Water and Waste Water Treatment
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Module No # 12
Lecture No # 60
Conditioning, Dewatering and Disposal of Sludge

Hello everyone finally, welcome back to the last session, so we are going to wrap this up in this session, let us get this started. We are looking at stabilization of sludge and we looked at different kinds of stabilization.

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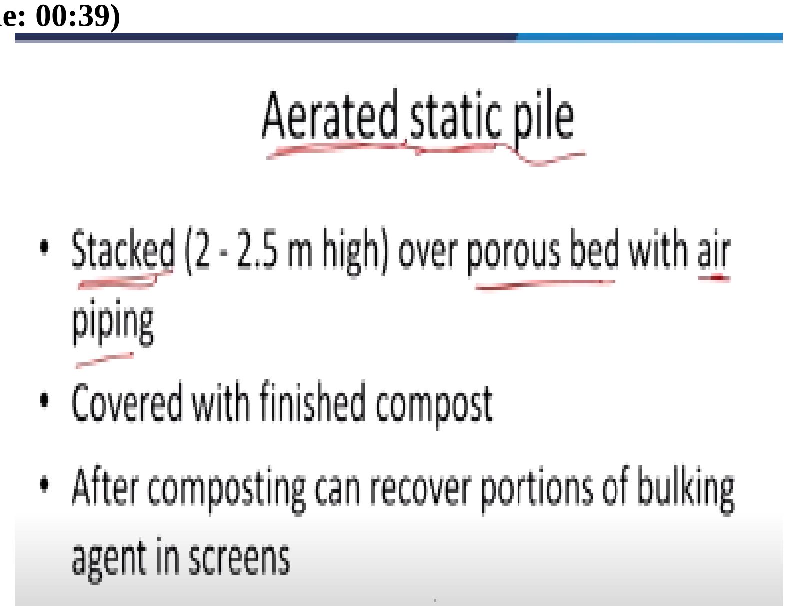

Here we have an aerated static pile as you can see most of the information is in the name of this particular process itself. It is a static pile that is aerated so what is it about? Typically, we are going to stack it over a porous bed which has air piping, so porous bed to allow for air or such to be pumped through. And on top of that you are going to stack the material that you want to stabilize.

And you are going to put some finish compost probably as a relevant seed or for nutrients. And after composting similar to the different kinds of composting we looked at earlier, you can recover some of the bulking agents in screens.

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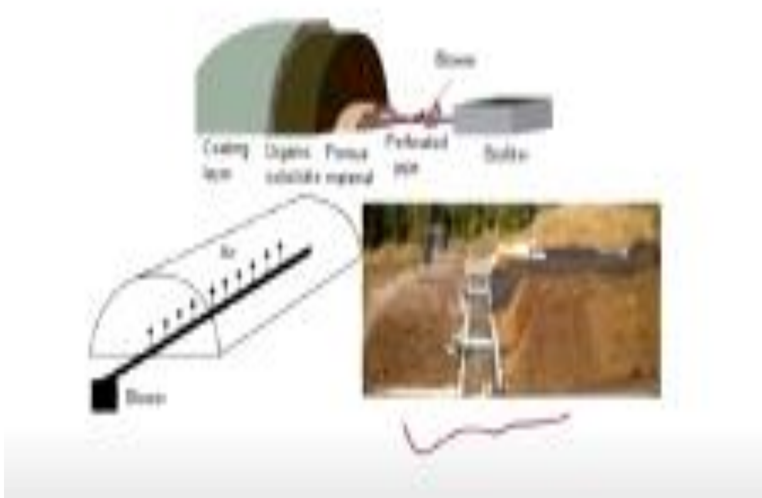

This is what typically it looks like, what do we have? You have a perforated pipe, not continuous it only requires intermittent mixing or air, that is one aspect to keep in mind. You have a porous material and on top of that is what you are trying to stabilize and then this coating layer typically made of compost and you can see the relevant pictures here.

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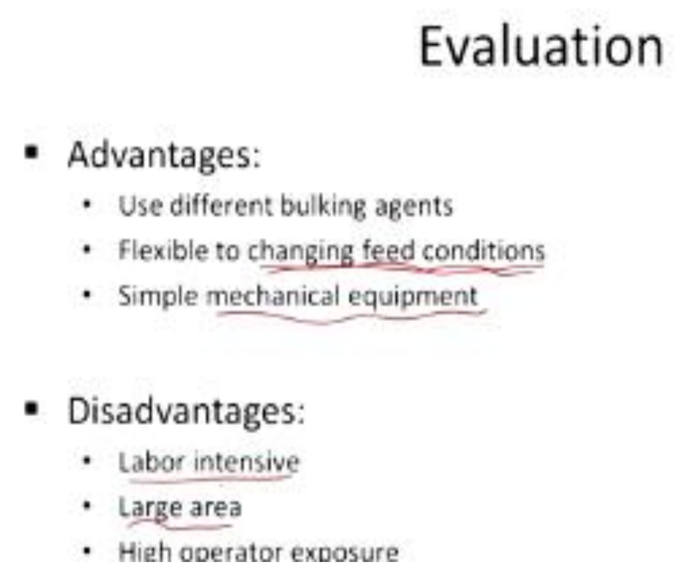

Let us move on, so evaluation I will only summarize the major aspects without going into detail here. We are going to look at flexible changing feed options, it is flexible to changing feed conditions. Different kinds of feed conditions, it is relatively more flexible or robust and as was seen earlier it require simple mechanical equipment. But disadvantages; labor intensive and as you can see it requires a lot of area.

You cannot have a considerable height of the static pile, why? Mixing is going to be affected, large area is going to be an issue and high operator exposure.

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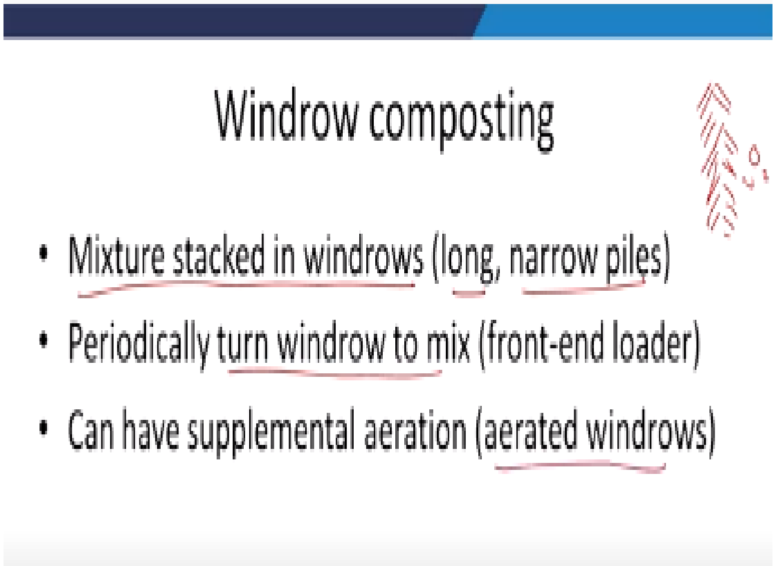

Another kind of composting, windrow composting that something you would have seen or come across at least in various forums. Mixture stacked in windrows meaning long narrow piles, key aspects with composting we discussed earlier; Carbon to nitrogen, temperature, moisture content and relevant aeration and thermophilic phase and mesophilic phase.

And you have to turn the windrow, why? To provide oxygen. You have to turn the windrow this is long narrow piles typically done with front end loader, can have supplemental aeration if this turning itself is not good enough and then you will have aerated windrows.

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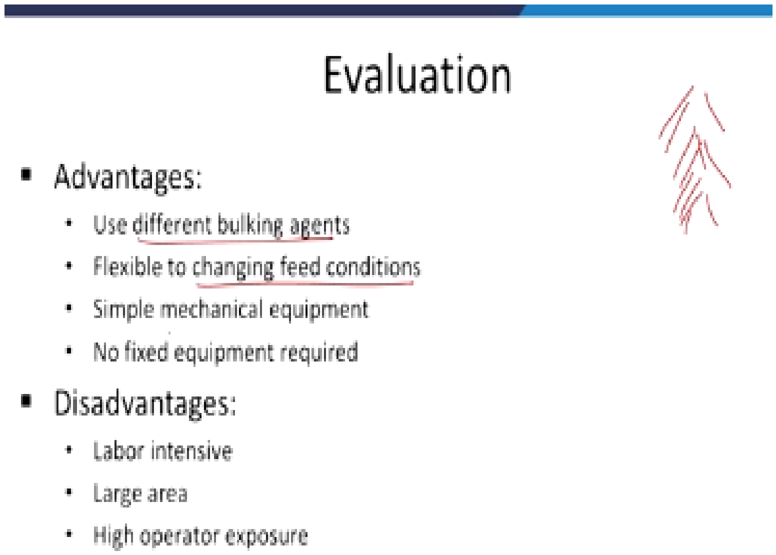

Let us move on, so advantages as was the scene in the case of other types of composting, here though you can use different bulking agents unlike the one where you had in-vessel composting. Flexible to changing feed conditions as can be seen you are just having a pile here and with the front end loader you are just mixing it. No fixed equipment required, disadvantages though its labor intensive, large area is required and high exposure operator exposure.

Why large area? Because you cannot have huge piles out here typical piles may be this height is also pretty high. May be to my waist, meter, depending on how well you are able to aerate it. Here the issue is with respect to aeration and also moisture control that is something to keep in mind.

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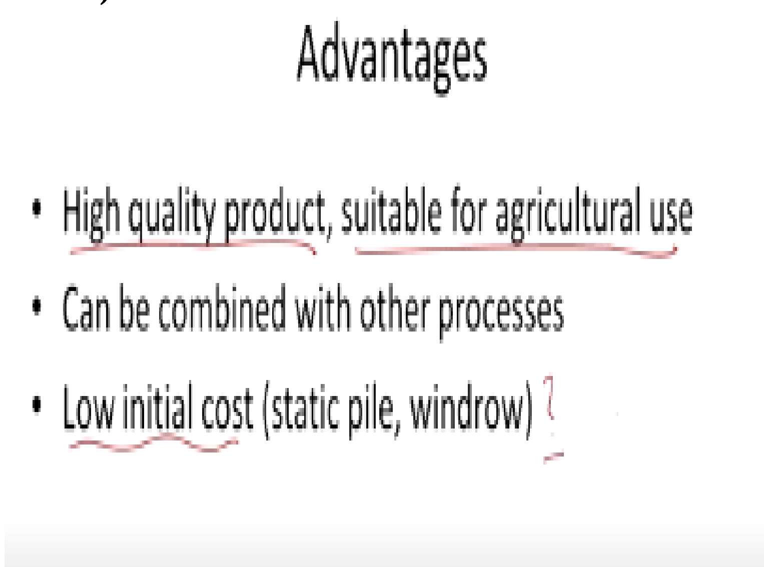

Evaluation of composting in general, high quality product which is always a great advantage and which is suitable for agricultural use. It can also be combined with the other process which typically preceded. And low initial cost but the issue in India though is now because of population density, the land prices are very high. And getting large areas for composting of kitchen waste and for sludge too is going to be an issue.

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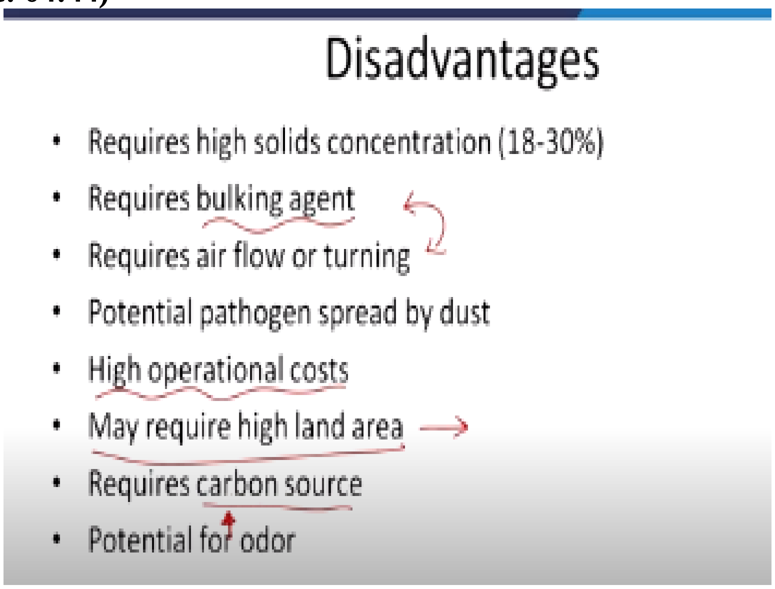

Disadvantages, high solids concentration is required initially, requires bulking agent to promote aeration, requires air flow or turning, all these are tied in. Potential pathogen spread by dust because keeping it open and aerating it and also you have wind blowing in so potential pathogen spread by dust. High operational costs but this depends upon how well you need to mix it or such.

But the key aspect is high land area and especially in India where the costs are high at least in the metropolitan areas or cities that is going to be an issue or a concern. Depending upon the type of sludge, you might need to add carbon source. And if you do not maintain it well, you can have odor problems.

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Stop gap stabilization is lime or alkaline stabilization.

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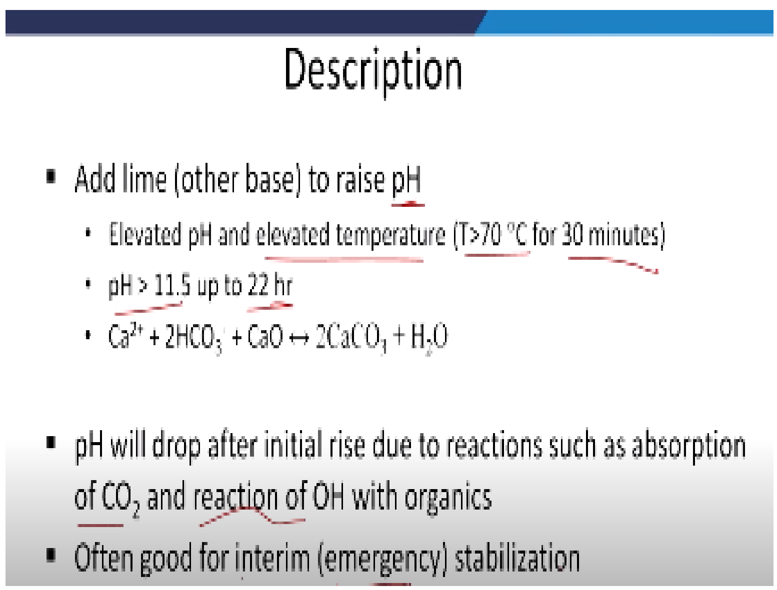

We are trying to add lime, when we add lime, we are typically increase the pH. And then we are going to increase the temperature T at pretty high value for around 30 minutes. And pH at 11.5 up to 22 hours, so we are going to increase the temperature and the pH. pH will drop after initial rise due to reactions such as absorption of carbon dioxide into the material and reaction R into the open atmosphere.

If it is open system and reaction of OH with the organics, so let me move on. As I mentioned earlier it is good for emergency stabilization, you are running out of options and your sludge anaerobic digester has failed or aerobic digester requires maintenance but you do not want to have pathogens being released or issues with respect to vectors and flies, what you are going to do? You can go for this emergency stabilization.

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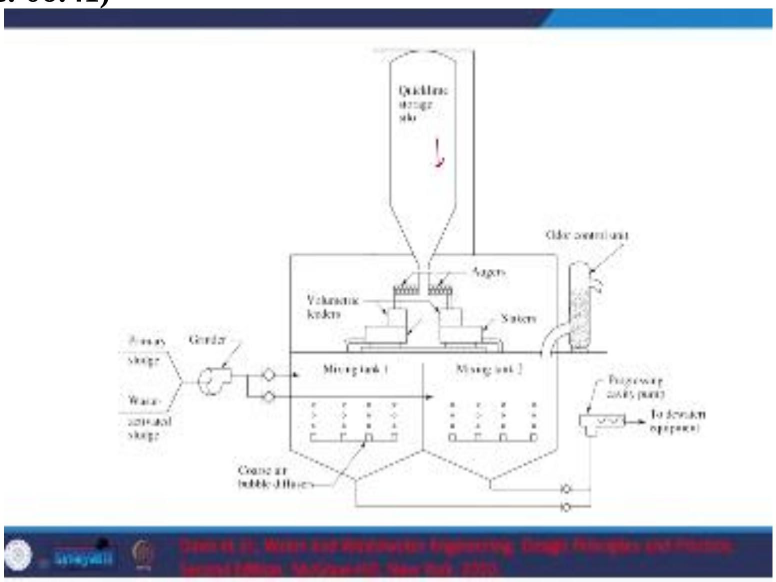

Quick lime storage, silo, mixing tank and odor control tank.

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Evaluation

- Advantages
  - Low capital cost
  - Easy operation
  - Good for interim stabilization
- Disadvantages
  - Not always appropriate for land application
  - Chemical costs
  - Overall cost is site specific
  - Volume increased
  - pH drop can lead to odors

Let me move on, so evaluation advantages; low capital cost, we are just looking at pH and temperature which is easy to achieve but high operational cost probably. And it is easy operation and as mentioned earlier, for interim stabilization, temporary stabilization it is pretty good. Not appropriate for land application later, why? The pH is going to be pretty high depending upon how much calcium is there or such in your relevant lime, that is going to be an issue too.

And chemical costs have to be taken into account, overall cost it depends upon the relevance site and volume can increase or will increase. If pH drops, it can lead to microbial growth and it can lead to orders.

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Conditioning

Conditioning, here we are going to look at, what did we do initially? We increase the solids concentration. Then we are looking at stabilization where the biodegradable content and most pathogens, we have taken care of them. And then we have to look at conditioning so that it we can go for dewatering later.

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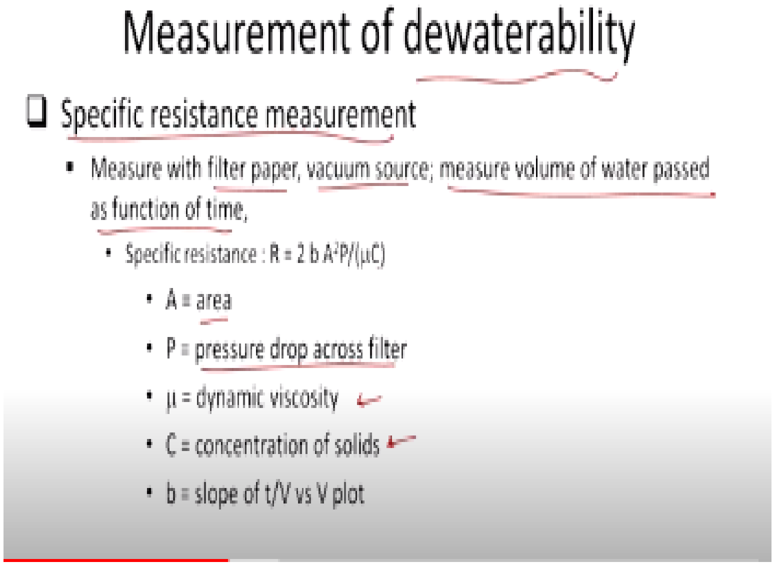

Conditioning, we are more or less talking about improving dewaterability by addition of relevant cations or sometimes polymers. It is similar to what we saw in coagulation and flocculation relatively similar but how do I measure that? I can look at specific resistance and try to measure it, here I am trying to look at specific resistance, so what will I do?

I will have a filter paper and to pump or pull this particular sludge through, I will have a vacuum source. And I will then measure the volume of water that passes through as a function of time. Here is the way to calculate, it its relatively straight forward formula so area pressure drop across the filter of that area of the filter that we looked at, dynamic viscosity, concentration of solids, so you can see the relevant interrelationship out here.

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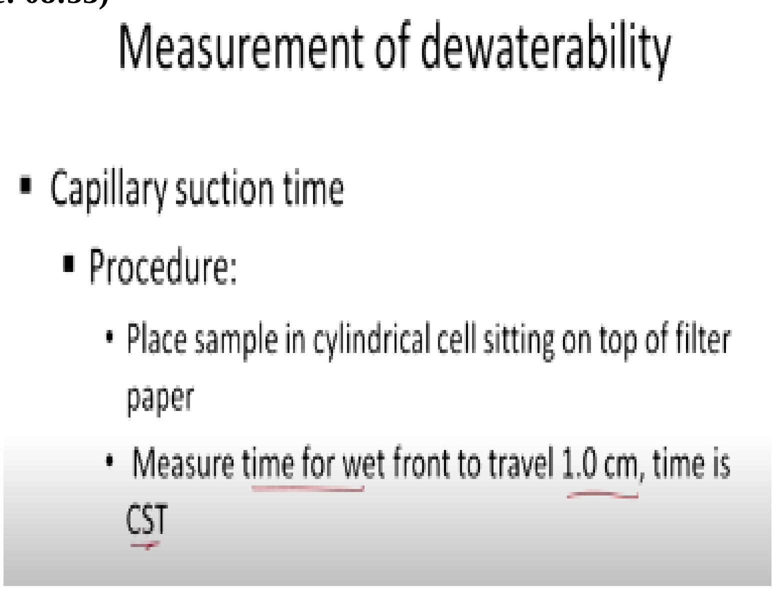

Let us move on. Capillary suction time, measurement of dewaterability. We are going to place the sample in a cylindrical cell on top of a filter. And we are going to measure the time for the wet front to travel 1 centimeter, the time will be capillary suction time.

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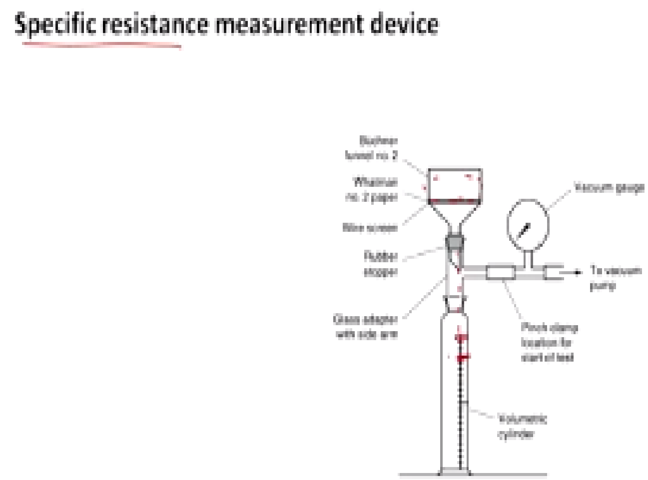

As mentioned earlier, we were looking at specific resistance measurement device. And you can see the relevant filter paper here and the relevant sludge or such that you are going to have here. And you will apply vacuum and you are going to have that volumetric cylinder where you will look at the distance of the wet front with time.

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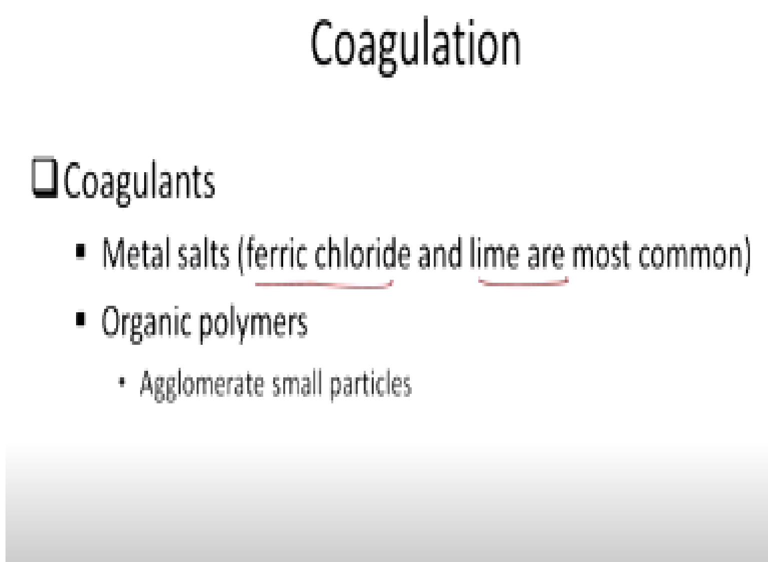

Coagulation, that is what we are talking about here, conditioning. Typically metal salts like ferric chloride or lime as we use in the context of water treatment or wastewater treatment. Organic polymers to agglomerate small particles and this is what I think we saw in the IIT Roorkee plant.

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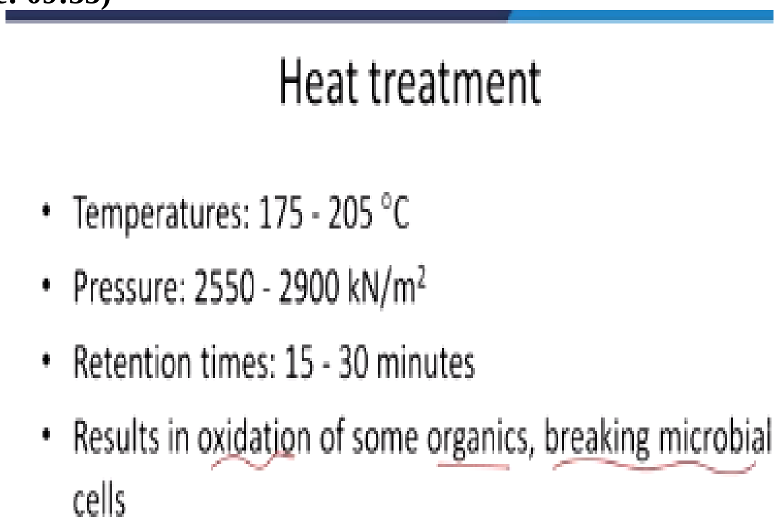

Heat treatment is also done sometimes but this is rarely done so relatively high temperatures and at relatively low retention times. Some organics are going to be oxidized at this high temperature and that can lead to breaking of the microbial cells.

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Dewatering, so I am done with conditioning as in preparing the sludge, so that it is now easy to remove or dewater it. Why am I trying to achieve dewatering? Because if not the sludge is going to be difficult to handle so at the end of it or the composted or stabilized and dewatered sludge, it should be more like a solid that is easy for me to transport and handle so that is what I am looking at.

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Dewatering plate and filter press, I am again as I mentioned going to summarize them, we can look at the relevant aspects in detail if required. What is it that we are trying to do? We are forcing the water from the sludge under high pressure. We have a plate and filter here, I am going to push this in and the water is going to come out because of this pressure through that particular filter.

And what is this filter press consisting of? Firstly, we have a number of plates that are supported in a common frame let us look at the picture and that will be clear. During dewatering, these frames are pressed together as I mentioned and filter cloth is mounted on the surface of each plate and then the water goes through this, let me look at the picture.

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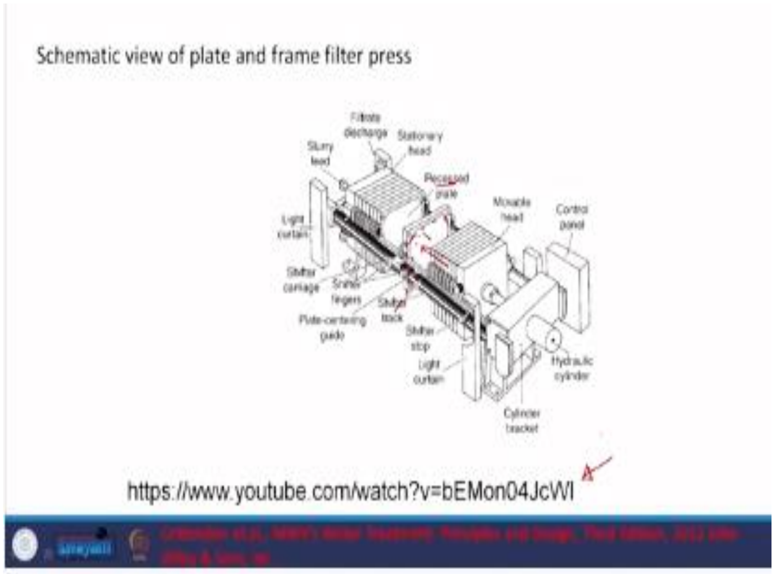

This is what you have. These are the different kinds of plates. And here you have a filter and the sludge will be here and then when I press up against it, the water will flow out through that particular filter. You can look at a relatively good video that explains the mechanism that is given in this link, not extensive mechanism, which will help you visualize the mechanism.

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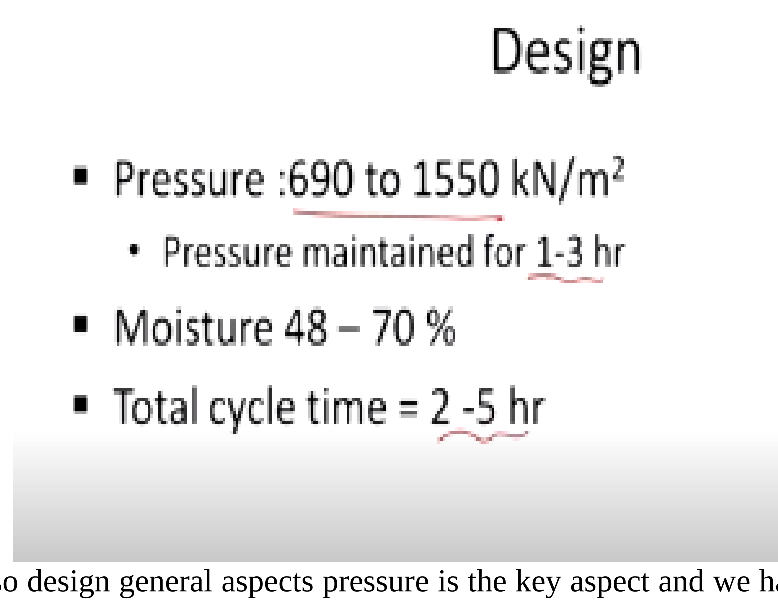

Let us move on, so design general aspects pressure is the key aspect and we have to maintain the pressure it is not one stop. And moisture content so total cycle time is 2 to 5 hours depending upon the extent of moisture removal that you want to remove.

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Belt press

- A belt filter dewaters by applying pressure to the biosolids to squeeze out the water
- Biosolids sandwiched between two tensioned porous belts are passed over and under rollers of various diameters
- Increased pressure is created as the belt passes over rollers which decrease in diameter

Belt press this is something similar to what we have seen in the video at the IIT Roorkee sewage treatment plant. We saw how sludge was being dewatered to my knowledge that was a belt press. Belt filter dewaters by applying pressure to the biosolids to squeeze out the water but here the key aspect is you are going to have a relatively porous belt. Biosolids which are sandwiched between porous belts are passed over and under as you saw there were rollers of various diameters typically decreasing diameter.

And increased pressure is created as the belt passes over rollers which decrease in diameter as we go along.

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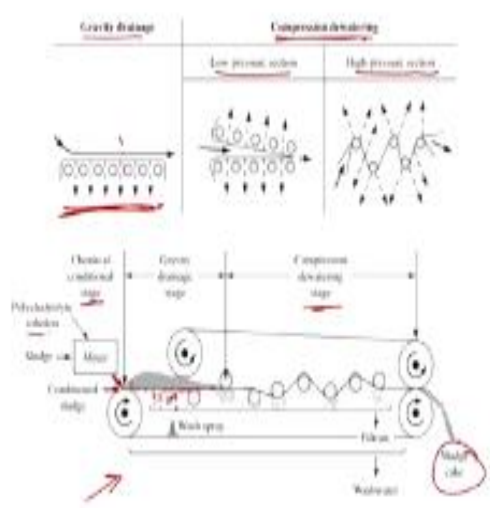
Belt press schematic



Here, we have a belt press a different kind but the principle is the same as what we saw in the IIT Roorkee sewage treatment plant. You have the electrolyte here chemical conditioning as we mentioned earlier and we are going to mix it up here and then you are going to have the conditioned sludge here. And initially, we are going to have gravity drainage where the moisture content is relatively high, it just drains by gravity.

As you can see here it just drains by gravity, the water grains by gravity through this belt. And then we move on to compression dewatering. Here, different mechanisms, one is low pressure section and the other one is high pressure section. You can look at the relevant schematic but primary aspect is one is just gravity and the other one is compression dewatering. And then final product will be sludge cake and wash water or the filtrate.

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This is a schematic and as mentioned we saw the live one in the video earlier.

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Type of sludge	Dry feed solids, %	Loading per metre belt width		Dry polymer[a], g/kg dry solids	Cake solids, %	
		L/min	kg/h		Typical	Range
Raw primary (P)	3–7	110–190	360–550	1–4	28	26–32
Waste activated sludge (WAS)	1–4	40–150	45–180	3–10	15	12–20
P + WAS (50:50)[b]	3–6	80–190	180–320	2–8	23	20–28
P + WAS (40:60)[b]	3–6	80–190	180–320	2–10	20	18–25
P + trickling filter (TF)	3–6	80–190	180–320	2–8	25	23–30
Anaerobically digested:						
P	3–7	80–190	360–550	2–5	28	24–30
WAS	3–4	40–150	45–135	4–10	15	12–20
P + WAS	3–6	80–190	180–320	3–8	22	20–25
Aerobically digested:						
P + WAS, unthickened	1–3	40–190	135–225	2–8	16	12–20
P + WAS (50:50), thickened	4–8	40–190	135–225	2–8	18	12–25
Oxygen activated WAS	1–3	40–150	90–180	4–10	18	15–23

[a] Polymer needs based on high molecular weight polymer (100% strength, dry basis).
[b] Ratio is based on dry solids for the primary and WAS.

Let us look at the performance of belt filter press, what is it all about coming to? It is coming to what is the solids concentration here. This is the key aspect. I want to have less water and more solids. What is the solids percentage here? Let us look at some aspects one is anaerobically digested, aerobically digested and let us look at the waste activated sludge and waste activated sludge here it is.

As you can see typically it is easier to look at dewatering anaerobically digested sludge than aerobically digested, so that is one thing that I wanted to point out or mention here. I was just trying to look at the only WAS, if not we can look at P + WAS, P is primary + WAS and P + WAS which is 16, so you can compare the values out here, so that is something to keep in mind. When we are looking at the kind of stabilization that you want to have.

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Typical continuous filter press manufacturer's data

Hydraulic loading, m^3/h	Solids loading, kg/h	Belt width, m
1–3	25–120	0.5
3–5	120–200	0.75
5–20	125–510	1.0
20–30	510–815	1.5
30–40	765–1,070	2.0
40–50	1,020–1,275	2.5
50–60	1,275–1,530	3.0

Hydraulic loading and solids loading and belt width, these are going to be interwined.

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Design

- Solids loading (width) = 90 – 680 kg/m-hr (depends on type of sludge, level of conditioning)
- Hydraulic loading (width): 1.6 – 6.3 L/m-s

General design aspects, solids loading as we saw earlier, the width was also an issue, so we have kgs per meter per hour. How much am I putting in? How much mass am I putting in per the meter width per time and hydraulic loading width 1.6 to 6.3 liters per meter per second. General values you do not need to mug them up but just need to be aware of them.

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Aerobically digested solids dewatered with CBFP

After that, here we have an example aerobically digested solids which have been dewatered with continuous belt filter press, this is what typically it looks like and this is much easier to handle now.

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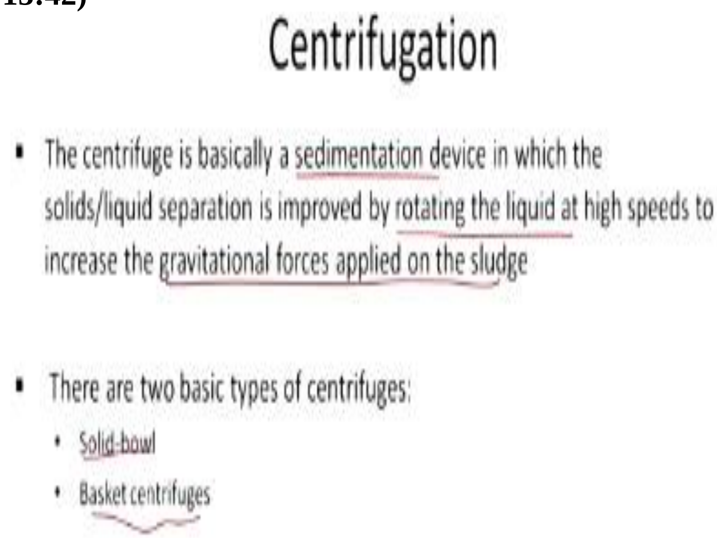

Centrifugation, typical aspect we know it is similar to sedimentation device. Here, what are we doing? We are rotating the liquid at high speeds to increase the gravitational force applied on the sludge so different kinds; solid bowl and basket centrifuge.

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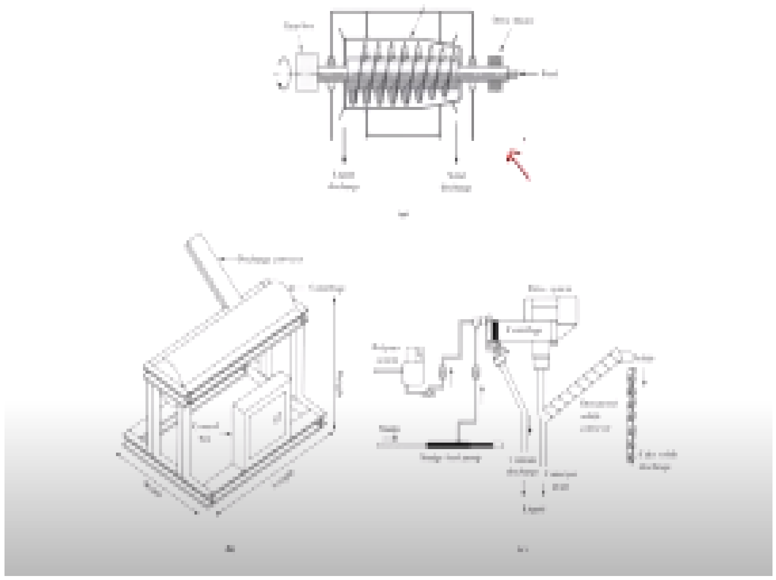

I will not go into this in detail, here we have particular schematic out here, so let me move on, this is a simple aspect.

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Sludge dewatering centrifuge even centrifuge too it depends, for example belt filter press the issue is that the loading rate is less but the energy requirement, the noise issues and also the output is typically better. But for centrifuge, more energy is required and that is always a key aspect. But it is not required to be run every time though or continuously it is not required, why? Because typically their capacities are higher.

But the noise is an issue depending on how well it was manufactured if I may say so. These are different aspects to consider.

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Typical dewatering performance for solid-bowl centrifuges

Type of sludge	Cake solids, %	Solids capture, %	
		Without chemicals	With chemicals
Untreated primary			
Alone	25–35	75–90	95+
With air activated sludge	12–20	55–65	92+
Waste activated sludge	5–15	60–80	92+
Anaerobically digested			
Primary	25–35	65–80	92+
Primary and activated sludge	15–20	50–65	90+
Aerobically digested			
Waste activated sludge	8–10	60–75	90+

Same aspect in the context of cake solids too, same anaerobically digestive and aerobically digested waste activated sludge. If you see anaerobically relatively better concentration of the solids. That is one aspect always keep in mind when choosing the kind of stabilization.

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Drying beds

- These beds are especially popular in small plants because of their simplicity of operation and maintenance
- Operational procedures common to all types of drying beds involve the following steps:
  - Pump 0.20 to 0.30 m of stabilized liquid sludge onto the drying bed surface.
  - Add chemical conditioners continuously, if conditioners are used, by injection into the
  - Sludge as it is pumped onto the bed.
  - When the bed is filled to the desired level, allow the sludge to dry to the desired final solids concentration. This concentration can vary from 18 to 60 percent, depending on several factors, including type of sludge, processing rate needed, and degree of dryness required for lifting. Nominal drying times vary from 10 to 15 d under favorable conditions to 30 to 60 d under barely acceptable conditions
  - Remove the dewatered sludge either mechanically or manually.

Another poor man’s option is drying beds, so just have a bed and you are going to look at some particular thickness of the sludge and lay it out there, this is when you have less sludge, when will you have less sludge? In smaller plants and which have access to area too. Small plants, what is it that we do? 20 to 30 centimeters stabilized liquid sludge on the drying bed surface and add chemical conditioners, in India they do not do that a lot.

And what is it that we have? We are going to let it dry and what is the source of energy? It is typically the sun and the moisture content or lack of moisture in the ambient air, so these are the relevant aspects so let me move on.

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This is a simple aspect, so we see this but one aspect to notice that typically you would prefer to have them lined. But in India I see that they are lined if depending upon the type of plant operator if not you can have issues with leaching especially during the rainy season and you will have to cover them too to prevent that aspect.

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Typical loading rates for open sludge drying beds

Type of biosolids	Sludge loading rate, kg dry solids/$m^2 \cdot y$
Primary, digested	120–150
Primary and waste activated, digested	60–100

Let us move on these are the aspects that we already looked at so sludge loading rate kilograms per meter square per this particular time.

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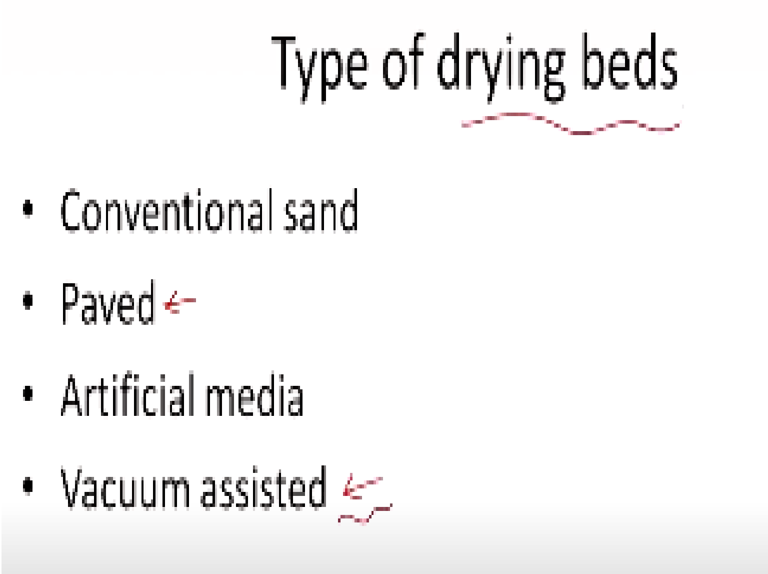

Type of drying beds; conventional sand, paved which is what I was typically mentioning and artificial media or vacuum assisted rarely looked at, so typically you are going to go for drying beds because of its simplicity in general at least in India and vacuum assisted, you are going to increase the complexity, typically in India we do not have that. Typically, we look at paved drying beds that is it. Solar paved beds that is what we typically look at.

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Disposal now that I am done with it; where is it that I can dispose this dewatered stabilized sludge. depending upon the kind of source and the kind of contaminants as in if it has remarkably high strength of different ions or god forbid of heavy metals, then you cannot dump it into the agricultural field.

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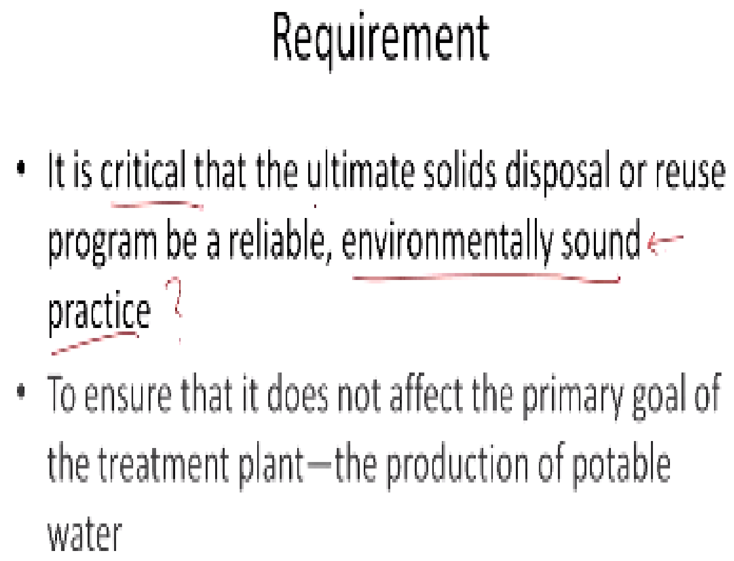

What is it that we are looking at? The ultimate disposal, it is critical that the ultimate solid disposal or reuse program be a reliable environmentally sound practice. Why is that? For example, you have a common effluent treatment plant where the sludge is coming in from different industries and concentration of heavy metals might be relatively high or typically, they are and after primary treatment,

You are going to have that sludge and dewatering that sludge by law is required to go to the hazardous waste storage facility. We are talking about the Indian context but even after biological treatment the heavy metal concentration in the sludge might be high. And in India typically sludge, they use drying beds a lot quite often so after drying if the relevant CETP operator thinks that he can give this to the farmers, is that a great idea? No.

And that is why farmers who initially took such kind of sludge burned their hands and saw that their productivity or such was affected or might have led to other issues and they stopped taking it. Trust is going to be an issue but more importantly we are looking at disposal which is environmentally sound.

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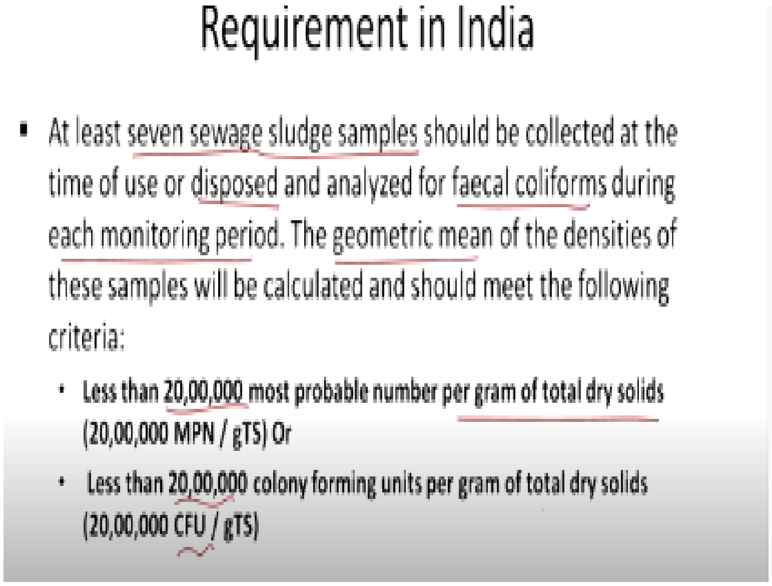

Requirement in India, what we have or what is required? At least 7 sewage sludge samples should be collected at the time of use or disposal. And what is it that they are required to be analyzed for? For fecal coliform during each monitoring period. And then we are going to get the geometric mean of these particular density of these samples and what is it that they should meet.

We have less than 20,00,000 most probable number per gram of total dry solids or less than 20,00,000 colony forming units per gram of total dry solids. In general, depending upon how well you are running it, typically that is going to be achieved but here in India looks like we are mostly looking at fecal coliform. But as I mentioned earlier heavy metals are of considerable concern too and the relevant concentration of cations that you might add to the relevant sludge too.

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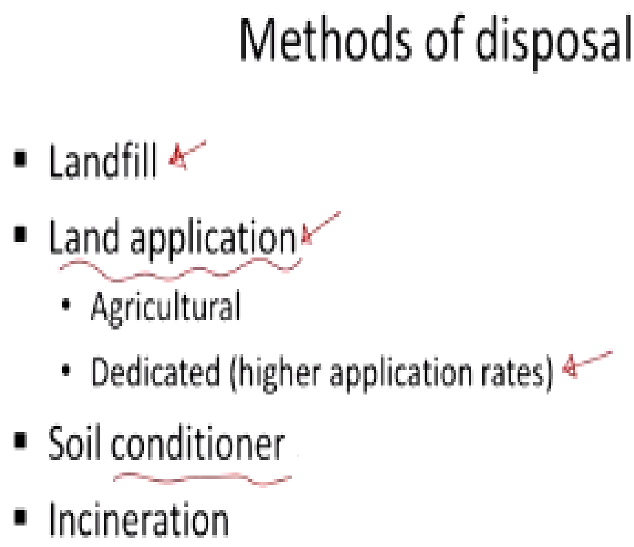

Methods of disposal; landfill but this is costly so depending upon the kind of sludge or as in is it industrial waste that was treated or is the sludge coming from industrial waste landfill. Or if it is a general sewage treatment plant, IIT Roorkee sewage treatment plant only the waste from the kitchens, bathrooms, that sludge after relevant digestion and dewatering or stabilization and dewatering can go for land application.

For agricultural uses and for other application rates. For example, Miyawaki forest, if you use this particular sludge it is going to lead to remarkably accelerated growth of the trees and plants or for soil conditioning, for gardening. Let us move on; incineration, but not a great practice.

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If you are trying to inject the bio solid into the soil, this is what it will look like in agricultural practice.

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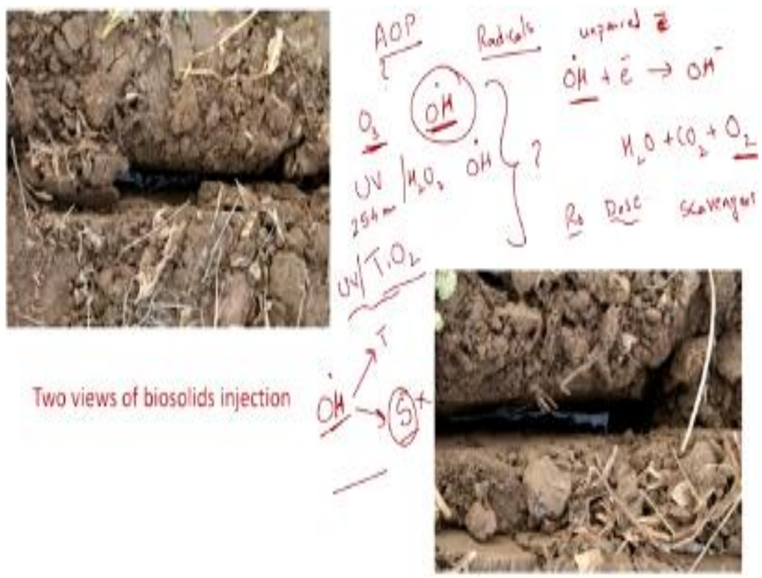

You are going to have these rows and you are going to inject the bio solids there. With that I am at the end of our course but my TA Bharat wants me to discuss one last aspect which looks like people are asking in some exams and more importantly in interviews though, let me just discuss this finally. We looked at different kinds of treatment plans and in that context, we primarily looked at activated sludge process.

And we looked at anaerobic process for sludge so at least you are aware of those aspects but we also mentioned some from time to time industrial waste. And these industrial waste microbes cannot degrade either it is too toxic or these aspects; shock loading microbes are not able to maintain it. And the structure of the relevant industrial waste sometime at least pharmaceutical waste is such that

They are not amenable to degradation by microbes within a reasonable amount of time. What can you do? You can look at advanced oxidation process, why are we calling that advanced? Because here we are going to look at formation of radicals. Radicals are those with unpaired electrons. OH, this one means it has an unpaired electron, so OH radical strong oxidizing agent.

What does it want to do? It wants to take an electron and go to more stable state of OH - or it can look at hydrogen abstraction from the relevant compound so these radicals are remarkably reactive. Like radicals out there among humans so they are remarkably restless active they want to bring about change very fast, that is good at least when the society is in different condition, anyway let me not diverse there so we have formation of these radicals.

And how is it that we typically do? There are different ways, let me just summarize the ones that are typically looked at either in interviews or such. With ozone you are not forming a radical especially if the pH is low. But if the pH is near about 7, 8 or higher depending upon the type of reactions, you will almost always have the radical being formed. O3 or ozone at low pH, just ozone but even then, we classify that as AOP because at neutral pH or higher pH it can lead to formation of this highly reactive hydroxyl radicals.

And the other one is UV at 254 nanometers and hydrogen peroxide, that will also lead to formation of hydroxyl radicals. Note that it is not only hydroxyl radical formation there are other radicals too that will be formed. But primarily, the chain will start with formation of hydroxyl radical or the primary species of interest is this hydroxyl radical. There will also be other reactive oxygen species.

Another one is titanium dioxide with the catalyst and you are going to provide the energy so that you move the electron or the electron can go from the conduction band to the valence band. And then you are going to have an electron and also a hole so you can have an oxidizing site and also reducing site or reducing agent, that is one aspect to keep in mind when you have UV, TiO2 or such process.

Now they are looking at carbon doping to bring down the band gaps, so sunlight can also be used. Some of the advanced oxidation process, why is this important or why is this relevant? Because these chemical processes first, as you can see at least with respect to ozonation and UV, H2O2, what are the byproducts going to be? The byproducts will be H2O, CO2 and oxygen if its ozone, by product is oxygen, so that is pretty useful.

If we are talking about industrial ways or even canals where people talk about constructed wetlands but their efficacy is limited especially during the monsoon seasons, so you are going to have to consider out of the box options. And advanced oxidation process, which are widely used all around the world in developing and also in developed countries.

But which are yet to catch up in India, so you can use these AOP's for this high strength and difficult to degrade waste. If you do not want to put in a lot of money, what you can do is you can apply these AOP's on wastes which are relatively less biodegradable. And transform them into more biodegradable waste and have a biological process later. But that is a simplistic information that I just presented but that is the crux of the issue.

And another aspect is when try to sell these UV, H2O2 or ozonation based process, always ask what is the dose, what is the dose of UV that is required? What is the dose of ozone required per liter of water, why? Because the greater the dose or greater the intensity and the duration, the greater the cost of your particular process. One last aspect to note is that after we looked at the relevant cost, as we just looked at the dose, one aspect to note is that you will have to be concerned about scavengers.

Whenever I have the hydroxyl radical, it will either react with my target which I want to happen or also react with my scavenger which I do not want to happen. But hydroxyl radical, it is not selective, it will react with whatever is out there so I have to be concerned with these parallel reactions.

With that I am done with the technical information, so before I end this session, I need to thank Dr. Batchellor from whom I learned all the material that I presented in this course and in the other 2 courses that I recorded. And also, I need to thank Mr. Sharath from our NPTEL office here who was patiently able to present all this material and edit it and remove the relevant blunders for all the 3 courses.

With that I will again thank you for your patience and hopefully you learnt water and waste water treatment from a different perspective and I will end this course.