Basic Environmental Engineering and Pollution Abatement
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Lecture – 51
Solid Waste and Hazardous Waste Management – 1

Hello everyone. Now we will discuss on the topic Solid Waste and Hazardous Waste Management part -1. Already we have discussed on the management and treatment of different type of waste streams like air, water. And the next part is with solid waste and the hazardous waste.

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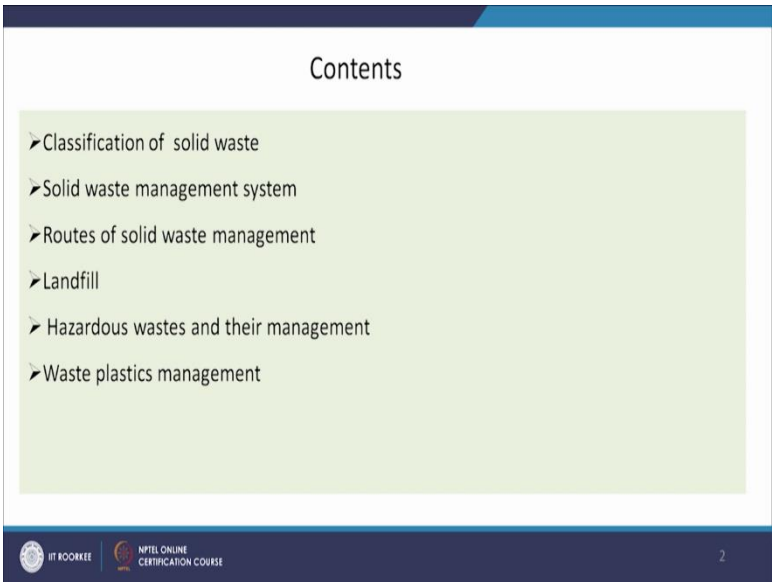

And the contents are classification of solid waste, solid waste management system, routes of solid waste management, landfilling, hazardous waste and their management and waste plastics management.

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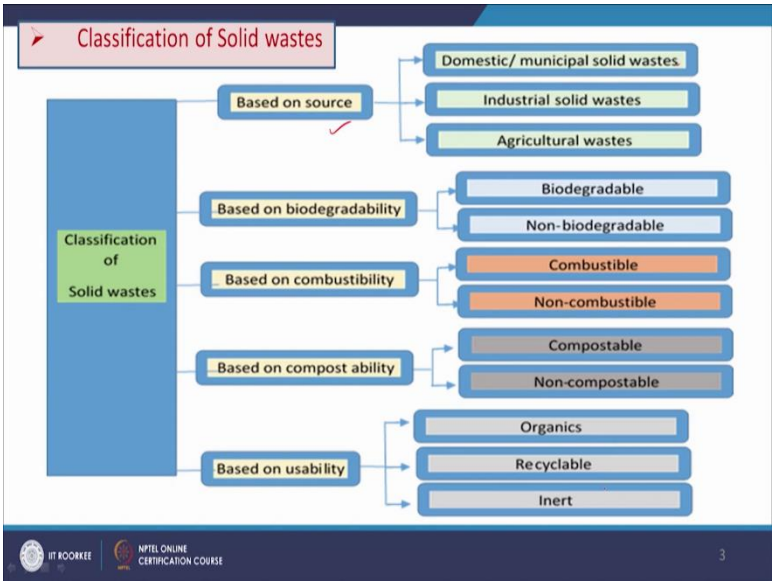

Now we will see the classification of solid waste. So, the name itself indicates that the waste will be in solid phase or solid state. So, we can classify the solid waste based on some criteria like say based on source. It can come from domestic or municipal sources; it can come from industrial sources or may it come from the forest.

So, industrial solid waste, agricultural wastes and domestic and municipal solid waste that can be the classification that agricultural and forest waste are under the same category and based on biodegradability. This can be biodegradable and non-biodegradable and based on combustibility may be combustible and non-combustible and based on compostability that is compostable and non-compostable and based on usability that can be organics, recyclable and inert. So, these are the different types of classification of solid waste.

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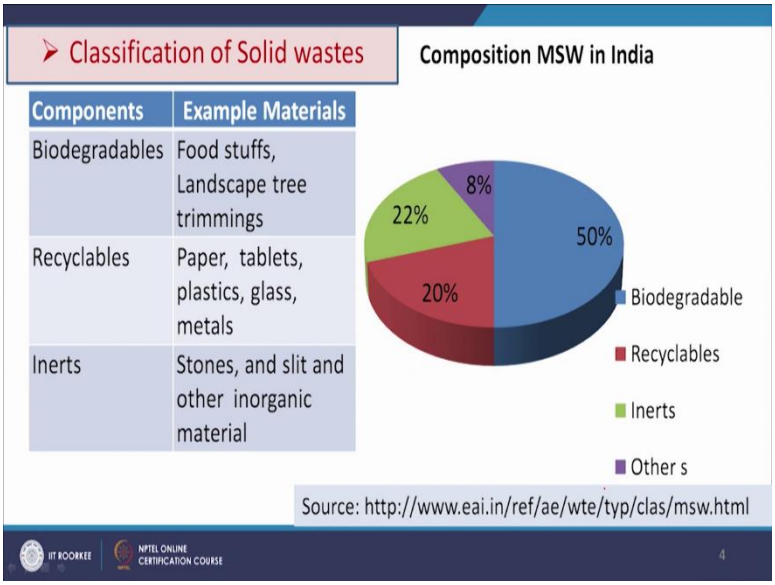

Now we will see the characteristics of municipal solid waste. So, municipal solid waste if we see around 50 % contains biodegradable material and around 20 % contains recyclables materials and around 22 % inert material and 8 % others.

Now we will see that biodegradables may be the foodstuffs, landscape tree trimmings and recyclables may be paper, tablets, plastics, glass, metals etc. And inerts may be stones and silt and other inorganic material that is construction debris etc. So, these are the different components which is available in the municipal solid waste and their relative contributions on the overall volume of the MSW.

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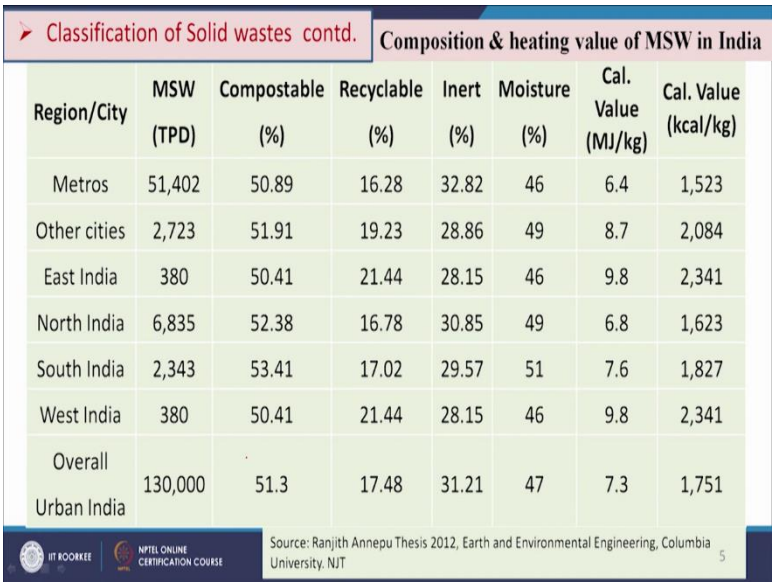

Here we will see the source of MSW from different parts of the country and their composition and some characteristics like say, if we see metro cities and other cities and East India, North India, South India, West India and overall urban India, if we classify these. And if we see the municipal solid waste, so their concentration of different types of materials will be different and their properties will also be particularly the heating value and moisture content will also be different. And this table shows are some example case study that is based on 2012 study.

So, these are the total production in tonne/day and these are the compostable present in it. So, it is evident that around ±50 %, some compostable material is available in the MSW produced in the different part of the country and recyclable materials also say, 16 to 21.44 % is mentioned here. So, around 20 % we can say or 22 % we can say that recycle level is there maximum.

So, inert is also present you see, 32.82 and somewhere it is 29. So, that way inert material is also present and moisture content is also mentioned and calorific value. So, calorific value is not very high but it can be recovered. So, this is the characteristics of MSW available in the country.

Now, although the calorific value is less, we see here but if you can segregate the different components because you have seen that here inert is around 20 %, somewhere, 32 %. So, if we can eliminate this part, this your calorific value will be increased. So, segregation of MSW, if you can do then the particular fractions we can get that can have very high heating value and less moisture content. Whereas some other part may have the reverse strain that is less heating value or high moisture content like this.

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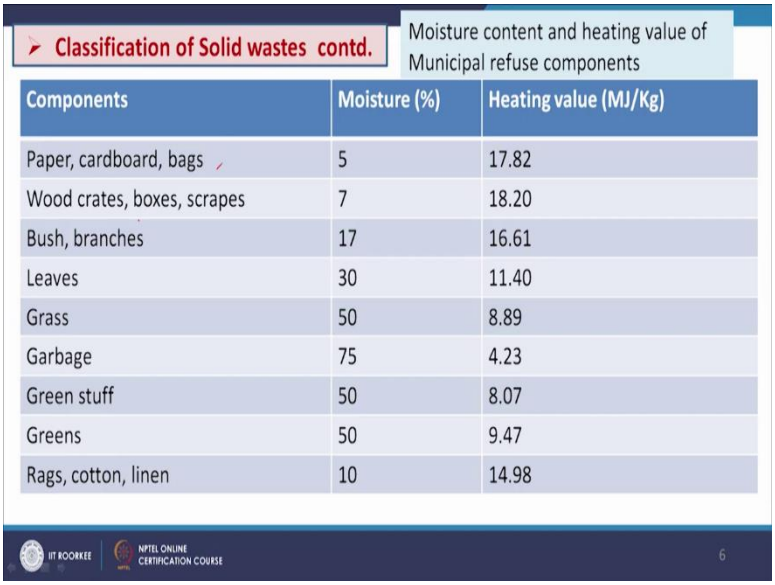

Components	Moisture (%)	Heating value (MJ/Kg)
Paper, cardboard, bags	5	17.82
Wood crates, boxes, scrapes	7	18.20
Bush, branches	17	16.61
Leaves	30	11.40
Grass	50	8.89
Garbage	75	4.23
Green stuff	50	8.07
Greens	50	9.47
Rags, cotton, linen	10	14.98

So, different types of components if we segregate that paper, cardboard, bags and then wood crates, boxes, and scrapes and then bush, branches, leaves, grass, garbage, green stuff, greens, rags, cotton and linen some examples are given. So, you see here the moisture content is varying widely 5 % to 75 %. And heating value is also varying widely that is 4.2 MJ/kg to maximum arrangements and here 18.20 MJ/kg.

So, 18.20 MJ/kg is a good amount of heat content this type of materials is having. So, this can be used for the energy recovery but where these materials the although the heating content is less but its moisture content is high so this can also be treated biologically for the recovery of the energy or the production of biogas. And overall value addition can be taken place through the treatment.

Similar to MSW, the industrial solid waste will also contain different types of materials but it will be having some specific characteristics. Depending upon the type of the industry a particular type of pollutants may be available in the solid waste and that has to be removed first before further treatment using the conventional solid waste management processes.

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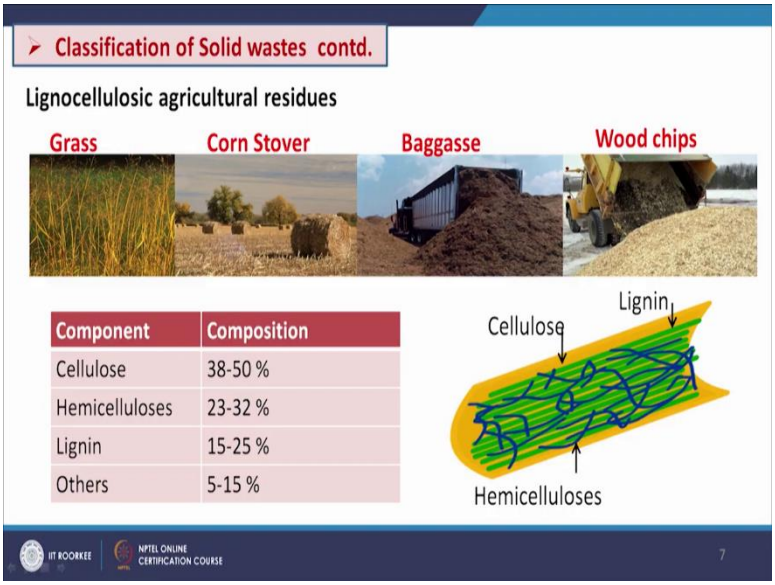

Now we will see the characteristics of the agricultural waste that is Lignocellulosic biomass or Lignocellulosic agricultural residues. So, here some examples are givens grass, corn stover, baggasse and wood chips. And here we see cellulose, hemicellulose, lignin and others component present in this type of materials is given in certain range.

So, suddenly you see that cellulose is present in the highest extent followed by this hemicellulose and lignin. And we see that lignin, hemicellulose and cellulose have different structures because all those compounds are having different chemical formula and their structure are different and some are having some crystal structure like say cellulose and hemicellulose having less organized crystals and this is the structure of this. So, this information will help us how to use these feedstocks or these wastes as a feed stock for the production of energy.

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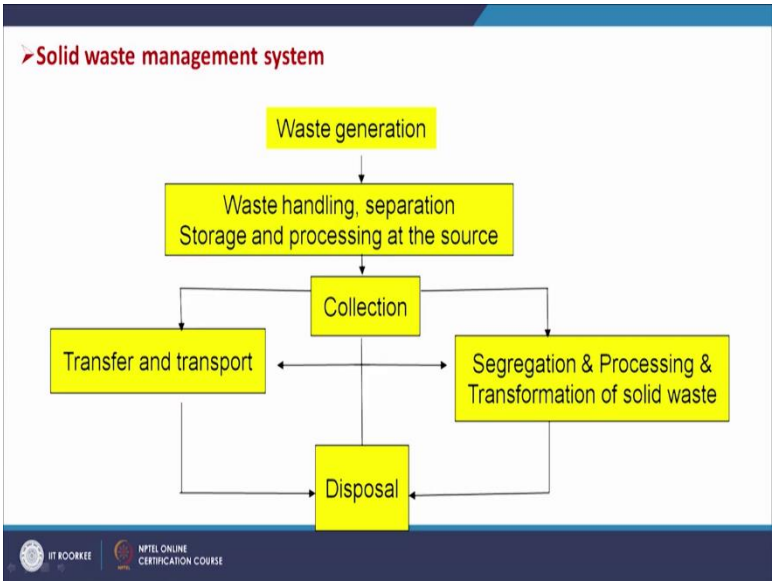

Now we will discuss the solid waste management systems. So, now we have seen that different types of solid waste are generated including MSW, industrial waste, agricultural waste etc. Now our objective will be how to manage these wastes particularly the management of MSW is a very big challenge. So, it requires technological application as well as the management concepts or management application. So, if we consider the management of solid waste, so first will be the source of generation of the waste.

So, we should try our level base to reduce less waste. So, that will be the first principle or first philosophy for the solid waste management. Then when it is generated then that has to be handled and collected properly. So, waste handling, separation, storage and processing at the source, each and every individual houses we produce solid waste.

So, we should take care that we will producing less solid waste, and once the solid waste which is generated that has to be managed properly. It has to be handled properly so that it will not create environmental hazards in the surroundings.

And after this storage and processing at the source level at each individual houses, we can segregate the solid waste into different fractions and municipality can implement a methodology to collect different fractions for their proper management.

And then collection system is there that collection, there are different techniques available for the collection of MSW from each individual households. And after this collection it has to be transferred and transport to the processing section where the segregation and processing and transformation of solid waste are taking place.

So, after that the segregation and processing that means as you have mentioned there are recyclables, there are organic compounds and there are inert. So, after these segregations we can select particular routes for the processing of different fractions for further utilization value recovery as well as to reduce the volume of the waste so that reduced volume will further be disposed. So, this is the scheme for the waste management particularly the MSW.

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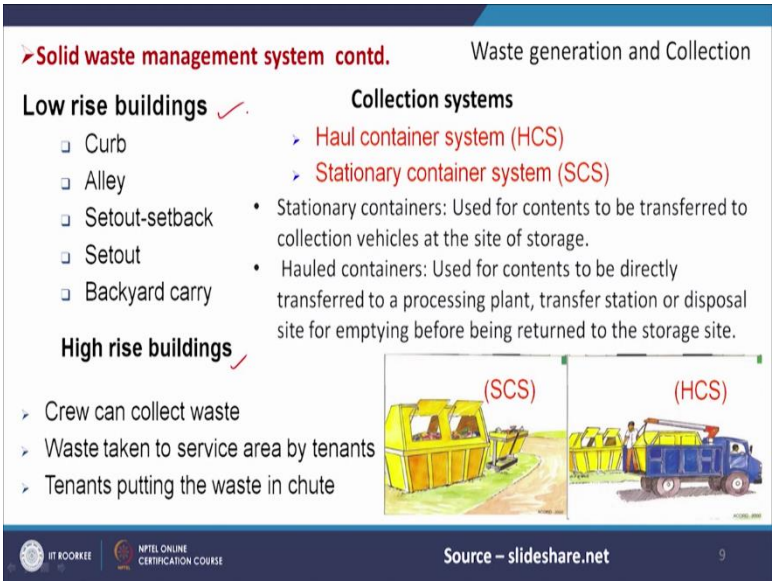

So, now we will discuss all these functional elements. So, waste generation and collection. So, waste can be generated in a low-rise and high-rise buildings.

So, for these 2 different types of buildings different types of methods have been applied and implemented for the collection of the solid waste. Like say for high rise building curb, alley, setout-setback, setout, backyard carry, so all those things are there. And high-rise building crew can collect waste, waste taken to service area by tenants and tenants putting the waste in chute.

So, these are some methods which are used in different part of the world for the collection of the solid waste. And if we think about the collection systems, so basically major 2 types of collection systems are used one is your Haul container systems and another is your Stationary container system.

So, stationary container systems are basically used for contents to be transferred to the collection vehicles at the site of storage. So, this is the site of storage, waste are collected here so transporter municipal vehicle will come, here this waste will be transferred. So, that is your stationary container system. But in case of Haul container system, this is used for the

contents to be directly transferred to processing plant, transfer station or disposal site for emptying before being returned to the storage site. So, this container directly it is taken to the disposal site or processing site with the carrier and then after unloading that is again returned to this place. So, that is called Haul container system.

So, these are the different types of systems which are used for the collection of the municipal solid waste in different parts of the country and in the world.

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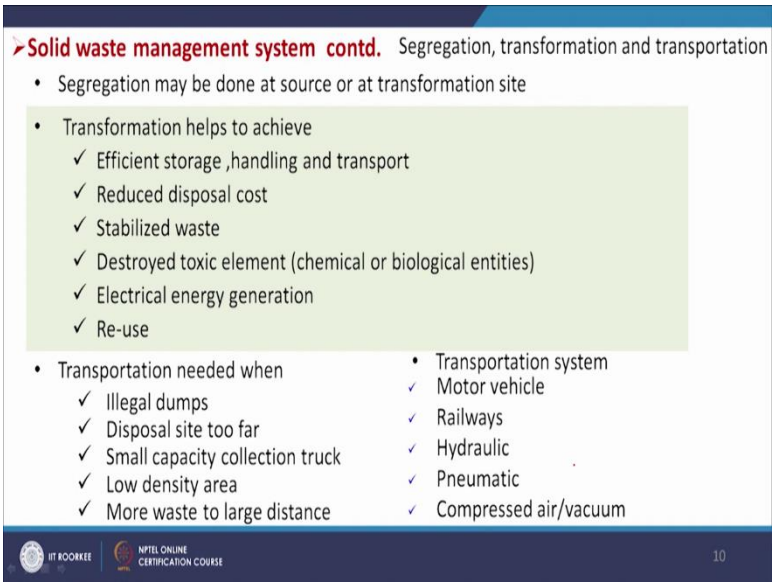

Now we will see the Segregation, transformation and transportation. So, segregation may be done at source or a transportation site. So, when it is transformation site, so when we are going to transform it that means we are going to extract energy or some other valuable from it, so at that site or it can be sorted at the site where it is being generated as well.

So, transformation means you know the value addition or extraction of energy and other products and reduce the volume of the residue basically. And this transformation helps to achieve efficient storage handling and transport reduced disposal cost stabilized waste, destroyed toxic element that is chemical and biological entities those are being destroyed, electrical energy generation and reuse.

So, these are the advantage of the transformation. And transportation needed and the illegal dumps we want to prevent and then disposal site too far and small capacity collection truck and low-density area and more waste to large distance.

So, we have a certain area where the waste will be collected and disposed and then at that time this will be far away from the main city. So, that is the reason why this transportation is required. And different types of transportation systems can be used like motor vehicle, railways, hydraulic systems, pneumatic conveying systems and compressed air or vacuum. So, these are depending upon the situation. In our country mostly motor vehicles are used.

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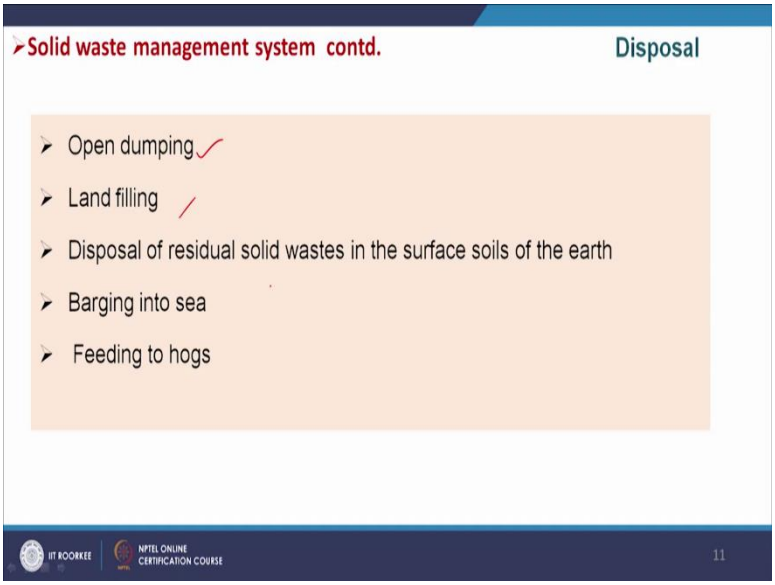

Now we will see the disposal options. So, disposal of the residual part of the solid waste after transformation which is remaining that has to be disposed and there are many methods through which the disposal can take place open dumping, land filling, disposal of residual solid waste in surface soils of the earth and barging into sea and feeding to hogs. So, these are some generally used disposal methods. We will discuss the landfilling and others also.

So, open dumping we have seen it is openly, it is practiced in most of the towns and cities in our country. And land filling is also implemented in metro cities and some other cities in the country. And barging into sea that was a good option once but nowadays it is not encouraged.

Now we will see the roots of solid waste management. So, those are the disposal option we have seen, we have seen that solid waste or MSW has to be collected. It has to be segregated then transformation and then residual will be disposed of. So, these are the basic steps.

Now we have also seen that MSW or solid waste may be of different types like say someone is recyclable, some part is non-recyclable, some part will be having organic content, some part will not be containing any organic or some part it will be containing more moisture, some part will be containing less moisture.

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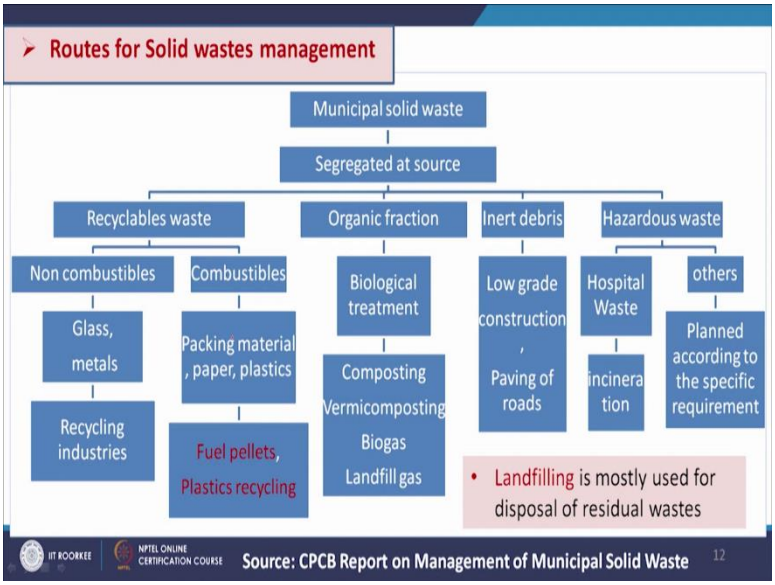

So, likewise we will see different type of wastes and how we can manage it. So, segregated at source, the first step is to segregate. Second is to identify different fractions like say recyclable waste and then organic fraction, inert debris and hazardous waste. So, if it is a recyclable waste that may be non-combustible or maybe combustibles.

If it is non-combustible like say glass, metals etc. So, those will be used in the industries through the recycling process and if it is a combustible, then those can be used for the energy production and like say packaging material paper, plastics these are some examples. So, those can be used for the fuel pellets productions and the plastics can also be recycled to produce different types of products.

So, this is one way of the management of the recyclable wastes and then some other type of materials which is having high organic fractions like a biological treatment can be suitable for that and composting vermicomposting biogas and landfill gas production can take place from this type of solid waste.

Already we have discussed about the composting, vermicomposting and biogas production and landfill gas is produced in the similar way. Similar types of reactions are also responsible for the production of landfill gas like anaerobic digestion. So, we will discuss this one.

And for inert debris, those are not having any carbon content and those are not suitable for energy productions or valuable extractions. So, those will be used or those can be used for the road constructions or paper productions or paving of roads. And if the material is of

hazardous in nature that may be from different sources maybe from hospital waste or maybe from other sources.

In the solid waste which comes from hospital waste all are not having the hazardous characteristics, some of those are having hazardous characteristics. So, this is classified as a special category waste and we will discuss it in detail for its management. And one example is given here that incineration that is one of the method which can be used for this type of, for managing this type of waste but we will be having more discussion on this in detail.

And some other type of wastes may be like say e waste or any other type of waste. So, those are maybe a special type of waste so for those waste materials some special methods are recommended and those are followed. So, the plan according to the specific requirements. So, management can be planned according to the specific requirement. And whatever may be the residual part generated from different methods that can be ultimately disposed through landfilling.

So, landfilling is the mostly used for disposal of residual wastes. So, this is the routes or schemes for the solid waste management. Now we have come to know that some part of the MSW which is having high carbon and hydrogen content and heating value those can be converted to energy.

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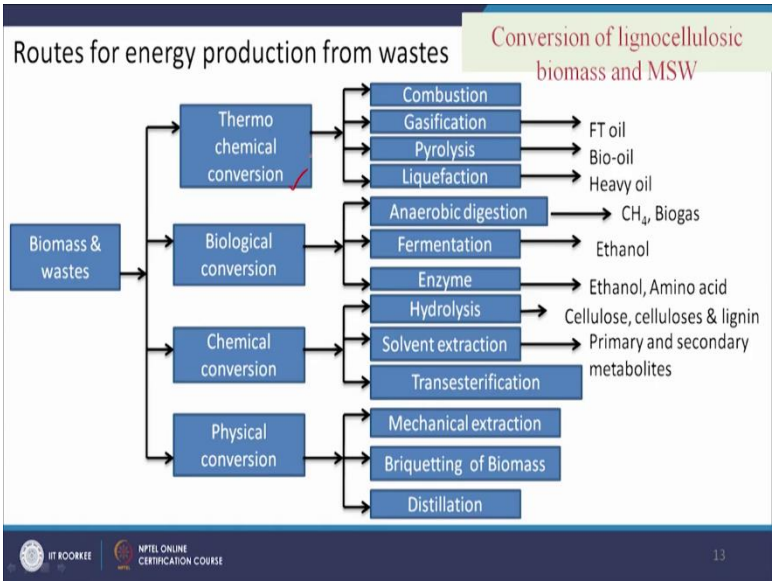

So, that conversion can take place basically through thermo-chemical conversion, biological conversion, chemical conversation, physical conversion. And physical conversion likes a mechanical extraction, briquetting of biomass and distillation.

So, these are the prerequisite for some other type of conversions. And thermo-chemical conversions like combustion, gasification, pyrolysis, liquefication which are very very important and those processes give us different products like FT oil to gasification, bio-oil from pyrolysis, heavy oil from liquefication.

And biological conversions anaerobic digestion, fermentations and enzymatic reactions. So, that can gives say methane or biogas, from fermentation ethanol and from enzymes ethanol amino acids etc. And chemical conversion like hydrolysis, solvent extractions and transesterification methods are used. So, here cellulose, hemicellulose and lignin we can get from lignocellulosic materials.

And then solvent extraction give us primary and secondary metabolites. So, these are the different methods which are used for the transformation of the solid waste for energy production. Now we will see what is landfill and we will discuss on it. So, we have seen that landfill is one of the important method, for the final disposal of the residual.

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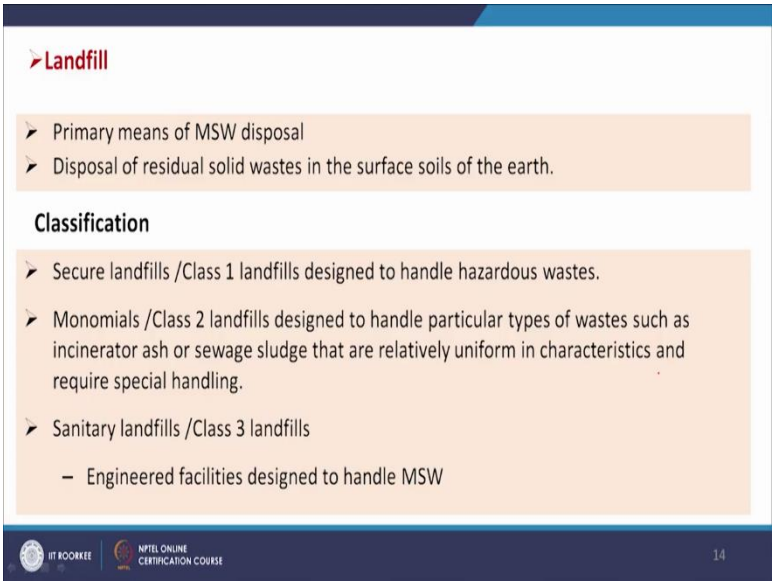

So, we can say it is the primary means of MSW disposal. And disposal of residual solids in the surface soils of the earth. How it is done? We will see depending upon the nature of the solid waste, the landfills may be of different types or may be classified into different category like say secure landfills, class one landfills that is designed to handle hazardous waste.

And then monomials or class 2 landfills designed to handle particular types of waste such as incinerator ash and sewage sludge that are relatively uniform in characteristics and requires special handling.

And sanitary landfills that is class 3 landfills that is basically suitable for non-hazardous materials and the residual part of municipal solid waste are processed through this route and engineered facilities are designed to handle MSW. So, these are the different types of land filling sites which are used for the handling of the residue of different types of solid waste.

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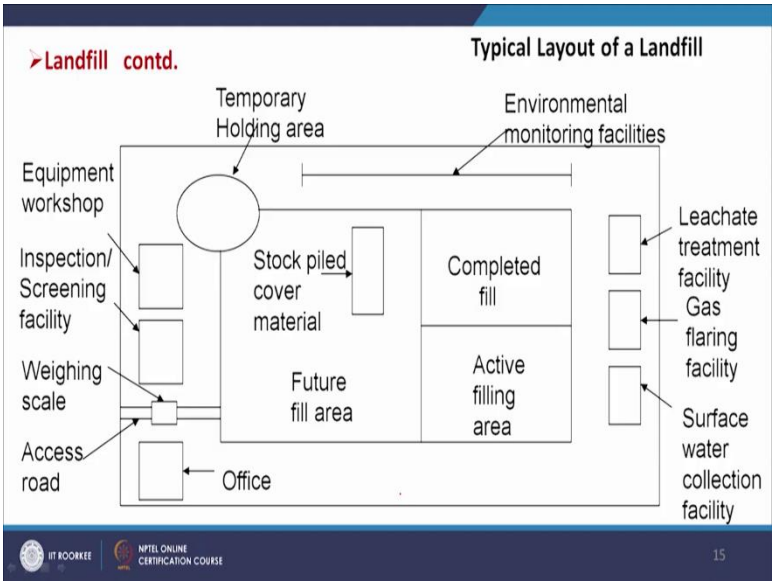

If we consider a land filling site, so we will see that there are some active filling area when daily the residual part of the MSW is coming and damping here. And this is low land and then there will be some soil cover for everyday filling there will be some soil cover and when it will be complete, then it completely will be covered with sand with certain thickness.

And then this will be filled and next there will be some area for future field area and certainly there are some areas where already the landfill has been completed. So, completed fill and then active filling area and future area those are very very essential area requirement for the land filling.

We also put some soil every day, so stock piled for cover material is also needed. We need to store somewhere so these are the different area requirement for the operations of the land filling. Apart from this we have discussed that this land filling will be creating some leachates and there will be some landfill gas production.

So, there will be some leachate treatment facility, gas flaring facility and surface water collection facility. So, these are very essential part of a land filling area. And we also need to manage the environmental qualities. So, environmental monitoring facilities are required and temporary holding area is also required. It also need one office space and road for access and weighing scale inspection and screening facility and equipment or workshop. So, these are the different parts of the landfill area or we can say this is the typical layout of a landfill.

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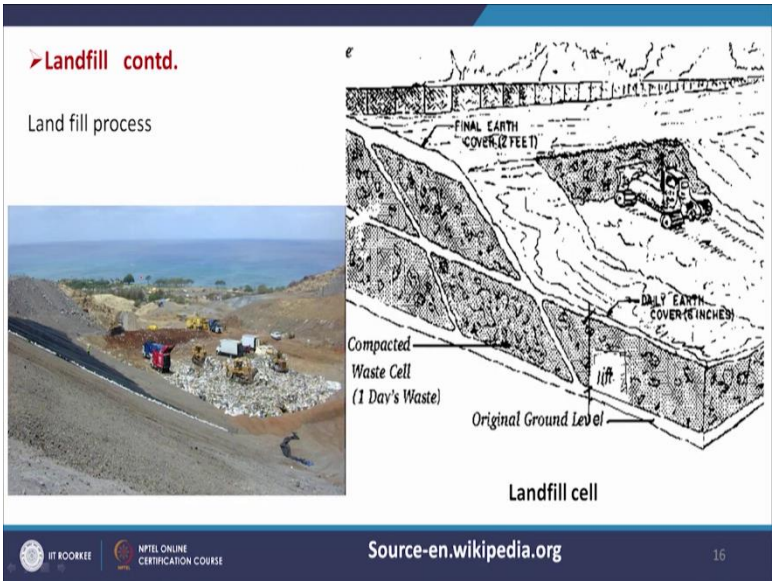

And if we see the landfill process, so here the residual material is collected and then it is put in the low land and it will be covered with the soil. As shown here, this is original ground level so this is compacted waste cell waste material is compacted here. So, you see some rollers are running, so it is being compacted and then daily earth cover so 6-inch cover is there, after one day compaction some earth is given on the solid waste.

Then solid waste residue some earthy material is given and then it is covered and then it is pressed and compressed. On the daily basis will be having the same type of filling and when the complete fill will take place then ultimately final earth cover of 2 feet has to be provided at the top. So, this is the fill process.

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And this slide shows us some live photographs of landfill sites at Gazipur, Delhi and this shows us, this is your active sites and this is your field site where the land filling has been done and that area is restored. So, landfill restoration that is covering a landfill once it has reached its maximum capacity and transforming it into usable land. So, this is the example of the restoration of the landfill.

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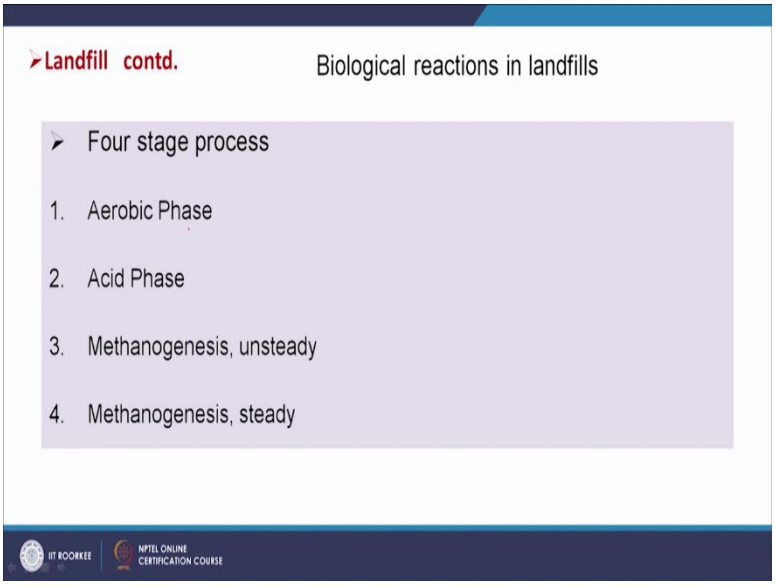

And different types of reactions which can take place in the landfills, those are similar to anaerobic digestion reactions like say aerobic phase and acidic phase and then methanogenesis unsteady and methanogenesis phase steady.

So, in this case at the top part there is the possibility of oxygen so aerobic reaction can also take place and as we go inside when the depth increases then acidic phase reacts then after acidic phase, methanogenic speed reactions takes place. This is unsteady and then steady state.

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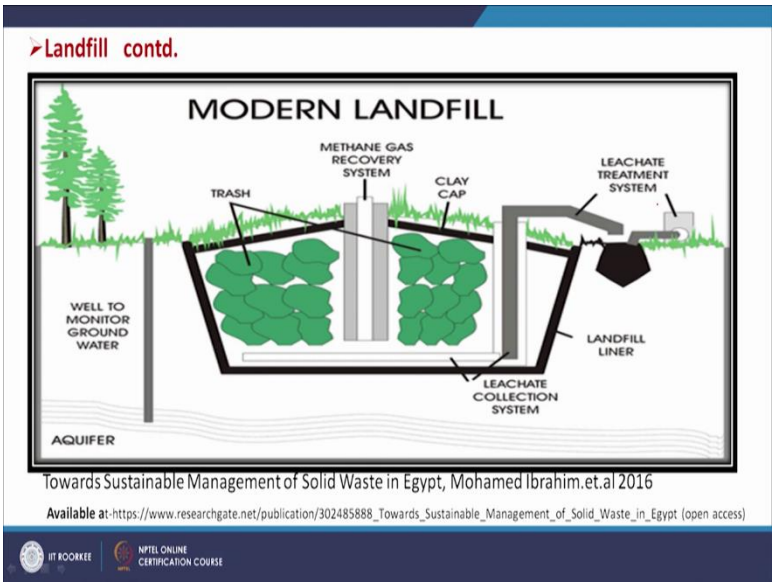

So, similar reactions which take place in anaerobic digestion and this is a modern landfill so here we see, this is your lining is done. So, for leachate collection and landfill liner is shown here and this leachate treatment system is there and trash and clay cap is provided at the top.

And inside the trash the material is put here and methane gas recovery system is also there where biogas is produced and water is going there. But this is not be installed or implemented near a ground water well. So, ground water well should be certain distance away from the landfill site.

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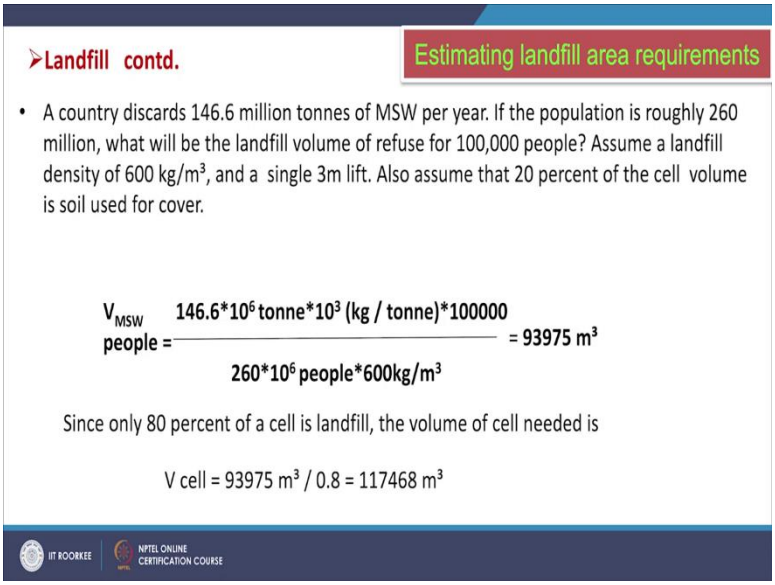

Now one example we will see, a country discards 146.6 million tons of MSW per year. If the population is roughly 260 million, what will be the landfill volume of reuse for 1 lakh people? Assume a landfill density of 600 kg/m^3 and a single 3 metre lift. Also assume that 20 % of the cell volume is soil used for cover. So, now we will calculate the volume of the MSW. So, how can you calculate?

$$V_{MSW}\text{people} = \frac{146.6 * 106 \text{ tonne} * 103 \text{ (kg / tonne)} * 100000}{260 * 106 \text{ people} * 600\text{kg/m3}}$$

Since only 80 percent of a cell is landfill, the volume of cell needed is

V cell = 93975 m³ / 0.8 = 117468 m³

The area of lift, at 3 m cell depth is

A = 117468/3 = 39155 m²

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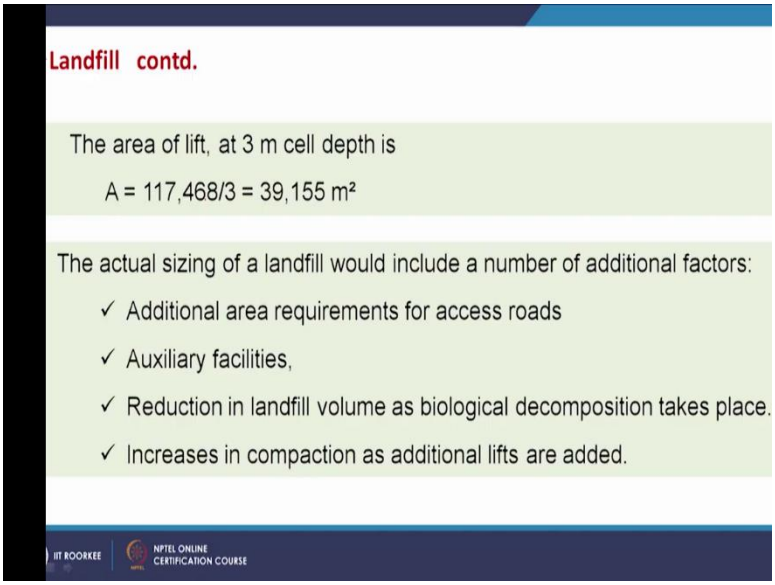

So, this value we are getting that is based on the material mass balance but we also discussed that it requires some other sites as well. This is the active filling side but some other auxiliary areas are required. So, actual size will be much more than this one.

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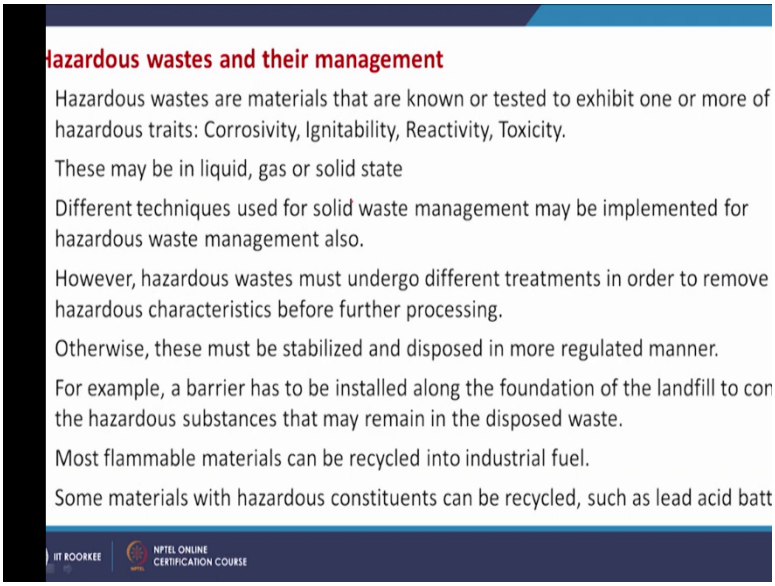

Now we will see the hazardous waste and their management. So, hazardous wastes are materials that are known or tested to exhibit one or more of the hazardous traits that is corrosivity, toxicity, flammability, ignitability, reactivity etc. So, these are the different traits, so these wastes have either one of this or all of these or any 2 or any combination of these properties. So, this may be in liquid, gas or solid state and different techniques used for solid waste management may be implemented for hazardous waste management also.

So, whatever methods we have discussed those can be implemented for this also but there is one condition that prior using this process it has to be decontaminated or the hazardous component has to be eliminated from it.

So, hazardous waste must undergo different treatments in order to remove the hazardous characteristics before further processing. Otherwise this must be stabilized and disposed in more regular or more regulated manner. For example, a barrier has to be installed along the foundation of the landfill to contain the hazardous substances that may remain in the disposed waste. Most flammable materials can be recycled into industrial fuel and some materials with hazardous constituents can be recycled such as lead acid batteries.

So, these are some examples of the removal of the specific characteristics from the overall waste so that the remaining part can be used following the same MSW management processes.

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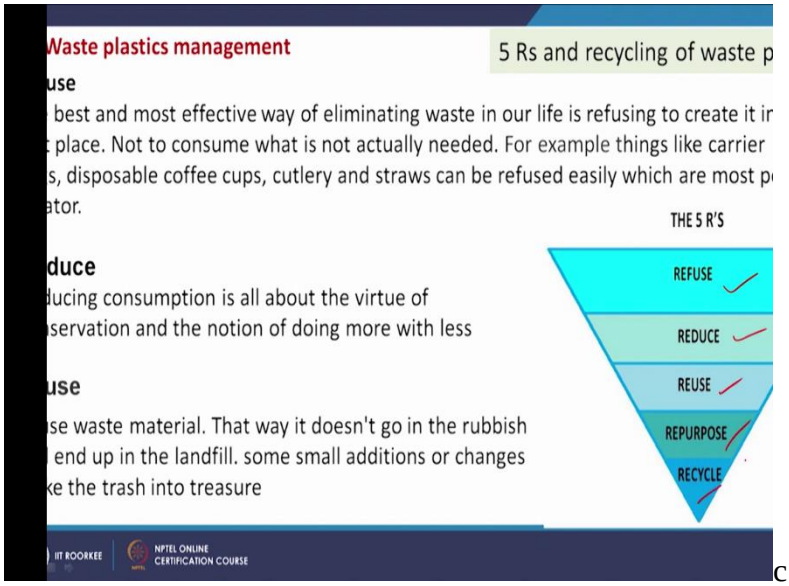

Now we will see the waste plastics. We have seen that municipal solid waste contains good amount of waste plastics, that waste plastics can be managed by applying certain rules. The waste plastic management certainly we can go for land filling but we can transform this part of the municipal soil waste into valuables.

And the philosophy for the plastic waste management is based on the 5 R's. So, those 5 R's are basically refuse, reduce, reuse, repurpose and recycle. Refuse means we should put our best effort not to use plastics. So, whenever applicable we should avoid the use of plastics.

For example, so when we go to shopping malls or any grocery shop, if we take a jute bag or any other bag, we can ask the shopkeeper not to give the plastics to us. So, if we all of us implement this practice, certainly the waste plastics will not be able to come into the waste stream. The volume of wasting will be reduced. So, that is refuse.

And reduce, that is reducing consumption is all about the virtue of conservation and the notion of doing more with less. So, this is another, similar type of philosophy somewhere it is inevitable. We need to use the plastic materials but we can optimize it, we can reduce it. And then reuse, reuse the waste which is being generated that can be reused, that way it does not go to the rubbish and end up in the landfill. Some small additions or changes make the trash into treasure.

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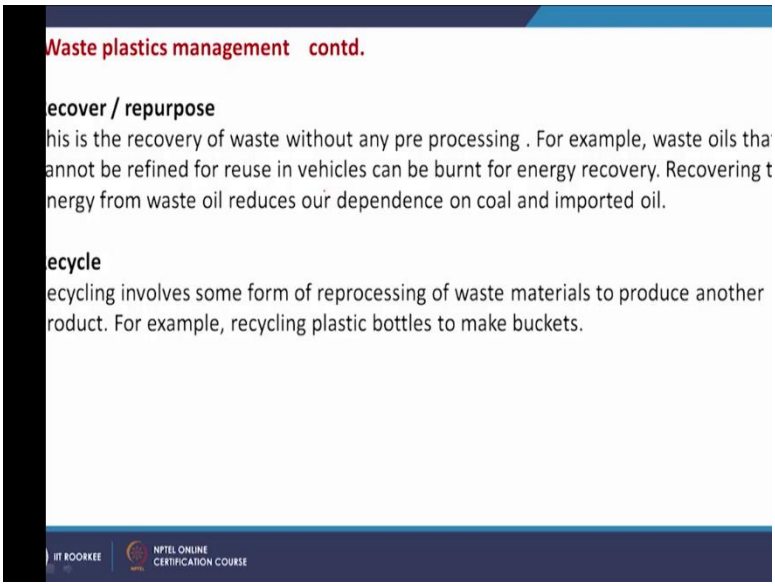

And recover repurpose, this is the recovery of waste without any pre-processing. For example, waste oils that cannot be refined for reuse in vehicles can be burnt for energy recovery. So, recovering the energy from waste oil reduces or dependence on coal and imported oils. So, similarly the plastics can be also converted to other form that can be used for other application.

And then recycle, recycling involves some form of reprocessing of waste materials to produce another product. For example, recycling plastic bottles to make buckets.

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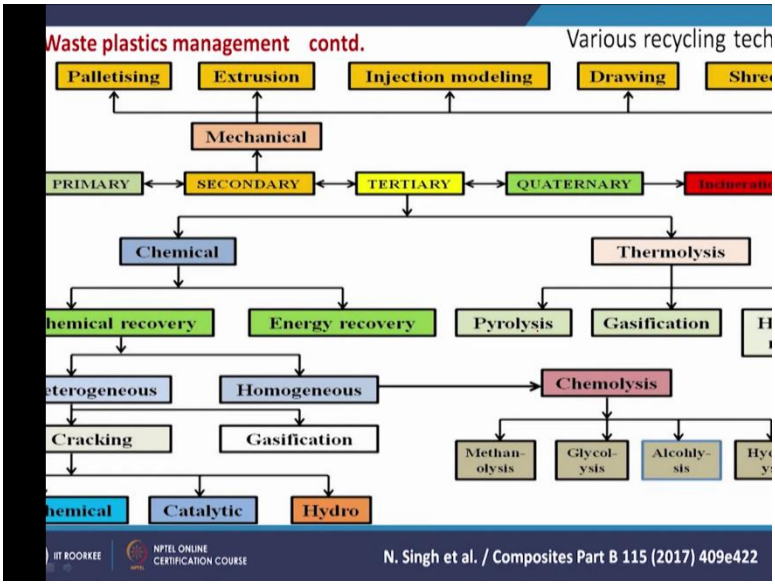

Now various recycling techniques which are applicable for the management of waste plastics if we consider then we are having say primary method, then secondary, then tertiary, then quaternary. So, this quaternary is basically incineration that is banned in the country that is not practiced and not allowed by CPCB. And this secondary and tertiary are mostly favourable, primary and secondary separations is bit difficult in some time.

And, secondary and tertiary are main important method. In the secondary that is mechanical transformations of the plastics that is palletizing, extrusion, injection moulding, drawing and shredding. So, these are the different mechanisms or processes which are used like say waste plastic to paper block or tiles production. One example of this mechanical conversion.

And chemical or thermolysis are the part of the tertiary treatment like say chemical recovery or energy recovery. So, chemical recovery that can be heterogeneous or homogeneous phase, if it is heterogeneous by using some catalyst that will be cracking, gasification and then this cracking can give us chemical catalytic products and then hydrocracking, catalytic cracking, and some other chemical reactions can take place through this.

And homogeneous that can be chemolysis that is methanolysis, glycolysis, alcohlysis and hydrolysis. So, these are the different methods and for thermolysis basically thermal application of heat for the breakdown of the compound, so that is pyrolysis, gasification and hydrogenation.

So, these are the different reactions or paths which can be used for the management of waste plastics. So, in this class we have discussed different methods for the management of solid waste including hazardous waste and plastic waste and we will be discussing some

transformation methods in conjugative classes, up to this in the class. Thank you very much for your patience.