Municipal Solid Waste Management
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Lecture - 35
Landfill Gas Collection and Treatment

Hello students, so we will continue today module 11, the disposal of solid waste. So, in the previous 2 lectures, I talked about the definition of landfill sites and or types of landfill sites the factor affecting site selection. And also in the previous lecture, I talked about leachate generation followed by treatment. Now today we will talk about the gas that whatever the polluted gas is coming out from the landfill site, how to control and what are the mechanisms to produce the gases? Different phases of gas production and also a few slides on the treatment part. So, is a landfill gas collection and followed by treatment.

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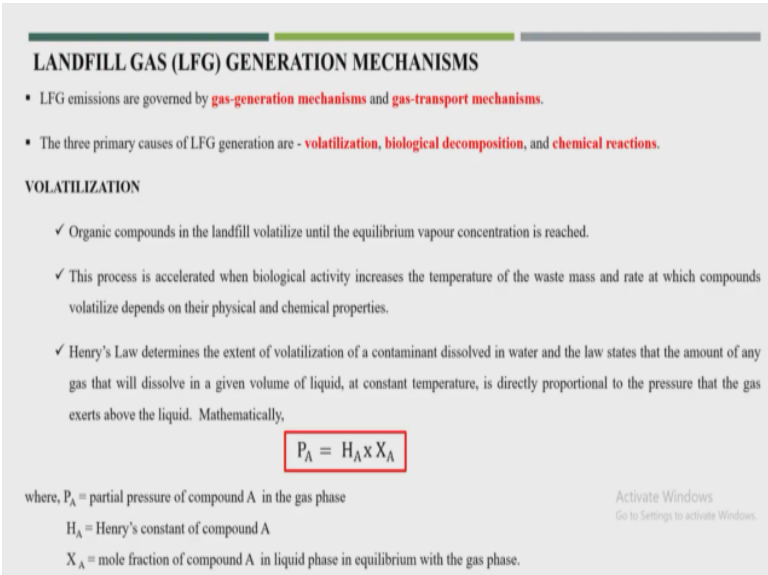

So first, we will go for landfill gas that normally called the LFG, generation mechanism. So, normally the mechanisms are by gas generation mechanism and gas transport mechanism. So, there are 3 major causes of landfill gas generation, first is volatilization, biological decomposition and chemical reaction. So, one by one we will see that what do you mean by volatilization?

So, what was the different cause of gas production? So, the first is through volatilization. So, an organic compound in the landfill will volatile or getting degraded without the addition of any kind of microbes, because microbes will grow very easily, whether it is an aerobic condition or anaerobic condition until the equilibrium concentration will reach. So, until that whatever is the volatile substrate is available.

Whatever the amount up to until that it will get volatile these organic compounds and this process will be accelerated again while the biological activity will increase based on the temperature also. So, the temperature will also increase and that is what if you see the gas production in an entire day in the night the gas production will be less compared to the daytime when the temperature reaches up to 35 or 40 degrees centigrade. So, obviously, at this temperature, the microbial growth will be very high.

So, in here very easy for those microbes to volatiles the organic compounds, which are very easy for biodegradation and now, these also we can explain by simply by Henry's law like mathematically we can explain this by pressure equal to Henry's constant multiplied by mole function of compound A in the liquid phase in equilibrium with the gas phase. So, likewise, we can calculate how much is gas production could be possible based on the pressure. How much is the pressure normally we will find in the gas phase. Now, this is the first one volatilization.

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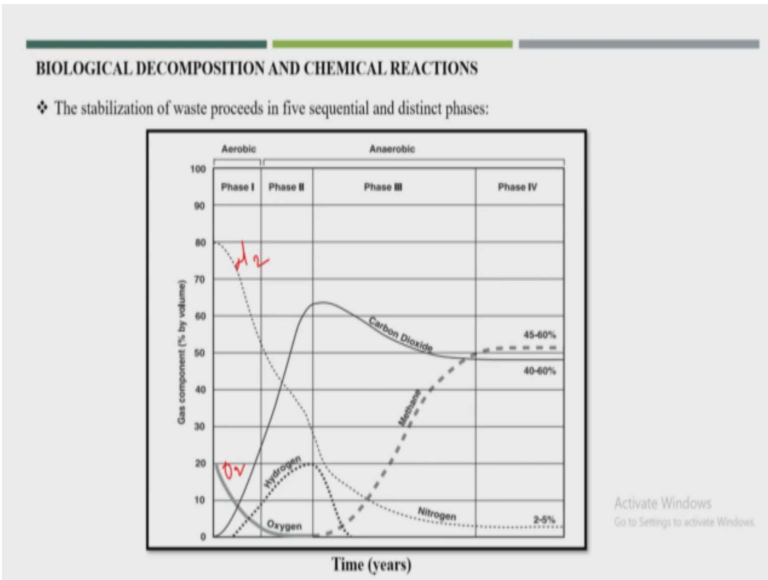

Next is biological decomposition. So, this biological decomposition we can easily separate out in the different phases. Normally there are 5 phases by that way we can easily explain the biological decomposition or what could be the chemical reaction could be possible and normally, these biological decompositions under the anaerobic condition, so, you already in I think, last one module, we talked about anaerobic digestion.

So, whatever the phases in the anaerobic digestion, almost those phases also will easily find in the landfill site. So, based on that you see here and different phases of the different gas production. So, normally in phase 1 which is a mostly aerobic condition because in the voids the air will be available? So, in that case, the nitrogen and oxygen gas is nitrogen gas. So, this is nitrogen gas this is oxygen gas. So, this will be produced very easily, but once it will change into the anaerobic condition.

So, slowly the hydrogen production will start and after that, carbon dioxide production will start. So, if you see the carbon dioxide production and methane production, now in the phase 3 mean mostly is the acid phase, where carbon dioxide will be amount will be more compared to the methane one. And finally, in the last 4th phase, the methane concentration will higher than compared to the carbon dioxide concentration in the last phase 5th phase will be the maturation phase finally, which will go one by one the different phases.

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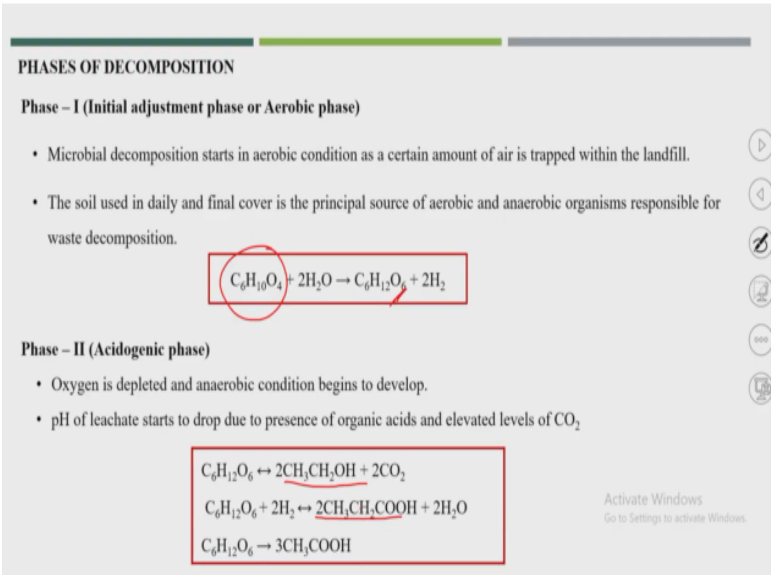

Phase 1 is an initial adjustment phase or is an aerobic phase. So, as I was explaining about that in the voids because is a simple waste has been disposed of and if you are not compacting that waste means the initial period especially will be under the aerobic condition only because in the voids there will not be any degradation. So, in the void also water would not be there in the voids so, mostly air will be there.

So, whatever the degradation could possible in that particular conditions will be the aerobic one and mostly the gases will produce like nitrogen and oxygen gas will get produced. So, here in the chemical reaction also if you see this is a simple glucose kind of or simple non-volatile matter organic compounds will get degrade very easily in the aerobic condition. Now, the next phase is acidogenesis phase, the same as in the anaerobic digestion process, but in the anaerobic digestion process, the phase 1 will be hydrolysis.

And followed by acidogenesis now, in this case, aerobic phase or initial adjustment phase followed by acidogenesis phase now, here the oxygen will be depleted and under we condition begin to develop. So, still, in the same phase 2, the entire amount will not be under the anaerobic condition clearly now is trying to because in the voids the because of degradation water will be there so, slowly is going to the anaerobic condition.

So, in that case; your pH also of leachate starts to drop due to the presence of organic acids and elevated level of carbon dioxide. So, in this case, same whatever has been produced here, we will again now producing is you see here this is the VFA volatiles fatty acids but is a mostly the carbon concentration is more into here like is a C_2H_5COOH. So, that that is in the acidogenesis means long-chain fatty acids will get produced and you see here because of that not only the gas production will be different, but also the leachate quality also will get change.

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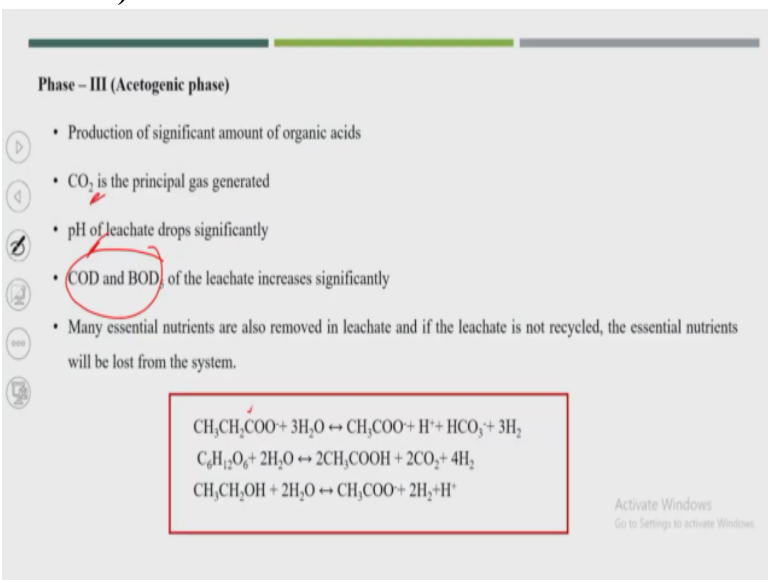

Now, the third phase is acetogenesis phase, where, most of these long-chain volatile fatty acids will convert into a simple acetic acid. So, here the major gas production will be the CO_2 and because of that the pH change or the acidic condition will be more into this one and the

COD and BOD_5 value will be maximum in this phase 3 and if you see the equations also now these long-chain VFA will convert into simple acetic acid these all acetic acid.

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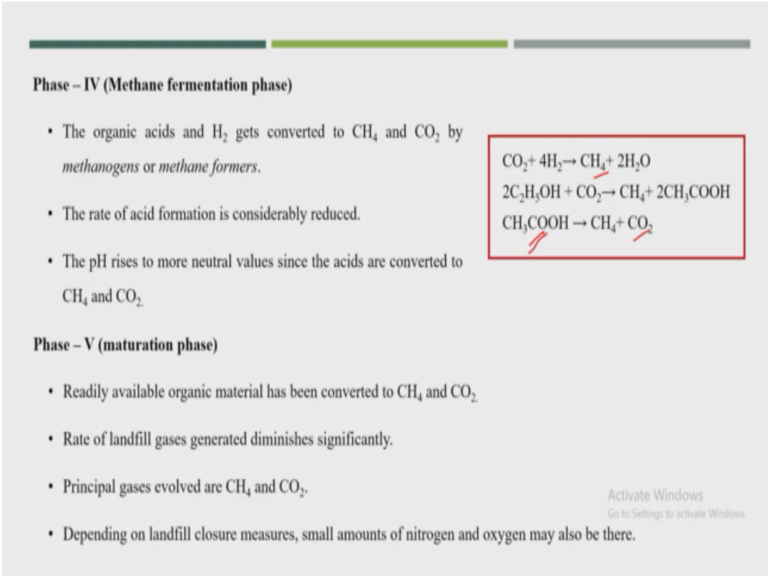

Now, the 4th phase is a methane fermentation phase obviously once the VFA production will be very high, though later on the methane phase will get started. So, now in this case that whatever the organic acids we are producing there is acidic acid and H_2 will convert to CH_4 and CO_2 and pH rise to more neutral value since the acids are converted to CH_4 and CO_2 and also nitrogen also will get degrade slowly. So ammonia production also will get increased because pH also will get neutralize.

So in this case, you can see that the same acetic acids are converting into methane and carbon dioxide, now the last phase is a maturation phase. So, now is a maturation means most of the biodegradable matter is got degraded under the rate of landfill gas generation also completely reduced and but still the principal gases will be the methane and carbon dioxide and also depending on landfill closure, measure the small amounts of nitrogen-oxygen may also be there.

So, this is also if you see the graph like in the last phase 5th phase here, if you see here also the small amount of nitrogen and oxygen you can find it in the last maturation phase.

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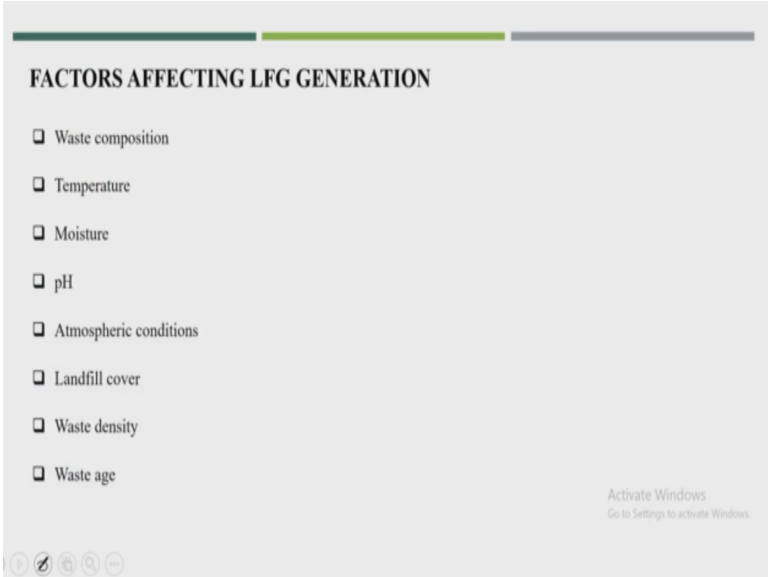

Now, what are the factors affecting landfill gas generation? So, there are a number of factors that are affecting when you compare all the factors the waste composition is a major one and again and again I am saying that if the waste composition will have more biodegradable fractions or more wet waste, obviously, the gas production will be more and continuously you are getting the more wet waste or biodegradable matters in the landfill site.

Obviously, landfill gas production generation will be very, very high and again depend upon the temperature also because as I was sharing that in the daytime the gas production will be more these also depend upon the local climatic conditions like if the normal temperature in a day or night if it is more than 20 degree or 25 degree centigrade. So, obviously, gas productions will be very high.

So, is somewhat good also because your degradation also will finish as early as possible otherwise, if atmospheric temperature is below 20 degrees, so, the degradation will not be that fast so, even landfill gas production also will be low and even the entire year also if you have similar kind of temperature, the degradation time for entire landfill site will be extended for more time also the moisture and pH are very important.

So, for moisture, I already explained in the last class that is what I think in the US these all whatever the leachate is getting produced that leachate again is getting recirculated because the upper part of the landfill area is getting dry and because of dry the microbial growth is not possible and that degradation also will be very slow. So, the moisture has to be maintained in the landfill site so that the pH gets neutralized easily.

So it will go for maturation as early as possible. Local atmospheric condition landfill cover is also important because that only you will be able to get the proper anaerobic condition in the landfill site. Suppose if it is a hybrid condition in the landfill, like somewhere is aerobic somewhere the top area will normally in the aerobic, bottom area be anaerobic. So obviously the gas productions also will be affected by that and waste density wastage.

This is also very important, waste density like if the density is more obvious, the degradation will be very high, but you have to compact the material. So, the conditions will be more anaerobic, but the anaerobic process normally is a slow process for degradation. Finally, in the wastage, the older the waste, the lesser will be the gas production from fresh waste and more gas production could be possible.

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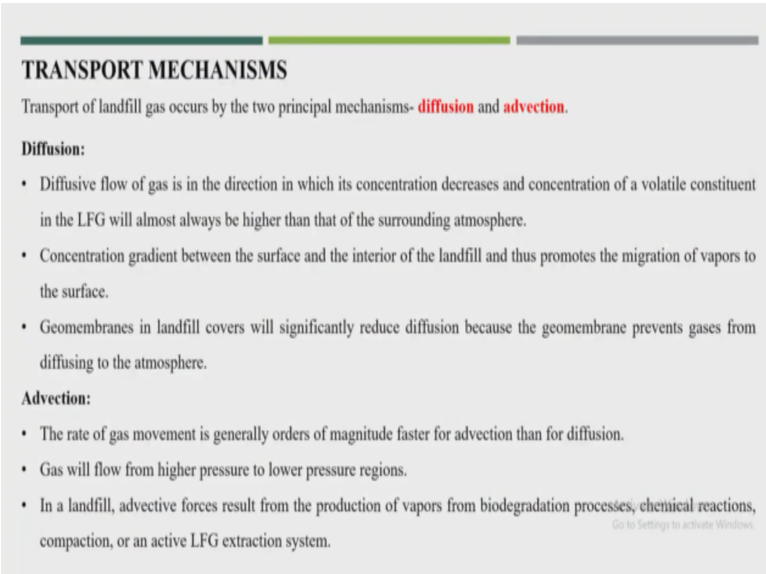

Now, the waste this landfill gas transport mechanism so, there are 2 major principal mechanisms obviously, that is in the diffusion and advection these are 2 mechanisms. So the diffusion is because of concentration. So, obviously the diffuse flow of gas in the direction in which the concentration decrease and concentration of volatile constituents in the landfill gas is almost always higher than the surrounding atmosphere.

So, the concentration of gas inside landfills will be higher than the atmospheric condition. So, whatever gas is getting produced inside the landfill, because of diffusion, the gas will come out very easily. So, it is because of concentration gradients and this is also one more like geomembranes in landfill covers will significantly reduce the diffusion, because the geomembranes prevent the gases from diffusion to the atmosphere.

So, suppose if we do not want to allow the gases to come out through the diffusion, so, maybe the geomembranes also will help us that is why in the geomembranes also are using normally in the into the landfill liner also because then it is possible that the gases will go into the could be a water-soluble into the leachate. So, and it will go to the groundwater that is also possible.

Now, next is the advection so, the advection is dependent upon the pressure so, the rate of gas movement is generally the order of magnitude faster for the advection than for diffusion. So, obviously, the gas will flow from higher pressure to lower pressure, and obviously, inside the landfill material that waste material obviously, pressure will be more compared to the atmospheric pressure.

So, in the landfill, this pressure because of the production of vapor from the biodegradation process, chemical reaction compaction, or active landfill extraction system, the pressure will be more so, that gases will come out easily into the atmosphere. So, these are the 2 major mechanisms from where the gases are getting generated in the landfill or getting transported from the landfill to the atmosphere.

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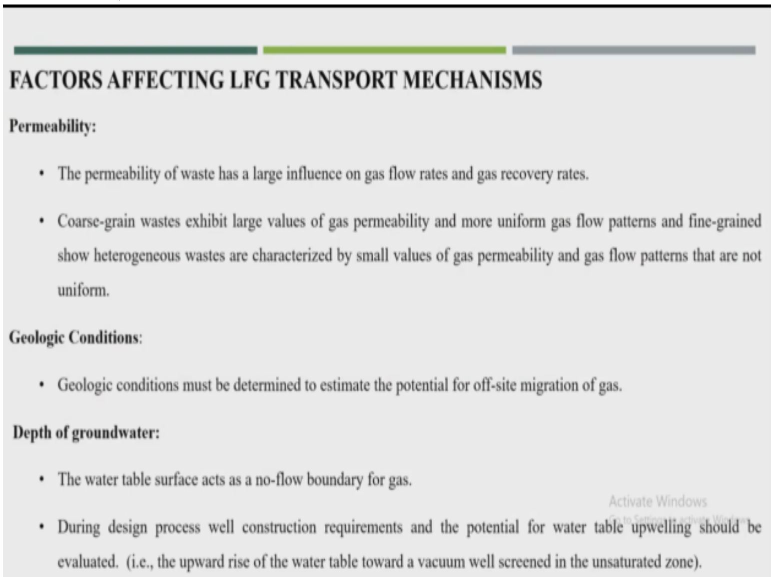

Next, is the factor affecting these transport mechanisms? So, the first is permeability if there is a highly permeable waste then obviously; whether is diffusion or whether is an advection will be very fast if there is a permeability, permeability means a lot of voids are available and easily that gas can come out from the landfill site to the atmosphere. So, normally these coarse-grain wastes exhibit large values of gas permeability and more uniform gas flow also could be possible.

But normally solid waste is coarse, obviously, the bigger size material, but it is not a homogeneous material. You need to remember that it is a heterogeneous kind of material. So, I think permeability will be very good. So, that gas can come out very easily. Next, is the geological condition, so, these are also important geological conditions and must be determined to estimate the potential off-site migration of gas and depth of groundwater, the water table is in the non-flow boundary for the gas.

So, what I was talking about the diffusion or advection could not only will possible in the atmosphere but also into the ground also in the water. So, if there is a water table surface it acts as a no-flow boundary for the gas during the design process well construct requirement and potential for water table upflowing should be elevated. So, that the; gas should not be leach out into the water.

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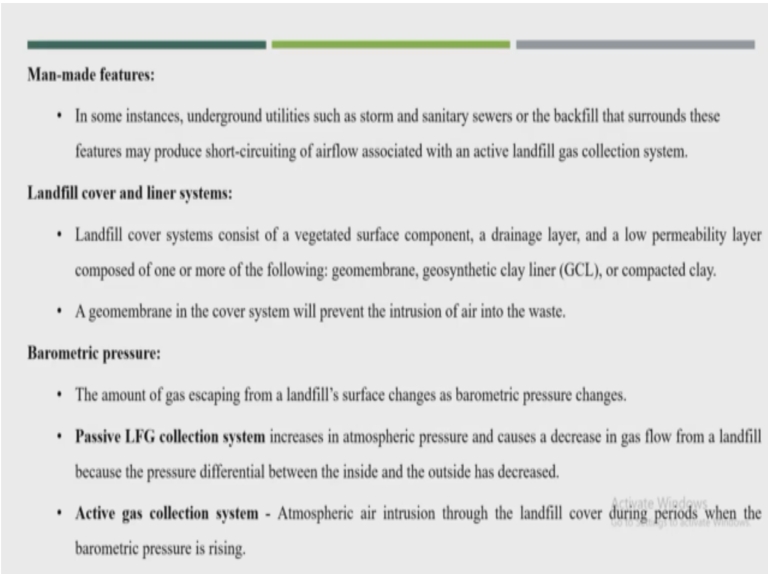

Next is a manmade feature, it is possible that in some instances like underground utilities such as storm or sanitary sewer is nearby. So, there could be a possible nearby to the landfill area could be possible to migrate those gases into such areas. Landfill cover in liner system so, landfill cover system consists of vegetated surface components or drainage layer and a low permeable layer composed of one or more following like geomembrane, geosynthetic.

So if that landfill cover is properly with geomembranes are your geosynthetic clay liners. Obviously, your migrations will be lower down from the landfill to the atmosphere and this another one like barometric pressure. So, in that case like passive landfill gas collection system increase the atmospheric pressure and causes the decrease in gas flow from the landfill, because the pressure difference between the inside and outside has decreased and in the active gas collection system, this is specially with the collection work.

So, if passive collection systems if you design so, increase the temperature or atmospheric temperature, so, that because of that your advection will be poor in that case and for active gas collection system like the atmosphere here, intrusions, through the landfill cover during periods when the barometric pressure is rising pressure is more so, we can get more amount of gas.

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IMPACTS, RELEVANCE AND TRENDS OF GAS-PHASE EMISSIONS FROM LANDFILLS

Compound	Concentration range	Scale of the impacts	Type of impacts	Relevance	Expected trend of emissions
Carbon dioxide	20-50%	global	global warming	high	↗
		local	vegetation, asphyxia	high	
Methane	30-60%	global	global warming	high	↘
		local	vegetation, asphyxia	high	(slow)
		local	explosion and fire hazard	high	↘
Aromatic HC's	mg m^{-3}	local	health hazard	low	↘
Halogenated HC's	mg m^{-3}	global	environmental persistence	high	
		local	health hazard, corrosion	high	
CFC's	mg m^{-3}	global	global warming	low	↘
PCDD / F's	mg m^{-3}	local	health hazard	punctually high (fires)	→
PAH's	mg m^{-3}	local	health hazard	punctually high (fires)	→
Other NMOC's	mg m^{-3}	local	odours, vegetation (ethylene)	low	↘ (slow)
Hydrogen sulphide	0 - 20 g m^{-3}	local	health hazard, odours, corrosion	high	↘

Now, here what are the gases the components or compounds are getting produced in the landfill gas and what is their impacts you can see here like carbon dioxide and methane are the maximum percentage like see the carbon dioxide and methane percentage is a maximum in the or you can say the principal gases, but also along with that and you see here their scale of impacts like global and local both means globally also and locally also could be possible.

And the type of impact could be global warming is a major one and relevance are very, very high, because both gases are greenhouse gases is a problem one and if you see their expected trend of emissions, so, carbon dioxide will be more the expected trend is more and from methane is low because this methane will produce only in phase 4 of the degradation. So, the concentration also will be low in that case, but along with that there are other more compounds like aromatic hydrocarbons, like see here pH this also could be possible along with that.

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Organosulphides	mg m[3]	local	health hazard, odours, corrosion	high low	➡
Carbon monoxide	0 - 3%	local	asphyxia, explosion	low	↘
Hydrogen	0 - 20%	local	explosion	low	➡
Mercury	10 - 24 ng m[3] a	global	dispersion and bioaccumulation	unknown	↘
		local	health hazard	unknown	
Si compounds	mg m[3]	local	wearing of equipment	unknown	↗
Ammonia	mg m[3]	global	NOx formation	low	↘
		local	odours, health hazard	low	
Nitrous oxide	mg m[3]	global	global warming	unknown	possibl ↗
Nitric oxide	mg m[3]	global	acid deposition	low	↘
Dust / aerosols	mg m[3]	local	health hazard	high for workers	possibl ↗

Carbon monoxide, hydrogen some metals like mercury also will get volatile and ammonia, nitrogen oxides and you see here the concentration is not that high, but their health hazard you can see that are the impact are there global or local impacts and the relevance also you can see is somewhat low. That is what the major relevance from the gases like carbon dioxide, methane.

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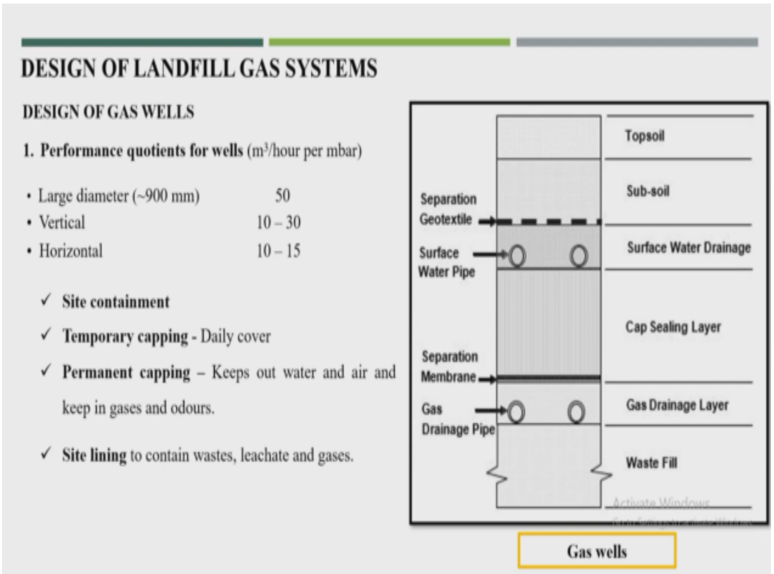

Now, when you talk about the design of landfill gas systems, so, first is the design of gas wells. So, normally we calculate the performance quotient for the well that is in the meter cube per hour or bar. So, normally the diameter, you can see that, here you can see diameter the vertical and horizontal also you can see and also again we have to see the site contaminants, what are the contaminants are there like temporary capping, we have to provide that is the daily cover on permanent capping keeping out of water and air and keep in gases and odors site lining to contain waste leachate and gas.

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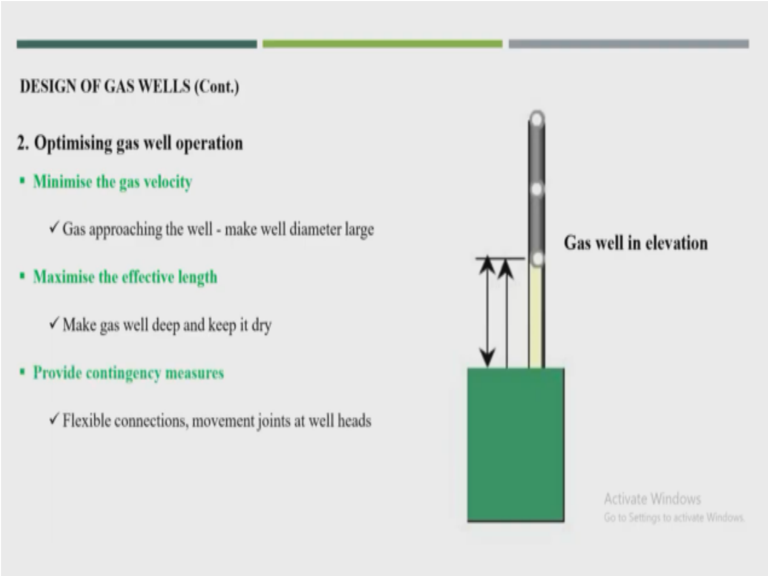

And also we have to optimize the gas-well operation and always you are saying that gas approaching the well, make well diameter large, the large diameter of pipe if you put if you use for gas collection that will be more beneficial and even the elevations also should be somewhat good for proper collection of the gas. So, what should be the maximize the effective length, make gas well deep and keep it dry. The pipe is deep into the waste and keeps it dry providing some contingency measures like flexible connections, movement joints as wellheads.

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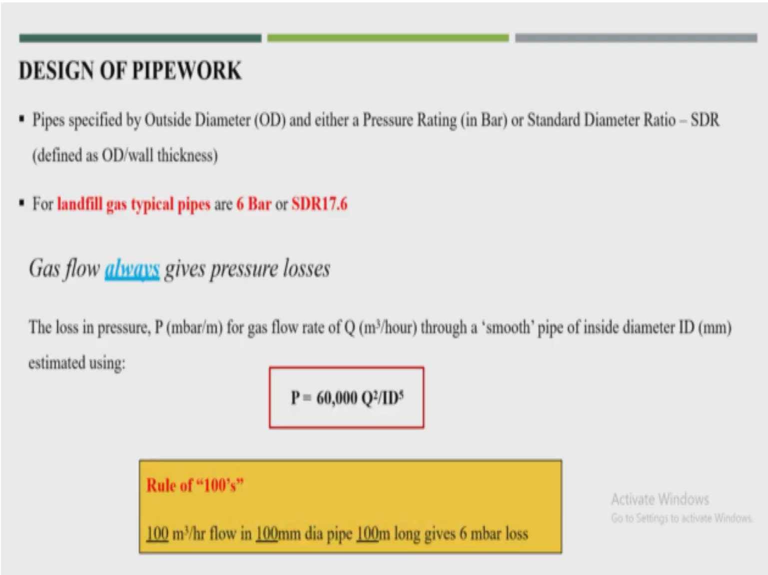

Now the design of pipe works so pipe specified by outside diameter and standard diameter normally we calculate. So, for landfill gas typically pipes are 6 bar and gas flow always gives pressure losses. So, the loss of pressure P for the gas flow rate of Q through a smooth pipe of inside diameter estimated using P = 60,000 into Q square / ID 5. So, this ID is the inside diameter of the pipe and normally we follow this rule we call normally called is a 100s that rule means, the 100 m^3 per hour of gas flow in 100 mm diameter pipe, 100 mm long pipe gives 6 millibar loss. So, normally we calculated based on these basics.

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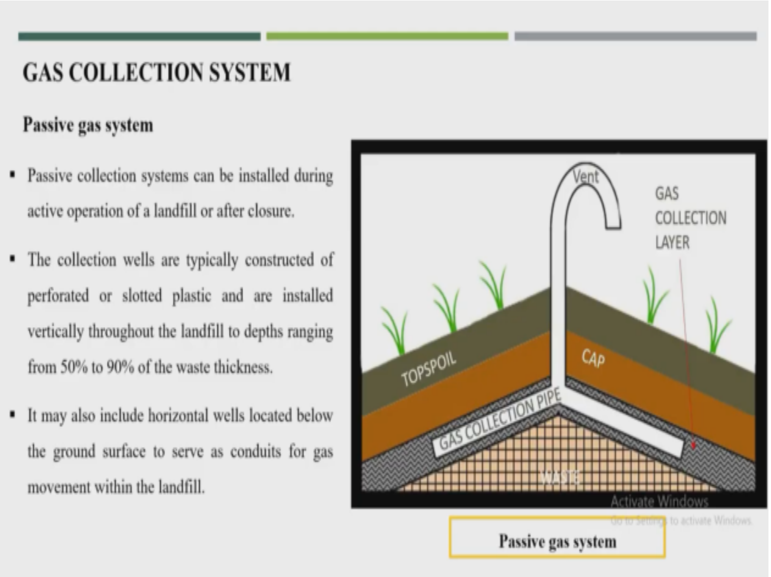

Now, for the gas collection system, there could be a passive gas system. So, these passive collection systems can be installed during the active operation of landfill or after closure also we can provide the collection wells that are typically constructed of perforated or slotted pipe slotted plastic pipes and are installed vertically throughout the landfill to a depth ranging from 50 to 90% of the waste thickness. So, even 50 to 90% thickness of the waste we can install these vertical pipes. It may also include horizontal wells located below the ground surface to serve as the conduit for gas movement within the landfill in the bottom also we can put.

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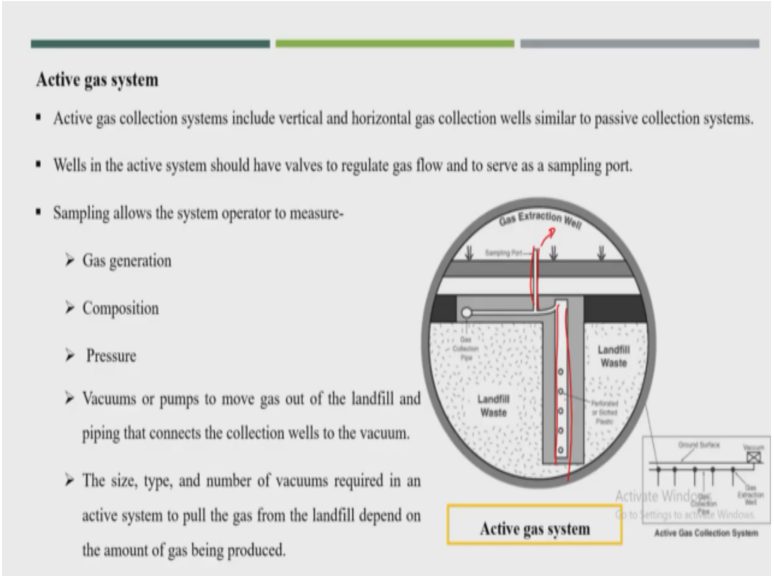

And also active gas system so, active gas collection system includes vertical horizontal gas collection well similar to passive collection system wells in the active system should have walls to regulate gas flow and serve as a sampling point. So, here is the vertical one. So, perforated slots this is normally plastic pipe slotted plastic pipe and now you can see here this is the sampling port also because time to time we can check what kind of gases are getting generated sampling allows the system to operate to measure the gas generation.

What are the compositions? What pressure? Vacuum or pump to move out of the gas landfill and piping that connects the collection well to the vacuum. So, while in the sampling, normally if you find that it is not possible to get the proper pressure or gas production is low, but you know that the degradation is there, but the gas production is poor. So, we can provide some pump or some vacuum pumps.

So, we can provide so that the gas can be collected by putting some pump and again the size and type and number of vacuums required in an active system to pull out the gas from the landfill depends on the amount of gas being produced. Otherwise, I think that even the pressure has to be fixed properly otherwise from these openings the water will come out easily.

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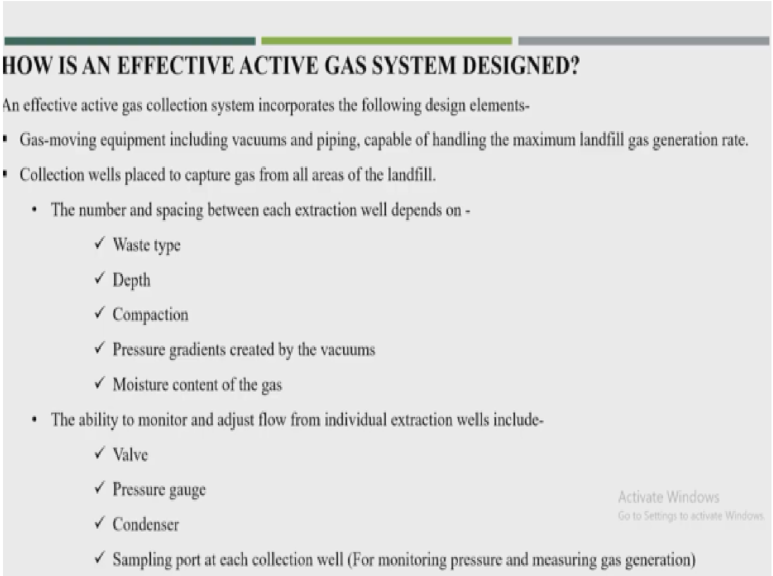

So, how is an effective active gas collection system can be designed with the following design elements the gas moving movement includes vacuum and piping capable of handling the maximum landfill gas generation rate, collection wells placed to capture gas from the oil areas of the landfill. The number and spacing between each extraction well depend on waste type, depth, compaction, pressure gradient created by the vacuum, moisture content of the gas.

So, again, I think it again depends upon the, what kind of waste? What kind of depth you are going? Based on that we can provide the number of gas collection pipes and even the spacing between those pipes also we can see that, the ability to monitor and just flow from the individual extraction will include the valve, pressure gauge, condenser, like when sampling port it each collection well.

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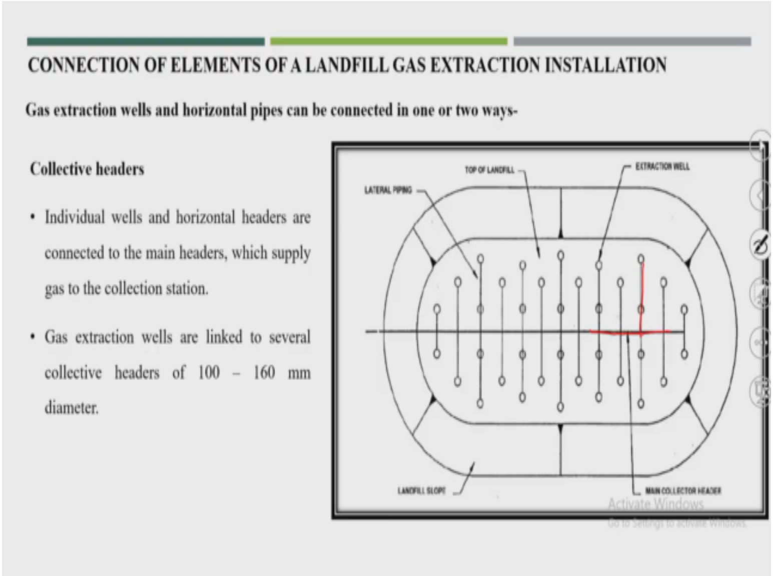

So, the connection of elements of a landfill gas extraction installation. So these gas extractions well and horizontal pipes can be connected in 1 or 2 ways. So the individual header could be possible. The individual headers required a single pipe running directly from each well to the gas collection system and the most popular pipe is 50 to 63 mm size pipe diameter size pipe is very common, so is an individual header.

So, each pipe directly from that directly gas going to the collection station, this is with the individual header and with collective headers, the gas extraction will link to the several collective headers of 100 to 160 mm pipe diameter. So, in this case, this will be your main collector header, this will be the main one and from these, the gases will come to the main collector header and will go to the collection stations finally.

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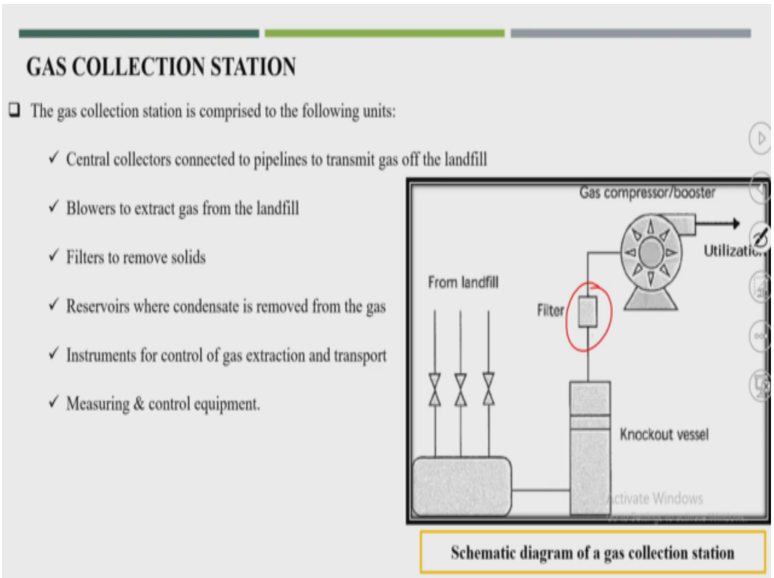

And, these gas collection stations also one side the entire gas is coming to the gas collection stations. So, which comprise the different units like central collector connected to a pipe to transmit gas of the landfill, blower to extract gas from the landfill and after that, we will be required 1 small filter to remove the solids could possible to come out and reservoir to condense it to remove from the gas and instruments for the control of gas extraction, transport and measuring and control equipment. These are the facilities you require in gas collection stations.

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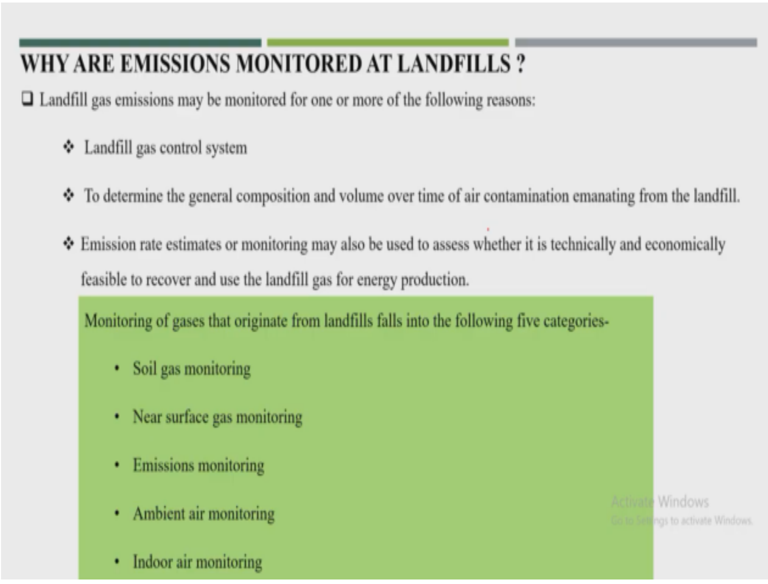

Why are emissions monitored at the landfill? So, landfill gas emission may be monitored for one or more following reason for landfill gas control system to determine the general composition volume or time for air contamination and emission rates estimated or monitoring may also be used to assess whether it is a technically and economically feasible to recover and use the landfill gas for energy production.

These are also the important point to monitor the landfill gas and monitoring of gases that originated from landfills falls into a 5 category. So, the soil gas monitoring, surface gas monitoring, emission monitoring, ambient air monitoring, indoor air monitoring.

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Key features of different types of monitoring of landfill gases

Monitoring	Description of Monitoring	Typical Parameters Reported	Relevance to Public Health
Soil Gas	• Soil gas monitoring programs measure the concentrations of chemicals in the vapor space of soils. Measurements of soil gas levels are taken at depth with the use of probes or wells.	• To report levels of methane around the landfill perimeter. Oxygen, carbon dioxide, and nitrogen are frequently reported. • Sometimes H_2S and other specific NMOCs, such as vinyl chloride.	• Because soil gas monitoring data at many MSW landfills typically (though not always) characterize levels of only methane, the data are generally useful for evaluating risks of explosion and for getting a qualitative sense of whether landfill gases are migrating in the soils to off-site locations.
Near Surface Gases	• Measures the concentrations of gases at a point no higher than 4 inches above the ground surface.	• Methane is the most common gas monitored but VOCs and H_2S are sometimes reported.	• Monitoring can qualitatively indicate whether high levels of landfill gas are escaping from the landfill surface or whether the landfill gas collection and control system is working well to minimize emissions.

So we will go one by one. Here you can see the monitoring of soil gas what kind of monitoring descriptions are required and what are the parameters normally measure in this particular soil gas monitoring phase and what is the relevance to public health.

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So, you can go through this like for emissions ambient air.

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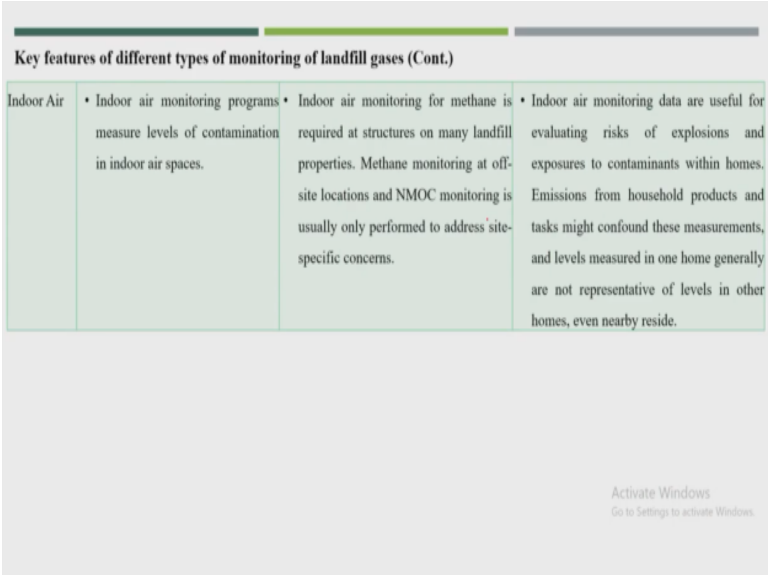

Key features of different types of monitoring of landfill gases (Cont.)

Indoor Air	• Indoor air monitoring programs measure levels of contamination in indoor air spaces.	• Indoor air monitoring for methane is required at structures on many landfill properties. Methane monitoring at off-site locations and NMOC monitoring is usually only performed to address site-specific concerns.	• Indoor air monitoring data are useful for evaluating risks of explosions and exposures to contaminants within homes. Emissions from household products and tasks might confound these measurements, and levels measured in one home generally are not representative of levels in other homes, even nearby reside.

And finally for indoor air like just an example like indoor air monitoring program measure levels of contamination indoor air spaces. So, indoor air monitoring of methane is required to structure on mini landfill property like methane monitoring of off-site locations is important to address the site-specific concern and indoor air monitoring data are useful for evaluating the risk of explosion and explosion to contaminants within homes. This is regarding public health.

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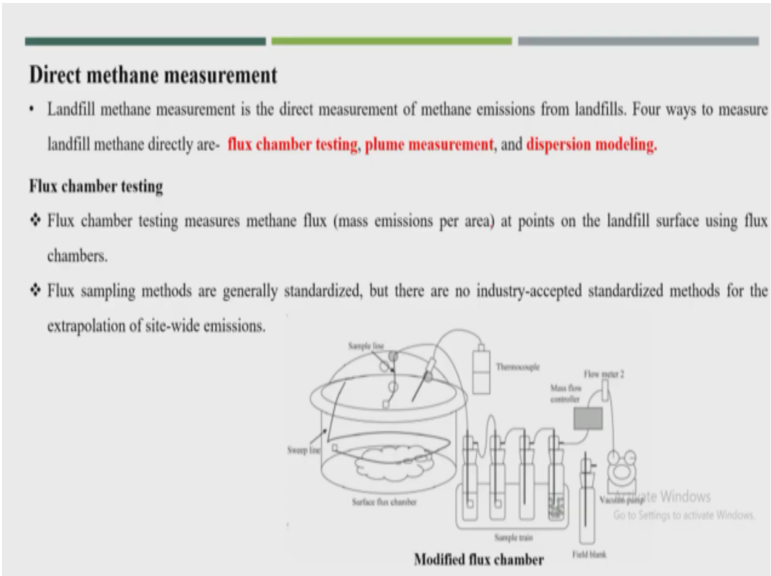

And there is another way we can calculate the methane concentration by direct methane measurement. So, there are 3 major methods or different ways we can calculate the direct method measurement like flux chamber testing and plume measurement and dispersion modeling. So, in flux chamber, this is one of the easiest methods you go to the one particular flux chamber this you can fabricate anytime very simple.

And with this one, we can collect how much is methane is getting produced that you can check in the laboratory how much is methane production could possible. So, normally researcher those who are working on to the landfill one and specially or air pollution scientists they want to know the how much is the gas production could be possible from landfill area? So, they can use this method very easily and can measure the methane concentration.

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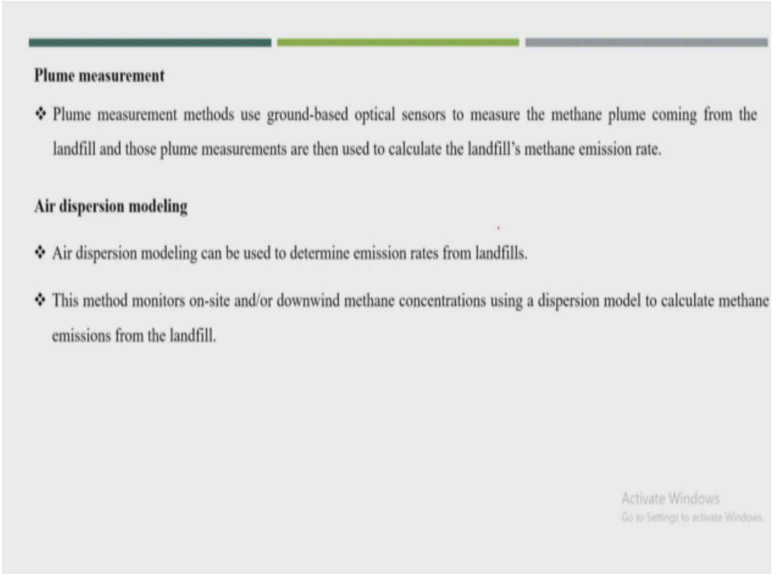

Next is the plume measurements flow measure methods are ground-based optical sensors to measure the methane plume coming from the landfill. And the air dispersion modeling also could be possible can be used for landfill gas this method monitor on-site and downwind methane conservation using a dispersion model to calculate methane emission from the landfill.

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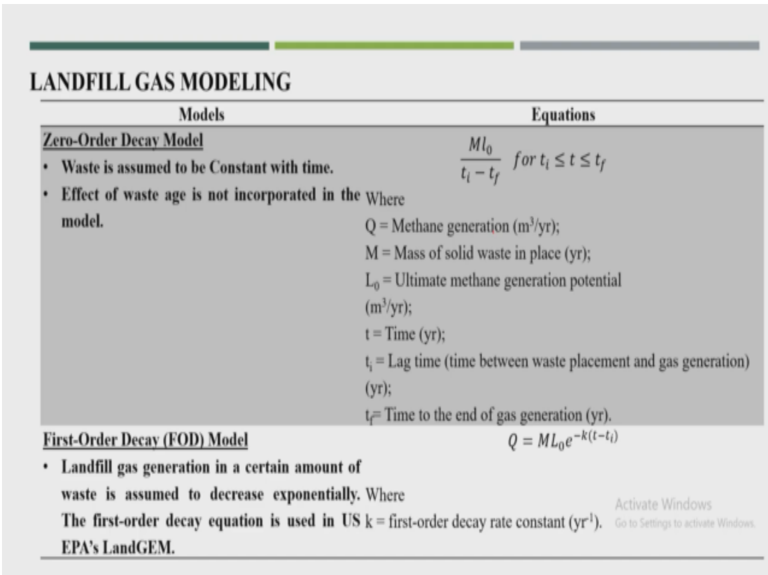
LANDFILL GAS MODELING

Models	Equations
Zero-Order Decay Model • Waste is assumed to be Constant with time. • Effect of waste age is not incorporated in the model.	$\frac{ML_0}{t_i - t_f}$ $for\ t_i \le t \le t_f$ Where Q = Methane generation (m^3/yr); M = Mass of solid waste in place (yr); L_0 = Ultimate methane generation potential (m^3/yr); t = Time (yr); t_i = Lag time (time between waste placement and gas generation) (yr); t_f = Time to the end of gas generation (yr).
First-Order Decay (FOD) Model • Landfill gas generation in a certain amount of waste is assumed to decrease exponentially. The first-order decay equation is used in US EPA's LandGEM.	$Q = ML_0e^{-k(t-t_i)}$ Where k = first-order decay rate constant (yr^{-1}).

So, now, I think once we know that how much is methane is produced or if you have the data for 10 years 15 years for methane production or gas production from the landfill we can model that and there are majorly few models are available initially started with the 0 order decay model is a simple model where the methane generation we can calculate by mass of solid waste or how much is the mass is available?

And how much is the ultimate methane generation potential that L_0 by that way we can calculate and again this has been modified with these zero-order decay model, then it has come to the first-order decay model this is the very popular one which is this also had been used by environmental protection agency the US in the LandGEM model, which I am going to discuss.

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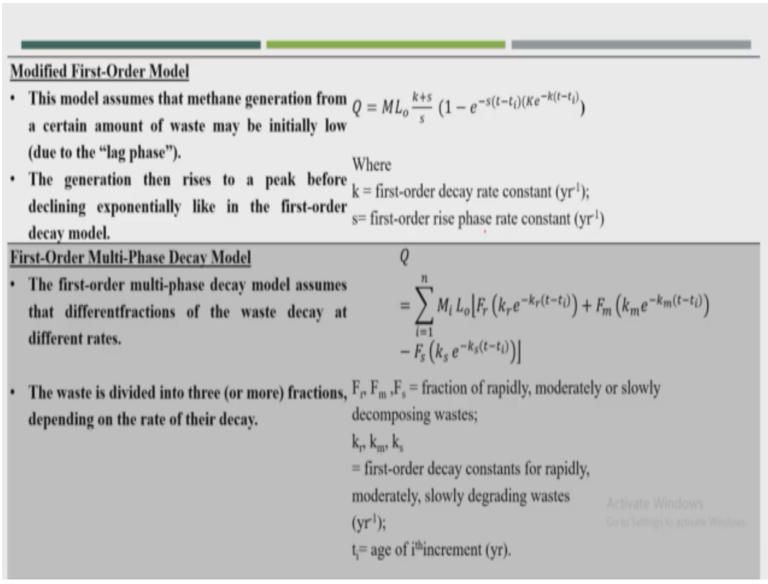

So, is a modified first-order model and first-order multiphase decay model these are the few models are available and those who are interested to know that how these gas generations are changing with the time or different environmental condition how the concentration of these gases is possible to change that we can easily model out.

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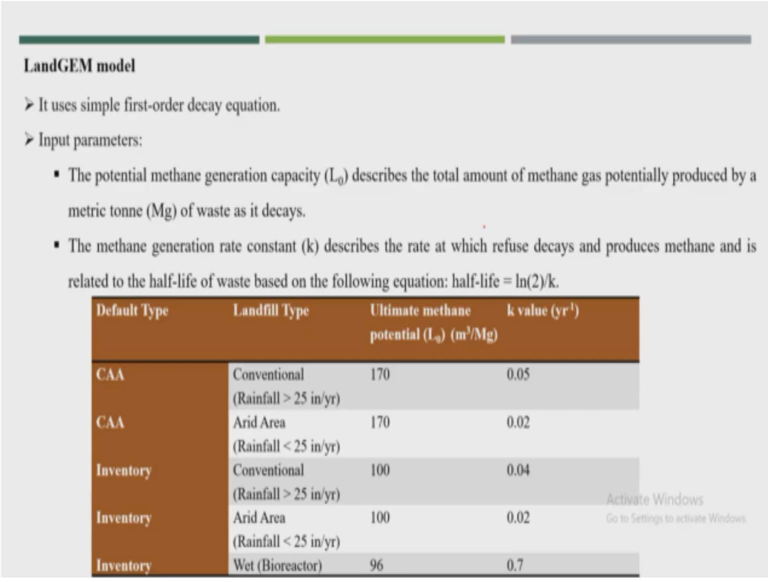

Now, and we have 2 major models. In that way, we can know how much is the gas emissions could be possible this is very simple is a first-order decay equation, where the input parameter is the same within potential methane generation capacity L 0 and by that way describe for a different amount of methane gas potential produced by the metric tonnes of waste as it decays and methane generation rate constant k described.

And these are the different values are given for ultimate methane potential in the different areas and the k value for that there is methane generation rate constants. And by that way, this model can calculate how much gas concentration is possible.

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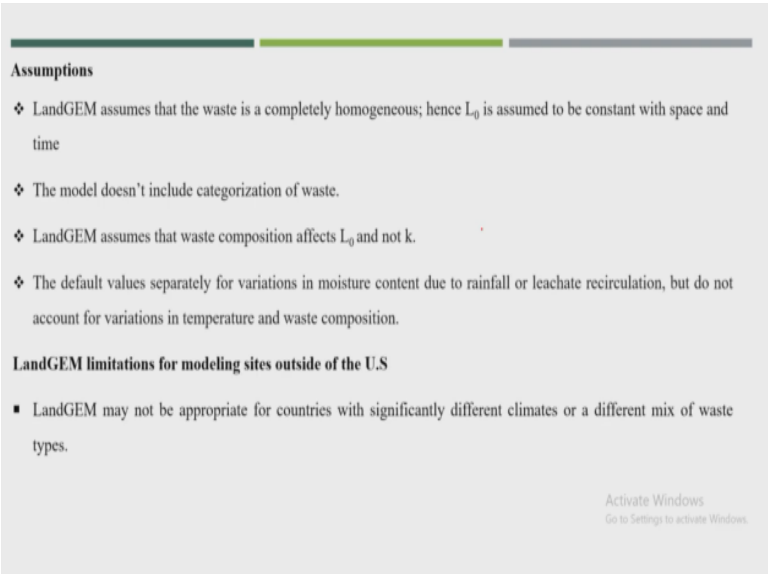

There are a few assumptions here like it is assumed that waste is completely homogeneous which is one assumption that has to be there in the LandGEM model, and the model does not include categorization of waste. LandGEM assumes that waste composition affects L_0 and not k. So, likewise, there are some other limitations of the model.

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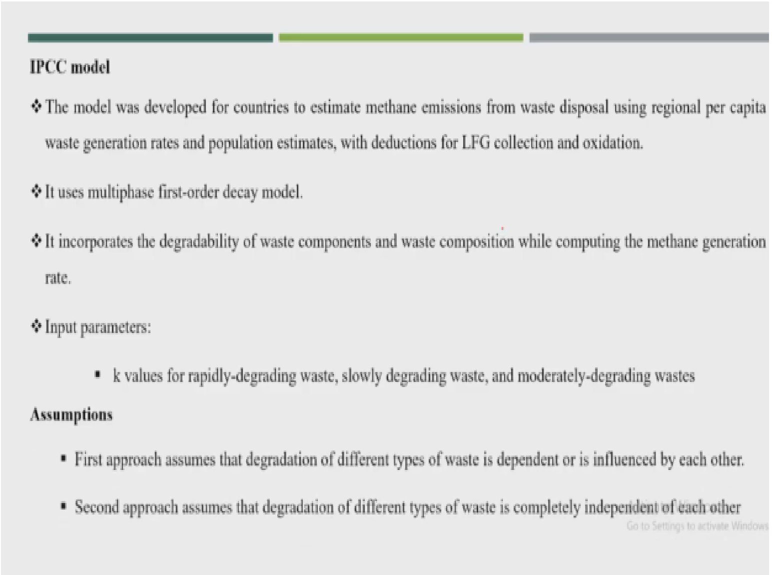

And next is an IPCC model which is a modified one, the model was developed in the countries to estimate within emission from waste disposal using regional per capita waste regeneration rate a population estimates with reduction of landfill gas collection oxidations, it uses the multi-phase, first-order decay model and it incorporates the degradability of waste components and waste compositions while computing the methane generation rate.

The input parameters are the same k value for rapid degrading ways and our assumptions also simple the first approach is to assume degradation of different types of is dependent or is influenced by each other and one is an independent.

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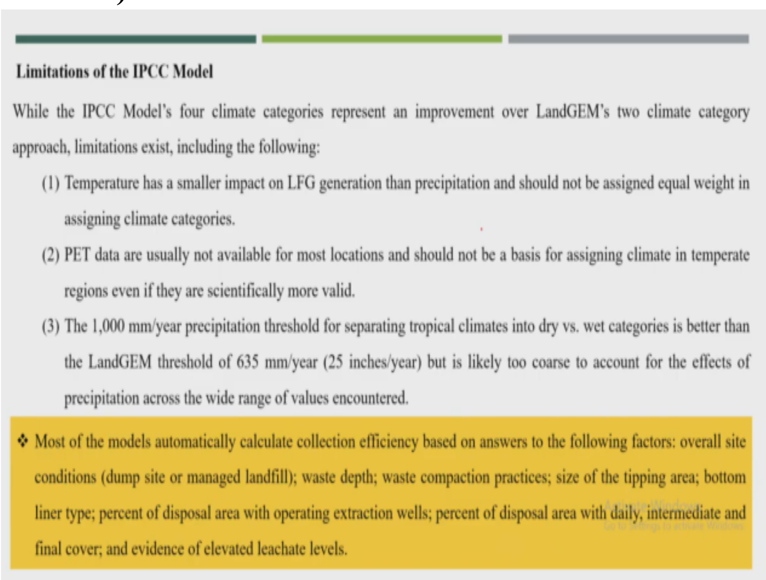

The limitations are also they consider 4 climate categories. So, most of the models automatically calculate collection efficiency based on answer to the following factors overall site conditions waste air, waste compaction practice, size of tipping area, the bottom liner type, percent of disposal area with operating extraction well, percent of disposal area with daily intermediate and final cover evidence of elevated leachate level I think by these 2 models you can easily calculate.

But again, I think I believe that for developing countries like India or other South Asian countries where more amount of biological waste is there. So there and here also the different kinds of biological waste are reaching to the disposal site. So, we need to have a special model for us. And our climatic conditions are also different in the entire country are different. Like if you take the example of the northeast where atmospheric conditions are completely different than the mainland part of India.

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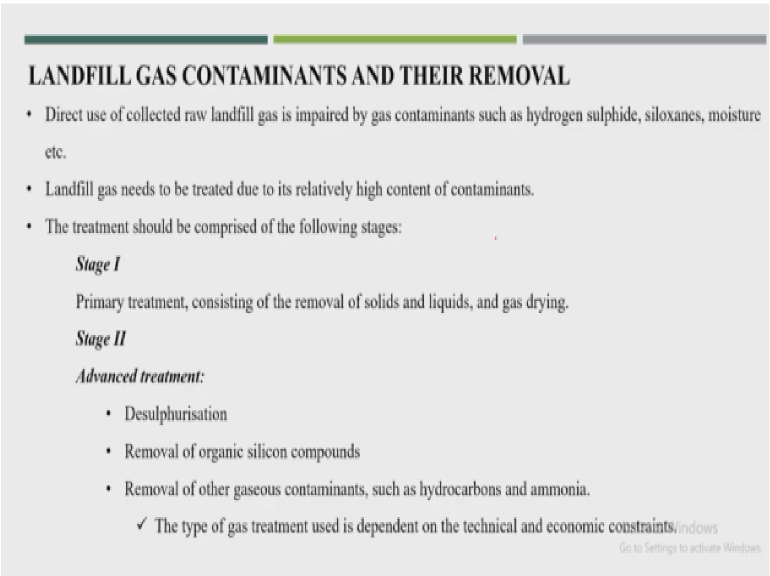

So, landfill gas contaminations and their removal direct use of collected landfill gas impaired by gas contamination such hydrogen, sulphide, siloxanes and moisture, landfill gas need to be treated due to a relatively high content of contaminations. And there are contaminations in stage 1 and stage 2. The primary treatment considered removal of solids, liquid and gas drying, that is the major treatment, and the stage 2 desulphurization or organic silicon compounds removal.

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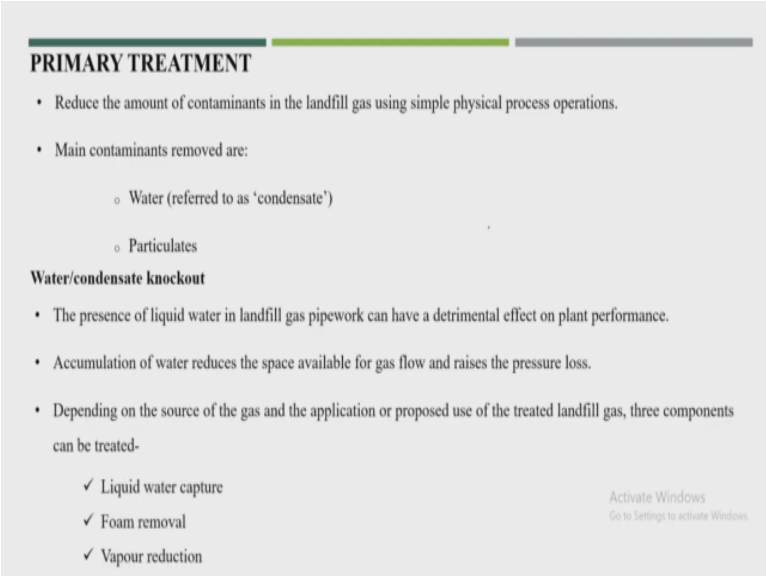

So, the primary treatment is very simple to remove the water in the gas particulates.

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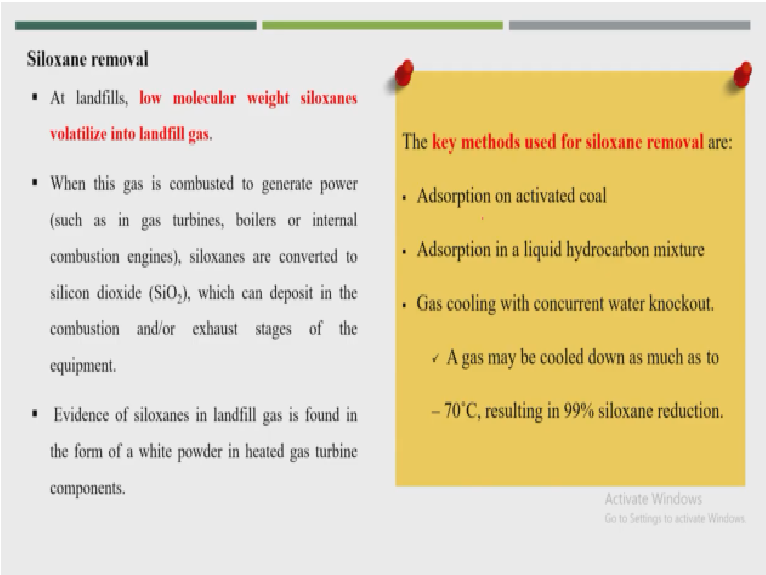

And siloxane removal this in the basic removal. But normally these siloxane removals could be possible by absorption on activated coal is one of the easiest methods to remove these concentrations.

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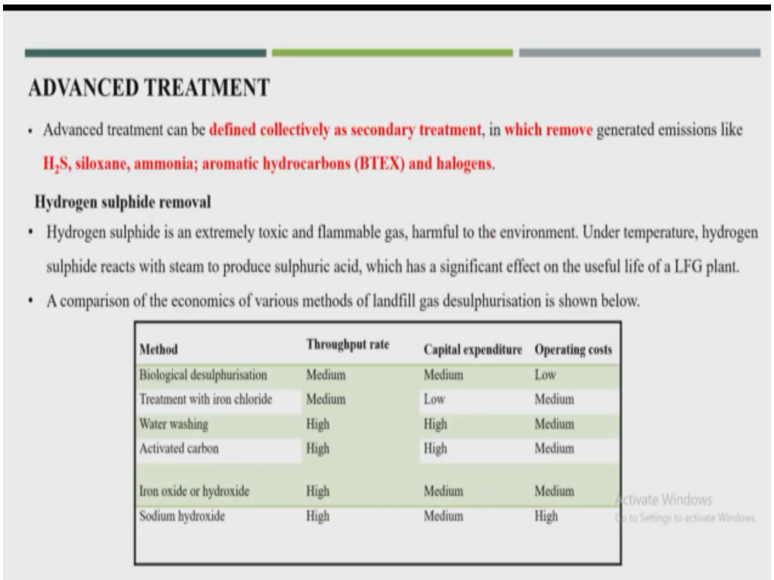

And for advanced treatment like desulphurization like hydrogen sulphide removal could possible and there are different methods you can see like biological desulphurization or water washing activated carbon is also a method to treat these gases.

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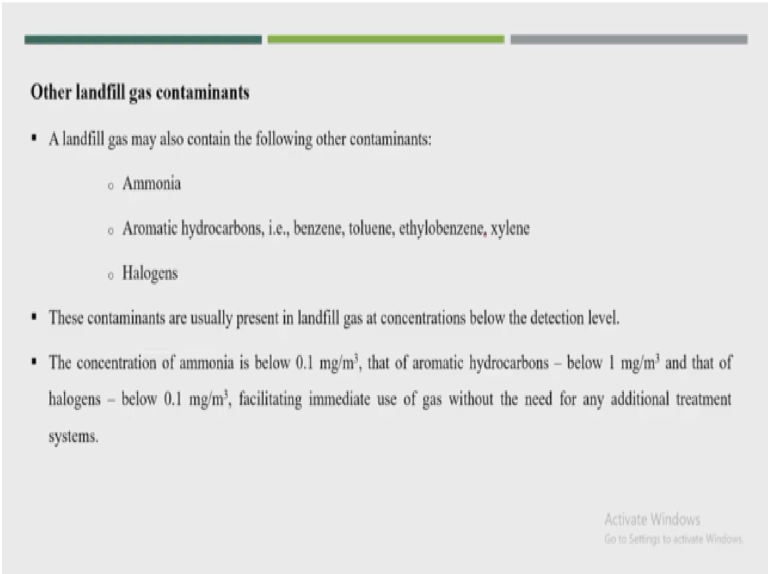

And some more like other gas pollutants could be ammonia, halogens or aromatic hydrocarbons could be possible and there are a number of contaminants are there, but their concentration very below to the detection level also.

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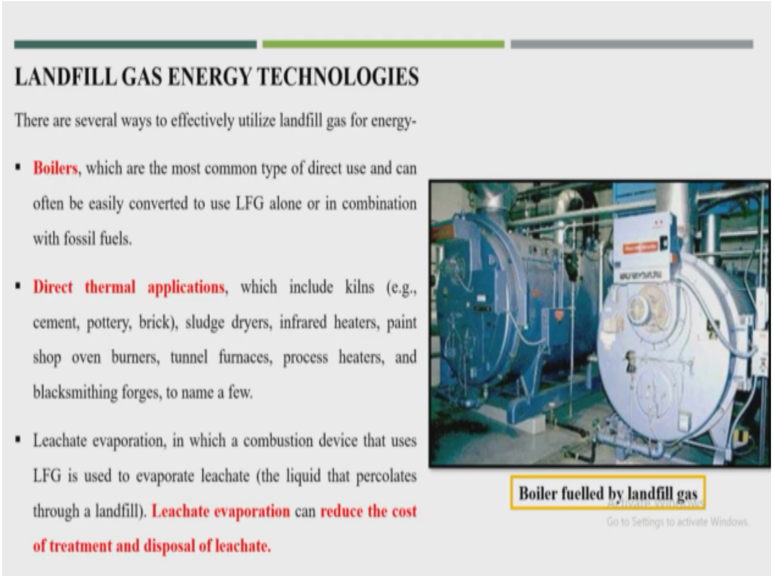

Now, energy technology the major energy whatever gas is purified gas is a combustible gas consist of methane and hydrogen. So, boiler technology is the most common technology to produce energy out of that or direct thermal application which includes kilns, sludge dying directly we can use these gas for energy production.

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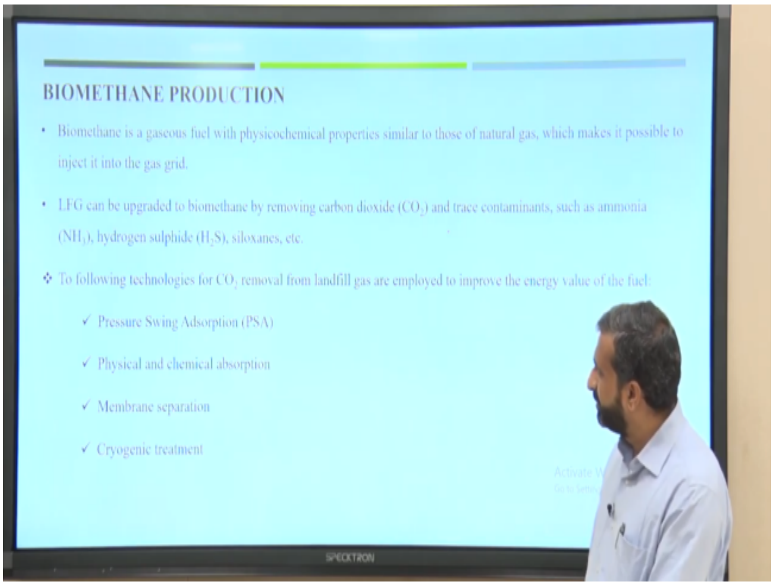

Biomethane production also is possible because the major gas concentration is methane, hydrogen, carbon dioxide, if you are able to remove these or separate out these carbon dioxide and methane like same in the anaerobic digestion process. So, we can get proper biomethane production could be possible and the CO_2 removal also could be possible by different methods like membrane separation and other techniques are available for that.

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OVERVIEW OF CO_2 REMOVAL PROCESSES

Separation Method	Process	Functioning Principle	Final Content Methane
Adsorption	Pressure Adsorption Swing	Adsorption of CO_2 a molecular sieve	> 96 Vol.-%
Physical absorption	Pressurized Wash Water	Dissolution of CO_2 in water at high pressure	> 96 Vol.-%
Chemical absorption	Monoethanolamine (MEA) - Wash	Chemical reaction of CO_2 with MEA	> 99 Vol.-%
Membrane separation	Polymer membrane gas separation (dry) and Membrane gas separation (wet)	Membrane permeability of H_2S and CO_2 is higher than CH_4	> 80 Vol.-% and > 96 Vol.-%
Cryogenic process	Low temperature process	Phase transformation of CO_2 to liquid, while CH_4 remains gaseous	> 99.9 Vol.-%

So, these are the different methods in that way we can remove carbon dioxide from the gas to get the proper biomethane.

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REASONS FOR LANDFILL GAS CONTROL

The following is a list of common reasons for controlling the gas produced by a landfill:

- Prevent air pollution and comply with regulatory air emission criteria.
- Reduce hazards due to off-site migration.
- Prevent damage to the landfill cover slope stability
- Odor control.
- Energy recovery. Prevent vegetation distress.

What are the reasons for landfill gas control? There are the following reasons like prevent air pollution and comply with regulatory air emission criteria, reduce hazard due to off-site migration, prevent damage to the landfill cover slope stability, odor control and also energy recovery is possible. So, you see here now as a conclusion that the gas collection not only is a difficult task, but also the treatment is also another difficult task in these particular for the treatment of these landfill gases.

So, again I am saying the same thought the major production is volatilization and biological decomposition, there is a major cause of this gas production. So if you are not allowing the biological waste to enter into the landfill area, then there will not be any volatilization there will not be any biological decomposition. So your gas generation also will be very low. So you need not worry much and because the gas concentration is low means here are the major mechanisms like diffusion and advection that is will be also very poor.

So, a very small concentration of gas will come up, this odor issue will be always there because methane is also odorless gas and along with that the ammonia, hydrogen sulphide production. This is always there but that that concentration also very, very poor. If you are not allowing the biological material to enter into the landfill area and is not only the landfill gas production will be very low, but also the leachate production also will be very poor in that case.

So, see saying that we have the sanitary landfill is available with us, you will be required very skilled manpower to collect the leachate and gas followed by treatment process will be required a lot of money, a lot of funds is required for running such kind of facilities. And there is no income from these kinds of facilities. So, rather than working for the again, I am proposing that rather than working for landfill or to get the sanitary landfill for us we need to more focus on the treatment facilities like biological treatment facility.

We can put a lot of fun into that, why not propose more recycling more in even the insulation facility, the capital cost will be very high, but I think you need not work into the landfill area because this is in an open area, the landfill and is a highly affected by the local conditions. And we cannot change the local conditions or atmospheric conditions, we have to work along with the local condition and difficult to work.

So, here were finishing the complete landfilling one, but in my next lecture I was thinking about having some examples or some numerical we will solve, and also here is very important to talk about legacy waste or the old land fields. Suppose, Indore has come up with a new sanitary landfill but before that, they have to remove out the old landfill or we can say they have to bio mine or bioremediation has to do in that site so that we will talk in the next lecture. Thank you.