. The height of the belt bed can be adjusted according to the expected rate of the extraction and difficult percolation is compensation by the bed height.

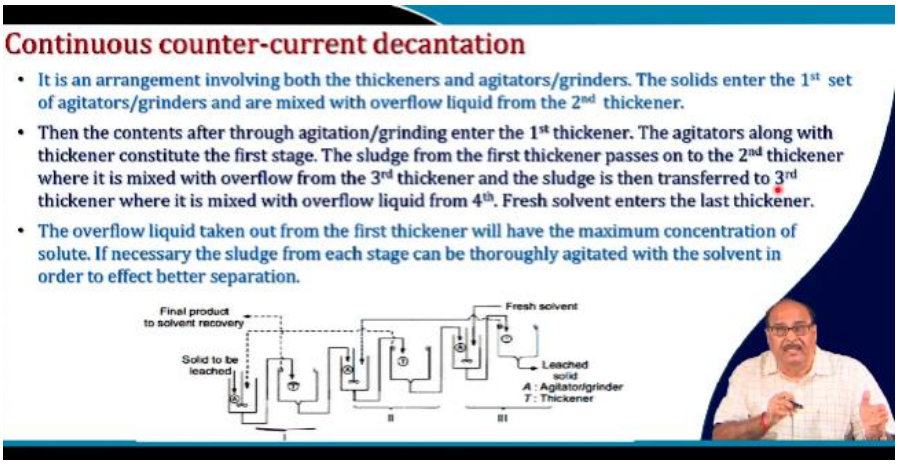


In agitated solid leaching, finely ground solids which can be readily suspended in liquids by agitation can be handled in agitated vessels. These must be arranged for continuous flow of both liquid and solid and out of the tank. The average holding time can be estimated for both the solids and the liquids separately in an agitated vessel by dividing the vessel contents by the rate of flow of solids and liquids. The average holding time should be adequate to provide the required leaching action. Short circuiting is a disadvantage encountered which can be eliminated by passing the solid liquid mixture through a series of a smaller agitated vessels such that the cumulative holding time is required leach time. The effect from continuous agitator that is the effluent from the continuous agitator are sent to a filter for separating liquid from the solid upon which the solid may be washed free of dissolved solids or to a series of thickeners for counter current washes.

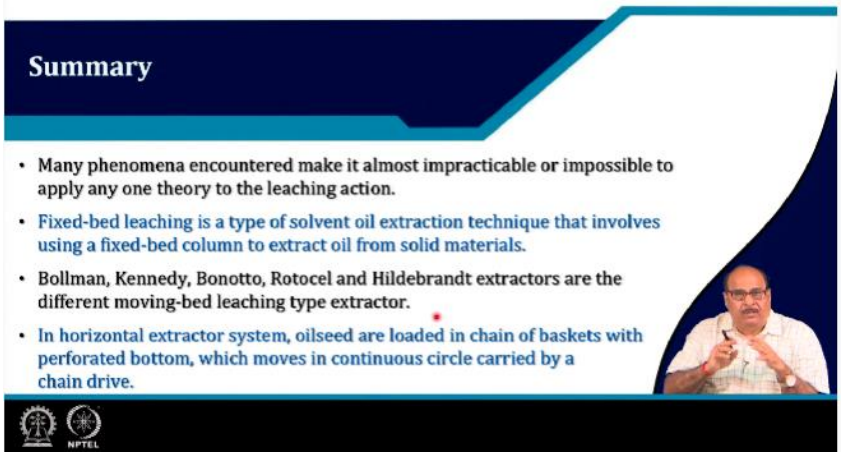


Thickeners are the mechanical devices which are meant for increasing the ratio of solid to liquid in a suspension of finely-sized particles by settling and decanting thus producing a thickened sludge and a clear supernatant liquid. They are generally installed before any filter to minimize the filtering costs. Since both effluents can be pumped and transported, thickeners are frequently used to wash liquid leached solids and chemical precipitates free of adhering solutions in a continuous multistage counter current arrangement and hence

worth their use in a leaching operations also. The liquid content in the sludge varies from 15 to 75 percent and is greatly dependent on the nature of the solids and liquids and upon the time allowed for settling.



The continuous counter-current operations, as you can see here in this figure, involves both the thickeners and the agitators or grinders. The solids enters the first set of agitators grinders and are mixed over with the overflow liquid from the second thickeners. Then the contents after thorough agitation or grinding enter the first thickener. The agitators along with the thickeners outside constitute the first stage. The sludge from the first thickener passes to the second thickener where it is mixed with the overflow of the third thickener and the sludge is then transferred to the third thickness where it is mixed with the overflow from the fourth thickness liquid from the fourth section and fresh solvent enters the last thickness. So, this is how the whole thing moves here in the fresh solvent you can see here in the last thickener it is moving. The overflow liquid taken out from the first thickener will have the maximum concentration of solute. If necessary the sludge from each stage can be thoroughly agitated with the solvent in order to effect better separation.



So, finally, I will summarize this lecture by saying that there are many phenomena encountered making it practically impossible to apply any specific theory or one theory to the leaching action, but it may be a combination of principles and one has to accordingly properly select the process parameters. Fixed bed leaching is a type of solvent oil extraction technique that involves using a fixed based column to extract oil from acid materials. Bollman, Kennedy, Bonotto, Rotocell and Hildebrandt extractors are the different moving belt leaching type extractors in horizontal extractor systems. Oil seeds are loaded in chain of baskets with a perforated bottom which moves in continuous size circle carried by a chain type.

So, these are the references used in this lecture and with this thank you very much for your patience here.