Biological Process Design for Wastewater Treatment
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Lecture: 36
Sludge Management - VI

Welcome everyone in this NPTEL Online Certification Course on Biological Process Design for Wastewater Treatment. So, in the last few lectures we have been studying the sludge management in detail. So, today we will be finishing off this sludge management section which is very important section for wastewater treatment because lot of sludge gets produced during biological wastewater treatment also.

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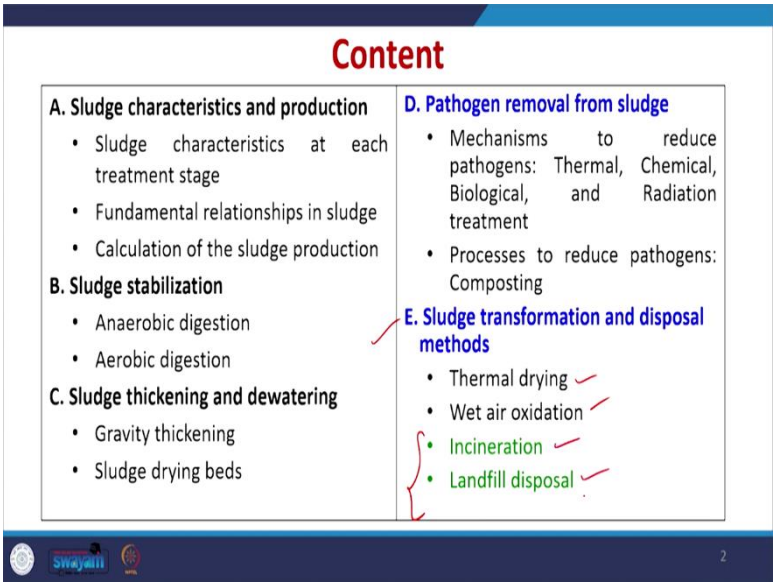

So, we have already studied different sections, we have come to the last section with respect to sludge transformation and disposal methods. In the previous lecture, we studied regarding the thermal drying and wet air oxidation. So, today will be understanding the incineration and then finally the landfill disposal.

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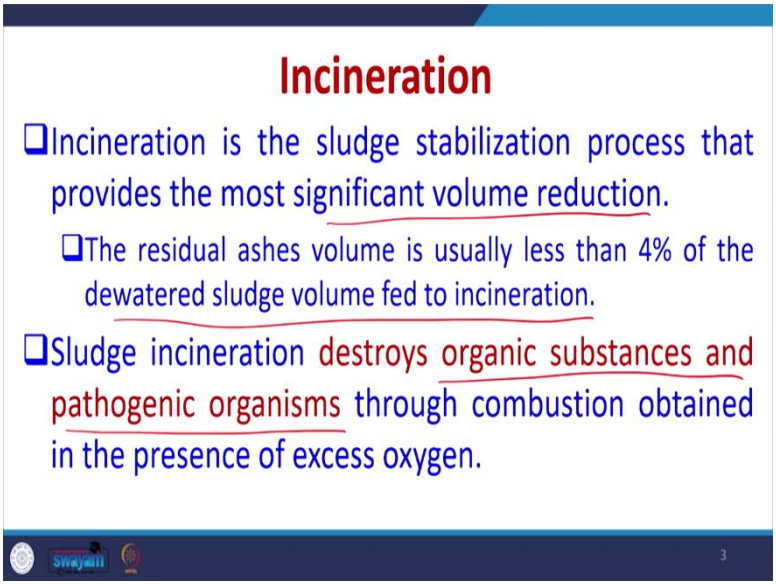

So, inspiration we are going to study today. Incineration is the sludge stabilization process that provides the most significant volume detection. So, during incineration we have the highest amount of volume reduction taking place and we get energy as well.

The residual ashes volume will be less than the four percent of the dewatered sludge volume fed to the incinerator. So, there lot of reduction takes place during incinerator. Sludge incinerator also destroys organic substances and pathogenic organisms through combustion obtained in the presence of excess oxygen, so this is there.

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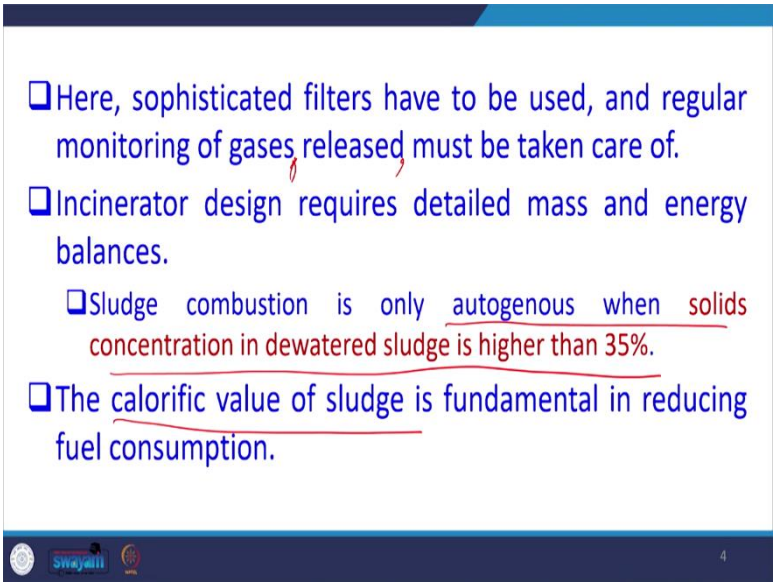

Here, but we have to take care of certain aspects, sophisticated filters have to be used and regular monitoring of gases released must be taken care of. So, we have to do the monitoring of the gases as well as we have to take care of that gases released if they are anything undesirable is happening. Incineration, their design requires detailed mass and energy balances.

So, this incinerator requires much more focus as compared to this lecture alone. But sludge combustion is only autogenous when the solid concentration in the dewatered sludge is higher than 35 percent. So, this is very important that we can take the sludge combustion as one of the processes when the solid concentration in the dewatered sludge is higher than 35 percent only.

So, generally this dewatered sludge will be having more than 40 to 45 percent solid concentration. So, for that we can go for incineration. The calorific value is the fundamental in reducing the fuel consumption. So, what is the calorific value of the sludge? So, and that in turn will depend upon the carbon content of the sludge. So, we have to check that what is the calorific value of the sludge, then we can get the energy which can be used, so, this is there.

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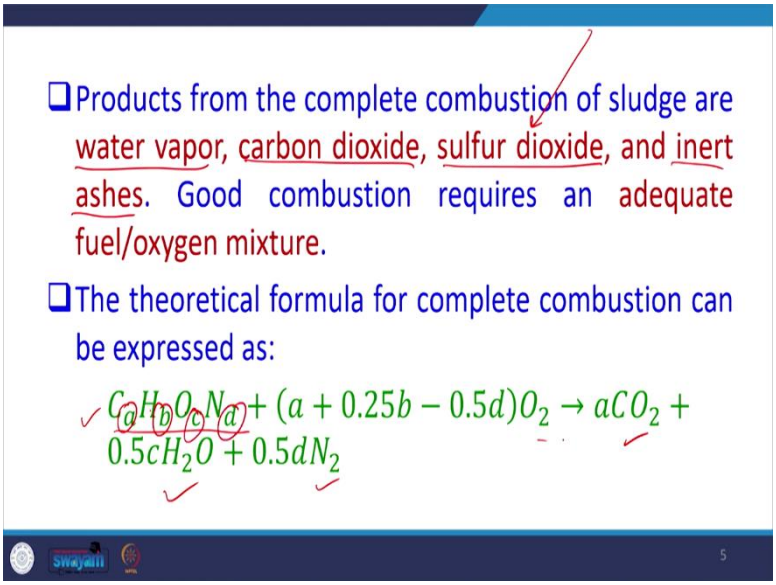

The theoretical formula for complete combustion can be expressed as:

$$C_aH_bO_cN_d + (a + 0.25b - 0.5d)O_2 \rightarrow aCO_2 + 0.5cH_2O + 0.5dN_2$$

Products from the complete combustion of the sludge are like water vapor, carbon dioxide, sulfur dioxide, and inert ashes. So, we also have to take care of the sulfur dioxide and

anything if they are coming in very high amount. The theoretical formula for complete combustion can be expressed as with respect to see carbon, hydrogen, oxygen, nitrogen, if they are present in the sludge. So, we can use this formula to convert that into CO_2, H_2O and then nitrogen.

So, depending upon the value of a, b, c, and d different type of possibility of combustion happening is possible. So, there are different types of incinerators.

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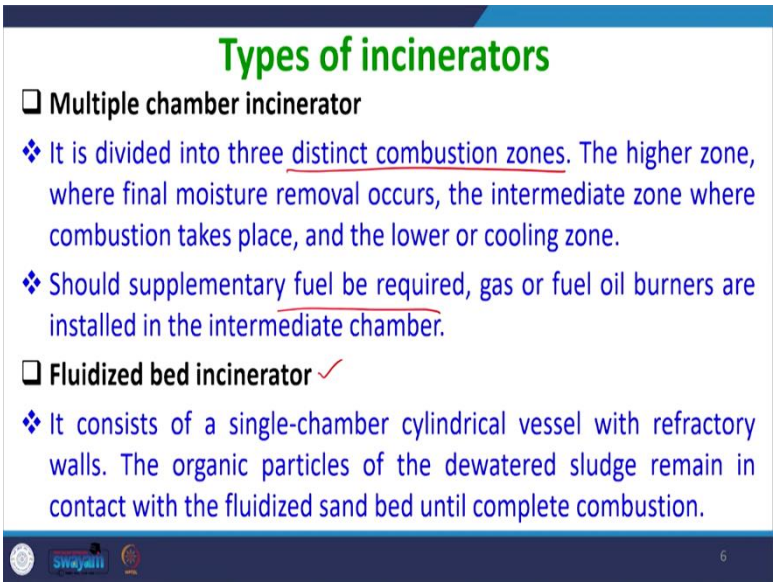

So, the first is the multiple chamber incinerator. In this incinerator, it is divided into three distinct combustion zones. The higher zone where the final moisture removal occurs. The intermediate zone where the combustion takes place and the lower or the cooling zone. It requires supplementary fuel gas or fuel oil burners have to be installed in the intermediate chamber where the combustion takes place.

So, some supplementary fuel is required for this multiple chamber incinerator. Then there is another category of incinerator which is called as fluidized bed incinerator. So, it consists of a single chamber cylindrical vessel with refractory walls. The organic particles of the dewatered sludge remain in contact with the fluidized sand bed until complete combustion occurs in the fluidized bed incinerator.

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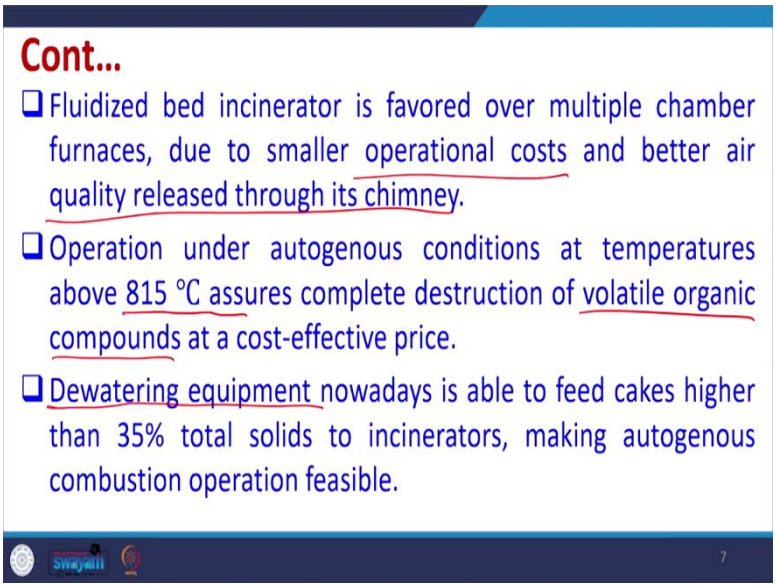

The fluidized bed incinerator is favoured over multiple chamber furnaces due to small operational cost and better air quality released through its chimney. So, generally the fluidized bed insulator will be preferred as compared to the multiple chamber incinerator and this is so, because the operation cost is also low and also the quality of air, the flue gas which are coming out are better as compared to the multiple chamber furnaces.

The operation under autogenous conditions occurs at temperatures above 815 degree centigrade and if the temperature is this, this assures complete destruction of volatile organic compound. So, that this temperature more than 800 is good and is desirable. Dewatering equipment nowadays are able to feed cakes higher than 35 percent total solid concentration to incinerator, making autogenous combustion operational feasible.

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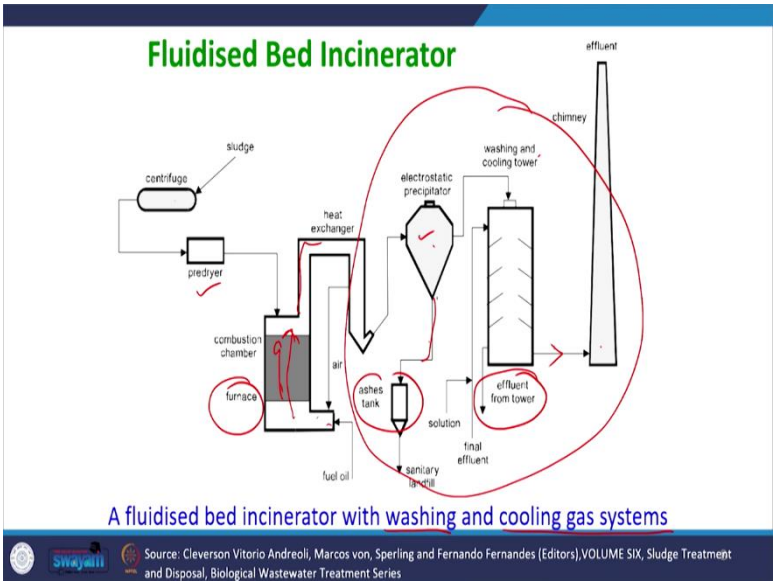

So, this is the fluidized bed reactor, schematic of fluidized bed reactor with washing as well as cooling gas systems, so both are there. So, this is the overall schematic diagram. So, this is the main furnace we can see here and after that this section you can consider as the air pollution or heat exchange area. So, we have sludge which is centrifuge and then we have pre-dire, it goes into the combustion chamber where fuel oil is there and air is there.

So, air helps in the fluidization of the sludge. Now the burning happens in this case. So, we have the flue gas which is coming out, from the flue gas we have to remove different materials. So, we have electrostatic precipitator which is there which helps in the removal of ash. So, ash is getting stored here it may be taken to sanitary landfill, then though ash has been reduced, but there may be some other gases which may be present.

So, washing and cooling towers are used where the other type of gases, etc., also are reduced, are there make soluble into the water, so we can strip them. Now we have effluent which is coming out from the tower and that has to be treated further. Then the flue gas, which is now has removed particulate matter and the undesirable gases also, it is now let off from the chimney. So, this is the fluidized bed incinerator and how it works.

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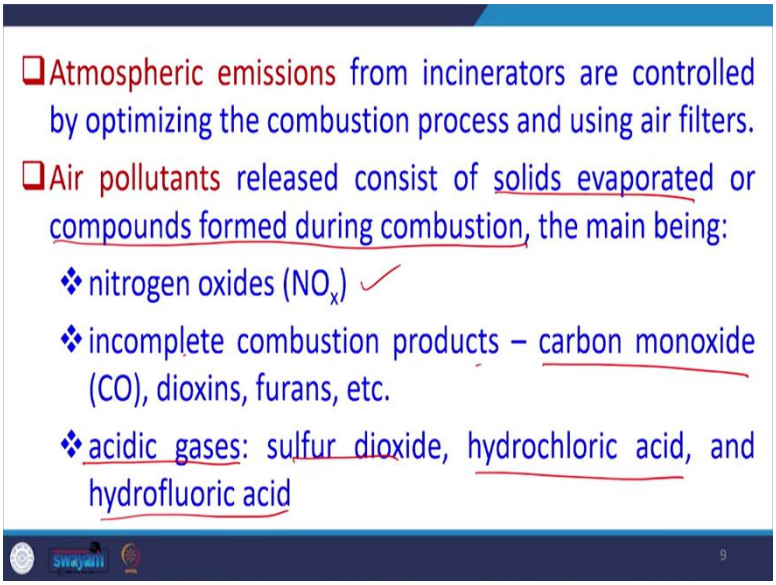

The atmospheric emissions from incinerators are controlled by optimizing the combustion process and using air filters. So, this is very important that we have this section which is like Air Pollution Control devices which are installed. So, you should control the emissions which are taking out of a combustion chamber. Air pollutants released consists of solids evaporated and compounds form during combustion.

The main being NOx, incomplete combustion products like carbon monoxide, dioxins, furans, etc. So, they have to be taken care of, this is very important. Then acidic gases may also get released, sulfur dioxide, hydrochloric acid, and hydrofluoric acid. So, if halogens are present in the sludge. So, these gases, the hydrochloric acid, hydrofluoric acid, etc., may also get formed.

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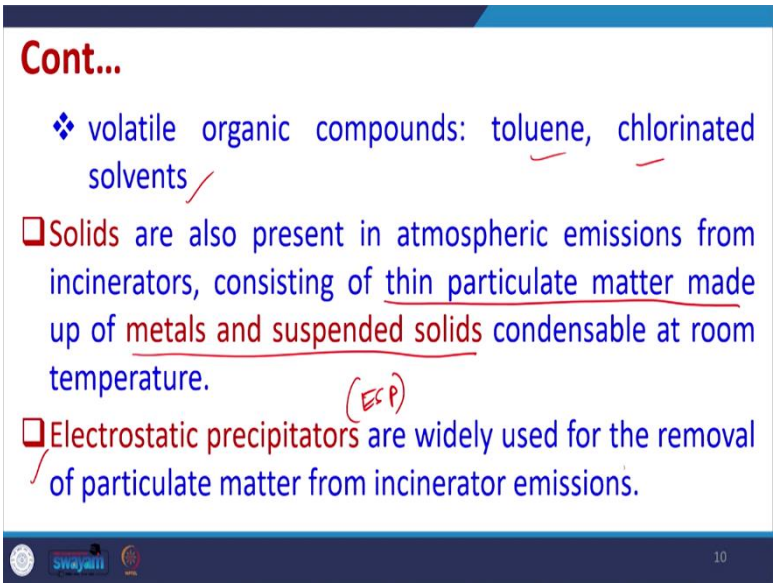

Volatile organic compounds such as toluene, chlorinated solvents, etc., may also get released during that incineration or combustion process. Solids are also present in the atmospheric emissions from incinerator consisting of thin particulate matter made of metals and suspended solids condensable at room temperature.

So, it is possible that non-incinerated materials are coming out and along with the air. So, that also we have to take care. So, we install ESPs which this is called ESP, the electrostatic precipitators are widely used for removal of particulate matter from the incinerator emissions and thus, we can take care of the particulate matter through the incineration.

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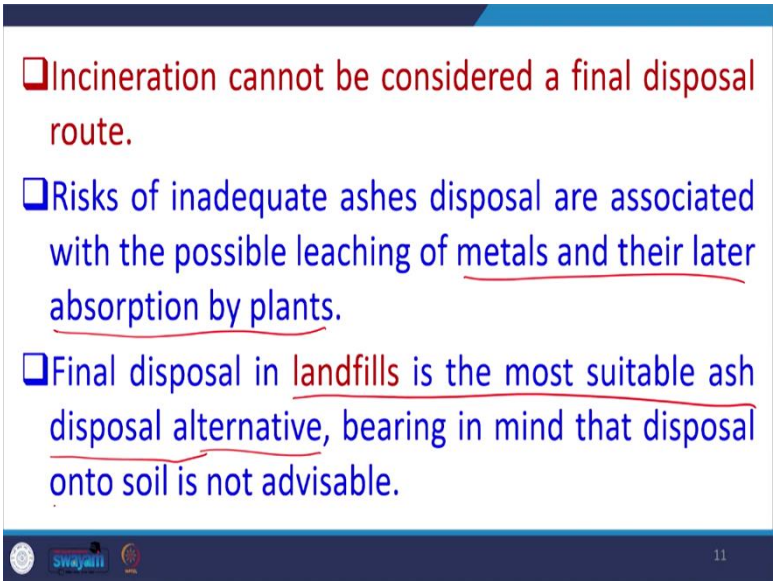

Now, the incineration cannot be considered a final disposal route. So, this is very important. So, we have to use other methods also. During incineration risk of inadequate ashes disposal are associated with the possible leaching of metals and their later absorption by plants, this is also there. So, final disposal in landfill is the most suitable ash disposal alternative.

So, we have to go for land disposal, otherwise the options are very less and if we do not go for landfill, then lot of problem may happen with respect to environment. Bearing in mind that disposal of soil is not advisor. So, these ashes cannot be disposed into soil, it is not advisable because leaching may happen, metals are present and they may be absorbed by plants etcetera. So, we have to go for landfill, this is the final disposal option with respect to ash which is obtained.

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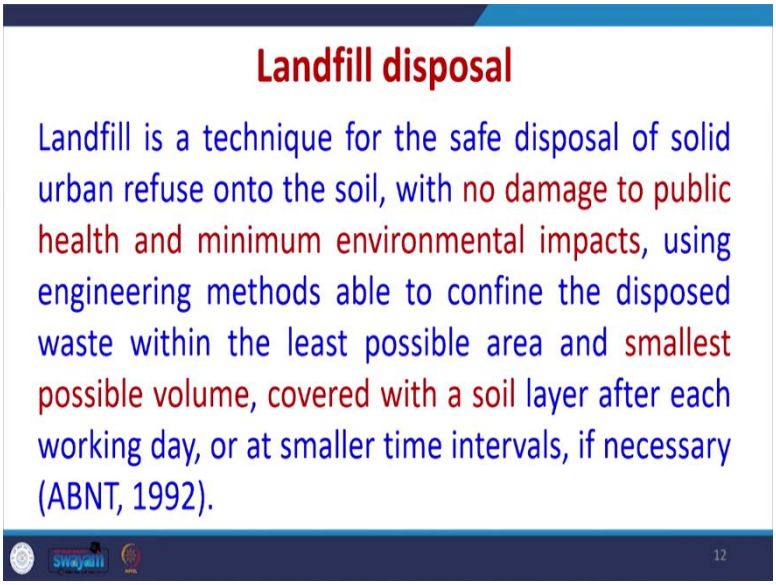

So, we are going to further study, the landfill disposal now onwards for this particular thing. Now, landfill is a technique for safe disposal of solids, urban diffuse into soil, with no damage to public health minimum environmental impacts, using engineering methods which are able to confine the dispose waste into least possible area, smallest possible volume, covered with a soil layer after each working day or at small time intervals as necessary.

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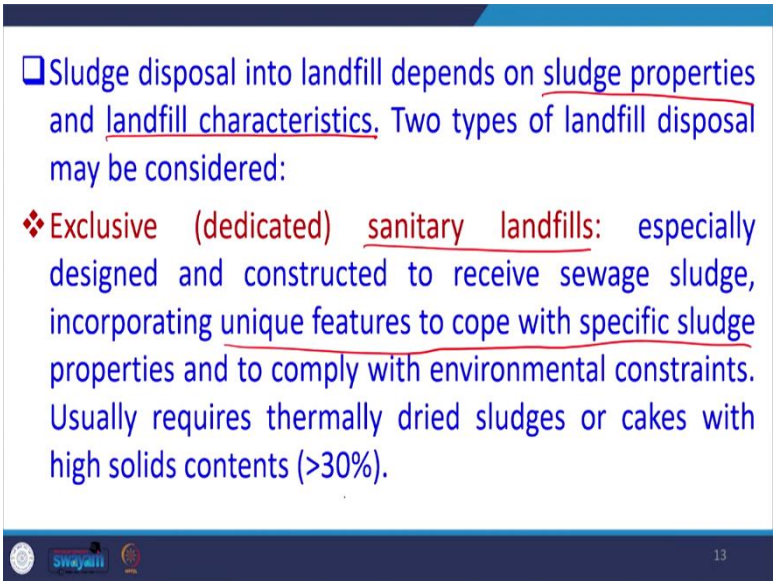

So, sludge disposal into landfill depends upon the sludge properties and as well as the landfill characteristics. The disposal will depend upon both. So, there are two types of landfill disposal may be considered. So, we have exclusive or dedicated sanitary landfill, which can

be used. They are specially designed and constructed to receive sewage sludge from the wastewater treatment plant.

They incorporate unique features to cope with the specific sludge properties and to comply with the environmental constants. Usually, they require thermal dried sludges or cake with very high solid content. So, this is exclusive sanitary landfills can be there.

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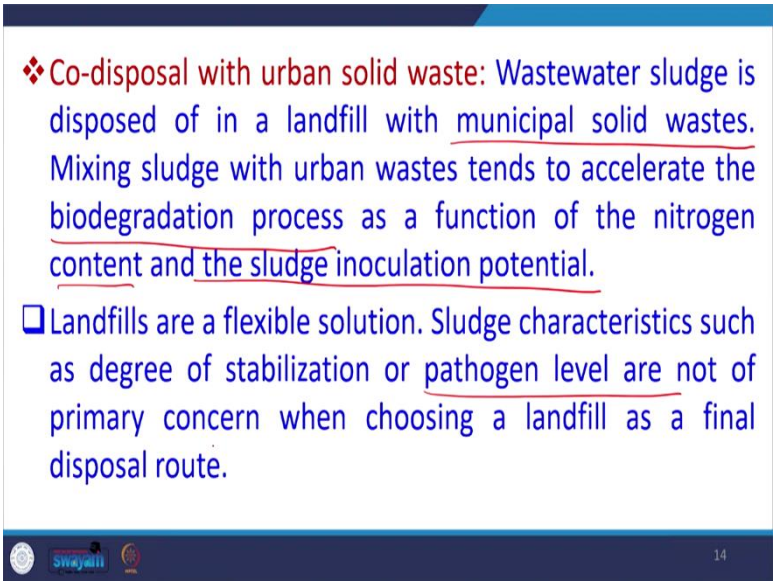

Then co-disposal with the urban solid waste. So, this second option is that we dispose of the sludge along with the urban solid waste. So, wastewater sludge is disposed of in a landfill with municipal solid waste also. So, mixing sludge with urban solid waste tends to accelerate the biodegradation process as a function of nitrogen content and the sludge inoculation potential also is higher.

So, landfills are flexible solution, sludge characteristics such as degree of stabilization, pathogen level are not of primary concern when choosing a landfill as a final disposal route. If you are going for incineration also again ash has to be disposed of, but the amount of ash is much lower as compared to the sludge itself. So, the landfill if it is used it can be used for very long duration.

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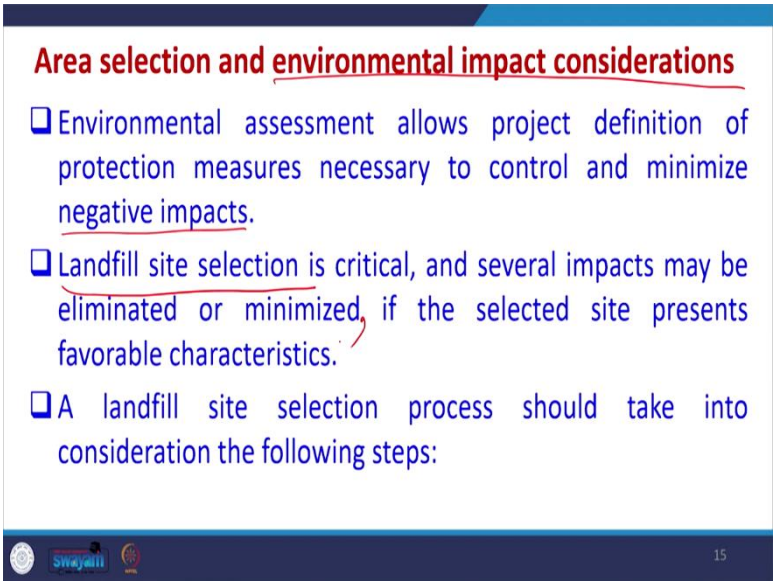

For landfill, the area selection environmental impact considerations have to be given. So, the environmental assessment allows project definition of protection measures necessary to control and minimize the negative impact. So, environmental impact assessment will be studying little bit in the next lecture.

So, this has to be performed, proper areas have exchanged and environmental impact consideration for any landfill. The landfill site selection is critical and has several impacts and they may be eliminated or minimized if the selected site presents favourable characteristics. So, this is important. A landfill site selection process should take into consideration various steps.

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And these steps are selection of macro-regions, considering access and waste generation points. So, how easily we can transport the sludge or the wastewater treatment plant? All the sludge or after treatment of the sludge, management whatever is the remaining, how easily we can access, and how easily we can transport to the site.

Identification of all legal constraints within the macro-regions and exclusion of the affected areas. So, if any eco sensitive zone is there or any other requirements are there, so that have to be taken care of. Preliminary evaluation of the remaining macro-regions. So we have to estimate a number of factors, both environmental, both legal as well as other issues like social issues also, that people are not residing in that area otherwise the challenges may occur.

So, field survey and preliminary selection, taking into account all gathered information is important. After that we go for development of technical studies comparing all potential areas which are there which we have identified. And finally environmental licensing of the selected landfill site.

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Now, we have studied that it can be possible to have exclusive landfill or monofills. So, we will try to understand this exclusive landfill now. The exclusive landfills are dedicated landfills or monofills are designed to receive wastewater sludge exclusively.

Narrow trenches, 1 to 3 meter wide, allowed truck unloading without vehicle traffic onto the disposal ditch and large trenches, more than 3 to 15 meter, allow the access to the disposal ditches to unload the sludge. So, we have to take care that whether the narrow trenches are there or large trenches are there.

So, we have to design. Narrow trenches may accumulate 450 to 2100 tons of sludge cakes, whereas white trenches may landfill up to 1200 to 5500 tons per hectare.

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If we are going for co-disposal with municipal solid waste, then it will require sludge cakes with solid concentration of at least 20 percent, otherwise leachates may increase exclusively in the landfill, threatening side slopes stability as well as leaching going into the water.

In many places, bulldozers are usually implied for waste compression and cell implementation when the solid concentration is less than 20 percent. So, we have to go for more than 20 percent, otherwise slopes are in stable and which is not desirable at all.

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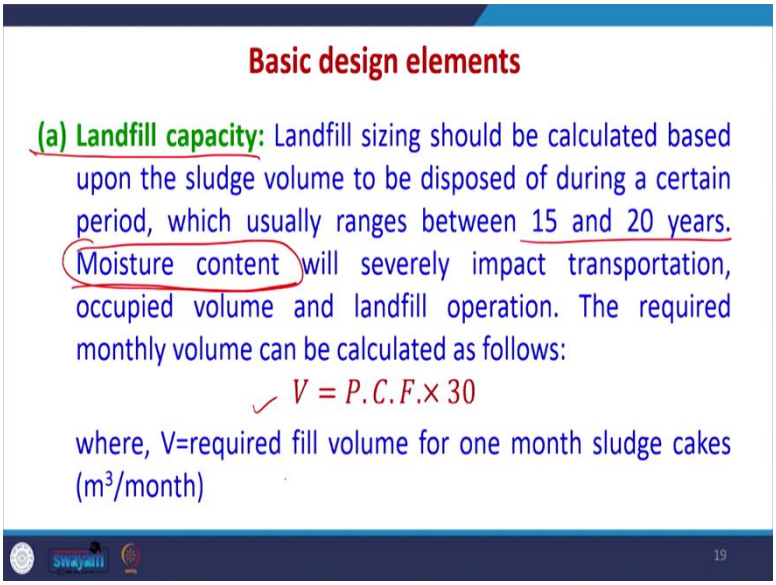

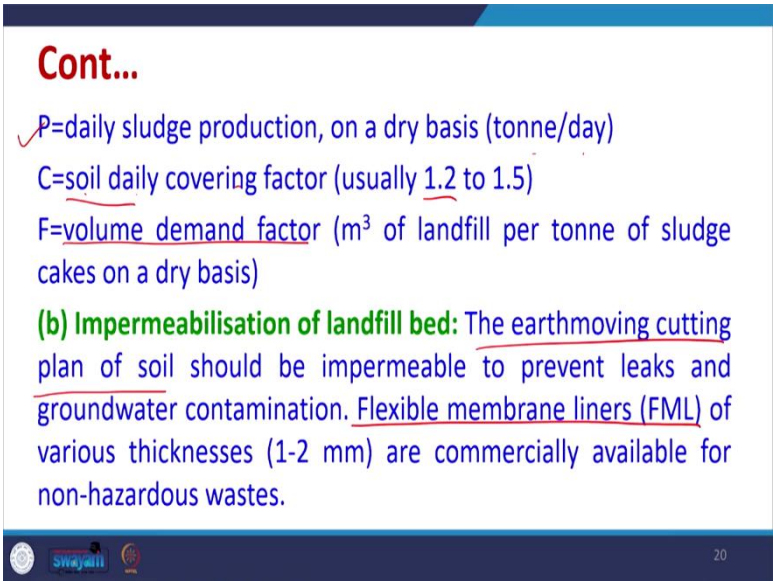

(a) The required monthly volume can be calculated as follows:

$$V = P.C.F. \times 30$$

where, V = required fill volume for one month sludge cakes (m^3/month)

Now, there are certainly basic design elements with respect to landfill. So, we are going to you study them. First is the landfill capacity. The landfill sizing should be calculated based upon the sludge volume to be disposed off during a certain period, usually ranging from 15 to 20 years. So, how much will be the sludge which is getting generated and how much time this landfill can be operated?

So, moisture content will severely impact the transportation, occupied volume and landfill operation. So, within this the most important consideration. So, if we can take care of this the required monthly volume can be calculated as follows. So, V is required fill volume for one month large where P.C.F into 30.

So, let us, P is the daily slash production on a dry basis, tonne per day. C is the soil daily covering factor, because this also, once we fill the sludge, the sludge has to be covered by a oil. So, how much soil is required? So, generally we take the factor of 1.2 to 1.5. Then we have F, F here, so F is the volume demand factor. So, this is the meter cube of landfill per tonne of sludge cakes on a dry basis.

So, we can consider this like reciprocal of bulk density of sludge. So, how much volume will be required? So, that we can calculate. So, if the back slash density is known, the F is just reciprocal of that and if this is known we can calculate the volume which is required on daily

basis and if you multiply by 30, we are getting with respect to per month. Then it is very important that the landfill bed should be impermeable that means there should be no leaching.

So, the earthmoving cutting plan of soil should be impermeable to prevent leaks and groundwater contamination. So, we may have to use liners. So, flexible membrane liners of various thicknesses are commercially available for non-hazardous waste and they are used, so that the landfill becomes impermeable and there is no leachate generation, etc., there is no water going into the groundwater.

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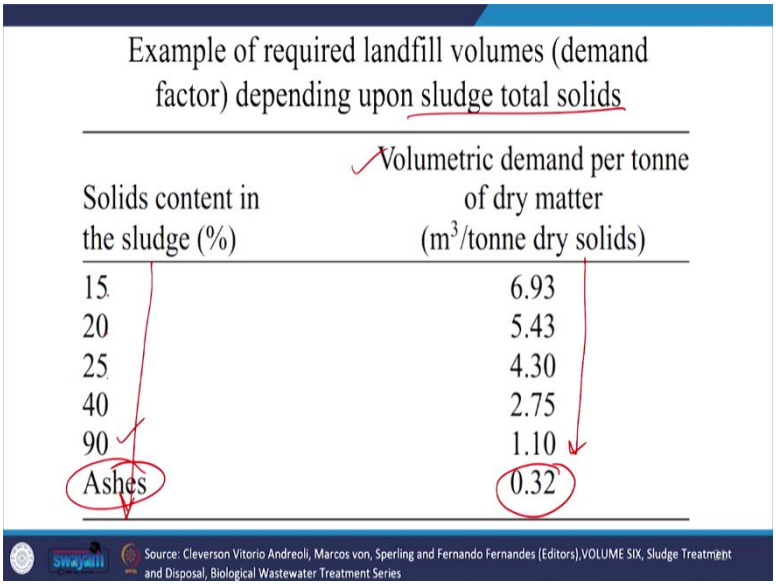

The examples of required landfill volumes with respect to demand factor depending upon the sludge total solids is as. So, solid concentration as it is increasing from 15, 20, 25, 40, 90 percent, the volumetric demand per tonne is decreasing you can see, this from 6.93 meter cube per tonne dry solid for 15 percent solid content, we can say it decreases up to 1.1 only when the solid concentration is more than 90 percent.

For ashes which are coming from incineration unit, the volume required is only 0.32-meter cube per tonne dry solids. So, this is the advantage if you are using ashes only for landfilling. So, if you perform the incineration combustion, etc., beforehand, in fact, the ashes can be easily disposed of also and we are already reducing the sludge so much that we can use the landfill for very long duration.

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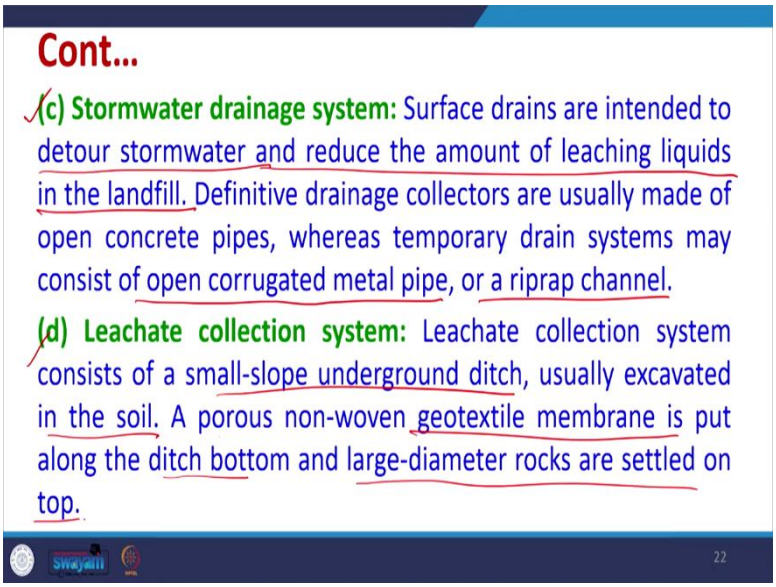

Now, within the landfill storm water drainage system is important. Surface drains are intended to detour the storm water and reduce the amount of leaching liquids in the landfill. So, this is very important consideration. Definite drainage collectors are usually made of open concrete pipe, whereas temporary drain systems may consist of open corrugated metal pipe or riprap channel. So, we should have a storm water then a system.

Similarly, leachate collection system is also very important. Leachate collection system consists of a small-slope underground ditch, usually excavated in the soil. A porous non-woven geotextile membrane is put along the ditch bottom and large-diameter rocks are settled on the top. And the leachate water gets collected in that and then the leachate water has to be treated properly thereof.

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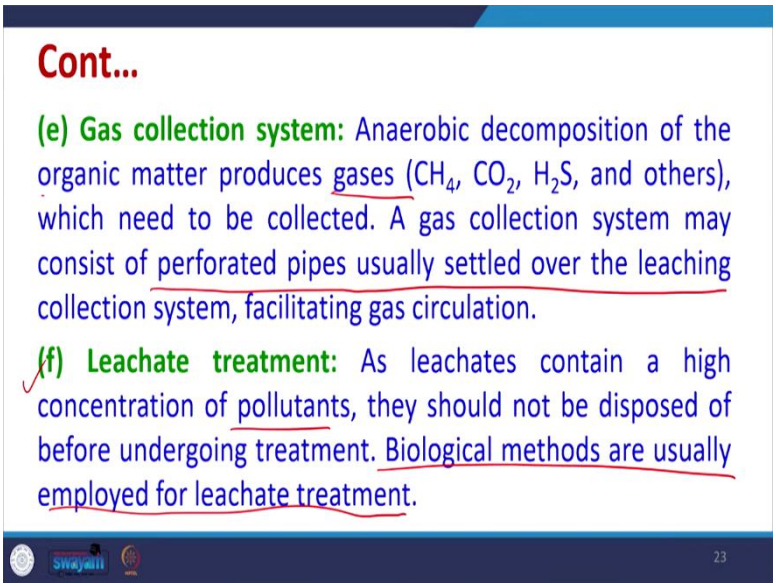

Then we have gas collection system also because in the landfill anaerobic decomposition may happen. So, anaerobic decomposition of the organic matter produces gases and these gases may be methane, CO_2, H_2S and others, which need to be collected and a proper gas collection system may consist of perforated pipes, usually settled over the leaching collection system and they in a way facilitate the gas circulation and further collection.

Then that since leachate is getting generated, so we have to go for leachate treatment also. As leachate contains a high concentration of pollutants, they should not be disposed of before undergoing treatment. So, biological methods are usually implied for leachate treatment. So, this is very important that a proper landfill will have all these four systems.

So, we should understand the landfill capacity, we should go for impermeation of the landfill bed, then we should have storm water, drainage system, leachate collection system, gas collection system, and leachate treatment, these are essential.

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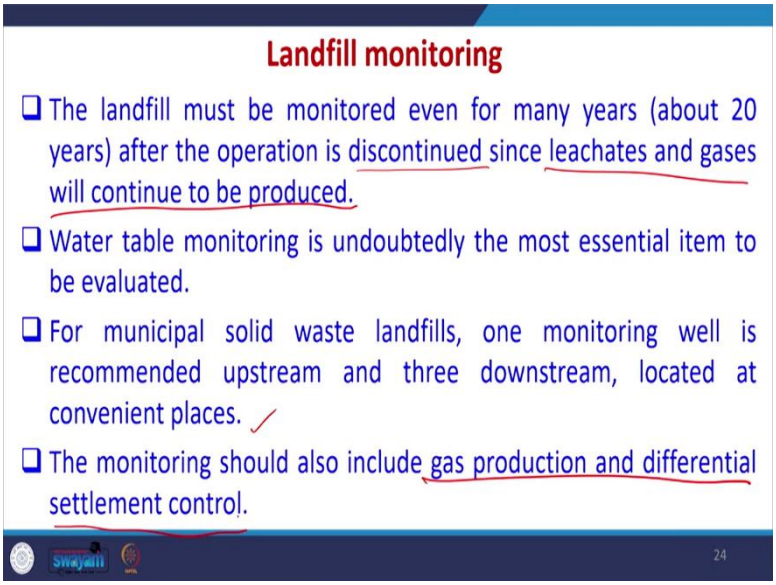

Now, since landfill operates for more about 20 years or more. So, landfill must be monitored even for many years after the operation is discontinued. So, once 20 years are over or 25 years, then also landfill must be monitored, since leachates and gases will continue to be produced. So, water table monitoring is the most essential item to be evaluated, wherever this landfill is there.

For municipal solid waste landfill, one monitoring well is recommended upstream and three in the downstream, located at the convenient places. So, whatever is the convenient places we can have four monitoring wells, one upstream and three downstream. The monitoring should also include gas production and differential settlement control, because the movement of landfill may also happen sometimes. Finally, after sometime we have to go for landfill closure.

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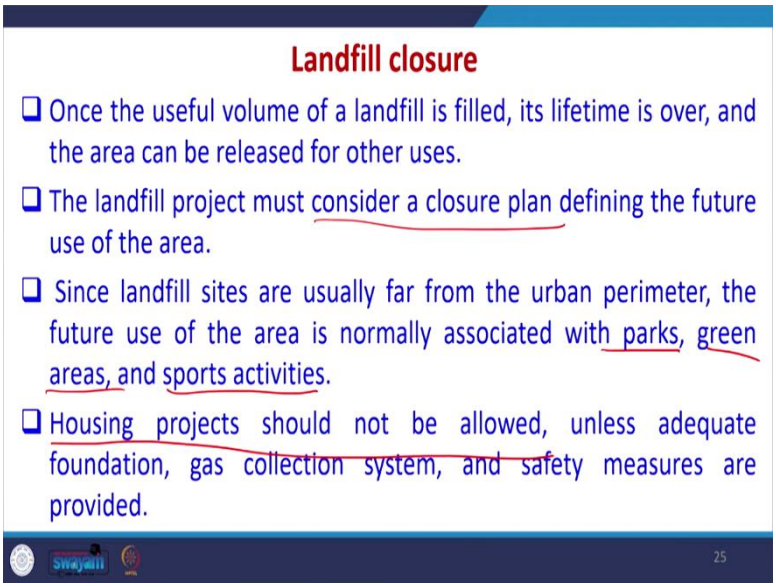

Once the useful volume of a landfill is filled, its lifetime is over and the area can be released for other uses. So, the landfill project must consider a closer plan defining the future use of area. Since landfill sites are usually far from urban perimeter, the future use of area is normally associated with parks, green areas, and sports activities.

So, these are the normal ways in which after closure the landfill can be used. Housing projects should never be allowed on the landfill, unless adequate foundations gas collection system safety measures are provided. Generally, landfills housing project should never be allowed on a closed landfill. So, this is it.

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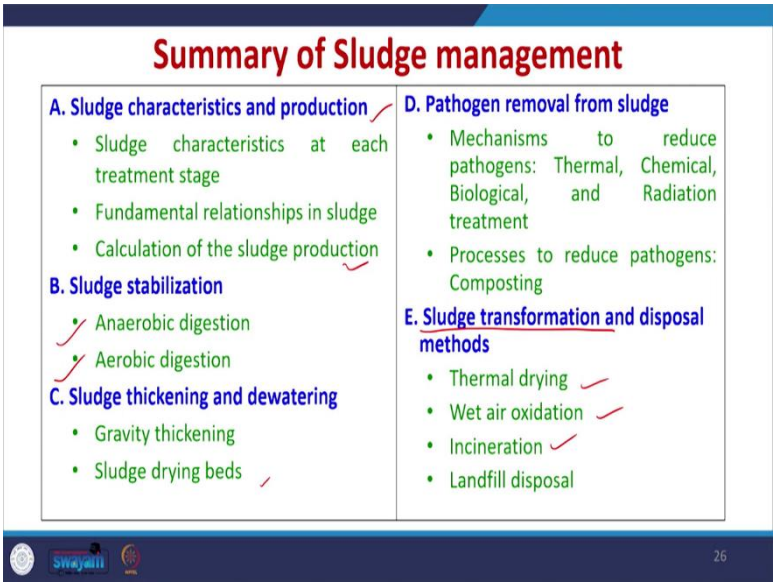

We have studied the sludge management various aspects of sludge management in the previous few lectures. We started with understanding the sludge characteristics and its production, how the sludge is produced and what are the different characteristics of the sludge in each of the stages. We also understood the fundamental relationship in sludge and further perform some calculation with respect to sludge production.

In the second section, we studied sludge stabilization via anaerobic and aerobic means. So, both of the systems we study in detail. In the third section, we studied the sludge thickening and dewatering, which is very important for easy transportation and further usage if any. So, sludge thickening and dewatering we studied using gravity thickening and sludge drying bed.

Then also we went for understanding the, how the pathogen removal takes place from the sludge via various thermal, chemical, biological, and radiation methods. So, these methods we studied and we studied composting in greater detail, which can be used for pathogens removal from the sludge as well.

Finally, we have studied the sludge transformation via thermal drying methods, wet air oxidation, incineration, etc. So, these methods actually, not only reduce the sludge, but they help in the proper disposal later on and this sludge transformation can help in proper application of sludge may be in the agriculture fields, etcetera.

So, there we study thermal drying wet air oxidation and incineration in detail. And finally, we studied the landfill disposal also for like a dedicated landfill or if we are using the, we are disposing of the wastewater treatment plant sludge along with the municipal sludge. So, we studied the landfill disposal today. These are the some of the characteristics or some of the content that we have studied with respect to sludge management.

Certainly, if we want to study them further, it is possible to go for a detailed lecture, but will end with the sludge management section today. We will continue with some general aspects of environmental impact assessment of any wastewater treatment plant and also further we will studies, take some case studies with respect to how the wastewater treatment is done in some industries. So, we will continue further later on. Thank you very much.