Basic Environmental Engineering and Pollution Abatement
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Lecture 41
Sludge Management - 1

Hello everyone, in this class, we will discuss on the sludge management part 1. In our previous classes, we have seen that after primary and secondary treatment, some residual is generated in primary and secondary clarifier and those are called sludge. And those sludge are basically slurry containing total suspended solid. And this sludge contents organic compound and inorganic compound as well and ditch materials may be useful or some harmful elements can also be available in it. So the management of the sludge is also an integral part of the wastewater treatment plant.

And in this class, we will discuss on the sludge management and we will be having three classes on which we will discuss on this topic and the content are.

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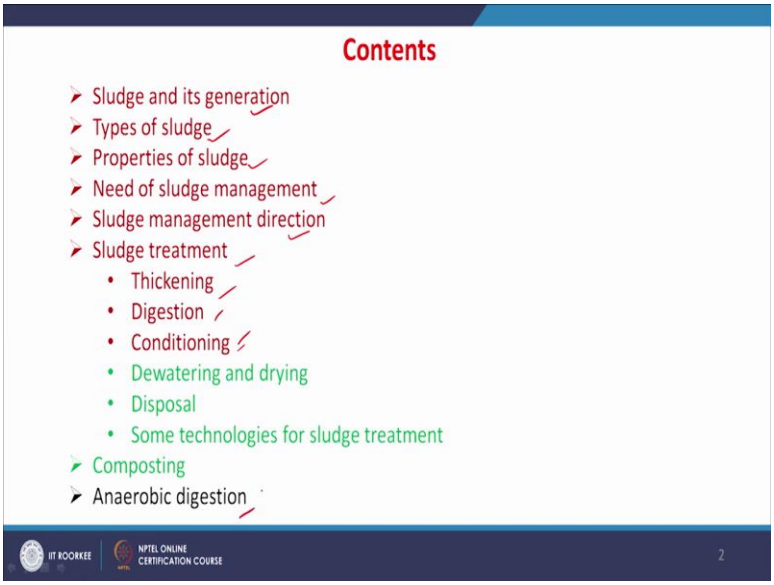

Sludge and its generation, types of sludge, properties of sludge, need of sludge management, then sludge management direction, then sludge treatment that includes thickening, digestion, conditioning, dewatering and drying, disposal and some techniques for sludge treatment. We also discuss on composting and anaerobic digestion. These are also the part of sludge management and the treatment also.

But we will be having more discussion on this composting and anaerobic digestion and we will discuss these contents in three classes. In the first class, we will be discussing up to this and the second class we will discuss this part and third class we will be discussing on anaerobic digestion.

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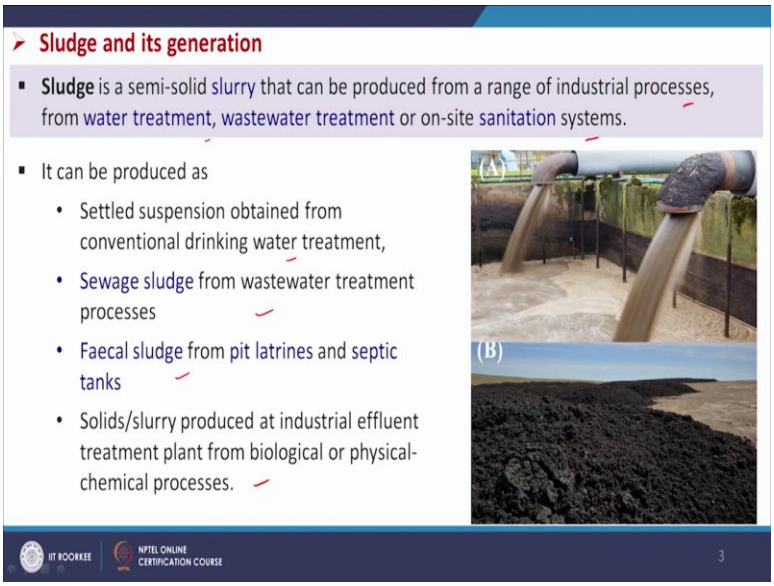

Now we will see what is sludge and how it is generated. So, sludge is a semi solid slurry that can be produced from a range of industrial processes from wastewater treatment, water treatment or onsite sanitation systems. So, this can be generated from any type of wastewater treatment systems. And it can be produced at settle suspension, often from conventional drinking water treatment.

Sewage sludge from wastewater treatment processes and faecal sludge from pit latrines and septic tanks and solids or slurry produced at industrial effluent treatment plants. So, that is primary and secondary clarifier as well as the solid material which is coming out from the tertiary treatment units, like say the residual part of the membrane processes or the retented of the membrane processes. So, those things will be called as a sludge and needs proper management. So, this figure shows that the sludge how it looks like and after dewatering, we will be getting this type of solid material which is having some nutrient value and some energy content as well.

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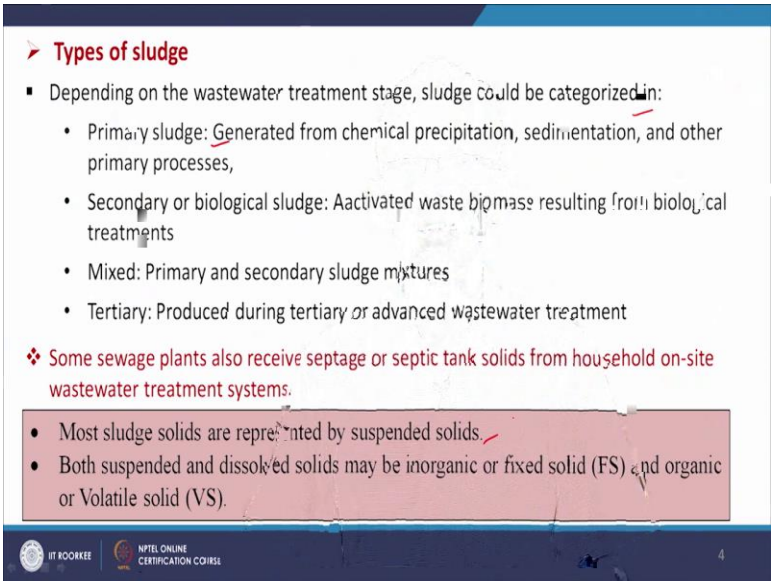

Then, depending upon the wastewater treatment stage sludge could be characterized in primary sludge that we are talking about it is collected from the primary clarifier bottom part and secondary or biological sludge that is called activated waste biomass, resulting from biological treatments that is secondary clarifier bottom material. And then mixed sludge that is mixture of primary and secondary sludge and tertiary sludge also that produced during the tertiary or advanced oxidation or advanced wastewater treatment process.

Some sewage plants also received septage or septic tank solids from household on site wastewater treatment systems. So, these are the different sources or these are the different types of sludge which can we generated. Now, we see that most sludge solids are presented by suspended solids. So, basically the sludge solids are suspended solid, and we know that there are two types of solids in the water. One is the suspended solids another is dissolved solids and both these solids can be volatile in nature or that is non volatile that is fixed. So, one is fixed solid and another is your volatile solids. Now, we will discuss on the properties of the sludge.

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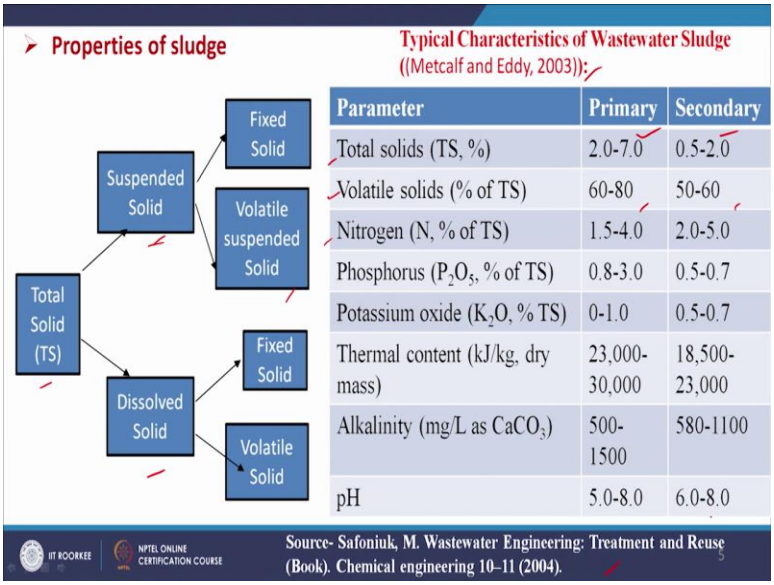

So, that sludge is having solid content that is total solid, that may be suspended solid and dissolved solid. Basically, this sludge deals with the suspended solids and fixed solid type or volatile suspended type. And if we considered two major type of sludge that is primary and secondary sludge, and we see the composition that is total sludge, total solids and volatile solids, then other component like say, nitrogen, phosphorus potassium oxide, thermal content and alkalinity as well as pH.

So, then we can compare these two types of sludges, here the total solid is 2 to 7 % in case of primary sludge, and in the secondary sludge it is 0.5 to 2 %, so in the primary settler or primary clarifier the bottom part we get more TS containing sludge than the secondary clarifier bottom.

Now, volatile solids we see that percentage of total solid so, what is the total solids present in it. So, if we compare what is the volatile out of it, so, that will be 60 to 80 % for primary and 50 to 60% for secondary. So, these values are typical value as provided here in these references, that it may change from place to place or treatment plan to other treatment plan to at some range.

Nitrogen percentage of TS with respect to total suspended solids, so nitrogen is 1.5 to 4 and here 2 to 5. Similarly phosphorus P_2O_5, it is 0.8 to 3 and in this case 0.5 to 0.7. Potassium oxide 0 to 1 and 0.5 to 0.7, Thermal content 23,000 to 30,000 kJ/kg, here it is 18,500 to 23,000 kJ/kg on dry mass basis, and alkalinity as mg per liter as calcium carbonate 500 to 1500 for the primary, and for the secondary 580 to 1100, and pH is 5 to 8 and here 6 to 8.

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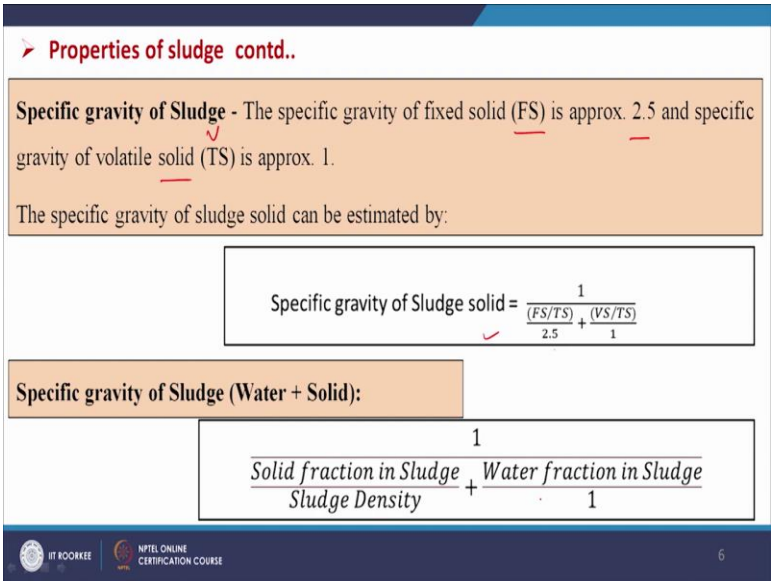

Now we will see some other properties like specific gravity of sludge. So, specific gravity is very important that you know the density of any material divided by the density of the water. So, this is the definition of specific gravity. And in case of sludge, the specific gravity can be defined as per this formula, so, what is happening in case of sludge, we have fixed solid and we have volatile solid which are giving the total suspended solid. So in this case, the specific gravity of the sludge solid

$$\frac{1}{\frac{(FS/TS)}{2.5} + \frac{(VS/TS)}{1}}$$

Where 2.5 is the specific gravity of fixed solid and 1 is the specific gravity of volatile solid.

Now, as per the definition of specific gravity, if we consider the density of water is 1, so mass/volume. So, in that case say 1 gram of sludge solid we are taking. So, out of these, FS/TS is the fraction of fixed solid, so, that mass divided by its specific gravity of density. So, then solid we are getting this is the volume due to FS and this is VS /TS that is the mass fractions and since we are considering total sludge solid is 1. So, this is VS/TS is the mass of the VS, so divided by the density so we will be getting this is the volume of the volatile solid so this plus this total volume and 1 is our mass. So, mass by volume is our density in terms of that is equal to specific gravity of sludge solid.

Now this is for the sludge solid, but if we think about the sludge itself, so there will be water and solid. So specific gravity of sludge that is (water + solid)

$$\frac{1}{\frac{solidfractioninsludge}{sludgedensity} + \frac{waterfractioninsludge}{1}}$$

So, that way we can calculate the specific gravity of the sludge.

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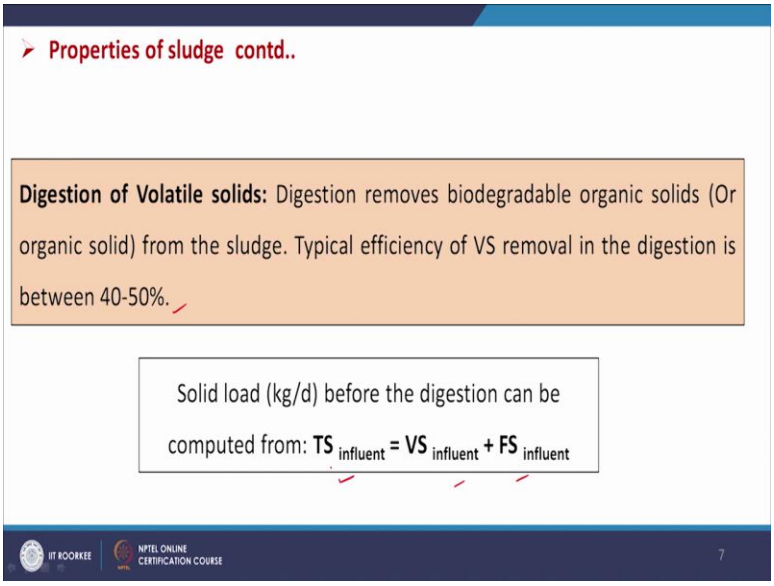

Now, digestion of volatile solids so the volatile solids will be digested by the microorganisms and the digestion removes biodegradable organic solids from the sludge typical efficiency of waste removal in digestion is between 40 to 50 %. And we can calculate the solid load before the digestion can be computed from $TS_{influent} = VS_{influent} + FS_{influent}$.

So in the influent, what is the, the volatile solids and what is the fixed solid? So, if we get the sum of it, so, then it will give us the total solid in the influent. So, these are the different properties or formula we can use to determine the solid content in the sludge.

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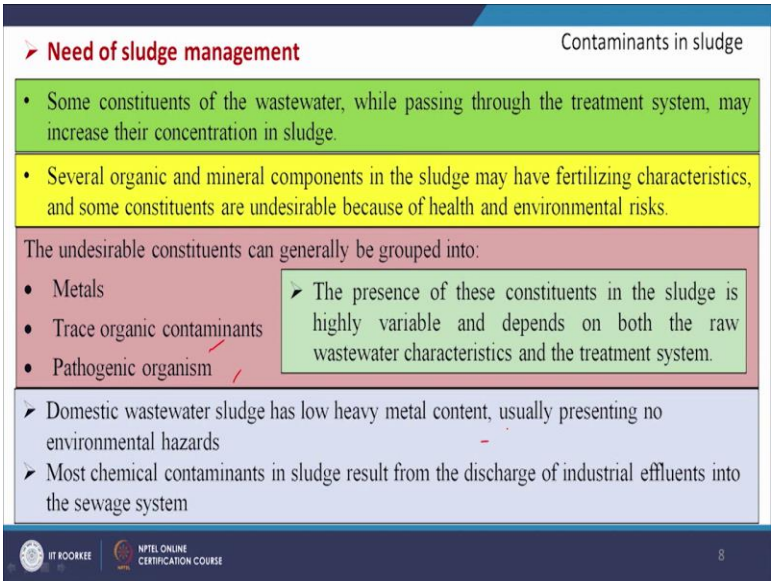

Now, we will see the need of sludge management. So, already we have discussed that the sludge contains solid and those solids may contain organic and inorganic compounds, those inorganic and organic compounds may be very useful for the plants, for the soil, for those can be the source of nutrients and those can also be the source of energy also these may have certain heating value and those can be used for energy generation as well.

But in some cases, depending upon the nature of the wastewater, the sludge may contain some specific elements, those are not desirable for health for the plants for the soil. For example say heavy metals which are toxic in nature, maybe pesticides or maybe some other organic compounds like phenolic compounds or others which are not desirable in the food chain or in the soil conditioning purpose. So, in that case, we need to remove those contaminants from the soil. So, it requires special treatment.

Other way the sludge which is generated that will be large in volume, because its solid content is less. So, the management of this if we want to dispose, that is also difficult. So we have to reduce its volume. And then the solid part which will be getting that can be processed further for its management and for its utilization. So that way the sludge management is very, very essential.

Now we will see that some constituents of the wastewater while passing through the treatment system may increase the concentration in sludge, several organic and mineral components in

sludge may have fertilizing characteristics, and some constituents are undesirable because of health and environmental risks.

And the undesirable constituents may generally be grouped into metal stress organic contaminants, pathogenic organisms. So, the presence of these constituents in the sludge is highly variable and depends on both the raw wastewater characteristics and the treatment systems used.

Domestic wastewater sludge has low heavy metal content, usually presenting no environmental hazards, but most chemical contaminants in sludge result from the discharge of industrial influence into the sewage system.

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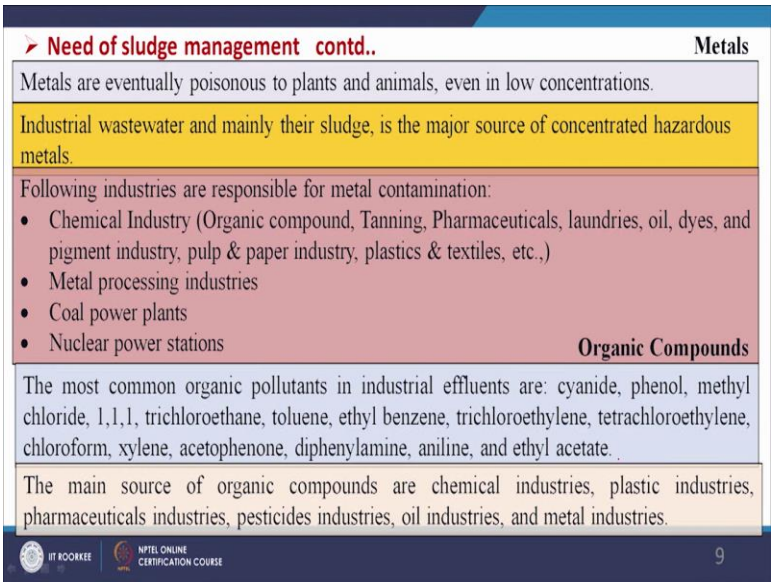

And metals are eventually poisonous to plants and animals. Even in low concentrations, industrial wastewater and mainly their sludge is the major source of concentrated hazardous metals. The following industries are responsible for metal contamination, like say chemical industry these are some examples like organic compound, tanning, pharmaceuticals, laundries, oil, dyes and pigment industry, pulp and paper industry, plastic and textiles and metal processing industries, coal power plants, nuclear power plants etc.

And different organic compounds may be available in sludge like say, most common organic pollutants in industrial effluents are cyanide, phenol, methyl chloride, 1, 1, 1, trichloroethylene,

and toluene ethyl benzene, trichloroethylene, tetrachloroethylene, chloroform, xylene, acetophenone, diphenylamine, aniline and ethyl acetate and many more. The main source of organic compounds are chemical industries, plastic industries, pharmaceutical industries, pesticide industries, oil industries and metal industries.

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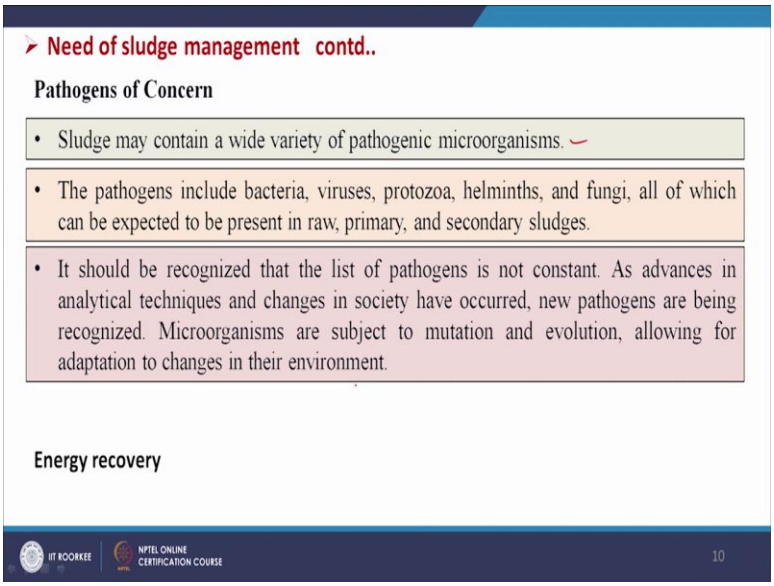

Similarly, pathogens may be present in it, like sludge may be contain a wide variety of pathogenic microorganisms and the pathogens include bacteria, virus, protozoa, helminths and fungi, all of which can be expected to be present in raw, primary and secondary sludges. And it is the fact that list of pathogens is not constant. As advances in analytical techniques and changes in society have occurred, new pathogens are being recognized. So, day by day some new pathogens are also being identified and recognized.

And, microorganisms are subject to mutation and evolution allowing for adaptation to changes in their environment so what is happening if we do not have any proper management of it. So, these microorganisms which are available in the sludge that can enter into the food chain and can be transmitted from plant to animal like this, and then there will be more health risk. Another is energy recovery as we have mentioned that the sludge can have good amount of carbon hydrogen and that can be the source of energy. So, by managing this, we will be having different options for the energy recovery of the material recovery. And overall, we will be able to reduce

its volume and properly it will be managed. So, now we will see some sludge management directions.

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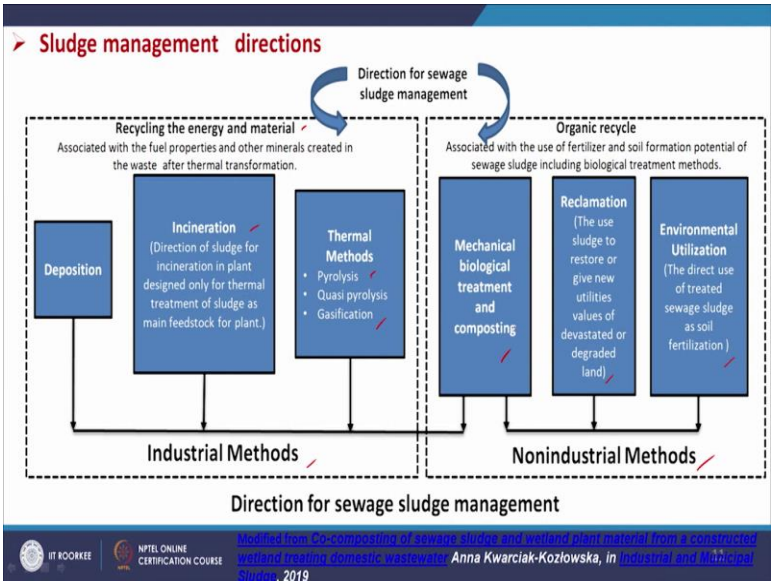

So, what we will see that we may get the sludge from different sources and we can process it through industrial methods and we can process it through non industrial methods as well. So, industrial method we can move for recycling the energy and material that is associated with the fuel properties and other minerals created in waste after thermal transformation basically, incineration and pyrolysis, gasification, etc. And we can also have some deposition and then we can have some another option that is organic recycling, we can recycle the organic content of it, like this can be used for the reclamation, for the conditioning of the soil, that can be you can be converted to fertilizer or organic manure.

So, we have that mechanical, biological treatment and composting that is one option. And this is the use of sludge to restore or give new utilities values of devastated or degraded land, that is the improvement of the land quality or environmental utilization, the direct use of treated sewage sludge as soil fertilization. So these are the different sources, different routes which you can follow, which is associated with use of fertilizer and soil formation. Potential of sewage sludge, including biological treatment methods.

We will be discussing all these methods in detail, that is gasification, pyrolysis and incineration with solid waste management. So the same process will be applicable for the sludge management

as well. And we will also have some discussion on this composting and also that biological treatment, anaerobic digestion, we will be having more discussion.

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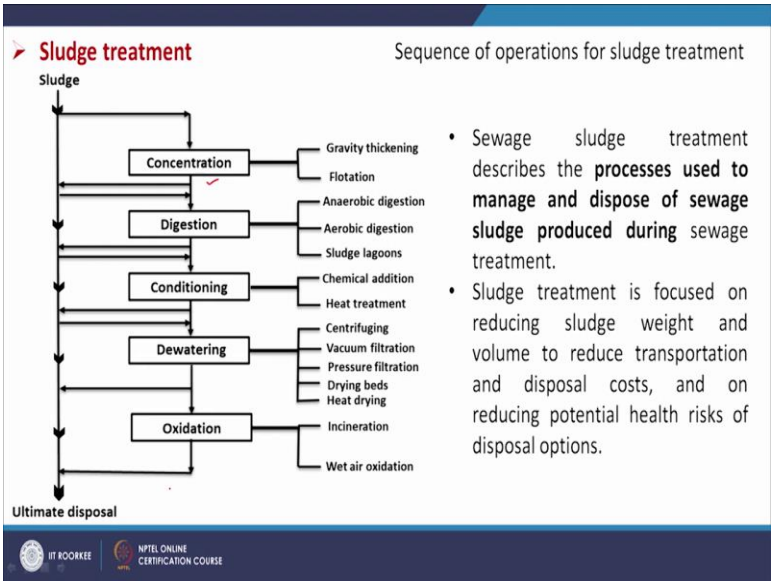

Now, we will be discussing on the sludge treatment. So, once the sludge is generated, then in this treatment, the main objective is to reduce its volume and to get the more concentrated solids for further conversion and the extractions of valuables from it and ultimately, to dispose of the residual material. So the sewage sludge treatment describes the processes used to manage and dispose of sewage sludge produced during sewage treatment. Sludge treatment is focused on reducing sludge weight and volume to reduce transportation and disposal costs and on reducing potential health risk of disposal options.

And you see the first stay for the treatment is concentration. So, certainly, we are interested to increase the solid percentage in the sludge. So, that is done by gravity thickening and flotation and next step is digestion then our objective is to convert some compounds to more simple form and reduce the volume of the sludge like say anaerobic digestion, aerobic digestion and sludge lagoons are some examples of it.

Next step is conditioning. In this step, some chemicals are added or some heat treatment is added. So, that the separation of the sludge or other solids within the sludge becomes more easier. So, that is chemical addition and heat treatment. Next step is dewatering. So, here the water content is removed from the sludge by likes a centrifuging, where computation pressure

filtration, drying weights, heat drying, etc. So, these are the different methods which can be used for this purpose.

And, then oxidation, then incineration and wet air oxidation, through wet air oxidation, again, the organic compounds are converted to CO_2 and H_2O and incineration through the combustion process, due to the application of heat, these organic compounds are also converted to CO_2 and H_2O and which is remaining that ass materials are non combustible materials, those are ultimately disposed off. So, this is the sludge treatment schemes and we will discuss each steps gradually.

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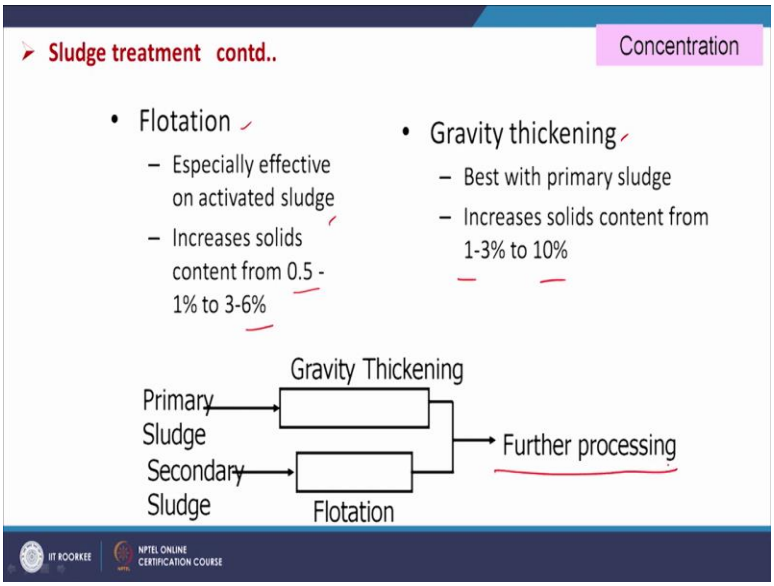

So, now, we will see the concentration. So, in this case, we have mentioned that this can be done by flotation and gravity thickening. So, and we have also seen that there are major two types of sludge one is primary and secondary sludge. And, secondary sludge is having less solid content and its density is also less, so this is more suitable for flotation process. So, especially effective on activated sludge and increases solid content from 0.5 to 1 % to 3 to 6 %. And for gravity thickening, the primary sludge is more suitable because in that case the solid content is more its density is also more so, its 1 to 3 % to 10 % solid content increment each possible.

So, the primary sludge through gravity thickening, secondary sludge through flotation, then we will be getting the concentrated sludge that will be used for further processing. So, this is the first step of the sludge treatment.

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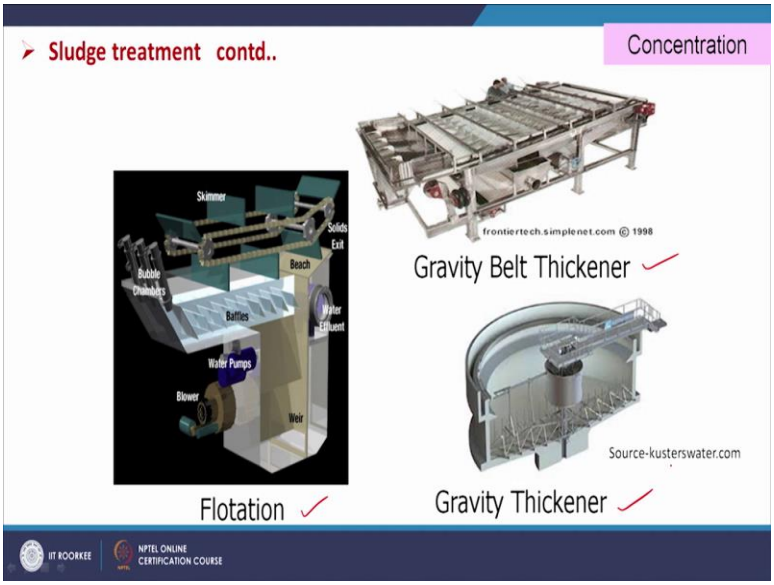

So, these are the different types of equipment which are used, like say for flotation, and for gravity belt thickener and gravity thickener, already we have made discussion on these equipment in our previous classes.

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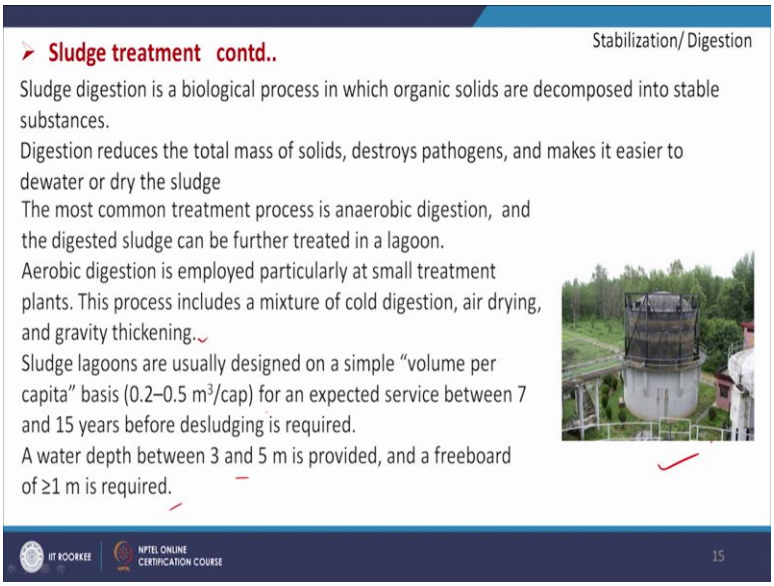

Now, we will discuss on the stabilization or digestion. So, in this process, the organic compounds are digested, are degraded by the microorganisms in aerobic or in anaerobic conditions and the solids content is reduced. So, the sludge digestion is a biological process in which organic solids are decomposed into stable substances. Digestion, reduces the total mass of

solids, destroys pathogens, and makes it easier to dewater or dry the sludge. The most common treatment process is anaerobic digestion and the digested sludge can be further treated in a lagoon.

So, aerobic digestion is employed particularly at small treatment plants. This process includes a mixture of cold digestion, air drying, and gravity thickening. And sludge lagoons are usually designed on a simple volume per capita basis that is 0.2-to-0.5 m^3/capita for an expected service between 7 and 15 years before desludging is required. And a water depth between 3 and 5 meters is provided, and a freeboard of greater than 1 meter is required. So, these figures show the anaerobic digestion plant.

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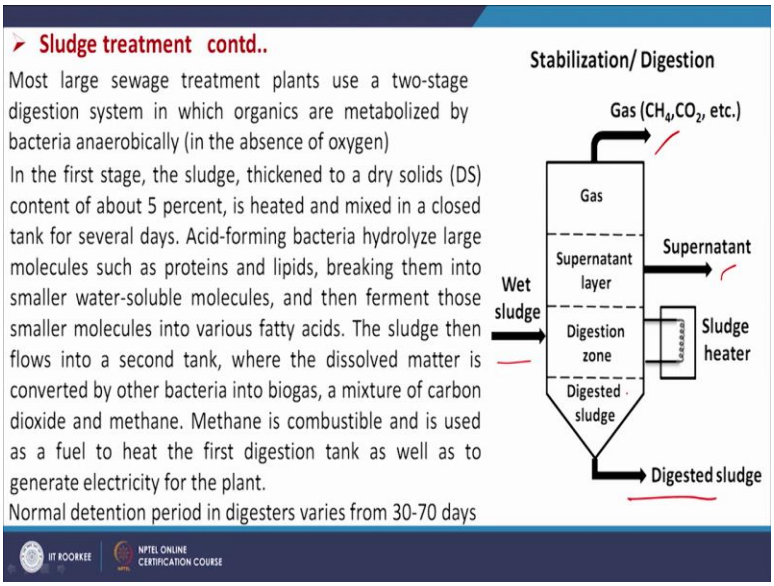

And in anaerobic digestion unit, we use wet sludge and then it is heated to maintain a certain temperature and then microbes work on it. Basically, this is two step, in the first step, the hydrolysis and then acetogenesis reaction takes place. And then organic compound which is present in it, it is converted to low chain fatty acids.

And the second step it is having where the methane formation takes place. So that acetic acid or acetate is converted to methane. We will be discussing in detail about this mechanism in anaerobic digestion classes. And then after this treatment, we will be having supernatant layer so that will be going out. And the gas will be produced that can be used for heating purpose and this gas can also be used here to heat this one or some part may be used for other application.

And digested sludge, which we are getting that will be having more organic content and we will process the sludge through other steps. So, this is the anaerobic digestion process and aerobic process is also used and some lagoons are also used. So, in this case of anaerobic process normal detention period in digester varies from 30 to 70 days.

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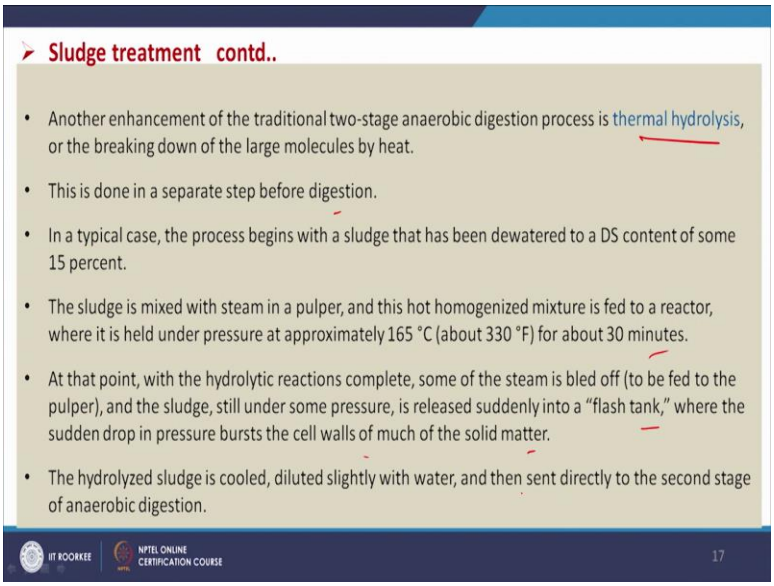

So, one another advancement of this anaerobic process is the use of thermal hydrolysis as we mention that there are major two steps, one is the hydrolysis acetogenesis and acetogenesis and then second is methanogenesis step. So, if the hydrolysis takes place in presence of steam, that is thermal hydrolysis, then it gives more easily breakdown of the organic compounds and then the performance of this process becomes superior and this is done in a separate step before digestion.

So, in a typical case, the process begins with a sludge that has been dewatered to a DS content of some 15 %. So, dissolved sludge content of 15 %. And the sludge is mixed with steam in a pulper, and this hot homogenized mixture is feed to a reactor where it is held under pressure at approximately 165 ^{o}C for about 30 minutes. So, by using steam the temperature increased to 165 ^{o}C and it is heated for 30 minutes.

And at that point with the hydrolytic reactions complete some of the steam is bled off and the sludge, still under some pressure is released suddenly into a "flash tank," where the sudden drop in pressure bursts the cell walls of much of the solid matter. So, this is the mechanism for the

hydrolysis of the organic compound. And, the hydrolyzed sludge is cooled diluted slightly with water and then sent directly to the second stage of anaerobic digestion.

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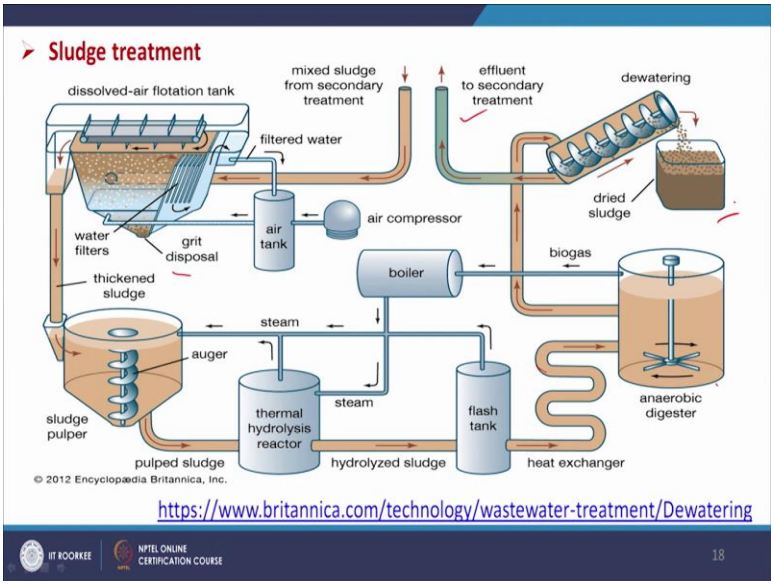

Here we will see the process. So, here mixed sludge from the secondary treatment, so it is coming, we are having air flotation. So, then flotation means we will be having sludge from the top, the sludge is coming here at the bottom we will be getting some grit material, if it is available, then this sludge is coming here we will be giving the steam here. So, thermal hydrolysis will take place.

So, after thermal hydrolysis, it is going to the flash tank, so, very high pressure and temperature. So, we are reducing it here and from this flash tank, since the pressure is reduced here, so, that again some water will be vaporized and it will go there. And the remaining part is coming here for anaerobic digestion.

After anaerobic digestion, we will be getting gas that will go out and can be used for heating purpose and steam generation and the supernatant or the slurry after digestion, it will be going through this step, that is dewatering step and dewatering step will be getting water that is a influent to secondary treatment and the solid part that is dewatered sludge so that can be processed further. So this is the scheme with thermal hydrolysis reactor.

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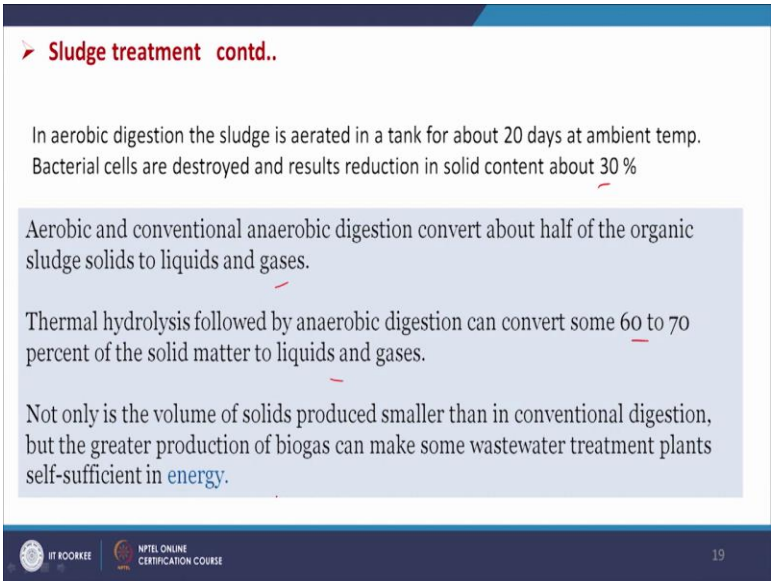

And in aerobic digestion, the sludge is aerated in a tank for about 20 days at ambient temperature bacterial cells are destroyed and results reduction in solid content about 30 %. Aerobic and conventional anaerobic digestion convert about half of the organic sludge solids to liquids and gases.

And thermal hydrolysis followed by anaerobic digestion can convert some 60 to 70 % of the solid matter to liquids and gases. Not only is the volume of solids produced smaller than in conventional digestion, but the greater production of biogas can make some wastewater treatment plant self sufficient in energy. So due to the use of thermal hydrolysis process, both reduction of the solid increase as well as the biogas production also increase.

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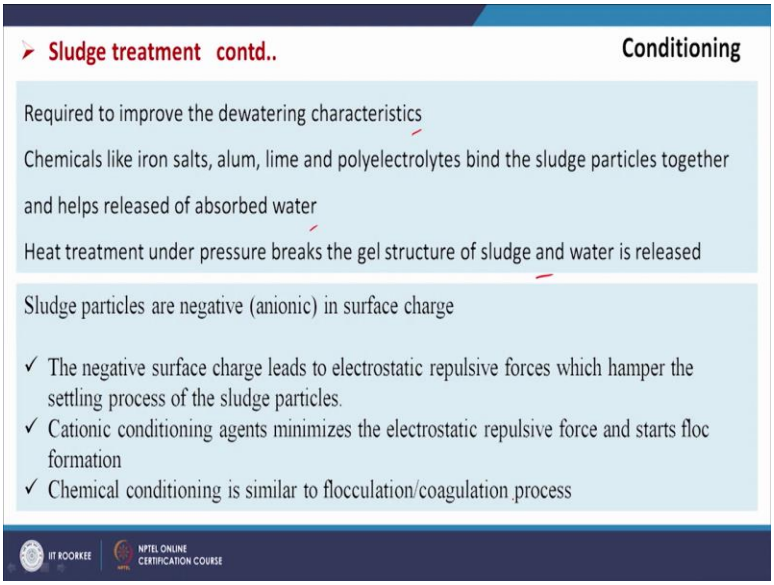

Next we will discuss on the conditioning as you have mentioned that this part is required to make the concentrated sludge more suitable for easy settling and then it is dewatering purpose. So it is required to improve that dewatering characteristics. So chemicals like iron, salt, alum, lime and polyelectrolytes bind the sludge particles together and helps to released of adsorbed water.

Heat treatment under pressure breaks the gel structure of the sludge and water easily. So, there are two types of mechanism for the dewatering, one is your filtration or drying and another use the heat treatment, then heat treatment under pressure breaks the gel structure of the sludge and water is released. So, sludge particles basically are negatively charged particles it is assumed that sludge particles are negative in surface charge and the negative surface charge leads to electrostatic repulsive forces which hampered the settling process of the sludge particles.

The cationic conditioning agents minimizes the electrostatic repulsive force and starts floc formation and chemical conditioning is similar to flocculation and coagulation process. So, once that surface charge is reduced, the particles will be easily coagulated and will be settled. So, this is the mechanism for the separation and the dewatering after conditioning. Upto this, in this class. Thank you for your patience.