Biological Process Design for Wastewater Treatment
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Lecture 34
Sludge Management - IV

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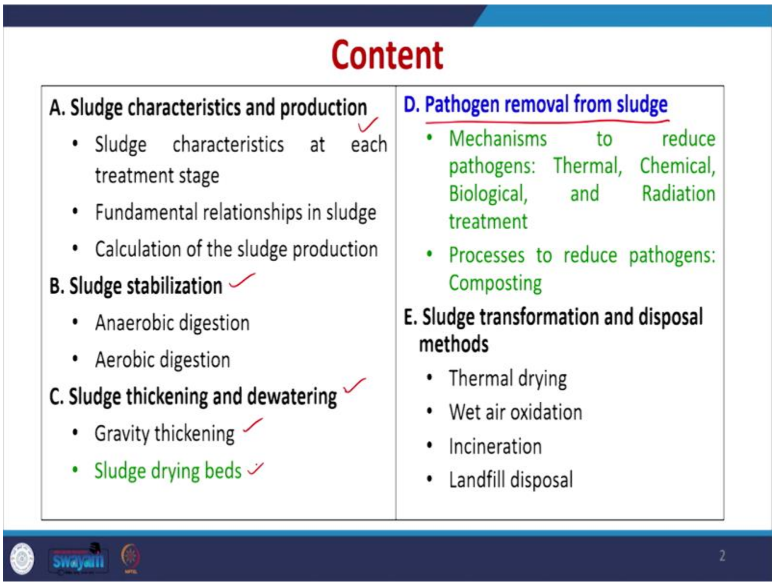

Welcome everyone, in this NPTEL online certification course on Biological Process Design for Wastewater Treatment. So today, we will continue our knowledge sharing with respect to the sludge management. So in the previous few lectures, we have started studying the sludge management and we have already studied the sludge characteristics and its production then how do we stabilize the sludge using anaerobic and aerobic digestions.

Further in the last lecture we studied regarding the sludge thickening and dewatering. In particular, we studied the gravity thickening in greater detail. So today we will be studying the sludge drying beds in greater detail. And also we will start the pathogen removal from sludge using various methods chemical, biological, thermal, radiation, etc., so we will start studying this. And then we will further study, maybe in the next lecture the process to reduce the pathogens via composting and further sludge transformation. So today we will start with the sludge drying beds which is one of the method of sludge dewatering.

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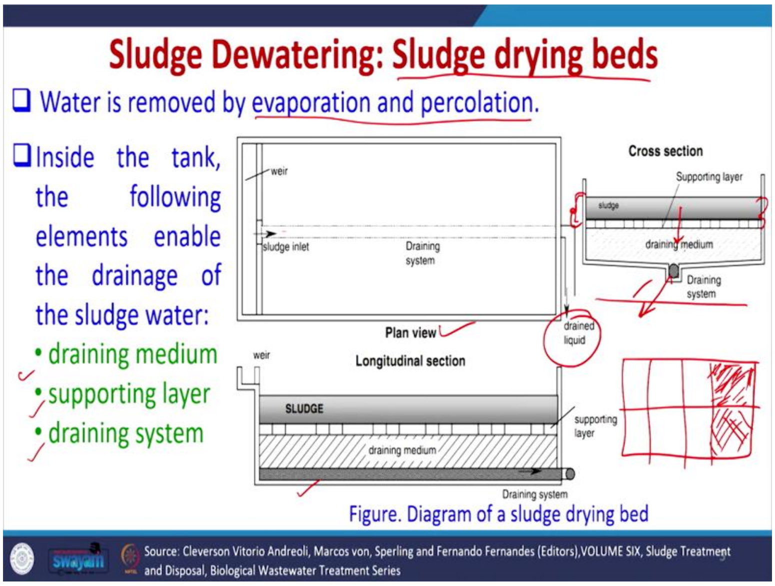

So now the sludge dewatering via sludge drying beds. So this already we have studied yesterday that dewatering of sludge is very important and we should remove maximum possible water. So that the transportation of the sludge becomes easy the processing of the sludge for the disposal etc., everything we get lot of benefits if you can dry the sludge. So that means water has to be removed.

Now in the sludge drying beds, these are very commonly used in various wastewater treatment plants. So in the sludge drying beds the water is removed via evaporation and percolation. So this is the mechanism that actually works for the sludge drying beds. Inside the tanks the following elements enable the drainage of sludge water the draining medium, the supporting layer, and the draining system.

So let us see how the drying bed actually is there. So this is one of the cross section and this is the plan view of the sludge drying bed and we can see the longitudinal section also of the sludge drying bed. So these look to be similar. So now here the sludge is comes uniformly it is supported or it is uniformly distributed all around the sludge drying bed. So we can have like the system work like this is the sludge drying bed section, we can have different sections within this.

The first the sludge will be like it will be distributed or it will be kept on this particular area, after this in the second case this particular section of sludge drying bed may be used. So we have sludge which is totally kept here. Now in this it will be supported by some supporting layer and then there will be a draining medium. So that the sludge by automatically compresses itself and the draining system is here. So this is very simple and the draining liquid has to be discharged. So and certainly it has to be recycled back, because it may contain some of the BOD, COD, etc.

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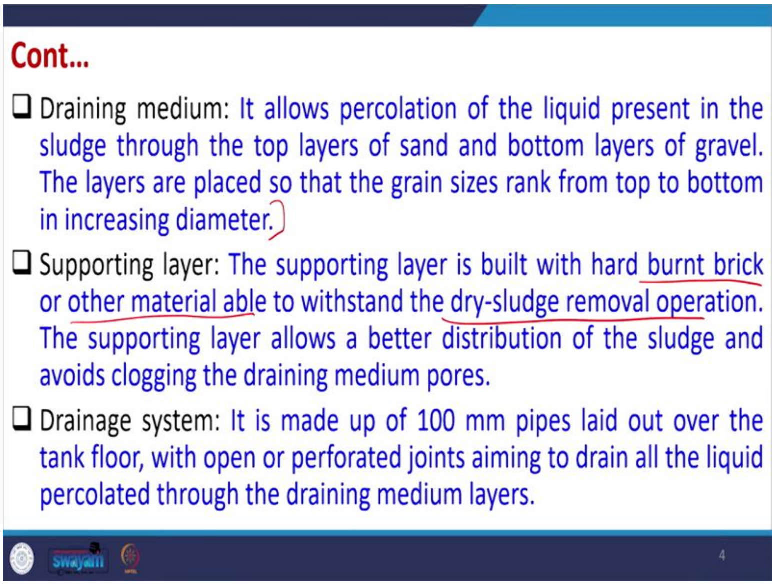

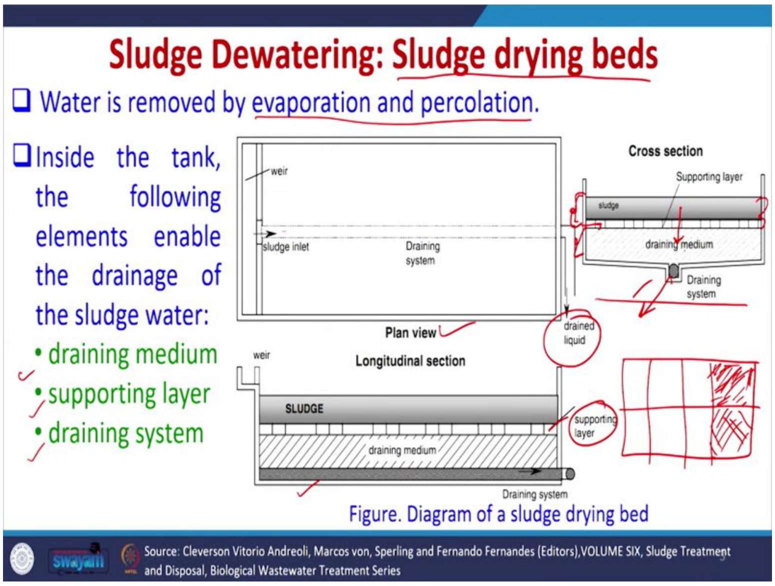

Now the draining medium it allows the percolation of liquid present in the sludge through the top layers of sand and bottom layers of gravels. Layers are placed so that the grain size ranks from top to bottom to increase the diameter with increasing diameter, so this is like this. This is the draining medium which is like this section. Now we have supporting layer also above that draining medium, we can see here the supporting layer here or here this is the supporting layer. So we have supporting layer also.

The supporting layer is built with hard burnt brick or any other material which are able to withstand the dry sludge removal operation. So because during the removal the operation may be little bit harsher as compared to otherwise. So we have to take the sludge out of the system. So the supporting layer should be good enough it should mechanically be stable and it should withstand those operations of drying sludge removal process.

The supporting layer also allows a better distribution of the sludge and avoids clogging the draining medium pores. So that also is the one of the important aspect when choosing the supporting layer.

Now the drainage system which is at the bottom. So we have a drainage system which is there at the bottom, it is made of 100 millimeter pipes laid out over the tank floor with open or perforated joints aiming to drain all the liquid percolated through the dining medium layer. So this is how it works. So we have three essentially sections, they are very simple, we have supporting layer at the top following by draining medium and following where the drainage system itself.

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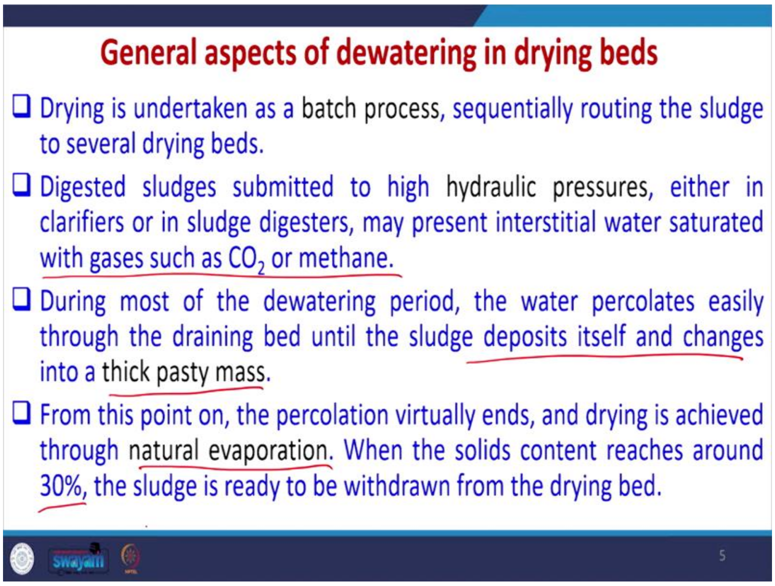

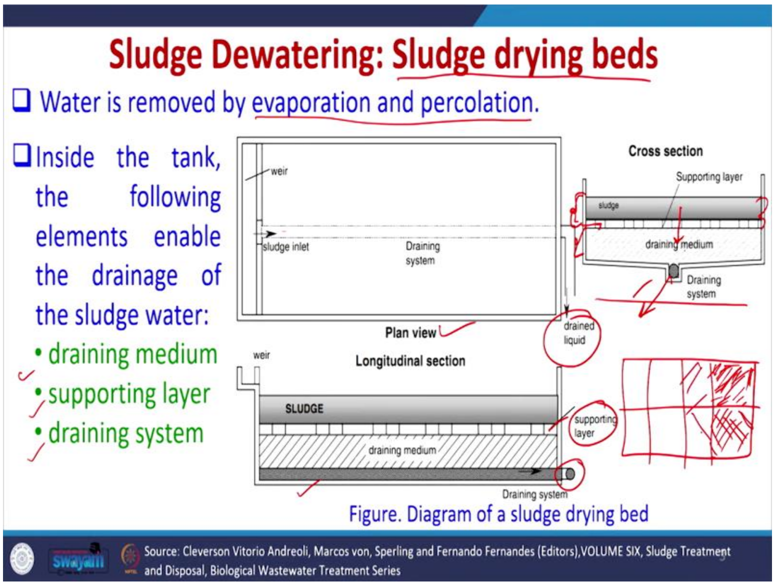

Now there are some general aspects of dewatering in the drying bed, so that we should understand. Drying is undertaken generally as a batch process, this is what I was trying to explain via this. So we have one batch, second batch, third batch will be coming here, fourth batch will be coming here. So it is a batch process and sequentially rooting the sludge to several drying beds.

So if you have several drying, the whole section will be divided into various drying beds. Digested sludge is submitted to high hydraulic pressure either in clarifiers or in sludge digesters may present interstitial water saturated with gases such as CO_2 or methane. So it is possible during most of the dewatering period the water percolates easy through the draining bed until the sludge deposits itself and changes into a thick pasty mass. So it is there.

From the point on the percolation virtually ends and the drying is achieved through natural evaporation. So we have two sections in a way of drying. So initially the percolation of water will happen and through that some drying will happen and we will get a thick pasty mass. After that, there will be natural evaporation that will happen and during that case the solid contains reaches around 30 percent and the sludge is ready to be withdrawn from the drying bed. So these are the general aspects.

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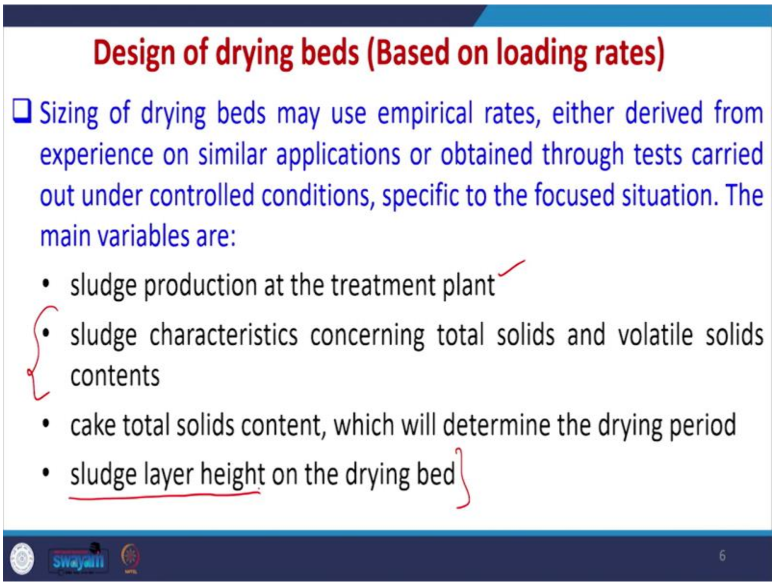

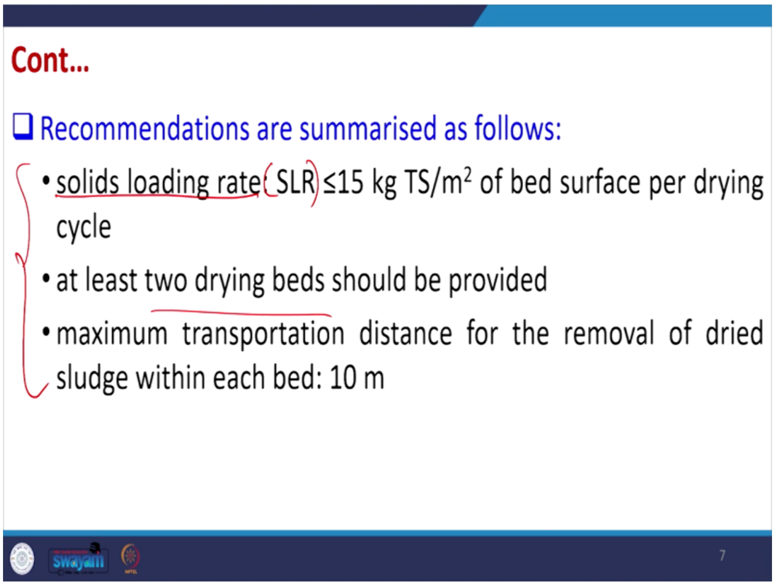

Now design of drying beds based upon the loading grades. So we can design the drying beds. The sizing of drying beds may use empirical rates either derived from experience on similar applications are obtained through test carried out under control condition, specific to the focus situation. The main variables in designing the drying beds are, the sludge production at the treatment plant that, how much amount of primary, secondary, which type of sludge is getting produced, and what is the amount.

The sludge characteristics also the total solid contain, the fixed solid contain, the volatile solid content, what are the percentage of those that also helps in the design of drying beds. Now in addition we have the K total solid contains which determines the drying period and sludge layer height we have to keep in the drying bed. So this is very important factor that we have to take care during the design of the drying beds.

Now there are certain recommendations also with respect to drying bed that solids loading rate SLR which is defined as SLR should be less than 15 kg total solid per meter square of bed surface per drying cycle. Then at least two drying beds should be provided. So we cannot have one drying but we can have multiple drying bed, at least two is compulsory. Then the maximum transportation distance for the removal of dried sludge within each bed should be 10 meter. So these are the rough recommendations which have been obtained with respect to design of drying beds. So and this is necessary then only we can easily dry.

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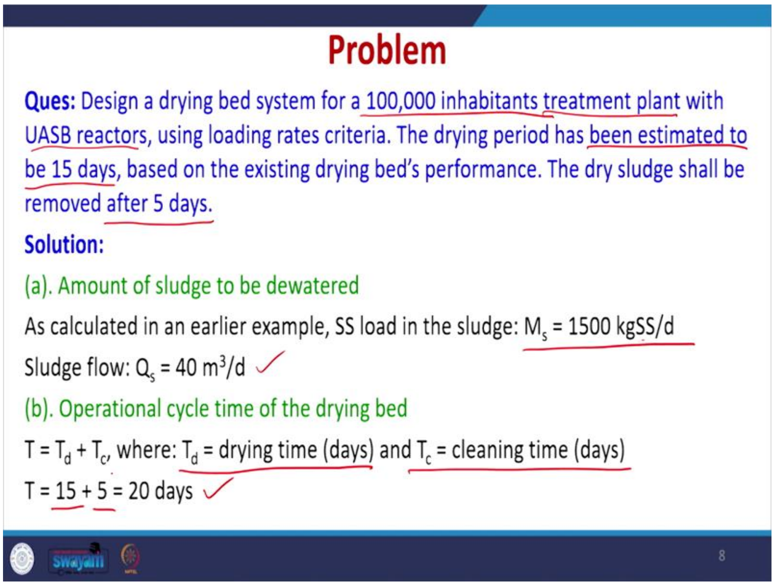

(a). Amount of sludge to be dewatered

As calculated in an earlier example, SS load in the sludge: M_s = 1500 kgSS/d

Sludge flow: $Q_s = 40\ m^3/d$

(b). Operational cycle time of the drying bed

$T = T_d + T_c$, where: T_d = drying time (days) and T_c = cleaning time (days)

T = 15 + 5 = 20 days

Now let us try to solve a problem. So as to further understand the design of sludge drying beds. So in this question, we have to design a drying bed system for 100,000 lakh inhabitant's treatment plant with UASB reactor. So this question we have been following since the whole this section on sludge management has been done and using the loading rates criteria. So whatever is there? The drying period has been estimated to be 15 days.

So this is the estimate that it will require 15 days to dry the sludge based upon the existing drying bed performance. So already some data is available. So based upon that the 15 days has been put as the criteria.

Now the dry sludge shall be removed after 5 days. So this is also given. So let us try to solve this problem on design a drying bed system for this condition. Now amount of sludge to be dewatered is the first step that we have to calculate. And as already we have calculated the amount of sludge to be dewatered in the previous question. So that data was 1500 kg total suspended solids per day and the sludge flow rate was 40 meter cube per day. So this is the sludge that we have to handle in this drying bed system.

Now the operational cycle time of the drying bed can be calculated here. So the total time will be equal to the drying time plus the cleaning time also. So we have 15 days is the drying time and 5 day is the cleaning time. So total time is 20 days. So already it is given if it is possible to reduce this cleaning time also but we are taking 20 days.

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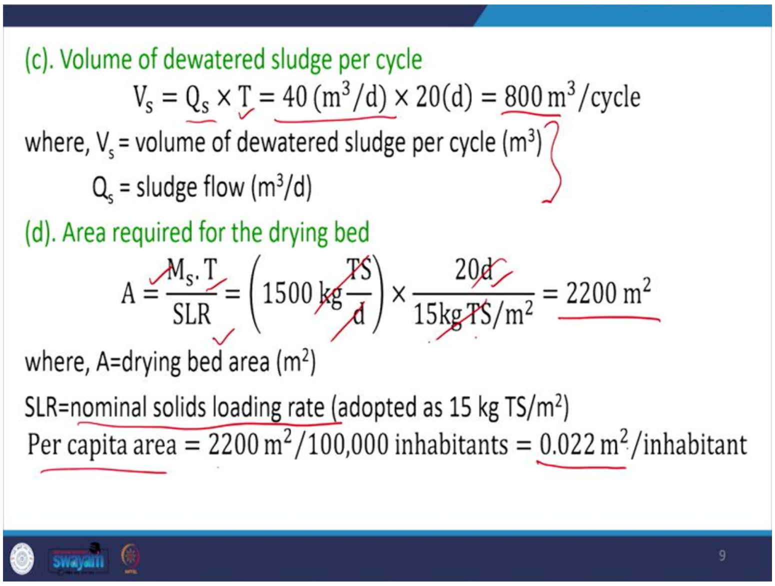


(c). Volume of dewatered sludge per cycle

$$V_s = Q_s \times T = 40\,(m^3/d) \times 20(d) = 800\,m^3/cycle$$

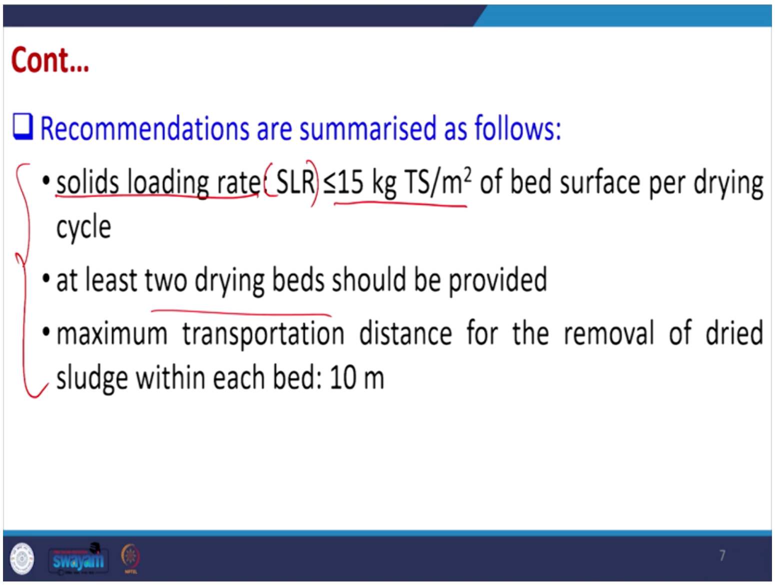
where, V_s = volume of dewatered sludge per cycle (m^3)

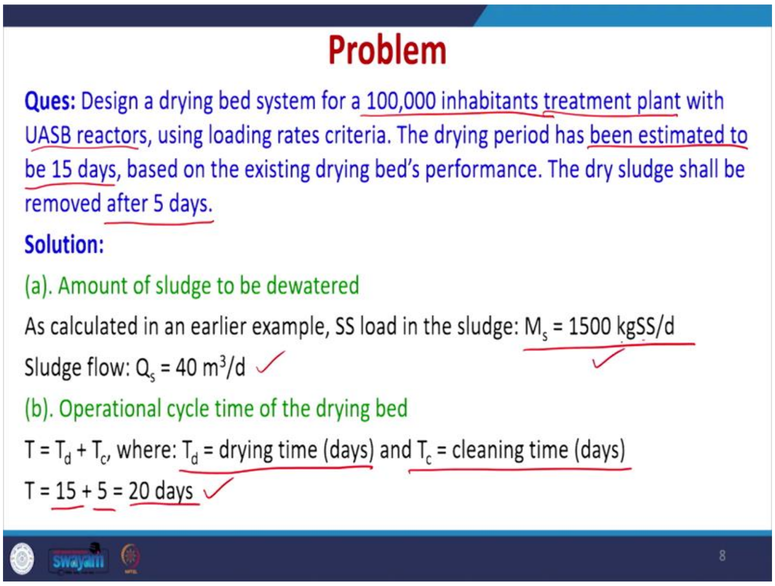
Q_s = sludge flow (m^3/d)

(d). Area required for the drying bed

$$A = \frac{M_s.T}{SLR} = \left(1500\,kg\frac{TS}{d}\right) \times \frac{20d}{15kg\,TS/m^2} = 2200\,m^2$$

$$\text{Per capita area} = 2200\,m^2/100{,}000\ \text{inhabitants} = 0.022\,m^2/\text{inhabitant}$$





Now the volume of dewatered sludge per cycle can be calculated and remember the Q_s was the flow rate in 40 meter cube per day and we can multiply the time 20 days. So this is the flow rate that we are going to handle. So 800 meter cube per cycle is the volume of dewatered sludge per cycle, so this we calculate back. Now the area which is required for the drying bed can be calculated based upon this. So the SLR remember the criteria is that we have to keep the sludge solid loading rate at less than 15 kgTS per meter square of the bed.

So based on this data, the area required for the drying bed can be calculated from this, what we do is that, we multiply the whatever is the total M_s, M_s means that what is the total kg of TS per day that we have to handle.

So we have already calculated this to be 1500 kgSS per day which is the sludge suspended solid load in the sludge. Now this when multiplied by the total cycle time, so this is already given, so it is 20 days. So this day will go off, we have kgTS. Now the SLR is 15 kgTS per meter square. So if we divide by this. So this kgTS also goes off. So we can solve it and we are getting the answer 2200 meter square is the drying bed area which is required for this particular condition.

Now SLR is the nominal solids loading rate adopted as 15 kgTS per meter square for this. Now per capita area is because we have 100,000 inhabitants. So that means 2200 divided by 100,000, so 0.022 meter square per inhabitant is the area which is coming. So this we know.

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(e). Dimensions of the drying cells

A total of 22 cells (greater than the cycle time of 20 days) with 100 m^2 each will be used. Each cell will be 10 m wide and 10 m long

(f). Height of the sludge layer after loading operation at the drying bed

The sludge is calculated by:

$$H_s = \frac{V_s}{A} = \frac{800\ (m^3/cycle)}{2200 (m^2/cycle)} = 0.36\ m$$

(c). Volume of dewatered sludge per cycle

$$V_s = Q_s \times T = 40\ (m^3/d) \times 20(d) = 800\ m^3/cycle$$

where, V_s = volume of dewatered sludge per cycle (m^3)

Q_s = sludge flow (m^3/d)

(d). Area required for the drying bed

$$A = \frac{M_S . T}{SLR} = \left(1500\ kg \frac{TS}{d}\right) \times \frac{20d}{15kg\ TS/m^2} = 2200\ m^2$$

where, A=drying bed area (m^2)

SLR=nominal solids loading rate (adopted as 15 kg TS/m^2)

Per capita area = 2200 m^2/100,000 inhabitants = 0.022 m^2/inhabitant

Problem

Ques: Design a drying bed system for a 100,000 inhabitants treatment plant with UASB reactors, using loading rates criteria. The drying period has been estimated to be 15 days, based on the existing drying bed's performance. The dry sludge shall be removed after 5 days.

Solution:

(a). Amount of sludge to be dewatered

As calculated in an earlier example, SS load in the sludge: M_s = 1500 kgSS/d

Sludge flow: Q_s = 40 m^3/d

(b). Operational cycle time of the drying bed

T = T_d + T_c, where: T_d = drying time (days) and T_c = cleaning time (days)

T = 15 + 5 = 20 days

The sludge is calculated by:

$$H_s = \frac{V_s}{A} = \frac{800\ (m^3/cycle)}{2200(m^2/cycle)} = 0.36\ m$$

Now the dimension of the drying cells that we have to use because this is very important that how many cells we are going to use. So from this data since it is roughly coming 2200 a total of 22 cells greater than the cycle time of 20 days with 100 meter square each will be used. So this is very important that whatever is the cycle time. So each day we have to load some sludge. So the number of cells should be greater than the cycle time.

So we have like two cells in a way which is available for us for better operation extra sludge in a way. So this is, and during that we can do if the cleaning is delayed also then also we can do it. So 22 cells greater than the cycle time of 20 days with each 100 meter square it will be used and each shall will be, because it is 100 meter square, we can take a 10-meter-wide and 10 meter long. So that will be good enough as a drying cell.

The height of the sludge layer after loading operation at the drying can be calculated using this, because we have the area which is 2200 meter square per cycle and also we have calculated beforehand that how much water we are handling. So it is 800 meter cube per cycle. So if we divide 800 by 2200, 0.36 meter is the height which seems to be okay. So we can go ahead with using this designed drying bed for our operation. So this is, with respect to sludge drying bed, how we can design the sludge drying bed. So now we have already studied the gravity thickening the sludge drying bed.

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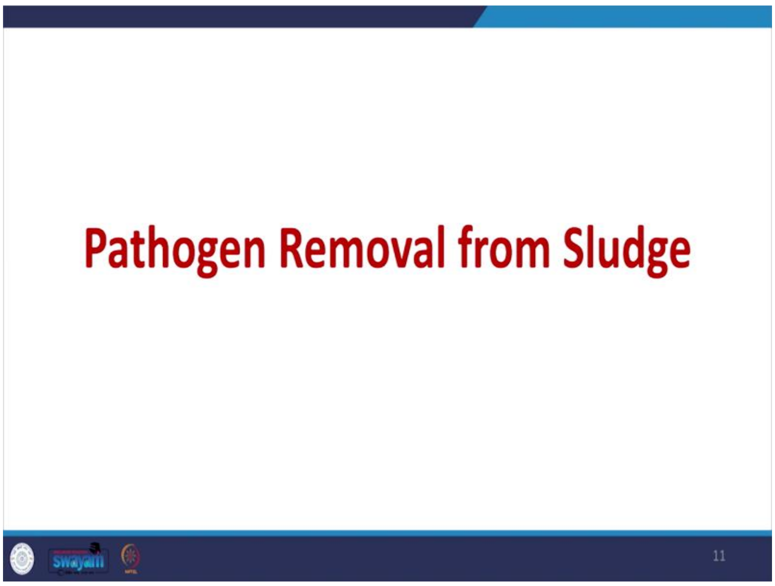

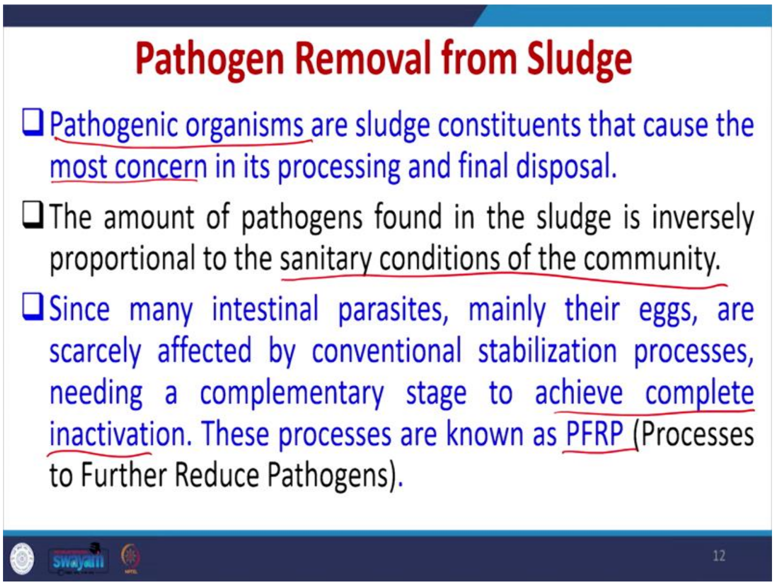

Now we will go to the next section which is the pathogen removal from the sludge because this is very important and we have to study this in greater detail. Now the pathogen removal from sludge is very important and it is one of the important section of sludge management. So pathogenic organisms are sludge constituents that cause the most concern in its processing and final renewal. So these organisms if they are available in the sludge that will be very difficult to handle and we have to remove these pathogens.

The amount of pathogens found in the sludge is inversely proportional to the sanitary conditions of the community. So from where the sludge is getting generated if it is municipal sludge what is the sanitary condition of the community where that the sludge, the wastewater is getting generated and it is going to the wastewater treatment plant. Then there are many intestinal parasites mainly their eggs are scarcely affected by the conventional stabilization process needing a complementary stage to achieve the complete inactivation.

So we require many times a complementary stage for this complete inactivations and this processes are known as process to further reduce pathogens PFRP, the processes which are used to further reduce the pathogens, so this is PFRP.

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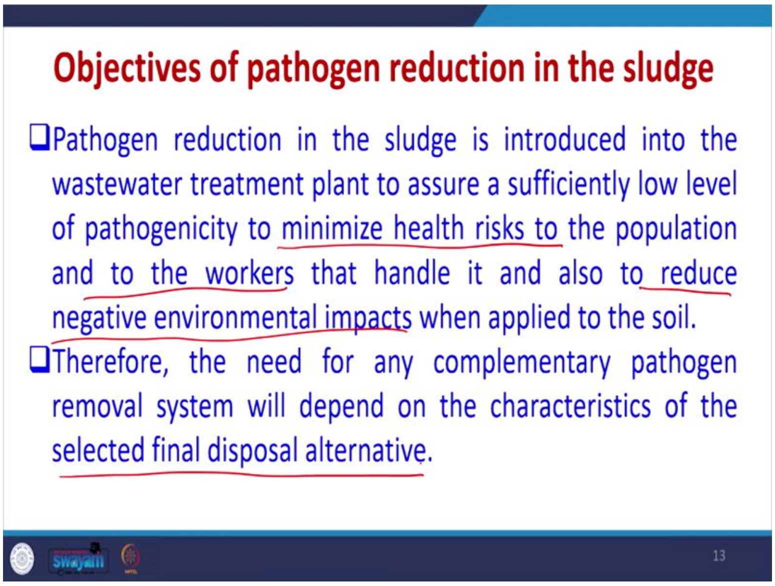

Now the objectives of pathogens reduction in the sludge. There must be certain objectives the pathogen reduction in the sludge is introduced into the wastewater treatment plant to assure a sufficiently low level of pathogenicity to minimize the health risks to the population and to the workers that handle it. So if pathogens are high there is likelihood of some worker getting affected and his or her health may go down. So we have to remove the pathogen.

Also to reduce the negative environmental impacts when applied to the soil. So there is a lot of possibility that we can use the, this sludge after the sludge management for agriculture use. Now if pathogens are remaining then they can affect the soil quality wherever they are being applied that is why we need to remove the pathogens.

The need for any complementary pathogen remote system will depend upon the characteristic of selected final disposal alternative. So whether we are going for agriculture thing, or we are going for land filling, or simple topsoil uses, etc., so depending upon that the objectives may change and whether requirement of any pathogen removal is there or not that will be decided.

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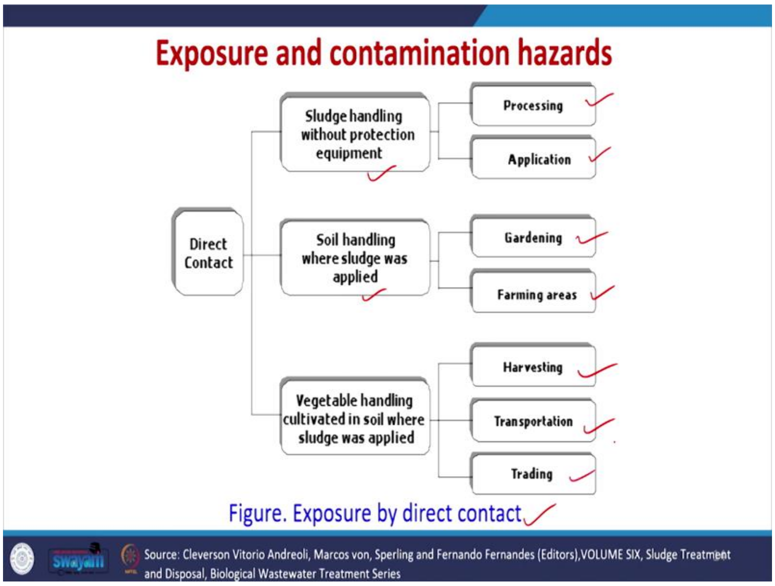

Now we will try to understand the exposure and contaminants hazard because of the direct contact of a sludge which contains some pathogens. So direct contact may happen during sludge handling without protection equipment. So that means we have to take care of that and if we are not using any production equipment that sludge handling can cause problem. So and this may happen during processing or during application.

Then sludge handling where the sludge was applied. So it is possible direct contact may happen during gardening and farming areas also. Similarly vegetable handling cultivated in soil where sludge was applied. So we have three sections where the sludge is being handed before application, then sludge handling where the sludge was applied, then third the vegetable if they are produced and they are cultivated in a place or in a soil where the sludge was applied, then during harvesting, during transportation, during trading, we can have sludge contamination or the pathogen contamination which is present in the sludge.

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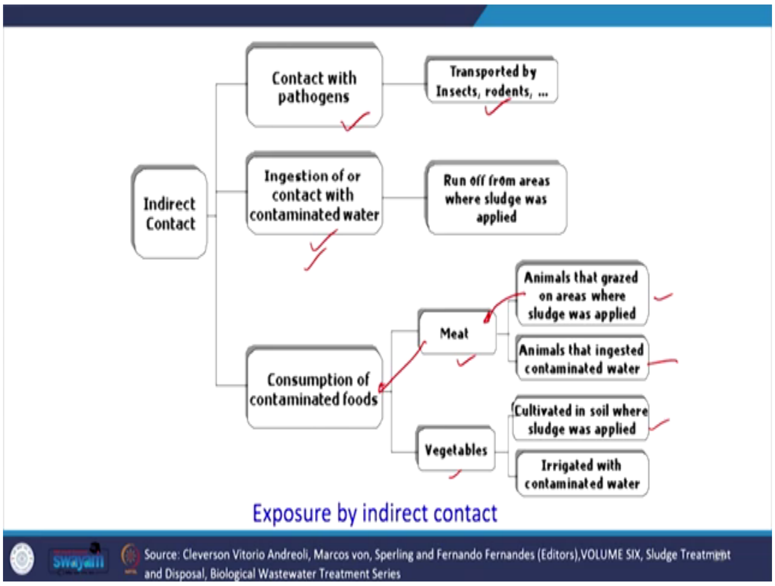

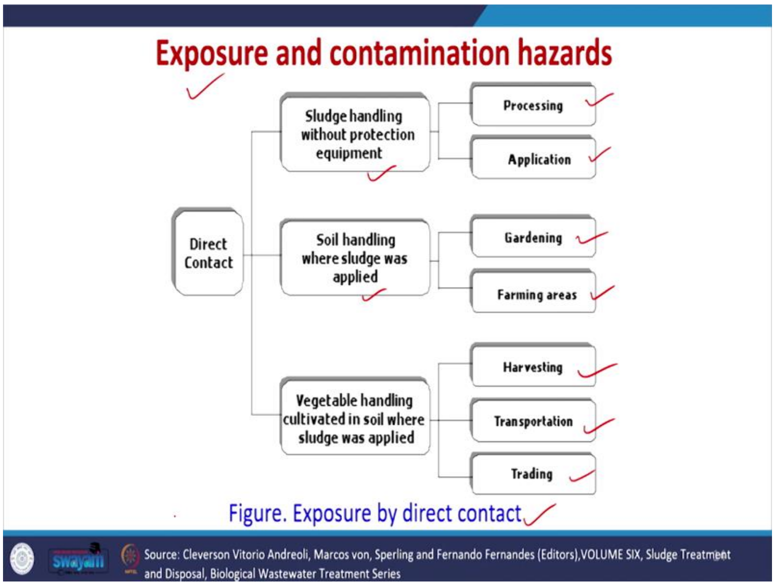

Now another indirect contact possibilities are also there. So these include the contact with the pathogens during transport because the pathogens may be transported by insect's rodents' etc. So that is one indirect contact which is possible then injection of our contact with contaminated water. So runoff from area, so sludge if it is applied to some soil and rain happens or some water is getting leached. So runoff may also be there. So if runoff goes into any aquatic system means river, canal, not canal but river, lake, reservoir, etc., and if you are using water from there then this is will find into the category of indirect contact.

Then consumption of contaminated foods. We can like consume meat and vegetable, meat if it is obtained from animals that grazed on area where sludge was applied. So then that mean if you are taking the way it is indirect contact. Similarly animals that ingested contaminated water, so it is also possible via that.

Then vegetables cultivated in soil where sludge was applied again in direct contact, but we are getting affected are exposed to the pathogens. Then irrigated with contaminated water. So it is possible that we are using the contaminated water run-off water for irrigation and that itself is containing some pathogens so we will be exposed to that. So these are the ways by which we can be exposed to the pathogens which may be present in the sludge and that is high probability.

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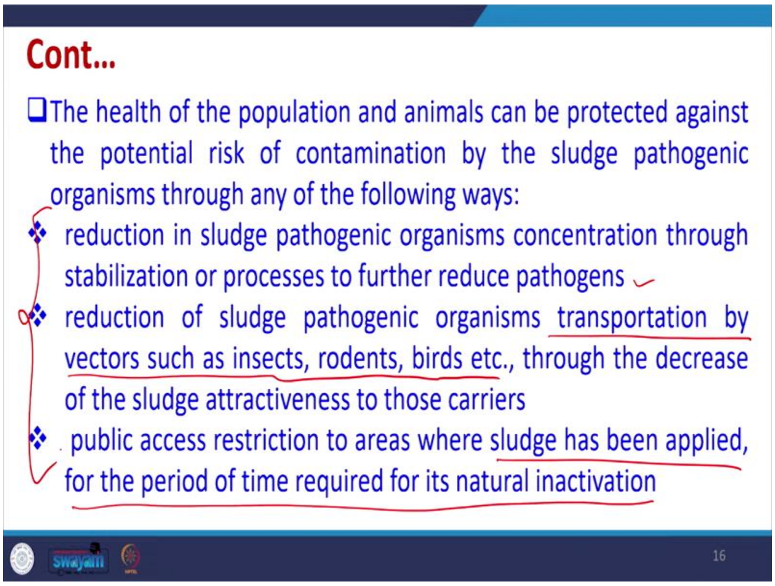

Now the health of population and animals can be protected against the potential risk of contamination by the sludge pathogenic organism through any of the following ways, the reduction in the sludge pathogenic organism concentration through stabilization or processes to further reduce the pathogens.

Then reduction of sludge pathogen organism's transportation by vectors such as inspects, rodents, birds, etc., through the decrease of the sludge attractiveness to those carriers. So then also we can take care. Then public access restriction, so we should restrict the public access to areas where sludge has been applied for the period of time required for its natural activation. So if through these measures we can take care of the potential risk should be reduced maximum possible.

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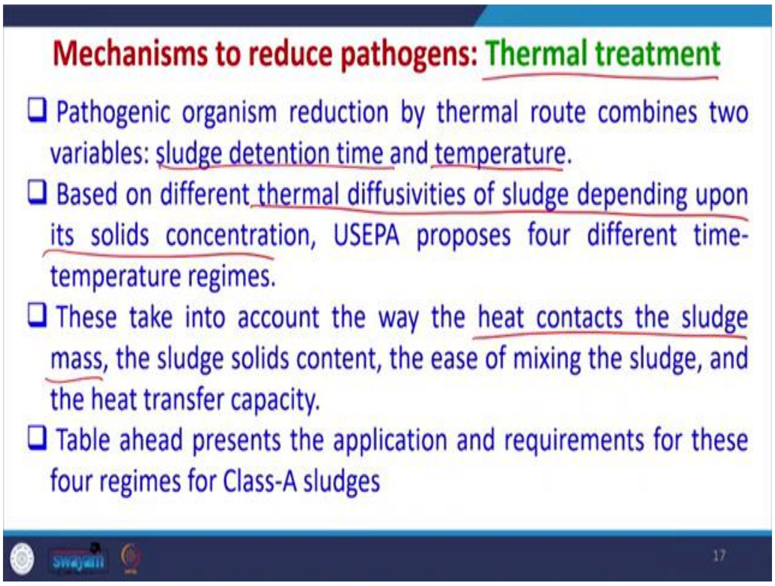

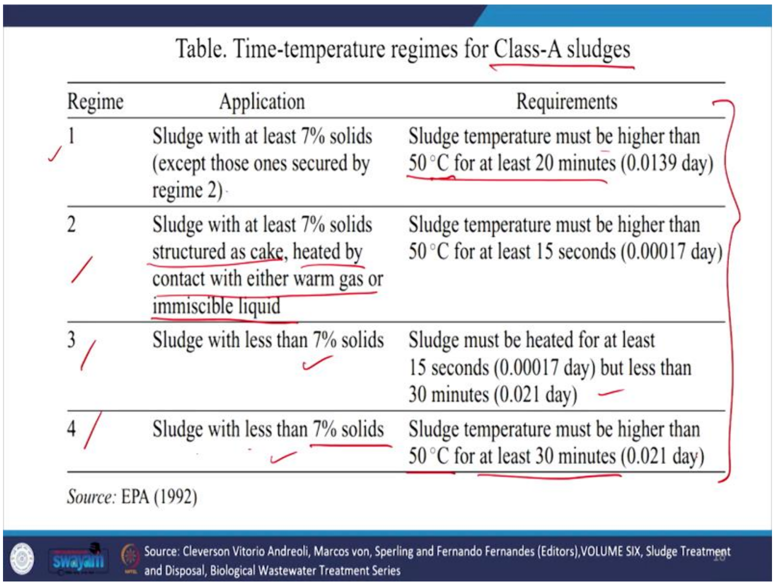

Table. Time-temperature regimes for Class-A sludges

Regime	Application	Requirements
1	Sludge with at least 7% solids (except those ones secured by regime 2)	Sludge temperature must be higher than 50 °C for at least 20 minutes (0.0139 day)
2	Sludge with at least 7% solids structured as cake, heated by contact with either warm gas or immiscible liquid	Sludge temperature must be higher than 50 °C for at least 15 seconds (0.00017 day)
3	Sludge with less than 7% solids	Sludge must be heated for at least 15 seconds (0.00017 day) but less than 30 minutes (0.021 day)
4	Sludge with less than 7% solids	Sludge temperature must be higher than 50 °C for at least 30 minutes (0.021 day)

Source: EPA (1992)

Source: Cleverson Vitorio Andreoli, Marcos von, Sperling and Fernando Fernandes (Editors),VOLUME SIX, Sludge Treatment and Disposal, Biological Wastewater Treatment Series

Now mechanisms there are other mechanisms also to reduce the pathogens and there are some of them we will try to understand them. The first is thermal treatment, the pathogenic organisms reduction by thermal route combines two variables sludge detention time and temperature. So we are going for thermal treatment. So how much temperature we are going to expose to the sludge. So that the pathogenic organism, they are getting reduced.

So based upon different thermal diffusivities of sludge, depending upon its solid concentration, because thermal diffusivity will depend upon the solid concentration. So USEPA US Environmental Protection Agency proposed four different time temperature regimes. And these regimes take into account the way heat contacts the sludge mass, and the sludge solid contents, the ease of mixing of the sludge, and the heat transfer capacity. So these four factors are taken into account.

We can see in the next table which is shown in the next slide presents the application and requirements of these four regimes for Class-A sludges. So we have different regimes which are for Class-A sludges. So we have four different regimes, 1, 2, 3, 4 sludge with at least 7 percent solid content except those ones which are secured by regime 2. So for that the sludge temperature must be as high as 50 degree centigrade for at least 20 minutes. So this is the exposure time.

Now sludge with at least 7 percent solid structured as cake, heated by contact with either warm gas or immiscible liquid. So under this condition again the temperature is 50 degree centigrade at least for 50 seconds or more. So if the gas exposure is happening, then sludge is less than 7 percent solid content for them. Sludge must be heated at least 50 second but less than 30 minutes and so this is there.

Then again another idea is that if regime 4 where the sludge temperature may be as high as 50 degree centigrade for at least 30 minutes. Because the solid content is less than 7 percent. So exposure time has to be there otherwise the thermal diffusivity will not happen. So these are the requirements with respect to time temperature regimes for Class-A sludge during thermal treatment.

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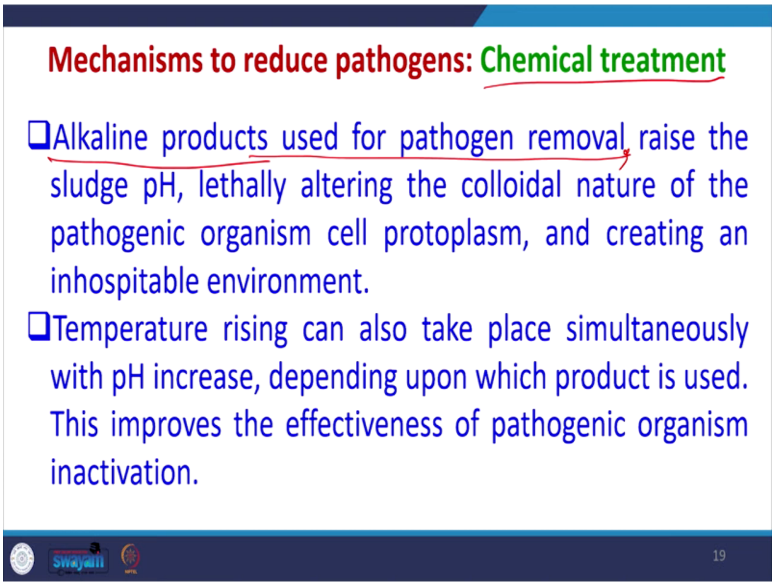

Now then there is another method which is called as chemical treatment. So we will try to understand how the chemical treatment works. So how chemical treatment can be used to reduce pathogens. So alkaline products such as pathogen are used for pathogen removal, what they do is that, they raise the sludge pH and lethally altering the colloidal nature of pathogenic organism cells protoplasm. So once pH is changed within the sludge bed the pathogenic cell protoplast chain and because of that in hospital well environment is there and they become inactivated because of that.

So temperature rising can also take place simultaneously with pH increase depending upon which product is used, this improves the effectiveness of pathogenic organism’s inactivation. So we can do the chemical treatment to remove this.

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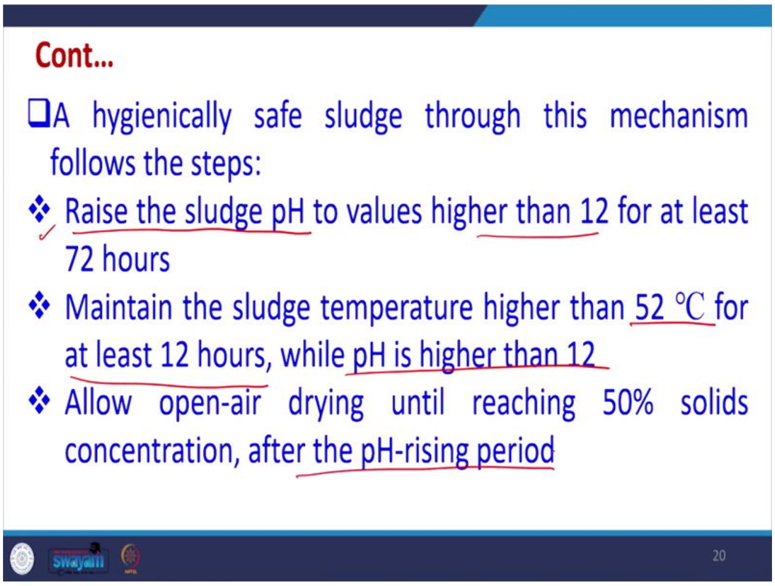

A hygienically safe sludge through this mechanism follows the following steps, what we do is that, we do carry out certain steps to do the pathogen removal via chemical treatment. In this case we raise the select pH to higher values than 12 for at least 72 hours. Maintain the sludge temperature higher than 52 degree centigrade for at least 12 hours, while pH is still higher than 12. This allows open air drying until the solid concentration reaches 50 percent and after the pH rising period. So through this we can control the pathogens present in the sludge.

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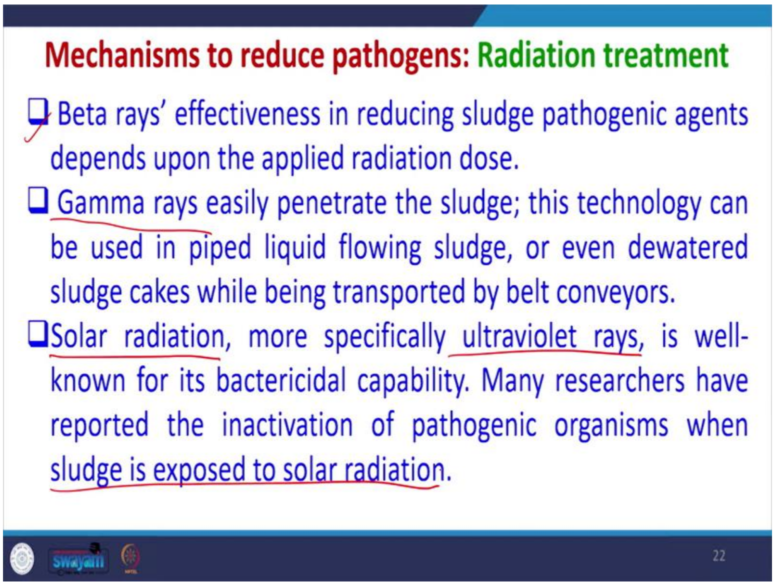

Now we have mechanisms to reduce pathogens via biological treatment also and radiation treatment. So let us first study the radiation treatment, so mechanism to reduce the pathogens via radiation treatment.

So beta rays effectiveness in reducing the sludge pathogenic agents depends upon the applied radiation dose. So what amount of radiation we are applying and at what lambda, so that helps? So gamma rays easily penetrate the sludge and this technology can be used in the piped liquid flowing the sludge or even when the dewatered sludge cakes while being transported by belt conveyor. So the sludge is exposed to the gamma rays then its pathogens may be killed.

Then solar radiation, more specifically the ultraviolet rays if it they are available generally they will be very less is well known for its bacterial capability many researchers have reported the inactivation of pathogenic organism when sludge is exposed to the solar radiation, when the amount of ultraviolet rays is higher but it is dependent because the ozone layer blocks fortunately both most of the ultraviolet rays, the ultraviolet layers which are available at the ground level are generally less. So the treatment by this method may change or may vary. So this is it.

Today, we will end the lecture on this note and we have studied the design of sludge drying beds, also we studied the pathogen removal by different mechanisms, we will try to further continue with respect to the pathogen removal by biological methods and other methods in the next slide and in the next lecture. So thank you very much for today.