Municipal Solid Waste Management
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Lecture No - 22
Solid Residue Generation, Characterization and Treatment

Hello students so we are in module 8 chemical transformations in the same function element. So today we are going to talk about solid residue generation characteristic and treatment as I have discussed in the previous classes. There are two major issues in the incineration process one was polluted gas that flue gas need to be treated properly. Before stacking into the atmosphere and another major issue was environmental issue from incineration plant is solid residue production and quantity is very large.

And again this as I told about characteristics also is again dependent upon the field, if suppose segregated waste is getting fed into the incineration was obviously the solid residue characteristics also will be somewhat able to utilize for production of some other kind of products. But suppose un-segregated waste or maybe some non combustible matter has been added into the incineration plant obviously those kind of material will come into the specially in the bottom ash the slag.

And that kind of waste, treatment is again very difficult and if not treatment for utilization of some other uses that will be also very difficult. So let us start, first I will tell about different ways or what different way the solid residue is getting produced during the combustion process or incineration process.

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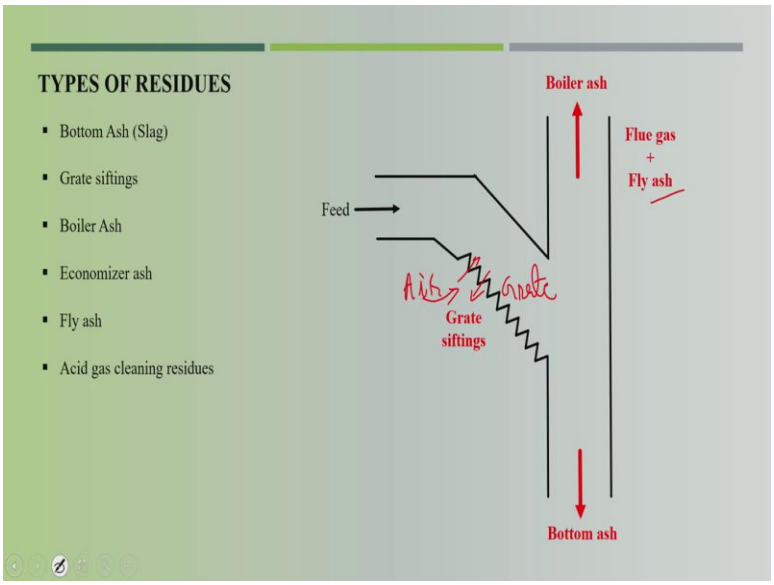

So suppose this is the furnace and this is the grate. So first we will be the bottom ash, so once this is the bottom ash, so once the feed will get combusted on the grate. So the combustible material for non combustible matter will be come out in the form of bottom ash that we can say is in slag also. Next is the grate sifting, so the grate sifting is coming out from the openings in the grate.

Because the entire composition is under the air, ok, so you need to provide air from the bottom of the grate for the complete combustion of the waste. So in these opening the very fine particles are coming out that will be called as grate sifting, and it is also possible that in the feed, some of the waste will be easily get combusted may be in the very low temperature could be 200-300°C temperature, entire waste is getting combusted.

So because of that also a lot of fine particles will get produce and that will come out in the form of grate sifting. Next is a boiler ash because whatever the heat is getting produced that is going for the boiler, ok to produce steam. So from the boiler also huge amount of ash was also getting produced, ok that we called boiler ash. Next is the economizer ash that while going to talk about from where it is getting produced.

and fly ash, this fly ash majorly gets produced from the air pollution treatment systems or whatever the flue gas treatment system that fly ash will get produce and along with that acid gas

cleaning residue which we saw in the previous class huge amount of the liquid effluent will come out from while treating the acid gases. So we will go one by one.

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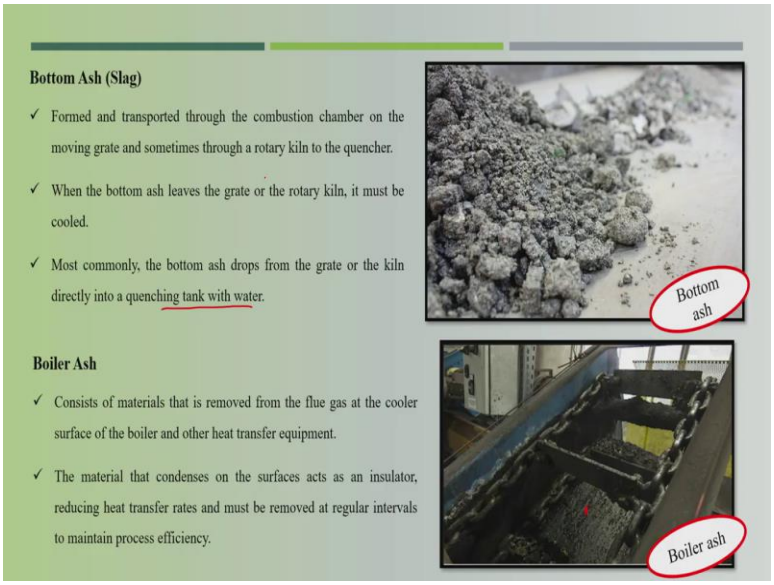

The first is the bottom ash formed and transported through the combustion chamber on the moving grate and sometimes from a rotary kiln to the quencher ok, so you can see this bottom ash because the temperature of this action is very high and even the size is small, so the storage is very difficult actually and you see in the given the coal treatment plants also a lot of particulate matter is getting produced. So because of that this ash is directly quenched in the water not on the sample on the particular area or field.

When the bottom ash leaves the grate for the rotary kiln, it must be cooled. So the most commonly the bottom as drops from the grate for the kiln directly into quenching tank with water. So that will benefit more in the both way because ash is getting cooled off, quenched into the water and also the storage is also very easy and beneficial. Now next is the boiler ash, boiler is consisted of material that is removed from the flue gas at the cooler surface of the boiler and other heat transfer equipment.

You can see ash is getting produced here ok, on the boiler. The material that contains on the surfaces as an insulator reducing heat transfer see reducing heat transfer and must be removed at regular intervals to maintain the process efficiency. So, time to time because once this particular

ash will be on the surface of the boiler. So because of that the heat transferred will get reduced and obviously the efficiency also will get reduced. So, that has to be removed time to time.

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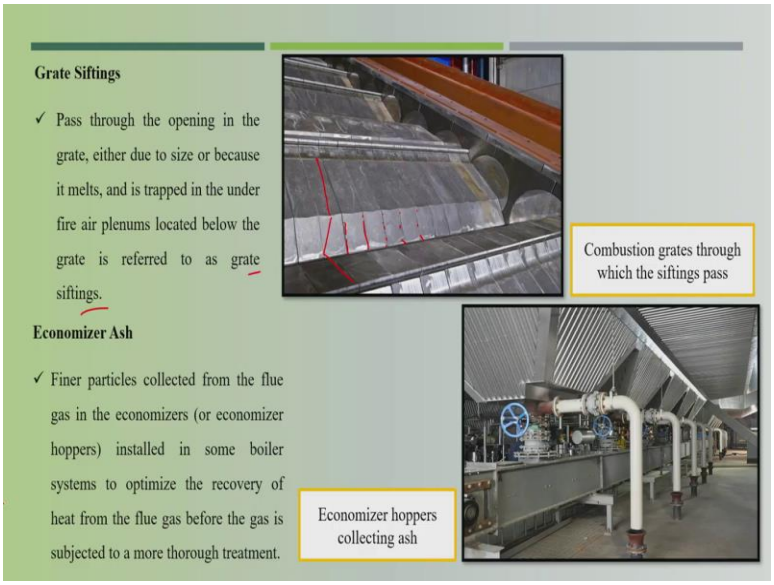

Next is the grate sifting so this is one of the photo you can see the grate this is the grate likewise so we saw in the one of the lecture the grate and this will be the small nozzles will be there in this area so that air could be available for combustion. So passing through the opening in the grate either due to the size because it melts and it traps the under fire air plenums located below the grate is also referred to as grate sifting. Like the same way from whatever the openings or nozzles under the Grate.

Now next is the economizer ash so this is one of the photograph from where the economizer ash is getting collected. So fine particle collected from the flue gas in the economizer is installed in some boiler system to optimize the recovery of heat from the flue gas before the gas is subjected to a more thorough treatment. ok. So that is also very fine particles.

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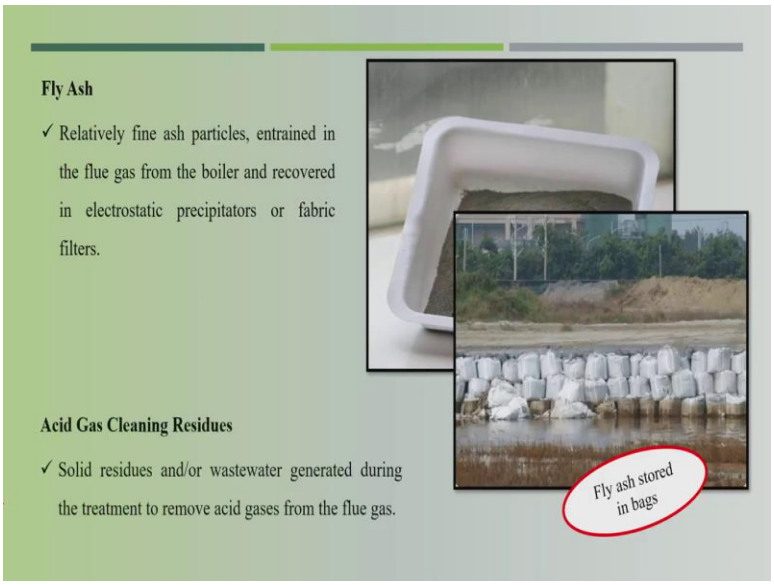

And the major concentration is fly ash after the bottom ash. So relatively fine ash particle entrained in the flue gas from the boiler and recorded in the electrostatic precipitator of fabric filter. We saw that in the previous lecture where we discussed about flue gas treatment system. So electrostatic precipitator, fabric filter on Venturi scrubber the dust is getting removed. The dust is nothing but fly ash. Why are these called fly ash? It is because they are very fine particle that will fly with temperature.

So because the flue gas will have a very high temperature, so because of that also these ashes are getting fired into the gas. That is why, it is called as fly ash, and you know that the fly ash production is very high in the coal power plants, and their storage is also very difficult. This is the flash storage in bags. Normally this is getting stored into the water ponds, So you see in the most of the incineration facility or in coal power plants they will have one special area they called as an ash pond.

So ash is go into the water always because the size is very, very small. Next is the acid gas cleaning residues. So, solid residue of wastewater generated during the treatment to remove acid, gases from the flue gas. Normally this acid gas we would not consider as solid residue completely because it mixed in water so that the that kind of solids is going into the wastewater treatment facility. And there with the sedimentation process getting removed off.

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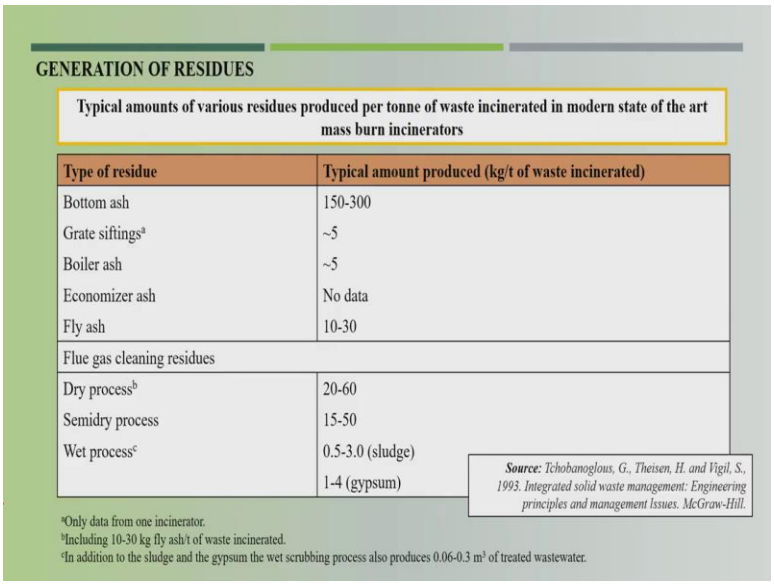

Now generation of residue was the quantity that is the important one this tweet to this is one of the very good book to read about the incineration facility. So here you see the typical amount produced. This is the kg per ton of waste incinerator. So the bottom ash is 150 to 300 kg and you see the fly ash is about 10 to 30 kg per ton of waste incinerated. So this is the major production of bottom ash and fly ash. These are the major production in the solid residue.

The flue gas cleaning system also with the dry process we saw the two major process, i.e. the dry process and wet process there also the large amount of solid residue will get produced ok specially in the dry process.

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Now the characterization of the residues and the chemical composition of bottom ash so you see here, not only I think these are some good nutrients like Sodium Potassium Magnesium is available but also it will have lot of metals, and these are all carcinogenic metal and even it will have PCB and pH. You see aluminum is there, silica is there and due to the presence of these materials we can use these materials in construction industries also, but before that we need to have a proper treatment.

So this is with the bottom ash and this is another table for fly ash. This is for fly ash, so in the fly ash also see, here the concentration of metals you see here in the very large concentration of metal under similarly in the fly ash also I think you compared with the bottom ash the concentrations of chemical composition are very high. You see here manganese lead concentration is 11000 milligrams per kg.

So the concentration of metals here is very high. The aluminium is 21000 milligrams per kg, I think normally these kinds of residue are called toxic because these toxicity is majorly because of metal concentration and very large concentration of metals available in the solid residue. So many times even in coal fly ash also coal power plant fly ash is also getting utilized for the brick making or for construction.

So it is always proposed to do the leachate characterization study. TCLP experiment has to be done that is testing for leachability, and the purpose is that whether these kind of metal is getting leached or have tendency to get leached once you are using for any construction material.

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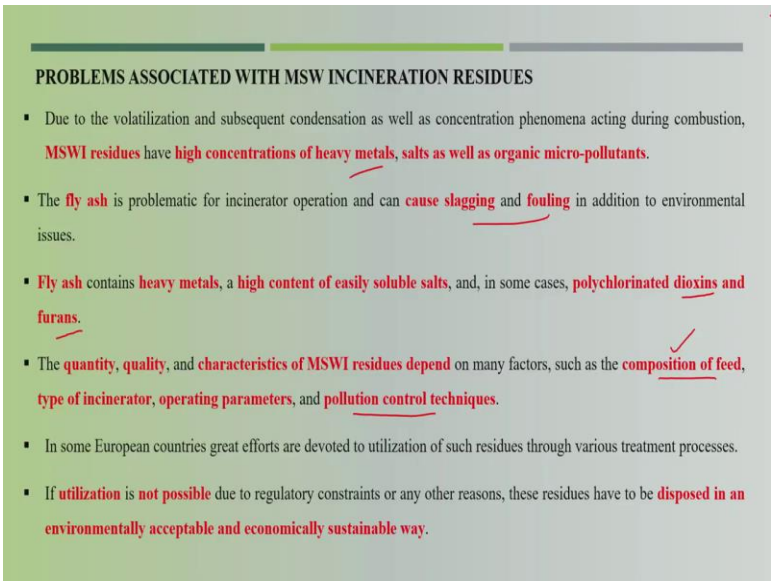

Now problem associated with the MSW incineration residue: so due to volatile action in subsequent condensation as well as concentration phenomena, occurring during combustion this MSW I MSW incineration residue have high concentration of heavy metal salt as well as organic micro pollutants. So the major concentration of heavy metals is problematic. So it is not that simply we can dispose on the land because these metals could be leached out and could be entered into the aquifer system.

So it will pollute the entire ground water. The fly ash is problematic for incineration operation can cause slagging fouling in the addition to the environmental issue. So fly ash is a fauling, slagging could be one issue and also because these kind of ash which is adding agent particulate matter is obviously this is not good for the human health. Fly ash contains heavy metal high content of easily soluble Salts and in some cases polychlorinated dioxins and Furins.

This is also important and one of the lectures I explained already when the temperature is around 200 to 400°C temperature formation of dioxins the furious could possible in flue gas and once you treat this flue gas it is always possible that the fly ash content of dioxins and Furins also. The quantity quality characteristics of these ashes or residues depend on many factors such as composition of feed. This is what I was talking about. Type of incinerator's operating parameter in pollution control techniques.

But I believe that the major one is dependent upon the composition of feed. If your feed is highly combustible one and is segregated one, in that case the quantity will also get reduced and for residue production also the characteristics will also be different. So in some of European countries grate effort are devoted for utilization of residue was through various treatment processes. So because the incineration was started long back in the European countries and some Asian countries like Japan so they were they were tried very hard and effort has been given to get utilise the such kind of ashes or treatment are utilization.

If utilization is not possible due to regulatory constraints are any other reasons this residue has to be disposed in an environmentally acceptable and economically sustainable way. So if such kind of material is not getting utilized properly, it has to be disposed of properly without creating any issues for the environment.

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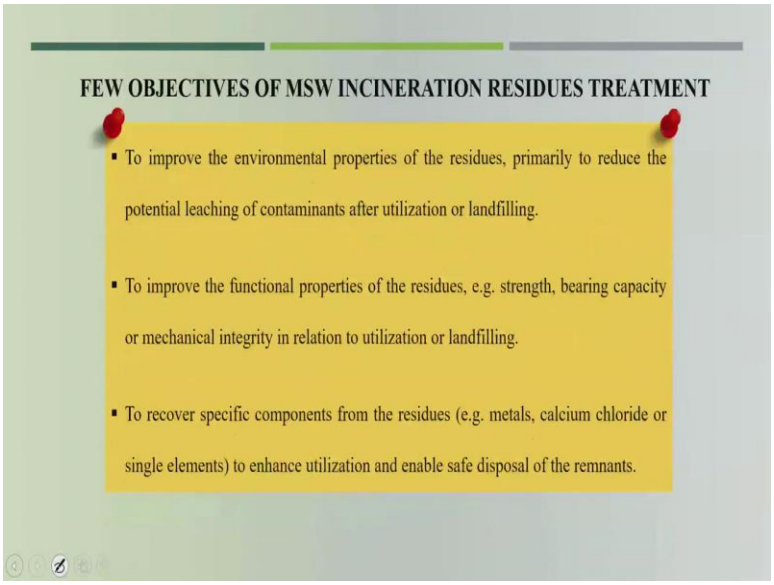

Now we will see the few objectives of MSW incineration residues treatment. So the objective what should be the objective and this text I took it from our solid waste manual in 2016, what should be the objective before treatment of solid Residue or incineration solid residue to improve the environmental properties of pressure to reduce the potential leaching of contaminants after utilization or land filling.

See this is what I was talking about potential leaching. So there we do the special experiment called TCLP. TCLP is a Toxic Chemical Leaching Procedure that is environmental protection rule based on that we do this TCLP test to know the leaching. To improve the functional property of the residue, it was like strength bearing capacity and mechanical integrity in relation to utilization. So, obviously such kinds of ashes are residues are mostly proposed for being utilized for construction purposes.

So obviously the strength and bearing capacity has to be known or has to be improved. So that it can be utilized for some particular purposes. To recover specific components from the residue was like metal that in the chemical composition huge amount of very large concentration of metals are there. If you are able to separate those metals from these ashes that will be also one of the benefits would be possible from the solid residue.

Now will go for treatment of bottom Ash so there are few technologies which I am going to discuss here and there are a lot of text available. You can go through, for detail. I've just put the few points about exactly the meaning of this kind of treatment processes.

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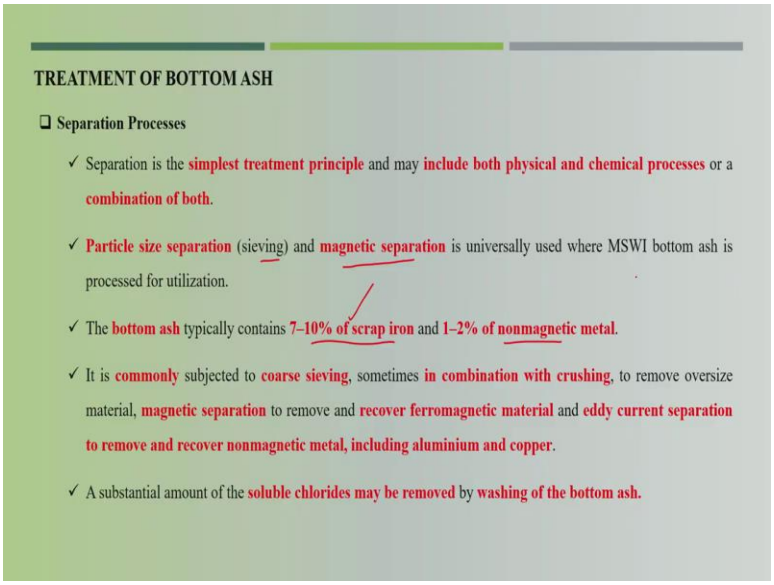

So now we will go for treatment of bottom ash. So there are few technologies we are going to discuss here, and there are a lot of text available. you can go through further details I just put few points about what exactly the meaning of treatment process. So, first treatment process is

separation process. So separation is the simplest treatment principle and may include both physical chemical process or combination of both.

The particle size separation or sieving: Sieving and magnetic separation from magnetic separation the target could be to separate the metal or ferrous metals from the remaining ash. This universally used where MSW incineration bottom ash is processed for the utilization. The bottom typically contains 7 to 10% of scrap iron and 1 to 2% of non magnetic metal at least from the magnetic separator the scrap iron we can easily get separate out.

And your own particle size separation also is one of the important unit because for different purposes different particle size is required for the utilization purpose. So suppose if their planning for use as an aggregate purpose of this ashes the size will be different and if you are trying to prepare a brick or to mix into the clay soil to produce the fired brick. So the size requirement is different you will be requiring very fine particle for such purposes.

It is commonly subjected to coarse sieving sometimes the combination with crushing's to remove the oversized material magnetic separation to remove and recover ferromagnetic materials and eddy current separation to remove recover non magnetic metal, including aluminium and copper. So there are different ways, separation could be possible. Also, substantial amount of soluble chloride may be removed by washing of bottom ash. But again bottom washing, will produce lot of wastewater by this process.

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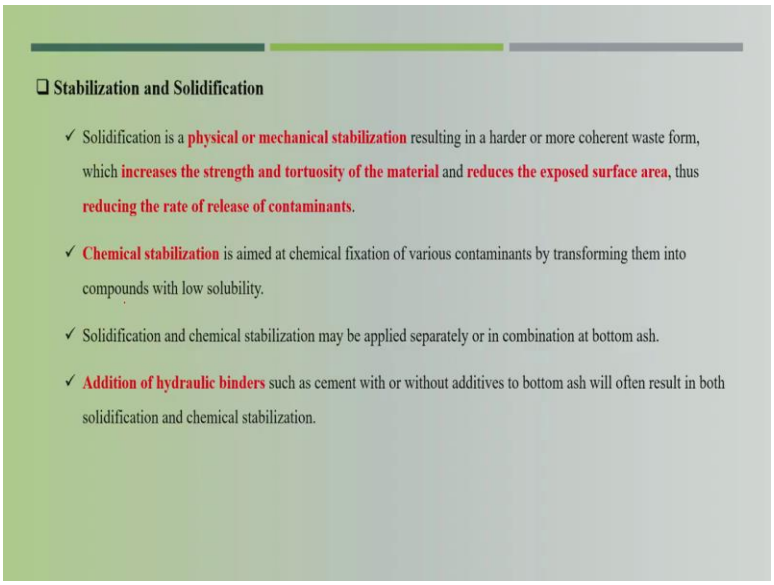

Next is the stabilization and solidification: So solidification is a physical or mechanical stabilization resulting in a harder or more coherent waste form, which increases the strength and tortuosity of the material and reduced the exposed surface area thus reducing rate of release of contaminants, that is one target I was talking about to reduce the leachability. So leachability can be possible when more surface area is available.

So if by this technology, you are able to reduce the exposed surface area then the rate of release of contaminants also will be reduced. Chemical stabilization is aimed is chemical fixation of various condiments by transforming them into compounds with low solubility. So this is also one of the very important idea. If you reduce the solubility of these metals because of that also, the leaching could be reduced and that is a thing one idea I am giving that pH is one of the very important parameter from which we can reduce the solubility.

Because mostly these metals are getting solubilized at low pH are mean acidic pH and if you are going for maintaining the very large pH of this bottom ash. Like if you maintain about 7, 8, 9 pH of this particular solid residue so it is very difficult to get leached out this metal at higher pH so that is also one of the way where we can reduce the solubility of this particular metal from the solid residue.

The solidification and chemical stabilization may be applied separately or combination at the bottom ash the also addition of hydraulic binders such as cement with or without, due to bottom ash will often result in both solidification and chemical stabilization. This is also one of the benefits.

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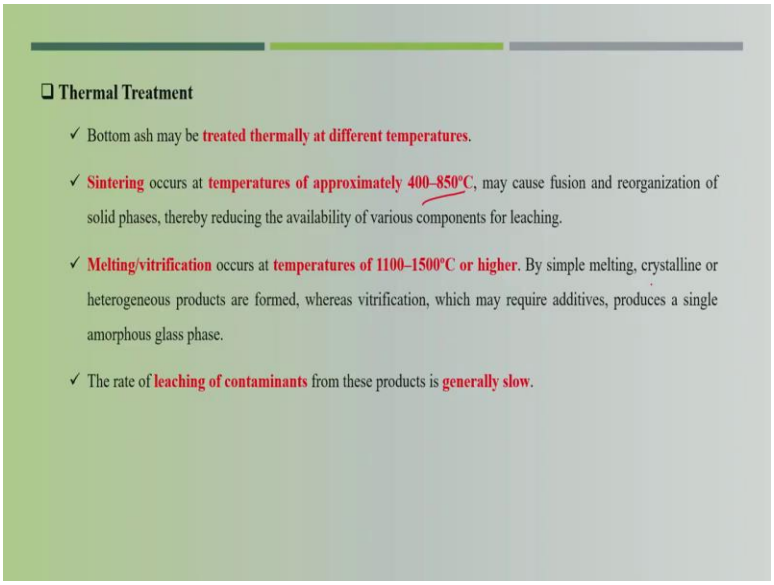

Next statement is thermal treatment. So bottom ash may be treated thermal at different temperature because if you see the calorific value of these ashes also is very high. So also could be combusted again or sintering occurs at temperature of approximately 400 to 850°C mainly causes fusion and reorganization of solid phases thereby reducing the availability of various components for leaching.

Every time you see all treatment targets are two how based we can reduce the leaching of these metals high concentration of metals available in the solid residue. So, melting or vitrification occurs at temperature of 1100 to 1500 degree centigrade by simple melting or crystallization of heterogeneous products are formed, whereas vitrification may require additives to produce a single amorphous glass face.

So at a very high temperature also we can combust and can reduce the rate leaching of metals from the solid residue. But the rate of leaching of contaminants from this product is generally

low so I was telling that once it gets converted into amorphous glass phase then leaching also will be low.

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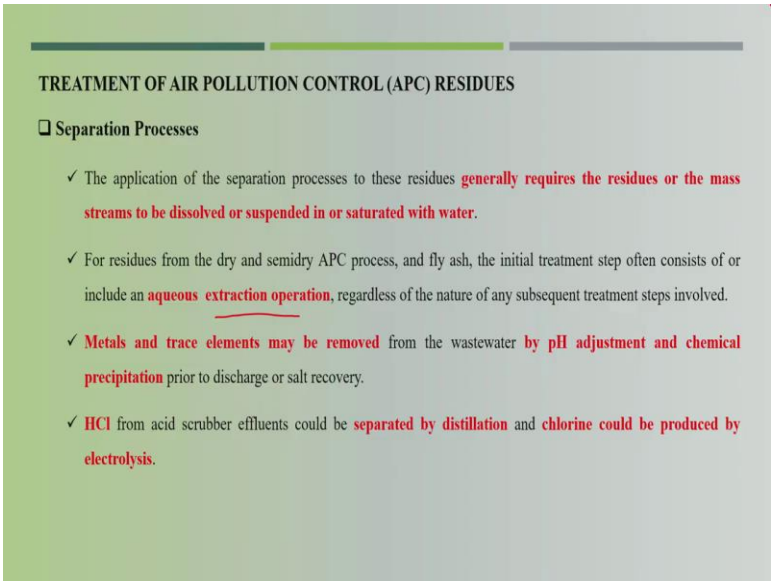

Now the treatment of air pollution control residue I think majorly it is fly ash there also we can provide similar kind of technology for flue gas treatment facilities, the solid residue production from the flue gas treatment. The first is the separation process: the application of separation process this residue generally required the residue or the mass stream to be dissolved or suspended in or saturated with water.

And for the residues from the dry and semi dry APC process and fly ash the initial treatment step often consists of or include in aqueous extraction operation regardless of the nature of any subsequent treatment steps involved. Metals and trace elements may be removed from wastewater by pH adjustment which I was talking about and chemical preservation prior to discharge or salt recovery and also the HCL from the acids scrubber. Affluent could be separated by distillation process of chlorine by electrolysis process.

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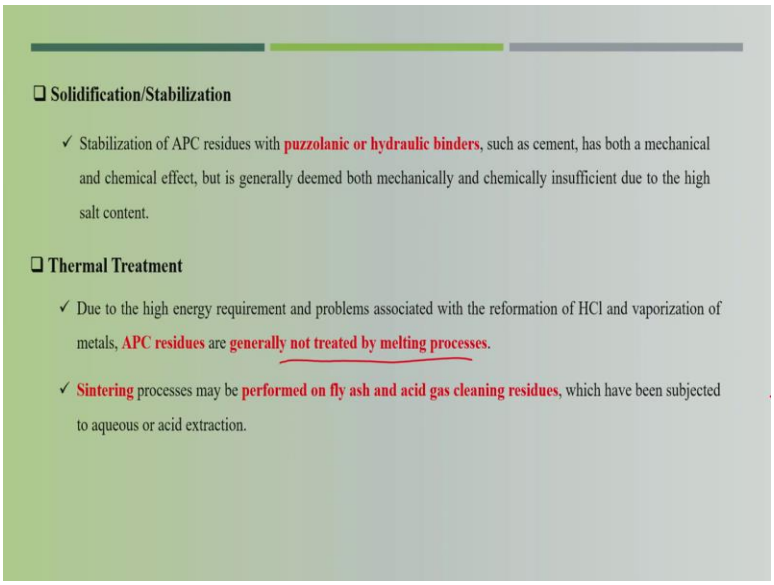

Next is the solidification or stabilization. So stabilizer APC Residue with hydraulic binder such a cement the similar way of bottom ash would be possible and for thermal treatment also. Due to high energy requirement problems associated with the reformation of HCL and evaporation of metal APC residue generally not treated by the melting process. Ok because the bottom ash will have large amount of combustible matter.

So that can be used for the thermal treatment, but normally air pollution control residue, could not have been treated without thermal treatment. Ok similarly the sintering process may be performed but I think that will be subjected to two aqueous acid extractions.

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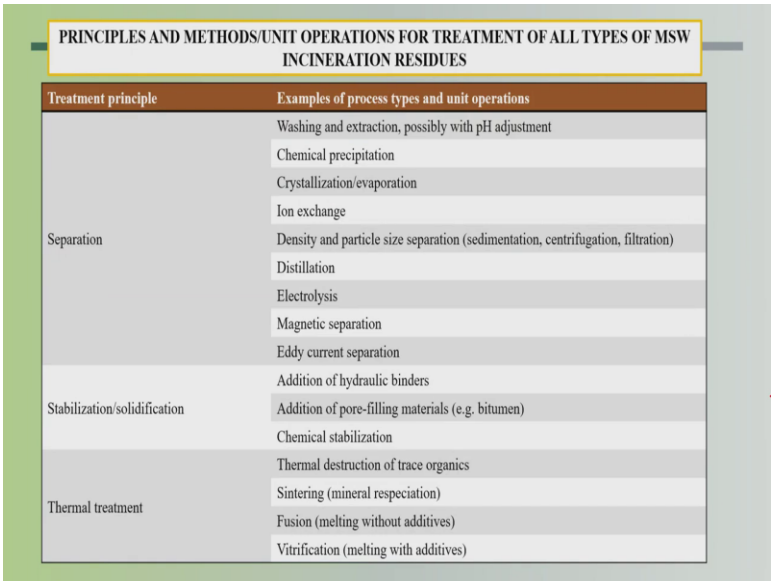

Treatment principle	Examples of process types and unit operations
Separation	Washing and extraction, possibly with pH adjustment
	Chemical precipitation
	Crystallization/evaporation
	Ion exchange
	Density and particle size separation (sedimentation, centrifugation, filtration)
	Distillation
	Electrolysis
	Magnetic separation
	Eddy current separation
Stabilization/solidification	Addition of hydraulic binders
	Addition of pore-filling materials (e.g. bitumen)
	Chemical stabilization
Thermal treatment	Thermal destruction of trace organics
	Sintering (mineral respeciation)
	Fusion (melting without additives)
	Vitrification (melting with additives)

Now principles and methods or unit operation for treatment of all type of MSW incineration residue, so these are the three major principles we talked about separation stabilization, solidification, thermal treatment. Now here this table has given the different technology this is the different unit operations or technology under the separation could be ion exchange process distillation or electrolysis, magnetic separation and Eddy current separation would be possible like in the stabilization of solidification.

Addition of hydraulic binder chemical stabilization could be made possible and thermal treatment like sintering, fusion or vitrification those kinds of unit operation could also be made possible.

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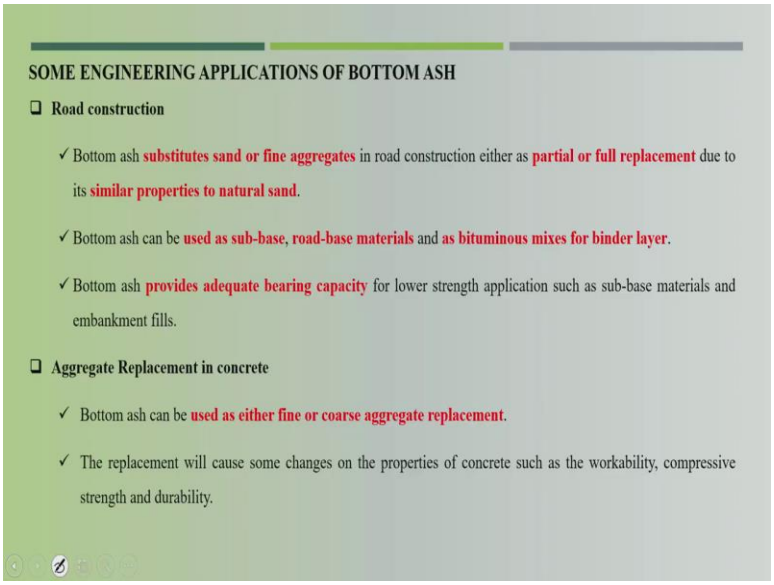

Now some engineering application of bottom ash: I think utilization would be possible like first for the road construction bottom ash substitute sand or fine aggregate in road construction and will be required large concentration of sand and fine aggregates for the road construction. So this bottom ash could be substituted, this material either as partial replacement due to its similar property to natural sand.

Only the right thing again, and again, I am saying the you do the leaching experiments that is the TCP, TCLP experiments if you are not finding large amount of leaching from that particular material, it can be utilized for these kind of purposes. Bottom ash can be used in sub base road

material and in bituminous mixes for the binder layers also. Bottom ash provides aquatic bearing capacity for lower strength in the application such a sub base material and embankment fills.

Next is the aggregate replacement in concrete. So which I was talking about like bottom ash can be used in either fine or coarse aggregate replacement. Ok and if you know the particle size in the separation process, we can separate out the particular size which we can use for the aggregate purpose. The replacement will cause some changes on the properties of concrete such as workability compressive strength and durability.

Now here I will come up with a very small video where it talks about separation process. I also show and I think this video is not showing, what exactly is neutralization which I will explain later on.

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So this is one of the energy recovery facility where the drive is getting a stack ok. It is an incineration furnace and huge amount of energy is getting produced from the combustion process. This is the bottom ash 12000 tons in a day so this is getting transported in particular island. So, the major objective use this bottom ash is for aggregate purpose. This is for their feeding for the separation process, you can see here.

So these are the different screens where you can see different target size. size less than 65 mm is getting separated and more than 65 mm. Then again this is getting cigarette in fine medium and coarse material, and here the metal is getting separated by Eddy current separation technique. So this aggregate size is using for the construction purpose, and is the fine material reminds material this is what they sent to mix for the filling of that particular area for the road construction.

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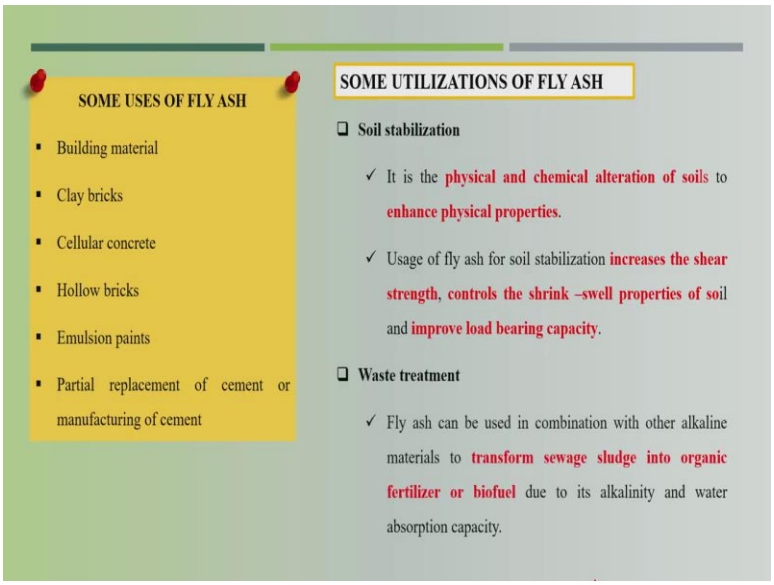

There are some more uses of this fly ash or solid residue like building material, clay bricks and in India also because we are using large amount of fire bricks and they are always using clayey soil. That is very one of the best agricultural soil we are using to prepare the fired brick. So in that case it was always proposed that whatever the fly ash is being produced in the coal power stations that could be added to prepare the fired brick maybe 5%, 10% if you add then compressive strength should be more than whatever the standards are available.

And why this kind of ashes is beneficial because it also contains calcium, it also contains silica, which also will be required to increase; the strength of the material, cellular concrete, hollow bricks, emulsions paints are partial replacement of cement even in the cement industry, also the 5%, 10% of this ashes could be mixed in the cement Some other utilization of the fly ash is for soil stabilization. It is a physical chemical alteration of soil to enhance the physical property.

Suppose somewhere some particular kind of embankment formation will be requiring large amount of soil, so this bottom ash could be utilized or replaced maybe 10%, 20% depending upon, what exactly compressive strength or what exactly the strength of that particular embankment is required to prepare but only again the same point I am saying and so do the leaching experiments and if it is under the standard we can always use them for such purpose.

Uses of fly ash for site stabilization to increase the shear strength and control the shrinkage or swelling properties of the soil and improve load bearing capacity would be possible. So, another utilization for the waste treatment the fly ash can be used in combination with other alkaline material to transform the sewage sludge into organic fertilizer or biofuel due to alkalify and water absorption capacity.

So in many countries because they are running large composting facilities and particularly the composting of the plants is using the sewage sludge for the composting purpose. So for that also, they will require one dry matter which will maintain the moisture content also increase the bulking density of that particular material. So these ashes could be utilized for such kind of particular areas. In some of the countries are developed countries, but if I talk about India's utilization of these ashes, the ash production of coal power plants is very large.

We are not able to utilise that particular ash and again the thing once you get the large number of incineration plants in India and you see the quantity of production is very large would be like you can see the pattern of waste incineration at the bottom ash production is around 100 to 200 kg, 150 to 300 kg. This you understand there is 1-ton incineration how much bottom ash is getting produced and also the fly ash.

Suppose that plant is feeding a plant capacity of 300 to 500 tons per day. So you understand that how much amount of bottom ash or fly ash is getting produced. So when you are planning for having an incineration facility in any city specially in India we need to look upon the two important environmental issues, one is flue gas. How best you will be able to treat that and before having the incineration facility you need to talk about the flue gas treatment facility or Air Pollution Control facility has to be installed.

And second is need to have the facilities of utilization of bottom ash not only directly the disposal method should not be available but are utilized and should not be possible. Need some kind of treatment or at least some chemical experiments have to be done before sending for the utilization purposes. Now, I believe that because India has number of medical waste incineration

facility. I am not much aware about that because there is a large amount of ashes which are getting produced.

But now under the MSW rule the utilization also has been given, how best we can utilise is ashes also has to be looked upon how best we can utilise the such kind of ashes. So yeah, I will finish this particular chapter of incineration processes where we talked about first basic database about utilization as fuel followed by incineration, types of incineration and two major aspects of incineration one is flue gas treatment and solid residue treatment and utilization.

Now one more discussion is remaining in chemical transformation. That is other kind of combustion facilities. Now here in combustion we discuss about in the presence of oxygen. Now there are few combustion facilities which do not require large amount of air supply like pyrolysis and gasification process. Although these kind of technologies are not that good for the MSW or mixed MSW but for separated MSW and specially MSW like plastic waste, separated plastic waste.

Separated paper waste or even agriculture residue separated agriculture residue also could be possibly utilized into the pyrolysis and gasification process and we have the large literature available on to that. So in the next lecture, I will just talk about this kind of technologies, not that particularly for MSW but I will give one lecture on pyrolysis and gasification, and the advantages disadvantages of those technologies. Thank you.