

Applied Environmental Microbiology
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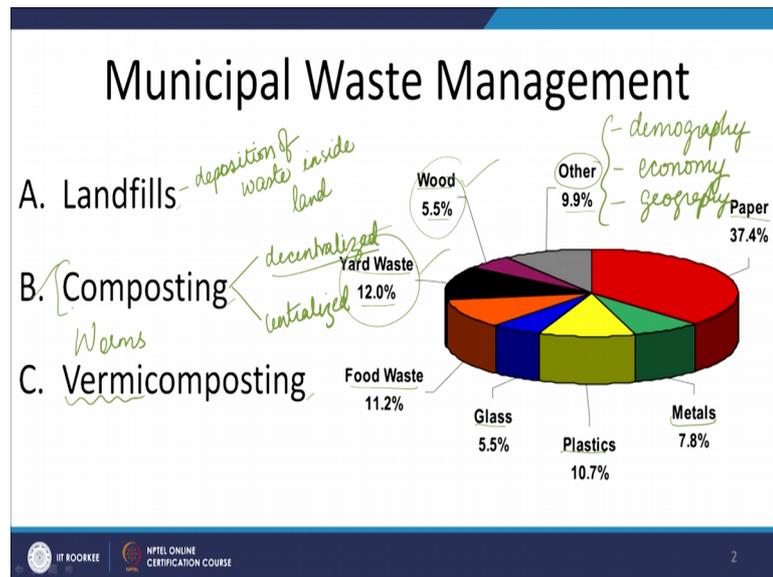
Lecture – 46
Solid Waste Microbiology I

Dear students previously we talked about wastewater microbiology and briefly about wastewater treatment. Now let us move on to solid waste microbiology in our house, in our towns, and in our industries, including our agricultural industry wastewater is not the only form of waste that we generate.

A large portion of our waste materials from the solid portion of the waste generated; now the solid portions might have certain biodegradable components which degrade biologically by microbes or recalcitrant components that do not degrade such as heavy metals. Over the time the biodegradable components of the solid waste to degrade leaving the recalcitrant materials behind, many a times the recalcitrant materials are very toxic to the environment and for public health.

Also many of the dotted products of the bio degradation could be harmful for the environment or for public health. Overall the solid waste if not properly managed, maintained and treated poses a big hazard to environment. A recent example would be the landfill, landslide that cost 23 deaths in Sri Lanka and 2 deaths in Ghaziabad in India. Now today in this lecture we will start with solid waste management techniques and then briefly go into the major microbiological processes that drive degradation of solid waste. So, the municipal waste that is generated might consist of wood.

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So, these are the parts of the trees that have dropped down let us say in stone or have been cut it could include paper. These are the output of educational institutions or offices it will have metals, plastics, glass, food waste, yard waste, yard waste as everything else we generated in the house and then we have a portion of other. Now this diagram is from a particular study that was done in an American town, some 10 years ago with different town, cities and villages the proportion of the different components of the waste solid waste would differ.

For example an industrial town that deals with dyes may have less amount of wood waste or yard waste, on the other hand it is possible that a largely forest based village town will have more wood based and yard waste in the solid waste generated. So, this is variable the percentages here would be variable, but overall there would be some consistency in the proportion of different components of solid waste generated for a particular cities in town.

So, we notice that the components of the solid wastes that are generated depend upon the demography of the place. A village will probably have lot of guber or cow manure, buffalo money, or animal droppings that it would generate compared to a city that will have higher number of metals, solvents, chemicals, household chemicals, such as bleach plastics. So, it also depends on the economy, if it is a rural economy we will see that the components of the wastes reflect the waste you expected from rural areas and it also

depends upon geography. So, a forest based village will have a very different ways to combine the composition compared to a river village that is adjacent to a river. So, these are few of the factors that affect the component of waste generated.

Now, once the waste has been generated the waste solid waste can be sent for land filling composting over my composting. So, land filling is basically deposition of the waste inside the land, now land filling can be done in many types and four major cities and towns across the world land filling serves as the most frequently used solid waste management practice.

The other practice we have is of composting, now composting is very relevant for Indian villages and many Indian towns they are composting can be done in two ways we can either have a decentralized composting mechanism or we can have a centralized composting mechanism.

Now, decentralized composting mechanism would look like every kitchen in the house or every house composting its own kitchen waste. And centralized would look like the compostable material which compostable material is collected from every house and institution and then composted at a municipal, municipal control and govern composting site, when we composting is when we use worms to metabolize our solid waste and convert them into compost there, there are many advantages of vermicomposting over bacterial and fungal composting, which is mostly the default composting and some of them are that they have their low odor, they do not alter the ph dangerously and they are very efficient in converting waste into compost.

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Now, these are the some pictures from different Indian landfills, I will briefly talk about this two pictures they are from Ghaziabad landfill. So, I live in turkey and when I go to ncr we drive through this landfill and this is very important landfill for many purposes, notice here that the waste has been piled up without any mechanism to make sure that the vase does not undergo a landslide light man like mechanism where the top waste goes down..

So, there is no mechanism here to prevent the top face from toppling down here. So, in case of an earthquake or in case of heavy downpour like happened recently, it is quite possible that this based on the top will and will fall down like in a landslide lake manner. So, this is not a very well maintained landslide at least support this portion of it is not very well maintained, now I another thing I would like you to notice here is that, how what a close relationship the flora fauna and human beings have with our landfill sites..

Now most of these landfills are where they are the convergence point of the community cities towns districts waste and as such over time when biodegradable components which is mostly the food waste then it degrades what we are left with is often the recalcitrant and very toxic waste. So, whenever we have human beings in ghost commune with the landfill side the end which is not properly screened, which is not properly bound and not contained then there is a very high risk that our animals our birds and human beings would be exposed to dangerous amount of pollutants and will be affected.

Now, the other thing I want you to notice, I these are some other pictures of human beings have a undergoing a very close interaction with our landfill sites and another thing I would like you to notice is that I have mentioned at least twice that the biodegradable component of the land waste material that is put into a landfill degrades over time.

Now, if I am talking about biodegradable degree degradation of biodegradable fraction; obviously, it is the microbes that are doing the business. So, in this lecture we will briefly go over the microbiology of landfills and in the next lecture we will elaborate more about them. The other thing I want you to notice in this particular slide is about the peculiar conditions of landfill in our country, the way a landfill looks and is maintained operated in developed part of the world and in a developing countries such as India are very different and they warrant a closer look.

So, for example, here we have rag pickers picking up their rags from the landfill site, I think this is again from ncr landfill same landfills Ghaziabad, I am not sure about it, but that is what I think because of the can all that is flowing from here, and the city that is established here. Now noticed that not only are these rag pickers being exposed to toxic amount of waste, but they are also doing a very good business in pointing out to us that of the waste that goes for land filling in India is not properly segregated.

And that is one of the major problems with our solid waste management is that we do not have good segregation practices. Now segregation would include removing everything that can be recycled or repurposed before putting into landfill and the advantage of this practice is that the volume of those lands that requires waste that requires to be filled inside the land reduces and thus environmental impact reduces. So, instead of having giant mountains of waste we have smaller manageable amount of waste piles.

So, these rug pickers are probably finding out of glass and plastic there can be repurposed or recycled, and if we want our solid waste management to be successful in the country it is very, very important that we learn and, and discover invent a sustainable feasible method for segregating the waste and it is now here is another landfill site and I am not sure where it is, but it is definitely in India, and you have children playing on a landfill site this is extremely dangerous and especially because children are have growing bodies, does their bodies absorb more nutrients and the whatever contaminant they are exposed to will last longer in their in their bodies they have more and their body

organs are very active the cells are rapidly growing dividing and thus they are more susceptible to developing diseases from exposure to contaminate.

Another example I would like to give here is what happened in Bangalore a couple of years ago was where they had poorly managed landfill sites people noticed that on the ground above the landfill, because ideally what we do is we have landfills and then this is above the ground landfill, but many a times landfills are done below the ground. So, many a time's landfills are actually below the ground, so basically we have ground level here.

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And we dig a trench, and in the trench we line it properly with a liner sufficient with sufficient impermeability to prevent any amount of toxic liquid that or liquid that accumulates from the waste to percolate into the groundwater. And then we fill it with our waste, and when we fill it with our solid waste eventually we seal it and typically we try to grow garden here, and the reason why we want to grow gardens here is because more often than not this is nutrient rich environment.

The plants trees help us create a positive in feeling and also help remediate many of the contaminants that can undergo phytoremediation. So, in Bangalore what people noticed was that where the land had been landfill had been covered properly. So, where the land had been covered the landfill had been sealed.

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Gases were coming out from certain holes, now indeed people also the local residents usually the economically and socially underprivileged people unfortunately they notice that this gas is inflammable definitely methane or some other inflammable organic gas and they started using it for cooking.

Now, it sounds pretty sweet that they found gas coming out from the earth that they could use for cooking, but it highlights that the landfill was not properly maintained the waste was not segregated, and lot of biodegradable components were allowed to be put in landfill. Typically we do not want highly biodegradable compounds to go in the landfill we want only the recalcitrant proper version to go. And there many reasons why we would want that because, let us say initially we have filled the line filled with up to the it's maximum cup capacity and then sealed it from here, if it is biodegradable over time the volume of the solid waste would reduce.

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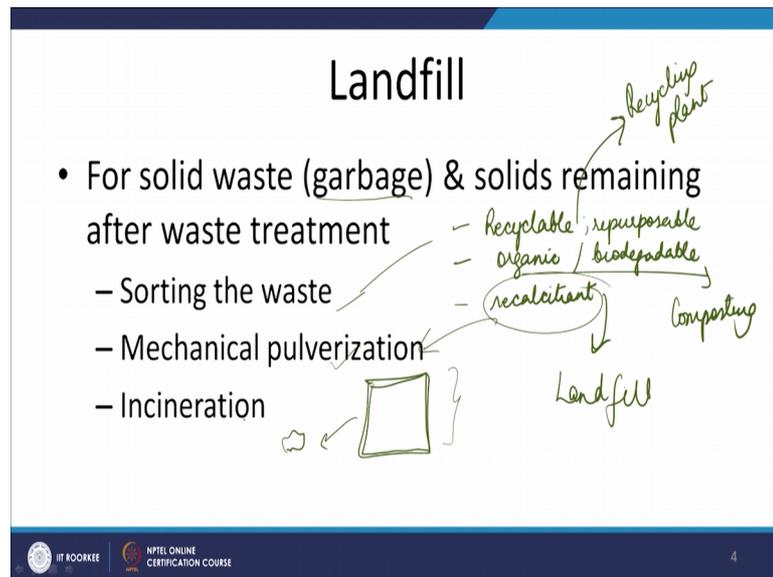


And this volume would be covered by liquids, which are leachates and if they permeate into groundwater they will destroy our groundwater and then another portion of it would be gases. Now these gases would escape into the environment as perhaps was happening in Bangalore and then they will cause these are good mostly greenhouse gases.

So, they will contribute to climate changing, climate change and they will also expose people the other thing is that now we have wasted this particular volume a very precious land is very precious in India, and we have wasted this entire volume that could have been used for putting recalcitrant solid waste. So, this is let us say mildly biodegradable waste.

But if I have very biodegradable, I might have a larger volume that can now that is now lying waste after the gases escape and the leachate has been drained out the liquid has been drained out. So, it is very, very important for us to segregate our waste properly and make sure that what comes to landfill is often the recalcitrant waste much like the plastic and minimum cans you see here, now let us talk about landfill; landfill therefore, is for solid waste.

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The garbage not very biodegradable portion and solids that remain after waste treatment. So, what the second part of the sentence is referring to is that the municipally collected solid waste must undergo a certain amount of pretreatment before being thrown into before being dumped into landfill. So, that would include sorting the waste, so we saw in the waste this is very important waste segregation it is economically not very attractive, and thus it requires mass public awareness and drive for people to sort the waste at home right away. So, we sort the waste we remove all the recyclables, repurposable we remove these materials.

We also separate the organic, rather biodegradable material and then we are left with recalcitrant material. Now this recalcitrant material can go to landfill the recyclable material should go to a recycle plant, and the biodegradable material should go for composting, ideally this is your ideal solid waste management practice you have landfill recycle and composting.

And after sorting the waste the recalcitrant material can undergo mechanical pulverization to reduce the size of solid waste for example, let us say I have one gallon or two gallon milk can. So, this is the size of my milk can it is needlessly occupying the more volume then its actual solid material, so basically this is just a thin can.

So, if it undergoes mechanical polarization now it can make it can occupy much lesser volume, so this is very important step and then have incineration certain parts of our wastes need to be incinerated.

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Landfill

- For solid waste (garbage) & solids remaining after waste treatment
 - recyclable, repurposable
 - organic / biodegradable
- Sorting the waste
- Mechanical pulverization
- Incineration
 - medical waste
 - leachate
 - high caloric waste

recycling plants
 composting
 Landfill

Typical among them would be medical waste, now dear students think about it why do we want to incinerate our medical waste and why do we not just want to put it into a landfill.

Well I hope you will arrive to the same conclusion that medical waste can be a source for spreading more diseases for example, blood borne pathogens and also certain components of medical waste can cause other emerging contamination by for example, certain pharmaceuticals are very bad for health, because endocrine disruption all caused antimicrobial resistance. So, in medical waste definitely you going incinerate it then there could be also the leachate.

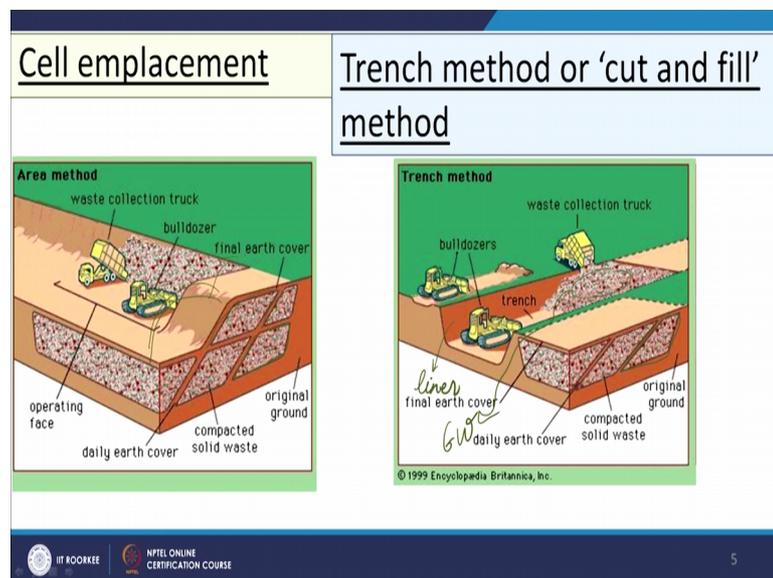
Now, this is a new term and we will be dwelling quite some about on the leachate, now the leachate is the liquid that over time develops into in the landfill and rivers talking about the solid phase, liquid phase and gas phase, liquid phase is in the land in landfill is the leachate.

Now, I have seen certain landfills in India, after they collect the leachate they condense it they do different treatment for it or try to remove certain contaminants and at the end of

all the treatment the solution they are left with is whatever waste you can't get rid off you cannot dispose it because it is very concentrated form of waste then they incinerated, the other advantage of incinerating high calorific. So, the other kind of waste we want to incinerate is high calorific or high calorific waste.

So, if the heat that would be generated by burning our solid waste is quite high, then we can actually use it as a source of thermal power and then thermal power can be converted into electricity and we can use that for running a landfill and or maybe even supplied with the electrical grid. So, at least these three kinds of wastes we want to incinerate them.

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Now let us look at landfill the first one, now there are two different kinds of landfills we have cell emplacement we have trench method which is also the curtain fill method. So, let us look about the cell emplacement method in cell emplacement method when we start making our land we usually we in it both of the cases we end up with these cells.

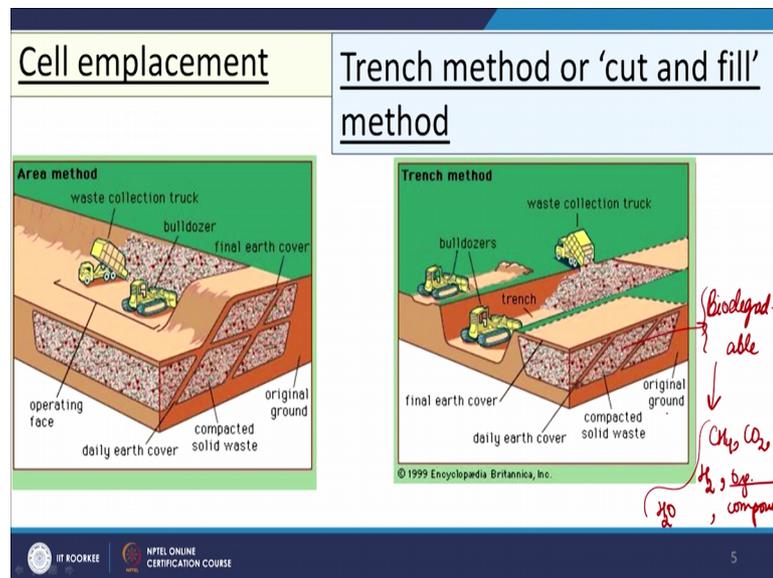
So, you look here this is a cell and the similar cell is here, but there is a big difference in which we are doing with the cell emplacement method, in cell emplacement method we have dug up a large portion of the land and we fill in compact. So, this is the filling of the waste that has been collected by waste collection truck this is the bulldozer that is trying to come back the waste material.

And then we will put a self mud cover over it and create the first cell, and then we will add more waste compacted and we will add another cell we will add more waste and then we will compact it and we will add earth layer to make another cell and so on and so forth, this is a cell investment method.

In trench method what we do is we instead of cutting in a long big portion, long big area of the ground we cut a trench and the trench is in properly lined one thing that is not clear with these pictures is that we are not showing the lining very well all these have to be lined. So, very good lining material has to be added here which will ensure that the liquids that will be collect generated in this waste do not end up contaminating the ground water.

Already so this is the trench method, this is the area method, now coming to the microbiology of waste. Now what happens when the waste has been put in the either in the landfill generated by trench method or the landfill generated by selling placement method, now there in this particular ways that we are putting in the landfill.

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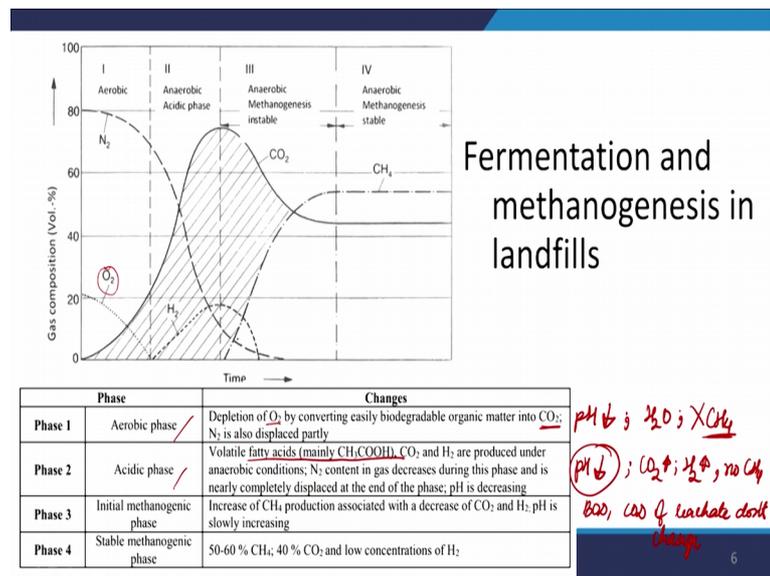


There are definitely some biodegradable fraction of it no matter how well we sort our waste, there is a biodegradable fraction and which will over time degrade into simple organics like methane, carbon dioxide may even form some amount of water and we from some other complex organic compounds, yes and they might even form water depending on the kind of degradation.

So, these materials will over time undergo degradation and form this and they and they do not undergo degree or all different kinds of possible bio degradation at the same time. So, if you remember in the initial lectures I talked about oxygen as being the best electron acceptor..

So, they undergo a sequential electron acceptor system. So, best electron acceptor oxygen carries out the aerobic oxidation first, which is then followed by anaerobic oxidation followed by methanogenesis, then decline of methanogenesis and overall it ends up with stabilization of the landfill over time. Which might take long time we talked we are talking geological scale here. So, let us look here initially we start with aerobic phase.

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Now, aerobic phase what happens we have plenty of oxygen available now this oxygen is consumed. So, it falls down and as oxygen gets depleted the aerobic degradation of waste of biodegradable waste also decreases.

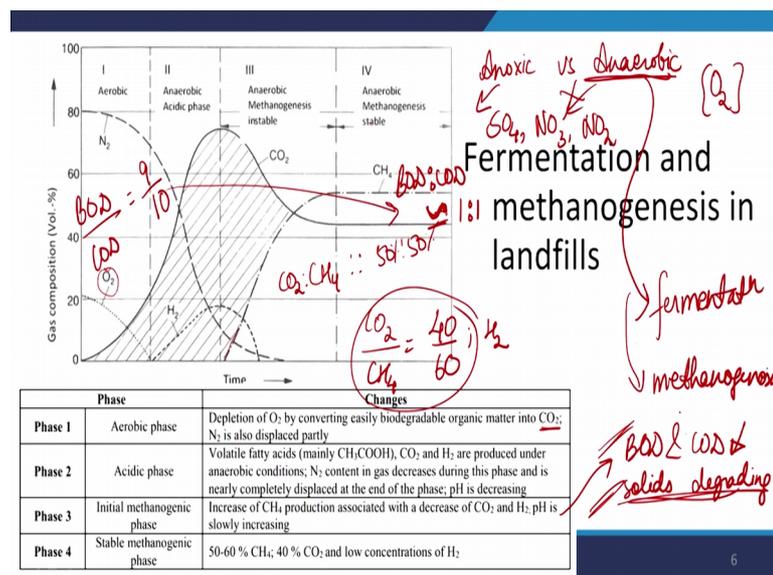
So, this is the first phase first phase is the aerobic phase and the typical characteristics of the aerobic phase are that the oxygen gets depleted and it CO₂ is formed not methane, but CO₂ the other thing is that the ph often goes down, we also generate some amount of water and absolutely no amount of methane. The conditions are not right for methanogenesis already and we are noticing that nitrogen is also decreasing then enter the second phase which is anaerobic ascetic phase.

Now, anaerobic ascetic phase what we have is the ph falls down very rapidly, the vise ph for falling down very rapidly because now we are producing lot of acidic material. So, and we have a generation of carbon dioxide and some hydrogen gas might also be generated again no methane or very bless methane minimal methane, but the important thing is that the ph decreases.

So, basically this is the acidic phase of your reaction the other important thing is that the leachate bod and CO d do not fall of leachate do not change much, another thing is whether it is an aerobic phase or acidic phase in both phases the solids are not degrading. So, let me remind you when we put our waste in a landfill there is some water content in their waste itself, that water content over time and with pressure with compaction and with the pressure of the weight of the waste above it separates and then we have the first kind of leachate it degenerates.

So, most of the aerobic degradation acidic degradation is happening of that or moist waste the solids are not degraded. Now when we enter the phase three and phase four which is initial methanogenic phase and stable methanogenic phase this is where most of the waste would be generated degraded. So, in the initial methanogenic phase which is another big methanogenesis, now it is a very good time for me to clarify that there is a big difference in anaerobic and anoxic.

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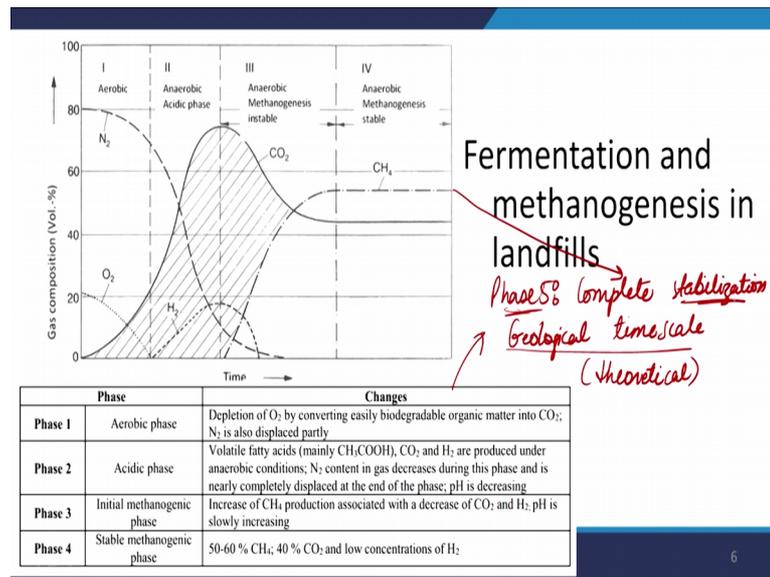
So, we have another word that we have used earlier anoxic and anaerobic. So, in both of them oxygen is not present as oxygen itself in anoxic we will have other forms of oxygen present such as sulfate or nitrate, or nitrite, but in anaerobic even these are absent. So, when even these are absent in an anaerobic will have fermentation they do not use oxygen at all we will have methanogenesis. So, here we have anaerobic methanogenesis this is typically unstable, but here this is where the somewhere here is where your methane production peaks.

So, here look the methane is increasing and it is it begins. So, this is the methane starts increasing and this is where we get CO₂ the CO₂ to methane ratio gets nearly 50-50. So, we have nearly 50 percent of carbon dioxide and 50 percent of methane the other thing is that in the third phase finally, the bod of and cod of leachate is decreasing they are decreasing and the solids are also getting degraded.

So, the solid degradation is substantial quite significant finally, we reach the stable methanogenic phases where the CO₂ to CH₄ ratio is different and in this particular case it looks like, it might be 40, 60 or something near that in the anaerobic methanogenesis stable phase here again the CO₂ production falls down it is less than CH₄, we might have we might still get some H₂ production this is where we have substantial or significant degradation of solid waste.

The Bod and Cod of leachate drop very much, so initially here the bod to cod ratio of the leachate might be 9 is to 10, and here by the time we come here the Bod ratio with Cod would be left as one ratio of one nearly. So, most of the biodegradable components have been biodegraded nearly now this is not shown in the figure, but after the four phases we have another phase.

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The phase five now, the phase five can be called as the phase where complete stabilization takes place, this is a phase of complete stabilization and what this happens in geological time scale. So, we do not know if it is really happening, but we believe it happens in this phase five the methane production falls down over long period of time because this is geological time scale whatever we are talking about in scientific community is still theoretical, humankind have not been present with this information long enough to see phase five coming to fruition all right.

So, this is where your landfill is stabilized and this is what we hope happens over time, dear students this is all for today in the next lecture we will be talking more about degradation of leachate, leachate material and the microbes that in that are involved in degradation.

Thank you very much.