Water and Waste Water Treatment
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Module No # 12
Lecture No # 59
Anaerobic and Aerobic Digestion of Sludge

Hello everyone, welcome back to the latest lecture session. We just have 2 more sessions to go before we complete this marathon course.

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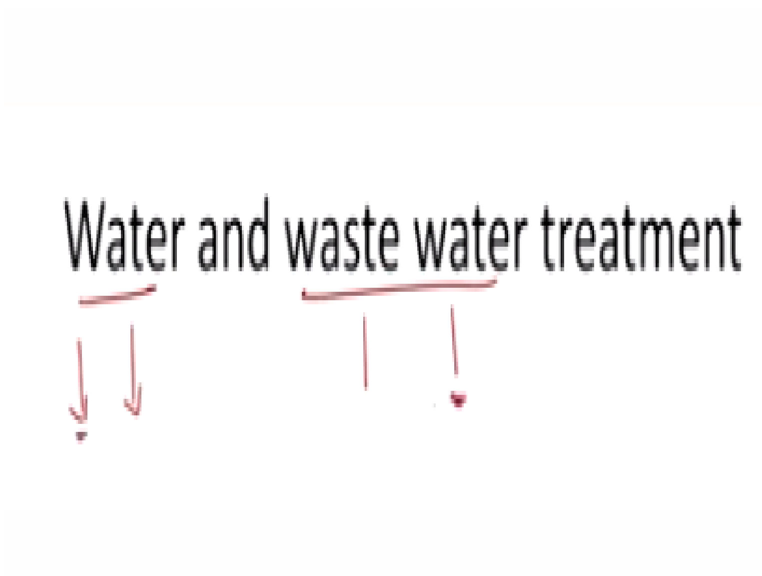

Let us dig into it. In the context of water and waste water treatment, we are looking at sludge that comes in from different levels of treatment primary, secondary treatment. We are looking at residual management. In that context we looked at or started looking at stabilization.

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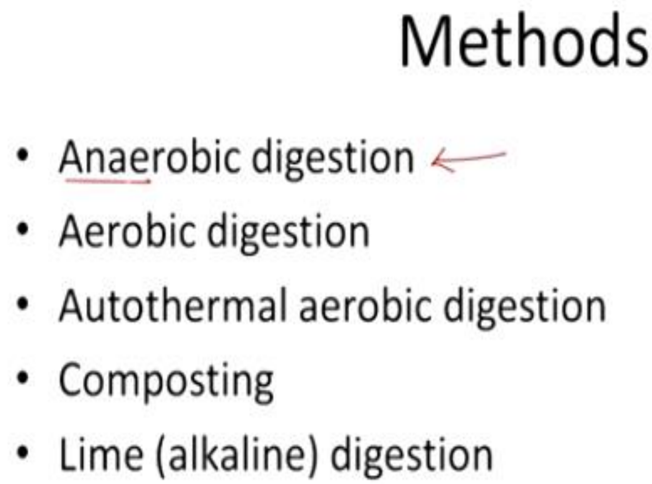

And the method we were looking at was anaerobic digestion, anaerobic, in the absence of oxygen.

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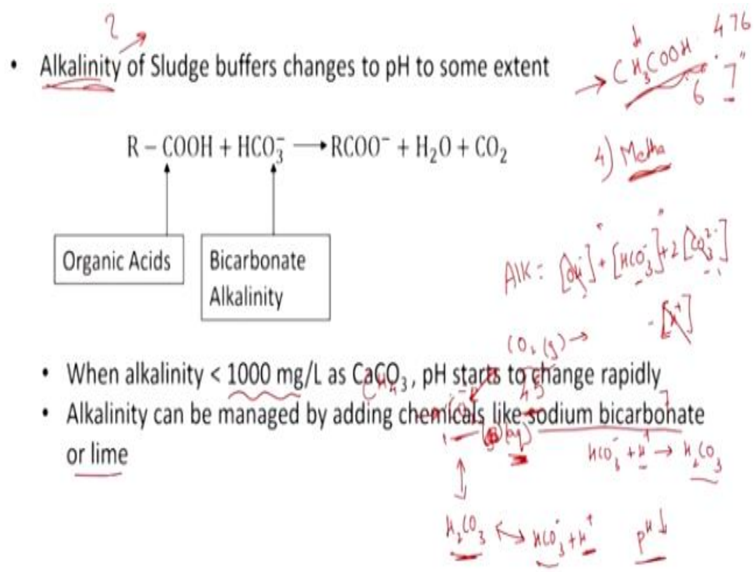

We looked at the relevant aspects and we were looking at alkalinity and why that is necessary? We can see that we are going to have acetic acid being formed, typically CH3COOH acetic acid, acetogenesis. This was one of the steps in anaerobic digestion, first hydrolysis and then you had acetogenesis where you have the intermediate volatile fatty acids typically being formed.

And then you have the acetogenesis acetic acid being formed and depending upon the type of the parent compound, you will also have hydrogen being formed and in that context we saw that these 3 steps typically or are the microbes that lead to these kinds of steps acetogenesis thrive and grow faster than the one that removes acetic acid from your particular solution.

That was the fourth step that is relatively slow is methanogenesis and so if the acetic acid is not being removed by acetogenesis as you can see is an acetic acid, its pKa is 4.76. It can bring down the pH, depending on the concentration from the neutral pH to may be 6 or so and as we looked at in the previous session, we know that methanogens which are the key to this process.

Are going to feel the effects or adverse effects when the pH is 6.5 or so. You want to control this particular anaerobic digestor turning sour. We do not want this digestion to turn sour. That is one aspect to keep in mind and here that is where alkalinity comes in, as ability to neutralize an acid. In general alkalinity we did talk about this earlier.

If I am not sure but let us just let me just write down the equation. I am writing down the relevant basis that will come into play. If we are titrating usual waters or natural waters from the relevant pH to pH of 4.5 or around 4.5, that is the standard method definition. And because these are the usual basis that you will come across that is why we have these, if there is other basis that can neutralize the acid in this particular pH range

Then you will have to add those bases too. Anyway, as you can see if the system is typically around pH 7 you can neglect these two and you can neglect this too and you will see in general alkalinity will be more or less equal to HCO_3^-, what can HCO_3^- means do? It can take up the relevant proton and go to H_2CO_3. Thus, there is no H^+ in the solution, pH is not affected.

Another aspect to keep in mind is that during the methanogenesis you saw that the methane or acetic acid can be converted to carbon dioxide. This carbon dioxide when it is dissolved it will be in equilibrium with H_2CO_3 and depending on the pH of solution this H_2CO_3 will be in equilibrium with HCO_3^- by releasing the H^+. By releasing the H^+ due to the production of CO_2 that is still not in the gaseous in the aqueous phase or dissolved in the aqueous phase.

You are going to have a decrease in the pH. These are the 2 aspects or ways that the pH can decrease. This, how will you control? By having a good balance between acetogenesis and methanogenesis. That is why you need skilled operators for anaerobic digesters typically most anaerobic digester that fail at least in India., fail because of poor plant operation. As you can see it is not just, I can put it out there and it is not like I turn on a switch and the fan keeps running.

These are microbes living organisms and you need to cater to their need that is the aspect. One way to look at this is that you will have to sponge it or let the carbon dioxide that is accumulating or that can accumulate. This will be in equilibrium with carbon oxide in the gaseous phase, that has to be removed then know you have less carbon dioxide that can be dissolved in the aqueous phase if not your pH will decrease.

That is one aspect to keep in mind. Let us move on from here. When alkalinity is less you will have to see to it that the pH does not drop too much. How can you do that? By adding alkalinity extraneously. How can you do that? By adding either NaCO3 or add lime, that is the way to go about it.

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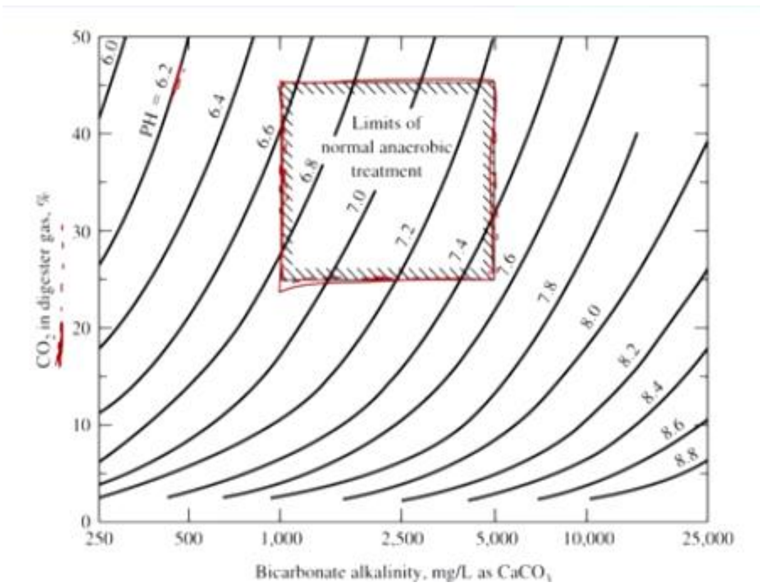

As you can see here, we have 2 aspects here carbon dioxide in digester gas and then we have the relevant pH here and also the bicarbonate or alkalinity measured as CaCO3, that is one aspect to keep in mind. As you can see there is a narrow range where the 3 variables of interest operationally; carbon dioxide in the digester, pH and alkalinity will be optimum for our anaerobic treatment.

As you can see 6.5 as we mentioned was one particular limit for the microbes or before which the microbes will not be adversely affected. And then too high pH too will not really work out. You can see that it is a narrow range out there.

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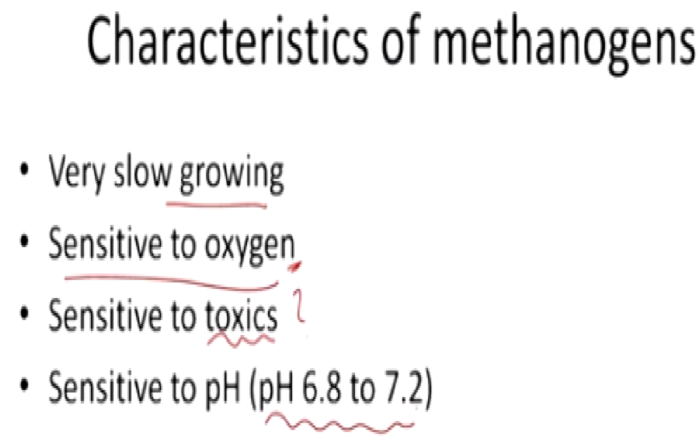

Characteristics of methanogens as we mentioned prima donnas. I will just summarize what we have already looked at, slow growing very sensitive to oxygen, some anaerobes, even though there is oxygen, if they are, facultative maybe they should not classify them as strictly anaerobic but there are obligatory anaerobic, those even if you have some oxygen that is going to affect their system.

They are pretty sensitive to oxygen, sensitive to toxics, which toxics? We will look at that soon. As I mentioned they have very narrow range of pH within which they can thrive. That is one aspect to keep in mind. Let us look at one anaerobic digester.

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Anaerobic digester with floating cover. Flexible compressed gas lines allow for traverse of floating cover

Here it is floating cover. It can move up and down so here they have compressive gas lines for mixing, this is the anaerobic digester and it is underneath the ground here, that is one aspect to keep in mind.

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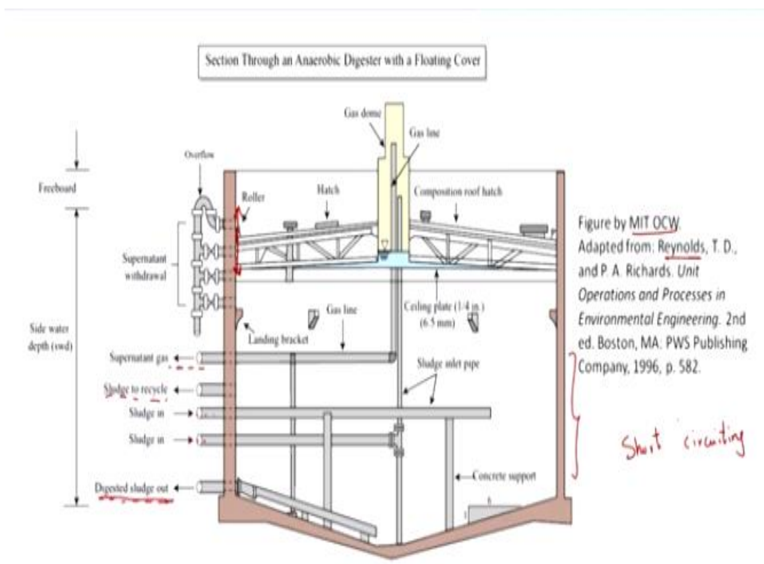

Cross section provided by MIT open course ware from Reynolds if I am not wrong, let us see what it is that we have. Sludge comes in, sludge inlet pipes, sludge in, that is one aspect to keep in mind. What else I will have? Formation of my relevant gases. Let us see where the gas is being removed, so first they have a gas dome and then they are having a supernatant gas here.

That is one aspect to keep in mind, supernatant gas line here and here as you can see it was a floating cover system not a fixed dome or such floating cover system and you can see that it can move up and down in this vertical direction. And you have to remove the digested sludge out from time to time, that is again based on the mass balance and sometimes sludge to recycle.

You have to maintain the relevant thickness of your anaerobic zone and digested sludge out this can typically go to the relevant farmland or agricultural land or for to your gardens that is something to keep in mind, let us move on. The other one you saw that cylindrical. But here some issues are you can have short circuiting. And you can also have accumulation of carbon dioxide here, that is something that you do not want as we saw earlier.

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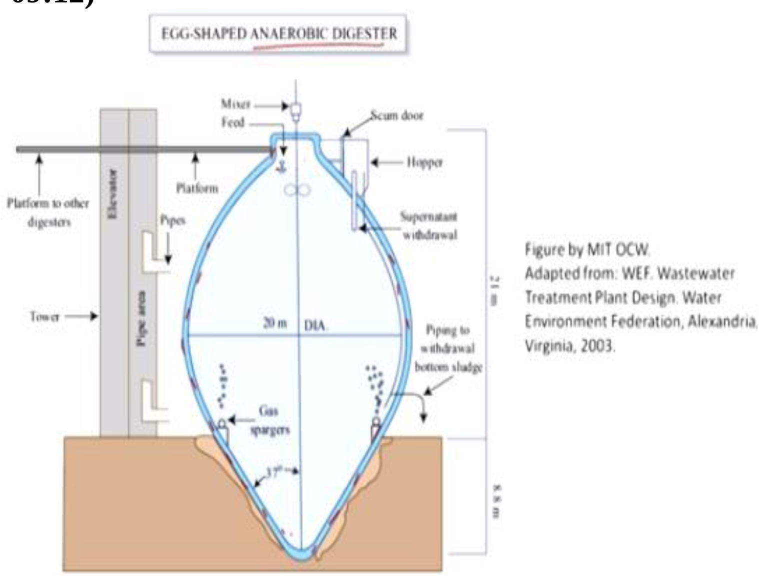

A shape of the anaerobic digester which has been seen to practically reduce the downtime or maintenance levels required is the egg shaped anaerobic digester. Firstly, this shape egg shape prevents short circuiting and secondly less head space at the top that also seems to be not only affecting the carbon dioxide or level of control that you can exert on the carbon oxide in that particular head space, it also seems to be, it is not clear why.

Preventing foaming or some issues with respect to certain kinds of unwanted microbial growth, that is one aspect to keep in mind. Let us move on.

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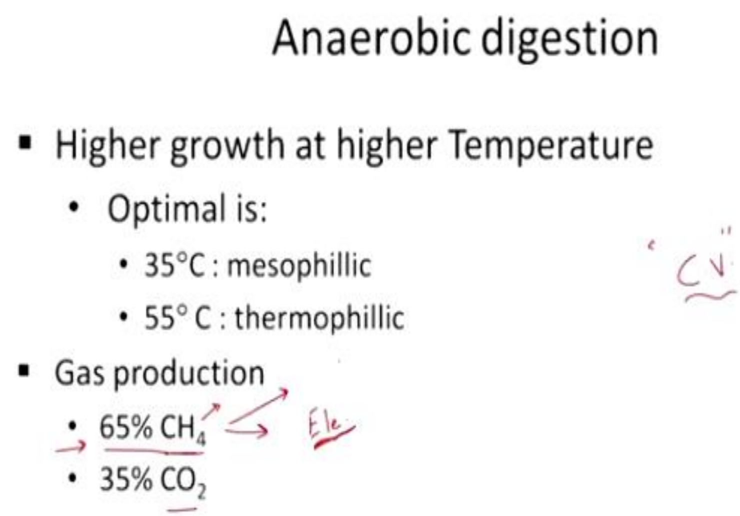

Anaerobic digestion higher temperature higher growth, optimal, you see this and gas production 65% methane and the other should be carbon dioxide, this is what we see, so if you are trying to generate electricity or use this for different purposes, you can try to capture this CH4 but if the content or CH4 proportion is very less than the calorific value of the gas, if I can call that calorific value, will be relatively less.

There are 2 options, one is you can burn it and then use it for electricity generation but you need to look at the cost of running that particular converter. And also, you have to look at the efficiency of this particular process. Another aspect which I came to know is also being implemented in India. At least in a large scale is that the Infosys plant at Bangalore if I am not wrong,

They have this anaerobic digester for kitchen waste, not for sludge and kitchen waste from the methane that is being produced they are not letting it out into the atmosphere or just flaring it or using it for a electricity. But rather they are trapping it or pressurizing it and using it for cooking. At least that is what I remember to have read, let us move on.

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SUBSTANCE	MODERATELY INHIBITORY CONCENTRATION, mg/L	STRONGLY INHIBITORY CONCENTRATION, mg/L
Na^+	3500 - 5500	8000
K^+	2500 - 4500	12000
Ca^{++}	2500 - 4500	8000
Mg^{++}	1000 - 1500	3000
Ammonia-nitrogen (pH dependent)	1500 - 3000	3000
Sulfide (un-ionized gas)	200	200
Copper (Cu)	—	0.5 (soluble) 50-70 (total)
Chromium VI (Cr)	—	3.0 (soluble) 200-250 (total)
Chromium III	—	180-420 (total)
Nickel (Ni)	—	2.0 (soluble) 30.0 (total)
Zinc (Zn)	—	1.0 (soluble)

NH_4^+

H_2S

Toxic and Inhibitory Concentrations of Selected Inorganic Materials in Anaerobic Digestion

Figure by MIT OCW.

Adapted from: WEF. Wastewater Treatment Plant Design. Water Environment Federation, Alexandria, Virginia, 2003.

SO_4^{2-}

H_2S

pH

HS^-

S^{2-}

As we mentioned earlier, we need to be concerned about toxic substances. We are concerned about some cations and the concentration is out here and strongly inhibitory range is given here. When we are looking at industrial waste waters by anaerobic digestion, even though now we are talking about sludge depending upon either the type of cations exchanger that you used.

Either if it was mixed with primary sludge. Primary sludge at least from water treatment, if you are mixing them up, you can sometimes have high concentrations of some of these ions. And as you can see, they can be strongly inhibitory at 8 gram per litre or 12 gram per litre. That is pretty high but as you can see moderately inhibitory unit, 2.5 gram per litre or in that range. And ammonia nitrogen, you do not want too much of that.

You do not want this too much and as mentioned earlier, hydrogen sulphide is going to be an issue even at low concentrations. You have sulphates or sulphur in your input or inlet then after reduction, H2S will be formed and as you can see that is going to be strongly inhibitory, you will also need to look at the pH may be look at the speciation. It typically will not be a S2- but may be HS-, you can try to manage that. As you can see it is the unionized gas and then some of the relevant heavy metals, let me move on.

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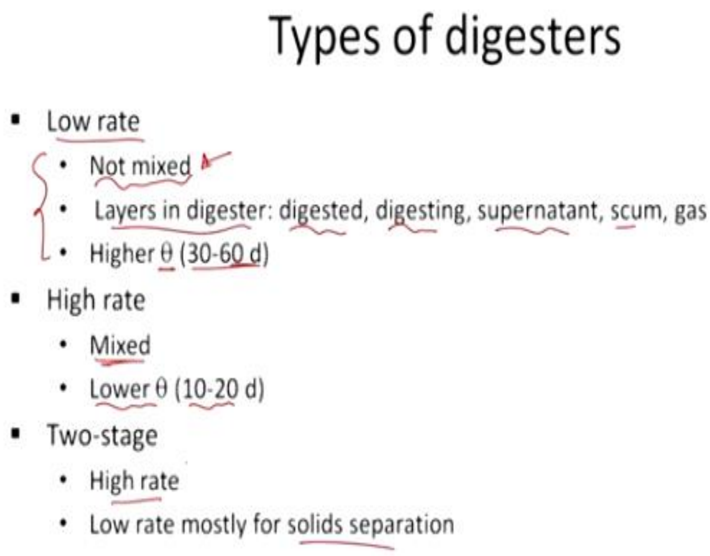

Types of digesters; Low rate, key aspect is it is not mixed, they are layers in digester digesting supernatant and scum, they are clear layers. And that is why because you are not mixing too and thus low rate, higher retention times are required. As you can see 30 to 60 days meaning larger volume, other one is high rate with the mixed one requiring lower retention time 10 to 20 days and 2 stages where they combine low rate, mostly for solid separation with high rate, let me move on.

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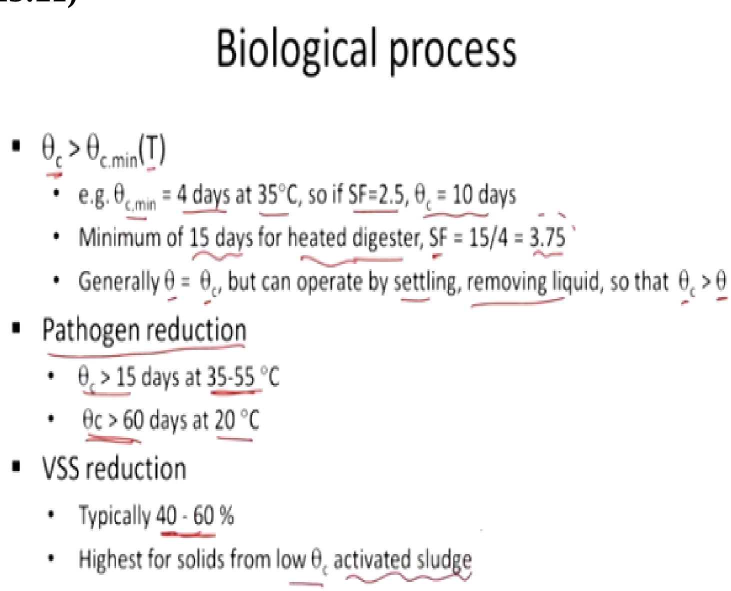

Biological process, so we have theta C being greater than theta C minimum at temperature, let us look at what we have. Theta C minimum, if it is 4 days at 35 degree centigrade, you are typically going to look at a safety factor and it is 2.5 and then theta C that you are going to use is going to be 10 days. But typically, the minimum for digesters is typically 15 days especially I or in general for the heated digester.

As you can see this safety factor that typically people end up using is relatively high enough. If you are operating it at theta equal to theta C but you can operate by settling and removing liquid so that theta C is greater than theta, that is one aspect as you know it is all about recycle and you can manage the operation such that theta is greater than theta.

And we are primarily concerned or one of the objectives of stabilization or residual management was about pathogens and pathogens different ways. You are not going to create the environment in which they can thrive and one of the ways is that you will increase the temperature or make it uncomfortable if I may say for them, as 35 to 55 if the theta C is greater than 15 days if it is low temperature then theta C, we are looking at a longer retention time.

Volatile suspended solids, reduction typically relatively high enough, 40 to 60% and it is highest for solids with low theta c activated sludge.

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Summary of design parameters for completely mixed suspended growth reactors treating soluble COD

Parameter	Unit	Value: Range	Value: Typical
Solids yield, Y			
Fermentation	g VSS/g COD	0.06–0.12	0.10
Methanogenesis	g VSS/g COD	0.02–0.06	0.04
Overall combined	g VSS/g COD	0.05–0.10	0.08
Decay coefficient, k_d			
Fermentation	g/g · d	0.02–0.06	0.04
Methanogenesis	g/g · d	0.01–0.04	0.02
Overall combined	g/g · d	0.02–0.04	0.03
Maximum specific growth rate, μ_m			
35°C	g/g · d	0.30–0.38	0.35
30°C	g/g · d	0.22–0.28	0.25
25°C	g/g · d	0.18–0.24	0.20
Half-velocity constant, K_s			
35°C	mg/L	60–200	160
30°C	mg/L	300–500	360
25°C	mg/L	800–1100	900
Solids retention time (SRT)			
35°C	d	10–20[a]	15
30°C	d	15–30[a]	N/A
24°C	d	20–40[a]	N/A
Methane			
Production at 35°C	m^3/kg COD	0.4	0.4
Density at 35°C	kg/m^3	0.6346	0.6346
Content of gas	%	60–70	65
Energy content	kJ/g	50.1	50.1

[a] Safety factors range from 2.5 to 5 times minimum SRT

Some of the aspects here this is similar to or these variables which have seen in the context of aerobic treatment too when we were looking at activated sludge in wastewater; Solid’s yield as you can see, for fermentation 0.06 for methanogenesis as mentioned slow growers, so you can see that it is relatively less 0.02 per gram of COD compared that with what you have for fermentation and decay coefficient.

Here we are talking about decay of the volatile suspended solids. Let us see fermentation and methanogenesis, as you see this is relatively faster, relatively slower, that is something to keep in mind because you want to balance out the amount of acetic acid that is being accumulated. And then specific growth rate; I would like to compare that with the one for aerobic systems, let us see what we have.

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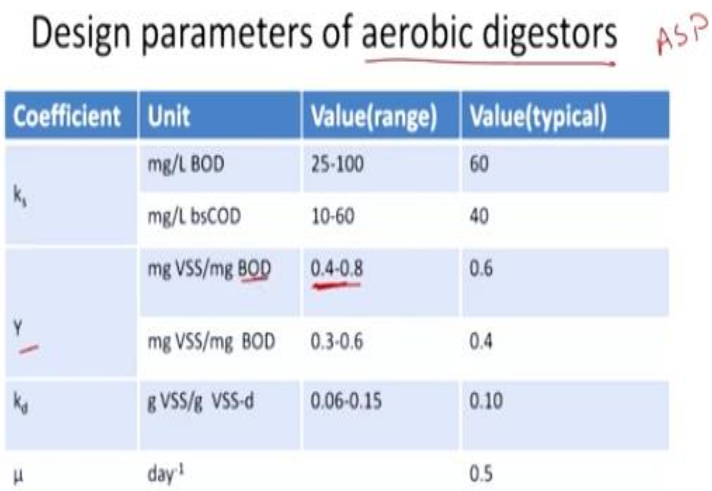
Design parameters of aerobic digestors ASP

Coefficient	Unit	Value(range)	Value(typical)
k_s	mg/L BOD	25-100	60
	mg/L bsCOD	10-60	40
Y	mg VSS/mg BOD	0.4-0.8	0.6
	mg VSS/mg BOD	0.3-0.6	0.4
k_d	g VSS/g VSS-d	0.06-0.15	0.10
μ	day^{-1}		0.5

Design parameters for aerobic digesters maybe I should have presented the one for activated sludge process but that is fine. Yield you can see is much higher; 0.4 to 0.8 and here it is milligram of BOD may be for COD it would have been slightly lower. But that is fine you can see that here the yield is point 0.06 and here we are talking about yield around 0.4.

And what else do we have? We have Ks and that too you can see is literally much higher and decay 0.06, let us look at what it is but in the context of decay there in the anaerobic direction too we will have to look at another aspect there. But I will mention that when we are looking at the decay, it is relatively higher.

As you can see typically anaerobic process are relatively slow and that is what I wanted to mention firstly they grow slower and also even the rate constants are slower. This is Ks. Let us move on.

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Range of physical design criteria for high-rate anaerobic digester facilities

Parameter	Range of values	Comment
Feed concentrations	2–6%	≥ 4% preferred > 6% will have mixing problems
Tank (cylindrical)		
Diameter	6–40 m	
Depth	6–15 m	≥ 7.5 m preferred
Bottom slope	1:3 to 1:6	1:6 preferred for gravity withdrawal
Mixing		
Mechanical	5–8 W/m^3	
Gas (unconfined)	0.27–0.30 $m^3/m^3 \cdot h$	m^3 of gas/m^3 of digester volume
Gas (confined)	0.30–0.42 $m^3/m^3 \cdot h$	
Gas production	0.75–1.12 m^3/kg VSS destroyed	
Lower heating value	20–25 MJ/m^3	22.4 MJ/m^3 typical
Heat exchanger transfer coefficient	0.9–1.6 $kJ/m^2 \cdot K$	External heat exchanger

The range of physical design criteria for high rate anaerobic direction typically, now in India people are pushing for high rate anaerobic digesters, let us see what it is that we are typically looking at. Diameter 6 to 40 meters but rarely will we go to 40 meters typically 8 to 10 meters is fine and depth 6 to 15 meters fine, slope for gravity withdrawal of your relevant sludge and the level of mixing.

If the gas is unconfined, confined. These are the aspects. Sometimes you will have to heat it but in India because of the relatively warm ambient conditions, heating is not required there, that is one aspect to keep in mind and gas production if you are concerned about how much gas you are going to produce, it is going to be 0.75 meter cube per 1 kg of the volatile suspended solids.

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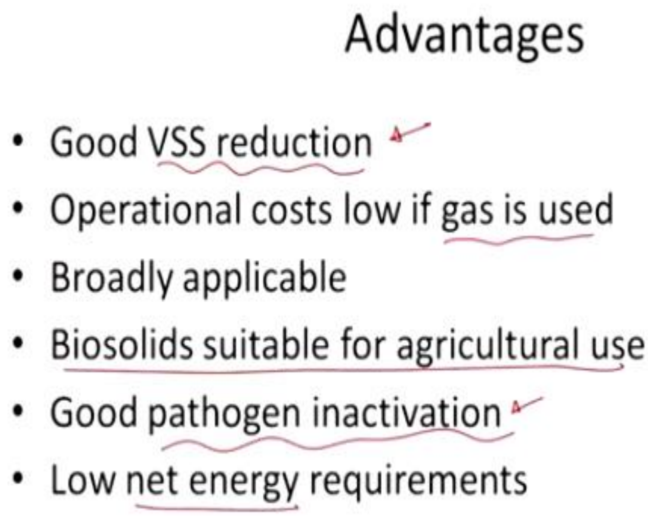

Evaluation, let me start summarizing from here without going deep into the details. One aspect to note is or objective which is the biodegradable organic matter should be decreased considerably and that is what we see here. And operational cost low if the gas itself is used especially for mixing or for energy generation. It is applicable to a range of wastes and the relevant stabilized sludge can be used for agriculture.

And as mentioned because of the temperatures that are going to be maintained typically you are going to have good pathogenic inactivation. And as you see it is an anaerobic process, you are not providing energy at best you need energy for some level of minor maintenance or for mixing if you are going to go for the high rate anaerobic digesters even that is not a lot. As you can see the key aspect is low net energy requirements.

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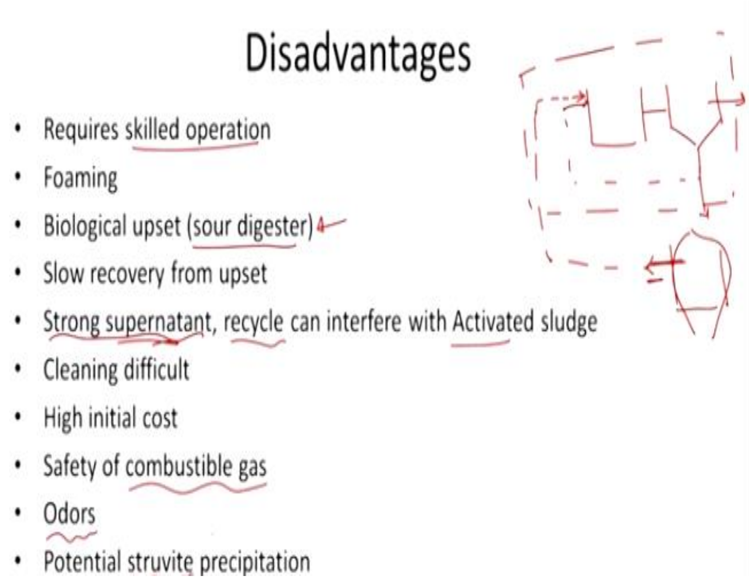

One aspect though is that they are Prima donnas, you need to really cater to their needs and look after them, that is one aspect or if I should say not disadvantage, one concern that you should be looking at especially considering the lack of skilled manpower. Disadvantage, let me summarize them. As I just mentioned skilled manpower is required can sometimes leads to foaming and sour digester.

This is what we talked about earlier with respect to pH dropping and once it turns sour or there is an upset in the or the microbes are upset and then it takes a lot of time for them to recover, that means your plant is not going to operate as efficiently. It is a very fine balance that is something to keep in mind. Another aspect is the supernatant is considerably strong, if you recycle that and if you recycle that to your activated sludge process.

For example, if we have activated sludge process and this sludge we are taking to our anaerobic digesters. Let me say this egg shaped one and you are going to have supernatant and if the supernatant you put this up here, it is all about mass balance, how much organics are coming in, if you put this in because it is such high strength supernatant, it can interfere with the activated sludge process if you not designed well.

Cleaning is difficult and initial cost is high for example for kitchen waste I am just talking about some rough numbers. For IIT Roorkee kitchen waste, around 3 tons or kitchen and relevant organic waste, estimated to be 2 and half tons or 3 tons for the 16,000 population and for that if you can get it relatively a fair price, the system anaerobic digestive system will be around 60 lakhs or so.

That is one aspect to keep in mind. Safety of combustible gas, if you are flaring it or using it for energy or for compression for using in the mess or such, that is the one aspect to keep in mind. Odours, if you let the methane or such or some of the anaerobic gases out, that is an aspect and struvite, this is one particular compound that can precipitate out and can lead to issues, that is another aspect to keep in mind.

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Let us move on, from now I will mostly start summarizing it because these are aspects at least the principles of aerobic digestion if not for digestion for aerobic aspects, we looked at the principles. From now on I will mostly be summarizing the aspects. What are we looking at?

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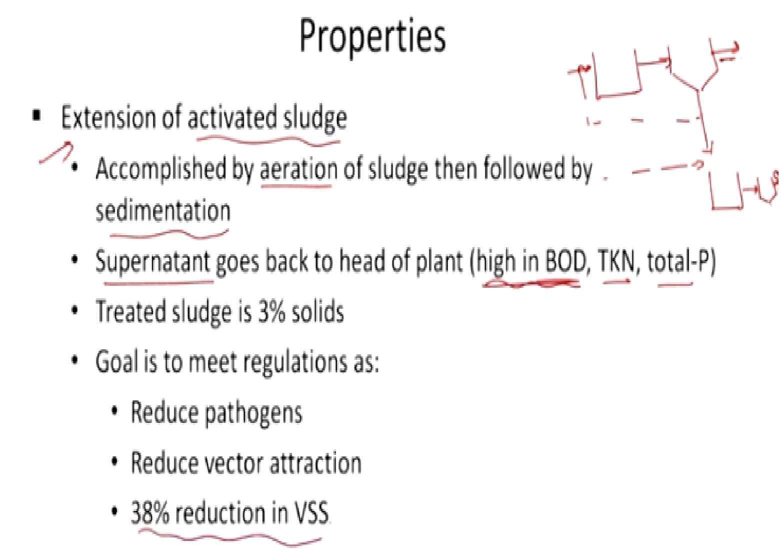

It is as I just mentioned similar to the activated sludge process. If it is aerobic, I need to supply air and then after that I am going to look at sedimentation where I form the relevant flocs, that is why it is an extension of the activated sludge process. Supernatant which is not of typically very high strength which is one of the advantages of aerobic digestion goes back to the head of the plant.

When i say it is not high it is not as high as that from the anaerobic digestion. That is what I say that but in general too it is going to be high compared to the effluent from the activated sludge process. Here we are talking about effluent from the aerobic digestion. If this is my typical activated sludge process and this is being recycled.

And if for this sludge or if there was a primary sedimentation zone even for wastewater and I am also collecting that sludge and I have another activated sludge process here for this. This particular supernatant is going to be higher in strength compared to this particular efferent here. I can recycle this back here too but you have to be concerned about TKN and total phosphorous. Treated sludge is around 3% solid, that is one aspect.

When do we use it? Typically when our major goal is to reduce pathogen and prevent attraction of flies and 30% reduction in VSS not great but well workable.

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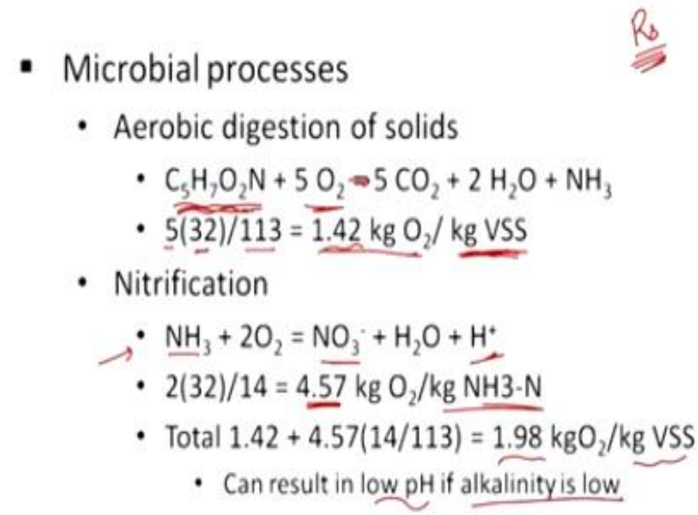

But what is the issue though? The issue is that for an aerobic process you need to provide oxygen. That means it is all about money, you need to provide air meaning pumping cost that is going to be considerably high. Especially because the concentration of your relevant sludge or the organics that you are going to degrade is going to be pretty high. Though the flow is going to be less the concentration is going to be pretty less.

Microbial process, this is general formula for the cells so to balance it out what do we have? We need 5 moles of oxygen for this generic formula of the relevant cells. It is 1.42 kgs of oxygen, 5 molecular weight of oxygen and 113 looks like the molecular weight of this particular compound, which we are using to represent the cell mass per kg of volatile suspended solids, anyway 1.42 kgs of oxygen per kg of volatile suspended solids.

If nitrification is also allowed to take place, first for nitrification so let us see what we have, we are going to require considerable amount, this we saw even in the activate sludge process, 4.57 kgs of oxygen per kg of NH3 or NH4+, that is something to keep I mind. It is around almost 2 case of oxygen per kg of volatile suspended solids. And as you can see especially when you are having nitrification and relatively high ammonia content, it can result in low pH affecting in the microbial growth especially if the alkalinity is low.

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Design

- First order VSS decay
  - $r_x = -K_d X$
  - $r_x = (X_0 - X)/\theta$
  - $X = X_0/(1+K_d\theta)$
  - θ = 20 days typical, (function of temperature)
    - can separate solids retention time from hydraulic retention time if settle and remove supernatant

Let me go ahead and start summarizing aspects. Here we are talking about degradation of volatile suspended solids. In the activated sludge process, we were trying to promote the growth of these microbes which you are trying to measure by VSS or MLVSS. Mixer liquor volatile suspended solids to degrade your waste. Here the waste itself that I am concerned in degrading is this microbial.

Microbes which I am going to measure by volatile suspend solids. I am concerned with decay of the volatile suspended solids, that is what I have. This has to be a k, r x is equal to–k d into x, x is the concentration, if it is for CSTR simple balance you can get the relevant equation. And typically looks like we are looking at the 30 days of retention time.

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Typical design criteria for aerobic digesters

Parameter	Range of values
Mixing requirements	
Mechanical aerators/mixers	20–40 kW/10^3 m^3
Diffused air mixing	0.02–0.040 m^3/min · m^3
Reduction in VSS	38–50%
Tank dimensions	
Depth for diffused air	4.5–7.5 m
Depth for mechanical air	3–6 m
Circular diameter[b]	12–45 m
Rectangular	
W:D	1:1 to 2.2:1
L:W	≥ 5:1

[a]PSRP = process to significantly reduce pathogens.
[b]Circular is the typical configuration.

General values but key aspect is that temperature but in India because the temperature is relatively warm that is why you see that the constants are relatively higher. And that is why even if the plant operation is relatively poor or such we can get by. But in most of the European or northern American or southern American countries, the temperature is more or less in this range if not lower and their plant operation becomes a key requirement.

As we can see oxygen requirements, one for the cell tissue, here they are talking about 2.3 Kgs of oxygen per kg of VSS destroyed but it depends upon the formula that is used for the one that we use we got a different number. Oxygen concentrations around 1 milligram per litre and then waste activated sludge but I will skip these aspects.

Mechanical requirements as you can see requirements are typically for aeration and for and or mixing, this is the key aspect which drives the energy cost and the other aspect is the depth for diffused air and the circular diameter as you can see concentration, high retention times, I think theta was pretty high as we saw that is why the dimensions are going to be relatively high here, so let me move on.

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Aerobic digester under air. The solids concentration must be controlled. Concentrations above 4 percent will impede mixing and adequate dissolved oxygen levels. A concentration above 2 percent yields a smaller digester volume, a higher oxygen input per unit volume and increased levels of volatile solids destruction.

This is what a typical one looks like let me see the information that we have here. This solids concentration must be controlled that something that we always know, concentrations above 4% will impede mixing. And adequate dissolved oxygen levels might not be maintained if the solids concentration is too high.

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That is something to know. These are general aspects, this is an aerobic digester, not a typical activated sludge process. You see the airline waste activated sludge that is coming in for recycle to maintain the relevant microbial activity at the relevant concentration.

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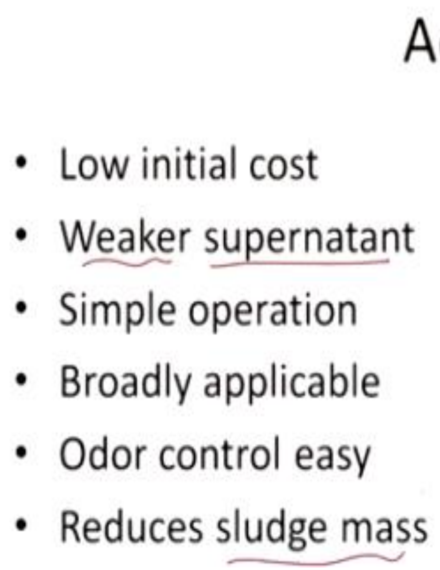

Evaluation, what are the typical advantages, relatively low initial cost, it is all relative. And one advantage is compared to the anaerobic digester, the supernatant is weaker relatively simple operation. And activated sludge process widely used and adapted applicable to considerable range of waste and odour control is easy and we can reduce the sludge mass.

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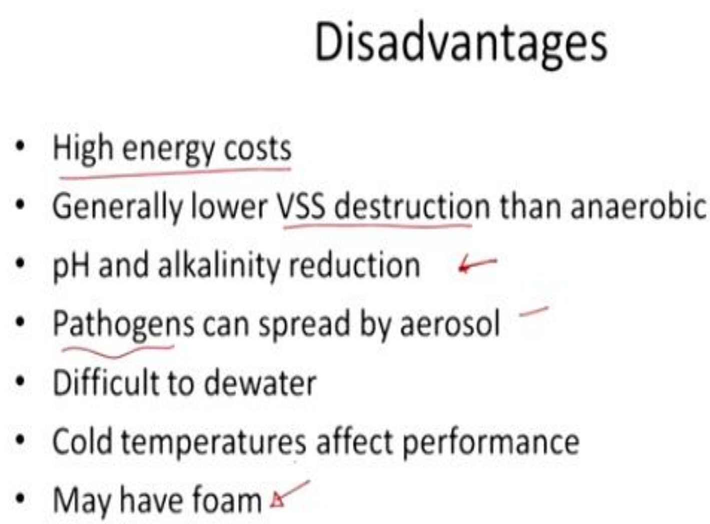

Let us see but disadvantage obvious issue is that as I have been parroting since quite some time it is remarkably high energy cost and compared to anaerobic as mentioned earlier the VSS degradation is going to be relatively lesser. And these are aspects that are always coming into play with respect to pH and alkalinity decrease. And one other key aspect here is unlike the anaerobic digester which is relatively close aerobic digester.

You have it open to the atmosphere and you are pumping air through it continuously. There is an exchange with the gaseous phase and so pathogens can be spread by the aerosol that is one aspect to keep in mind. And looks like it is difficult to dewater later on relatively difficult to dewater and cold temperatures as with any biological process are going to affect the performance.

And we also looked at some of the foaming related issues. Depending on the type of F by M we have different foaming related issues.

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Autothermal aerobic digestion

And then auto thermal aerobic digestion, let us see what it is.

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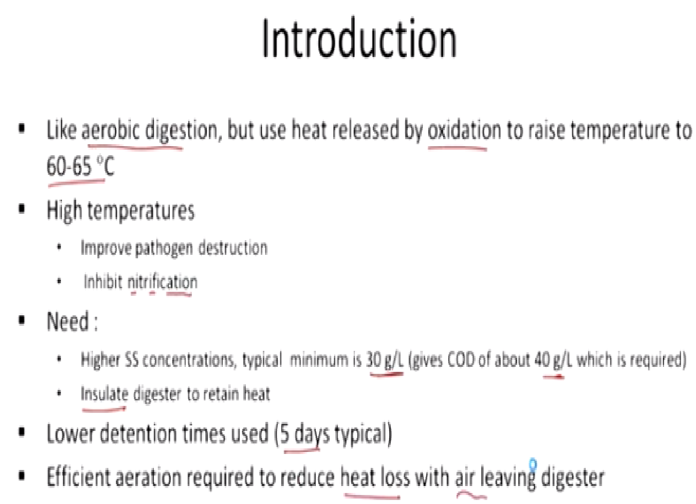

I will more or less start summarizing from here, its aerobic digestion its autothermal aerobic. It is aerobic but thermal too but we use heat released by oxidation to raise the temperature to 60 to 65. During oxidation, energy is released in that particular process, rather than allowing that heat to dissipate we are going to try to use that heat to heat up the system, that is why it is auto thermal.

High temperatures meaning improved pathogenic reduction destruction and also preventing nitrification or inhibiting nitrification if required. What do we need? We need higher suspended solids concentration. And typically, it looks like we have the minimum is around 30 gram per litre meaning COD is around 40 gram per litre, that is something to keep in mind, 40 gram is 40,000 milligram per litre.

Now you get an idea about the high concentration that is needed. And if I am trying to retain the heat, I have to insulate the digester and because of the higher temperature, kinetics are faster. And that is why retention times are relatively lower and efficient aeration is required, why? Because I do not want the heat to escape along with the air leaving the digester.

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Relevant aspects come into play with respect to design and the relevant operation. Let us quickly look at the advantages.

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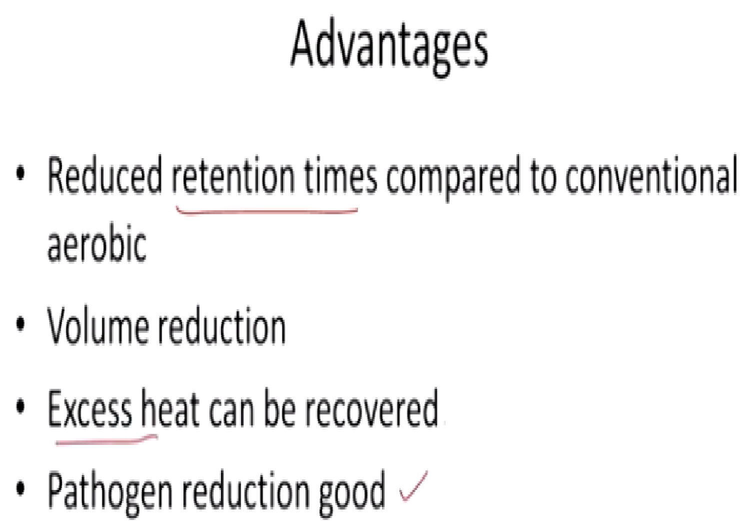

Retention time is relatively lesser, why? Temperature is higher volume is reduced. If the kinetics is faster the retention time lesser, then theta is equal to V by q the kind of the volume is going to decrease. Excess heat can be recovered and pathogens reduction, because of excess heat is going to be pretty good.

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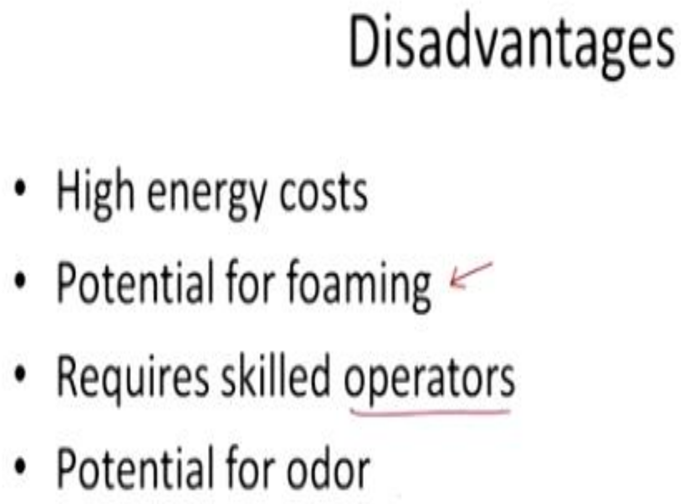

And disadvantage, high energy cost depending upon how well you are running it? Foaming is an issue and as mentioned earlier skilled operators, why? You are talking about trapping the heat that is generated having a high strength waste in their suspended solids concentration is such that is around 40,000 milligram per litre in terms of COD, you have to maintain these aspects.

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Let us move on to different kinds of composting now.

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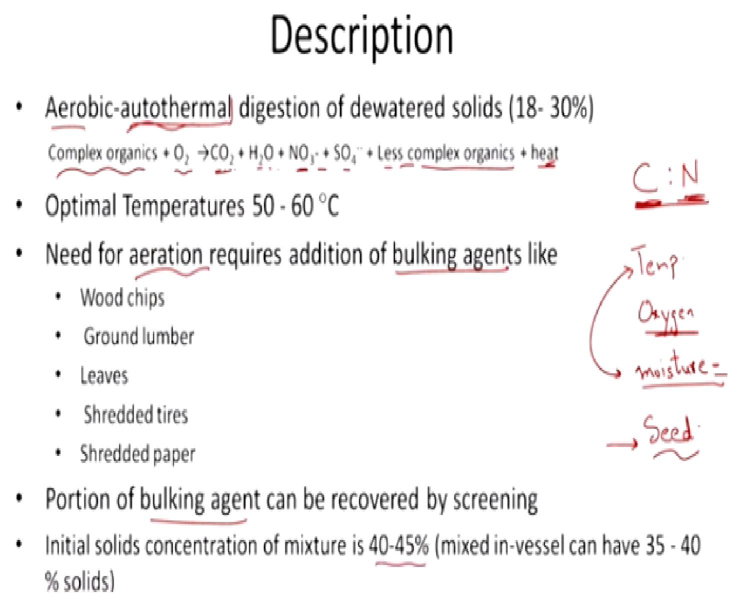

We are still in the context of stabilization. In stabilization, we have looked at anaerobic, aerobic and aerobic where the heat is reused and here, we are talking about composting. Composting, you would have heard that a lot, let us see what it is about. Aerobic autothermal digestion of dewatered solids fine and what is it that we are talking about? We have complex organics you are going to provide oxygen and then they are going to degrade to relevant oxidized products.

Carbon dioxide and NO3 and less complex organics and heat is also given out. That is why its auto thermal. Optimal temperatures 50 to 60, we need aeration and if we are aerating it, this is composting you would have heard of different kinds of composting especially with solid waste management or the waste from your kitchens.

If I am providing air and if my particles are pretty small, the air would not flow through it. You do not have the voids or interconnected voids for the air to flow through it relatively freely, that is why you are going to provide bulking agents. What is it that we typically add or can add? Wood chips, ground lumber, leaves, shredded tires. And after screening, later on the bulking agent or part of it can be recovered, that is one aspect to keep in mind.

In general, for composting if not for sludge at least if you are trying to composite it in your homes, so what is it that you need? Depending upon the type of waste the key aspect is to maintain a ratio between the carbon and the nitrogen. Primarily most waste that you are trying to compost, the process fails. Here we are talking about both the digestion in our context and also composting of your solid waste.

They fail because there is not sufficient carbon to nitrogen ratio as you know the microbes need carbon and nitrogen in different quantities. If one of them is missing, nitrogen is too low, carbon is too high and nitrogen is too low or if your carbon is too low and nitrogen relatively compared to the requirement is too high, then microbes are not going to thrive.

Here it is the mixture of adding a source of carbon, if required typical source of carbon can be dry leaves as such which they call as brown matter and nitrogen is typical organic waste from your kitchens. If you have a good enough ratio and then you can aerate it well and also you need to seed it, as in where are the microbes to grow from? They can go from what is in the nature, but then it is going to be too slow. You can add some seed initially, so that these are the relevant requirements.

Carbon to nitrogen, temperature, oxygen, moisture control too high and it will fail too low and microbes will not want thrive. If the moisture is too high, you are going to have issues with respect to the temperature that is being maintained as we can see here. And oxygen, these are the relevant aspects and seed, this is for the kitchen waste. But for sludge from secondary waste, do you need seed? Not really because you have the microbes depending upon the age of that sludge.

Let us see what else we have here but one aspect is initial solids concentration of mixture is 40 to 45 %.

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That is a high requirement. Aerobic stabilization, here I am showing the pictures for solid waste management also because I think that is relevant in our context. It can be different kinds of food waste and after this, all this will come into this particular form which is relatively more stable, this is composited organic which can be reused as a fertilizer or such or for gardening depending on what kind of waste you are putting in, that is one aspect to keep in mind

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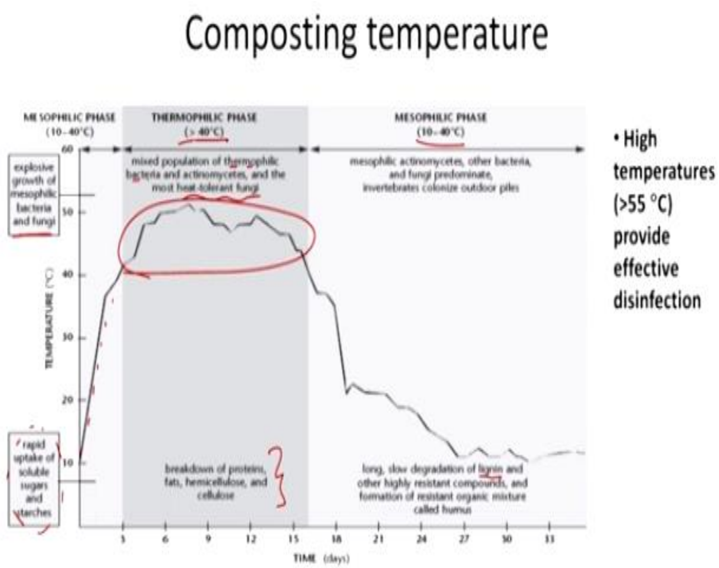

And in general, we have a thermophilic phase and a mesophilic phase. Here we have 2 stages; one is breakdown of proteins, fats and cellulose and the other one mesophilic which is relatively long and slow. Lignin remarkably difficult to degrade and those are going to be taken care of in this way, typically you have 3 phases but it is repetition of 2.

Mesophilic, initially rapid uptake of soluble sugars and starches, that is why you have explosive growth initially and then you are going to have thermophilic phase. And here you have thermophilic bacteria and actinomycetes and the most heat tolerant fungi, why? Because as you can see considerable is heat is generated during this aerobic composting. And that heat will ensure that the pathogens are going to die.

And only those kinds of microbes or organisms that can resist that heat will thrive in that, so temperature is a key requirement here in going from one phase to the other.

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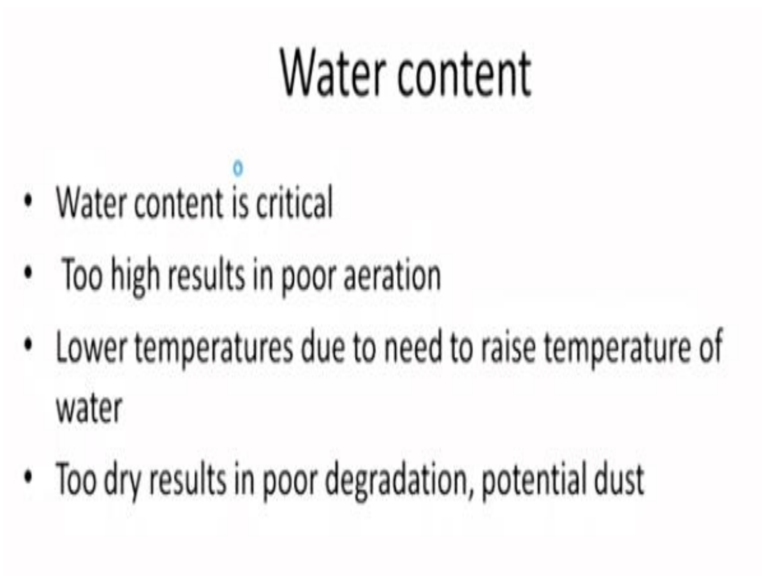

Water content, as I mentioned is critical if it is too high poor aeration and temperature will be affected. If it is too low then you are going to have microbial activity that is going to be very strongly effective and let us move on.

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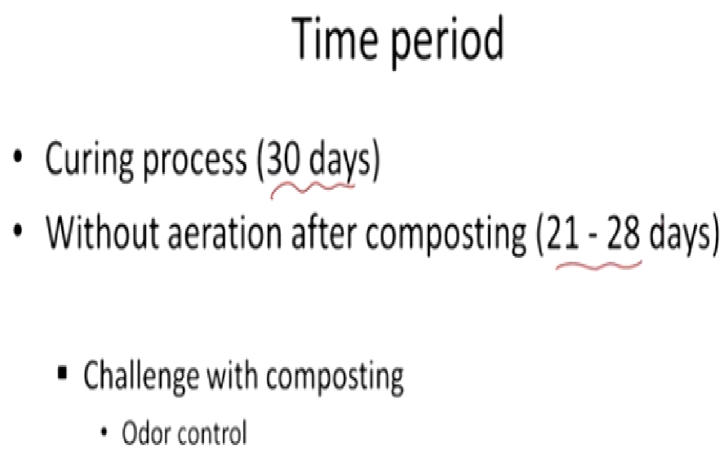

Looks like I am almost out of time let me finish up this composting and we will move on to the next session. Time period, what is it that you are typically looking at? 30 days, that is considerable lot. Without aeration after composting that is going to be 21 to 28 days relatively later. Challenge; Odour, if you are going to have composting in your surroundings and you do not take care of your process.

That can lead to odour, that is the one aspect to keep in mind and that is why even when the solid waste management or the municipality wants to set up composting units in the locality, that is why people typically either with or without knowledge typically push against it. But with considerable operational control you can prevent odour, that is the one aspect to keep in mind.

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In-vessel Composting

- Enclosed reactor
- Aerated
- May move as plug or be mixed
- Aeration control important as:
  - Too low temperature
    - Effects degradation
    - cause odor

In vessel composting that something that can be done as in you are going to have a reactor, its in vessel not open to the atmosphere which can be aerated. And it can be moved, such it is either a plug or mixed depending on how you are going to maintain it or design it. If the temperature is too low, it will affect the degradation and it will also lead to odour.

The kind of microbes that are going to thrive when the temperature is too low, it can lead to order problems and thus aeration and relevant control is required let us see.

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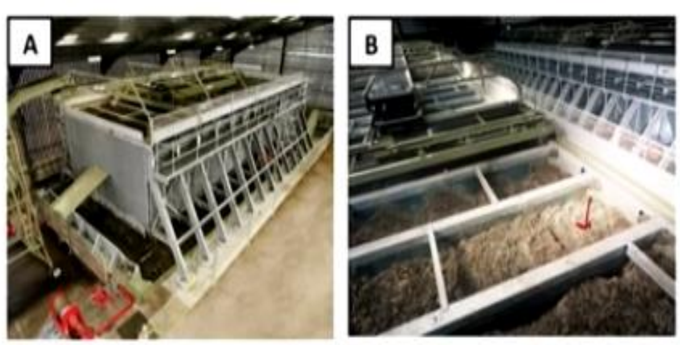
In-vessel composting



Here you have different kinds of In-vessel composters.

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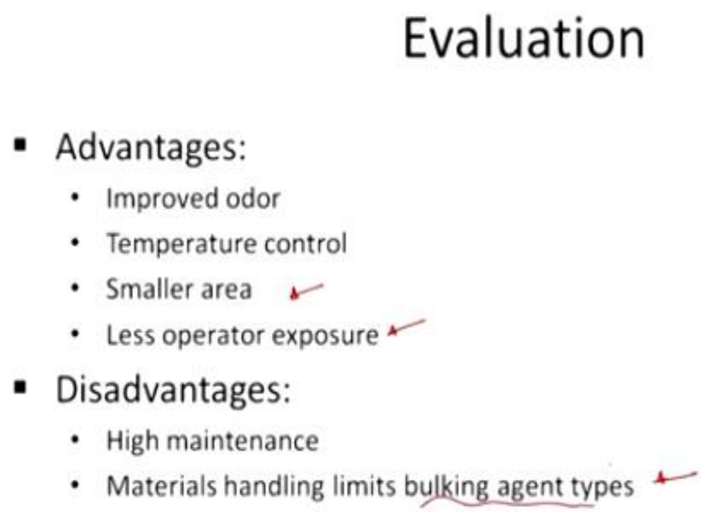

Evaluation, advantages; Improved odour, especially if you maintain it well. Temperature control, smaller area, that is the key aspect and less operator exposure. What are the disadvantages? High maintenance, material handling limits the type of bulking agents or material handling limit the type of bulking agents that can be used.

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With that I will end this session and in the next session which will be our last we will move on to the aerated static pipe. What are we discussing? We are discussing composting the sludge or stabilizing the sludge. Thank you for your patience.