

**Geoenvironmental Engineering (Environmental Geotechnology):
Landfills, Slurry Ponds & Contaminated Sites
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**Lecture – 41
Geotechnical Reuse of Waste Materials – Part 2**

Good day and welcome to this class. We are going to continue talking about geotechnical reuse of waste topic which we started last time last time we looked at reuse of coal ash, reuse of tailings, reuse of tires, reuse of slag and I hope that after the discussion if a new material is offered to you very often a person from the industry will come and say; sir, I have this white powder and I have a huge mound of it can you use it for x, y or z purpose, mostly the industry guys will know whether it is hazardous or not. But the fact is that if a person from the industry says he has got a material which is not hazardous in his opinion then you should be able to check its suitability for using in earthworks.

The moment it is very fine; you have a problem because it is likely to be silt or clay sized and normally plasticity will not be there in the fine particles, why do we get plasticity in soils because of the net negative charge on the fine particles and the net negative charge on the fine particles come on account of the manner in which the clay particles have been formed in a process in the industry. These very fine particles may be mostly physical crushing or physical breaking down of grains into a very fine powdery range.

So, there may be no net negative charge on the particles. So, they may be like rock dust which may be in the clay size range, but when you try and classify a material which is in the clay size range which has non which is non plastic how would you classify it in soil mechanics term I give you a material I say 100 percent of this material is what is the clay size range.

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Below 2 microns; so, 100 percent of this material is below 2 microns, but it is non plastic, how will you classify the soil? Will you call it sand, will you call it silt, will you call it clay; what will you call it? You will go to your chart (Refer Time: 02:57) is done 100 percent of material is finer than 2 microns and you will go to your chart and plasticity index is 0. So, how will you classify it, it is not clear of low plasticity because non plastic. So, it is a non plastic soil in clay size range, there is no word given for the soil which is there separately, but it is not clay because the moment, you say it is clay, you imply it has plasticity and you imply it has a liquid limit and plastic limit you can call it non plastic clay size material that is fine, actually, it is silt in the clay size range actually it will behave like silt, but it is in the clay size range anyways.

So, when you get a new material you have to perform all the tests chemical physical environmental impact. So, that before you start working with it you are able to say that this material will not degrade with time this material will not harm the environment with time, it is workable as a soil like material and it can be worked with the existing earth moving equipment today we are going to look at 2 new issues municipal solid waste goes to a landfill and what kind of biodegradable content does municipal solid waste have anybody would try to recall from what we discuss in the beginning, it can be as high as what and as low as what biodegradable content in municipal solid waste.

So, I may not be wrong if I might say that biodegradable content can be from 35 percent to 75 percent. It is the rare municipal solid waste which will have 100 percent biodegradables because something or the other must be mixed in it and it is the rare municipal solid waste which will have less than 35 percent biodegradable because municipal solid waste is primarily the material which is coming out from the rejects from the households and the residential areas and fruit and vegetable markets and commercial centers and everything.

So, in a sense 35 to 75 percent biodegradable is what the waste has; now if bury it for 20 years, one would expect this ways to stabilize and the processes in landfill are in aerobic. So, anaerobic processes will decompose and degrade this waste, I am hoping that in 20 years, it will have fully stabilized do you think it would have fully stabilized and I am talking of it being in a waste dump which will open every year it rains and water would go through it. So, one would tend to think that old waste the biodegradable would have decomposed whatever Leachate had to come out would have come out whatever gases

had to come out would have come out and the non biodegradable matrix is what which will remain.

So, the question is can I use 20 year old waste as soil that is the question. So, one would go to a landfill and pick up waste which is 20 years old and see what it comprises off and just to remember, other than those 35 to 75 percent biodegradable what did we have a good thumb rule always is that you have one third is biodegradable one thirds inodes, you know construction and demolition debris silt from the drains or dusting sweeping dust that is 30 and 33 percent are others plastics, cloth, wood, rubber, leather, whatever you want; you want to say this are good thumb rule you know in different countries different things will happen in some countries a lot of paper will come because there is no [FL] system in India there will be no paper because you are very efficient [FL] system.

So, depending on the kind of recycling system you have which may have different compositions. So, over a period of time we would like to see whether a remains municipal solid waste becomes stable if it has not become fully stable is it almost stable and can be use it. So, that is the objective the other the other aspect we are going to discuss today is that there are several waste to energy plants which have come up across the world more than 2000 to be precise now they burn the waste.

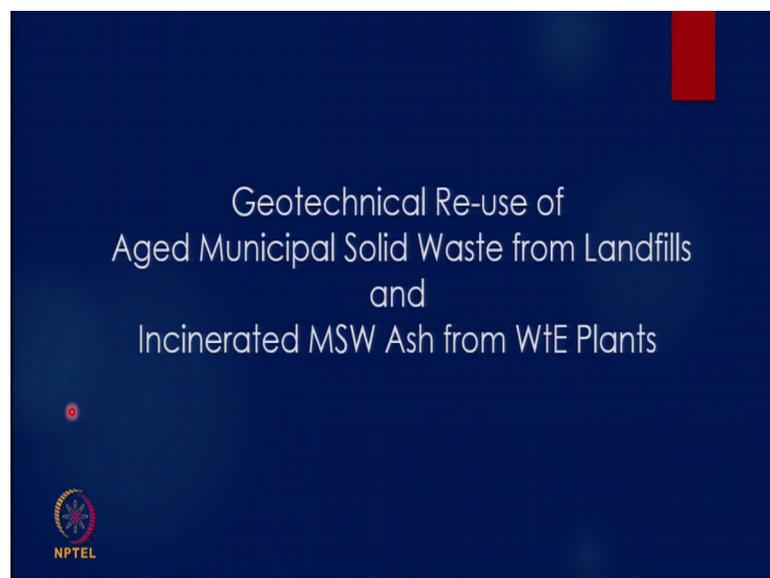
So, you burn coal, what do you get, what is this ash in the coal, how much ash do you get in coal in India, if I burn 100 units of coal how much ash will come out? We have got poor quality coal 30 to 40 percent ashes there what is this ash. Is it I burnt the carbon and it became ash and likely $C + O_2 = CO_2$.

So, what is this ash in the coal soil or rock when the coal was formed, it was not formed by a pure industrial process that you will get pure coal after all these trees and vegetation and everything which got compressed and a time soil must have fallen in it also? So, the original coal has a ash content of 30, 35,40 percent means it has soil it has impurity and that impurity in soil you burn it what remains some of the ash which is formed from the coal , but what is this ash this ash is actually the silica which is embedded in the coal. So, out comes ash.

Now, if I burn waste what do will come out will come; ash, if I burn wood, what will come out will come ash, may be in wood the ash will be or need 5 to 10 percent because

in its silica will be in the matrix of the wood it cannot have 30-40 percent wood kind of 30 percent soil inside it, it would not live. So, you burn municipal solid waste outcomes ash how much ash will come depends on how much soil you sent in. So, in some countries they will burn something called mass burn, they will burn the waste totally high ash will come out because entire waste was sent in some countries they will send segregated they will do some segregation and only sell the combustibles low ash will come out we will also look at that ash can that be reused and what is happening in the world these are really both cutting edge topics right at the front developments in the last 5 to 7 years.

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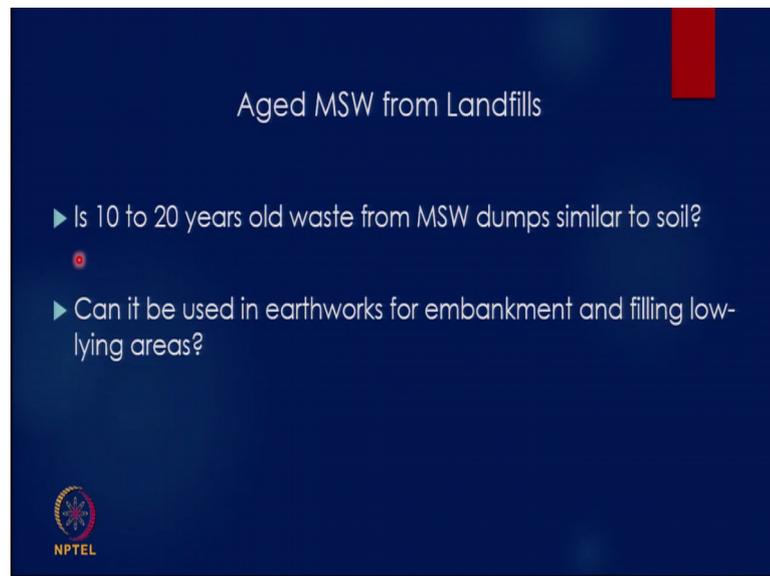
So, we are going to address geotechnical reuse of aged municipal solid waste. So, the word that we are going to use is aged which we get from landfills and incinerated municipal solid is ash from WtE plants, but just as an equivalence please see the equivalence here we are saying that maybe in 10 to 20 years all the biodegradable have decomposed and that is what the waste to energy plant is doing in an hour depending on the retention time inside that what is it burning its burning the organics.

Now it is not burning the soil, if it had paper, it will burn, if it had cloth, it will burn, if it had food waste it will burn, if it had leaves it will burn and what is the landfill doing landfill is decomposing them over a period of 20 years by anaerobic processes, what will

be decomposed the same stuff that will burn except that plastics will burn in the incinerator plastics will not get degraded in the landfill.

So, let us look at aged.

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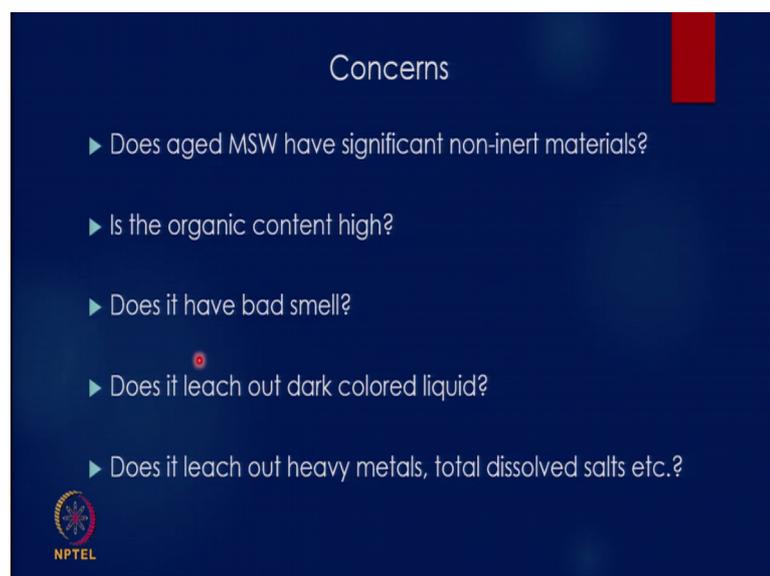
Aged MSW from Landfills

- ▶ Is 10 to 20 years old waste from MSW dumps similar to soil?
- ▶ Can it be used in earthworks for embankment and filling low-lying areas?

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Municipal solid waste the question is 10 to 20 years old waste from MSW dump similar to soil can it be used for earth works in embankment filling low lying areas and as backfill.

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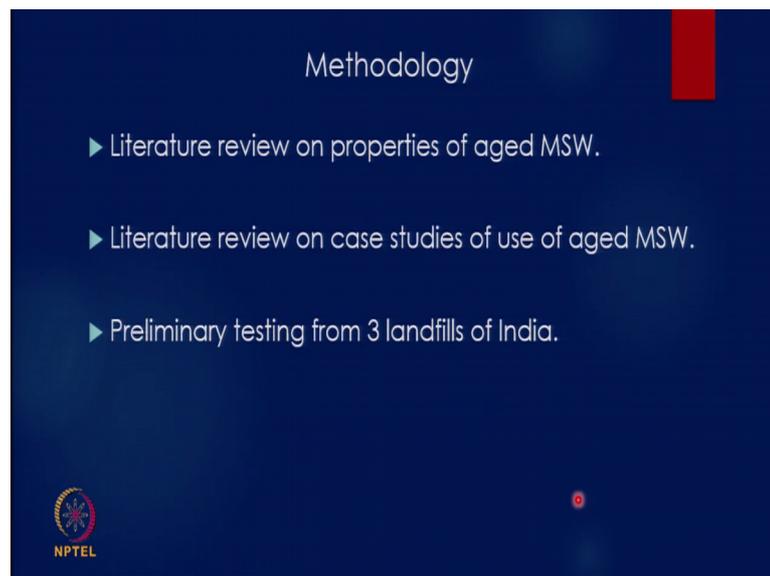
Concerns

- ▶ Does aged MSW have significant non-inert materials?
- ▶ Is the organic content high?
- ▶ Does it have bad smell?
- ▶ Does it leach out dark colored liquid?
- ▶ Does it leach out heavy metals, total dissolved salts etc.?

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So, does age municipal solid waste have significant non inert material when you send up. So, it the material that we should have should be physically and chemically stable. So, is the organic content high if it is high you have a problem the question is what is high is one percent high is 10 percent high or is 50 percent high, does it have bad smell does it came out colored water does it leach out colored water and does it leach out heavy metals or any other deleterious materials like sulfates chlorides and other salts.

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So, the methodology is we look at the literature look at the case studies of use of aged municipal solid waste and also look at the data emerging from India.

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Objective

Assess the suitability of Aged Municipal Solid Waste for recycling in bulk geotechnical applications such as in embankments and filling of low-lying areas.



This I have already said the objective is to see whether bulk geotechnical applications of aged municipal solid waste in embankments and filling of low lying areas is feasible.

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Comparison of properties of different aged MSW

Location	Southern California, USA	Seoul city, Korea	Deonar landfill, India	Kodungaiyur landfill, India	Perungudi landfill, India
References	Oettle et al., 2010	Song et al., 2003	Anna University	Kurian Joseph et al., 2003	
Age of waste	60 years	25 years	4-12 year	15 years	15 years
Grain size distribution	Passing 75 μ sieve (35.5-28.9)	Not reported	passing 8mm sieve- 63.5	Passing 2mm- 56-68	Passing 2mm - 33-41
Specific gravity	Not reported	2.58-2.44	Not reported	Not reported	Not reported
Liquid limit	48-62	Not reported	Not reported	Not reported	Not reported
Plastic limit	24-32	Not reported	Not reported	Not reported	Not reported
MDD (kN/m ³)	16.5-15.2	15.5-6.77	9.41	8.8-11.77	9.4-9.7
OMC	10.9-18.8	7.4-13.9	14	30-40	23-30
Organic content	6.3-12.4	6.06-12.45	14.5	8.9-20.7	8.9-15.8
Other geotechnical parameters	C _c =0.04	$\phi=12-35^\circ$ c= 0.05-0.25 t/m ² C _c = 0.1-0.2	Not reported	Not reported	Not reported
Remarks	Waste can be blended with soil and can be used in fill	If organic content is more than 8, it can't be used as sub-grade	Blended with dolomite, gypsum, neem cake and sold as fertilizer.	Fine fraction can be applied as compost to non-edible crops or as cover material after determining the geotechnical suitability.	



If you look at the literature and I am talking about some data from California some from Korea and 3 from India and typically the age of the waste 60 years, 20 years, 4 to 12 years, 15 years, 15 years bulk of it the waste is soil sized please understand. So, if I say if I come from this side passing 2 mm sieve about 40 percent passing 2 mm sieve about 60 to 70 percent passing a 10 mm see you 60 to 70 percent. So, gravel downwards or force

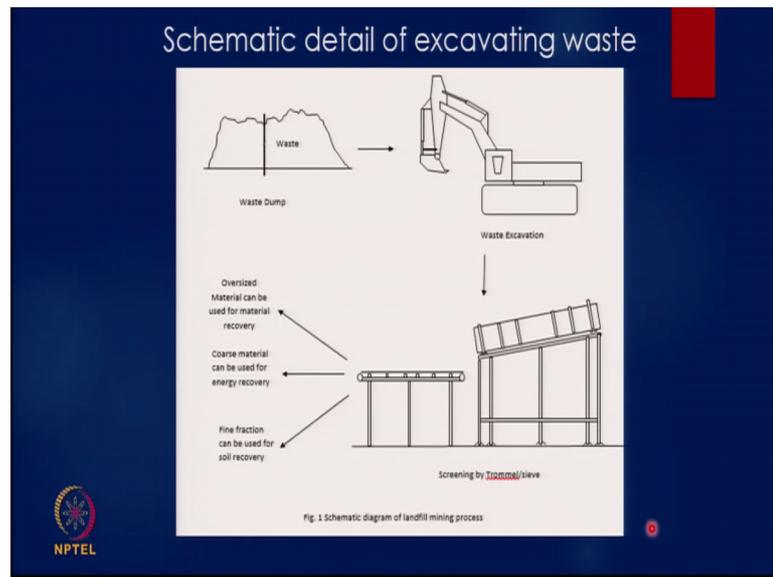
and downwards 60 percent of the material not reported passing 75 micron sieve is about 30 percent.

So, it means the others are more here some liquid limit and plastic limit has been reported by California, but not reported in the others maximum dry density good high range indicating more soil like behavior little lower ledge OMC white variations. So, the question is how much biodegradable content 60 years; 6 to 12, 6 to 12-14, 9 to 20, 9 to 16. So, what was 35 to 75 has come to about 10 percent that is all I can say, maybe 15 sometimes as low as 5 percent.

So, what is low what is high that is the only question which is your acceptance line currently the acceptance line of defining organic soils is 3 percent may be extendable to 5 percent if we do a lot of research maybe single more extendable to 7 to 10 percent, but we have to be cautious when we do that because there are materials which are having more organic content their compressibility as low, but you can see phi dash the only one which has been reported from Seoul is from 12 to 35 degrees you can be Seoul that 35 degrees is when the organic content is low and 12 is when the organic content is high.

So, organic content does play a role in reducing your angle of shearing resistance. So, we will see how this material has been used as we go forward, but in this study from southern California, they said because you see how do you bring this down to the acceptable level of 5 percent well at California, they said if you want to use it you will blend it with soil it is like you know dilution you mix soil with 6 percent organic content to 100 grams and take another 100 grams of soil with 0 organic content mix the 2 and the organic content will fall to 3 percent and you can say I can use the soil. So, that is what they suggested and they were very clear that if you are having organic content more than 8 percent the soil behaves very badly and of course, this is other materials.

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So, some of the work done by some of our students here including Mohith and Garima is basically what is happening in India.

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Hyderabad Landfill



- ✓ Age of the landfill- 15-17 year
- ✓ Dumping started - 2001
- ✓ Waste dumped- 4400 tons/day
- ✓ Area occupied – 320 acre
- ✓ Height of landfill- N.A. (on an uneven terrain)

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So, they have taken; Mohith was mainly the taken material from Kadapa landfill which is in Andhra Pradesh waste as old as 40 to 50 years I mean that is the oldest waste, it worked from 1970 to 2014 from Hyderabad landfill started in 2001. So, 15 to 17 years, do you remember 15 to 17 years will be at the dead center getting to that waste and taking it out is not that simple the landfill keeps on going like that? So, what is the oldest waste is in the center and then there is a Delhi landfill which is started in 94 and age is about 10 to 22 years.

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Delhi Landfill



- ✓ Age of the landfill- 20-22 year
- ✓ Dumping started - 1994
- ✓ Waste dumped- 1800 tons/day
- ✓ Area occupied – 32 acre
- ✓ Height of landfill- 50-60 m

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So, here is the kind of activity which one does this is the at Kadapa is a good site because that is a World Bank headed project where they are doing landfill mining. So, if you if you set up a landfill mining.

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Location and depth of sample collected

S.No.	Landfill site	Age of waste	Depth	location
1.	Delhi	20-22 years	5-6 m	28.51308°, 77.82248°, 251.90 m
		10-12 years	3-4 m	28.51268°, 77.28258°, 271.70 m
		3-4 years	4-5 m	28.51438°, 77.42418°, 240.90 m
2.	Hyderabad	8-10 years	2-3 m	17°31'29", 78°35'30"
		3-4 years	4-5 m	17°31'4", 78°35'31"
3.	Kadapa	-	-	14.48009°, 78.84491°

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Because they had dug up everything and mind it you are not sure exactly; what is the age of the waste because everything is no mixed, but in Hyderabad and in Delhi, one could get samples 8 to 10 years old and 10 to 20 years old.

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So, here is the Kadapa operation will the material excavator is excavating it from the landfill you use a trammel; a trammel is nothing, but a round screens with holes in it when they rotate. So, trammel is a rotating screen cylindrical rotating screen what is the advantage? The soil keeps on dropping as a sum of the soil will pass through and your other will go up and drop as it drops it breaks itself and passes through.

So, these are not like a greenside solution. So, here is the conveyor belt which takes the material up and here is their while screen through which the material passes through. So, that this excavator will put the material in this pit and this is the conveyor belt which is coming out of the pit and as it goes up these people are removing the large size material and you see and this is the large size material which is collected they do not allow it to go to the screen it will damage the screen, but this is the kind of material which comes out.

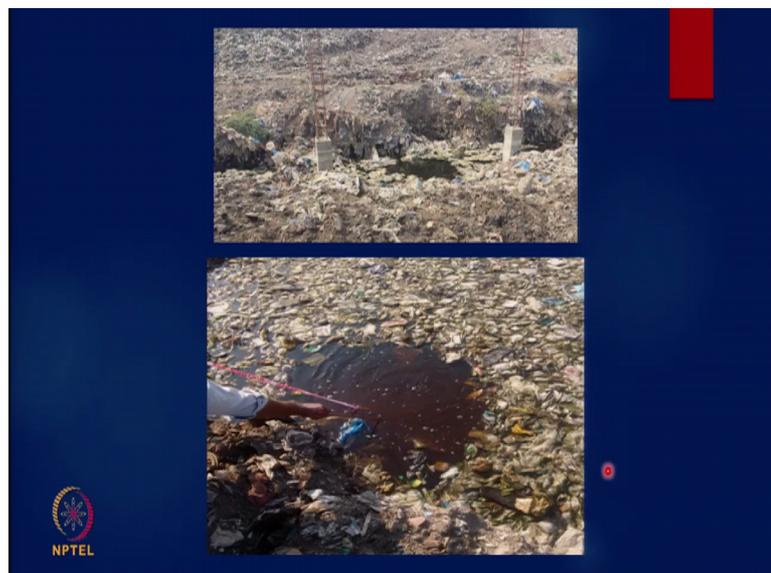
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Once it goes up the screen, these are the rotating screens. So, this is the material that will fall out; this looks like soil, right. So, some will fall out here some will fall out here and some will come out completely and what comes out completely is the oversized fraction.

So, here you can see the oversize fraction falling here. So, this is falling from here this is the oversize fraction. This is soil like more sand gravel like and this is the oversize fraction plastics and cloth and so and so forth that is the soil like material that is the oversize fraction and that is the landfill mining operation.

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But at the same site which is now closed since 2004-2014, 2004-2014; you will still get dark colored liquid out which not operational there is no fresh waste coming out this is Leachate. So, that is an indication that some colored liquid is still coming out it does not come out by itself when it rains it seeps through and comes out at the bottom this is what was done at Hyderabad, here you can see a young man we all familiar with digging out the old waste this is what it looks like and taking Leachate samples.

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And coming in to the trammel; this is the excavator bringing it dumping it that is the type of soil in one location you get you get dark another gets fresh brown soil.

So, now, which has got more organic content the light colored soil other darker soil.

Student: Darker soil.

Darker soil, good.

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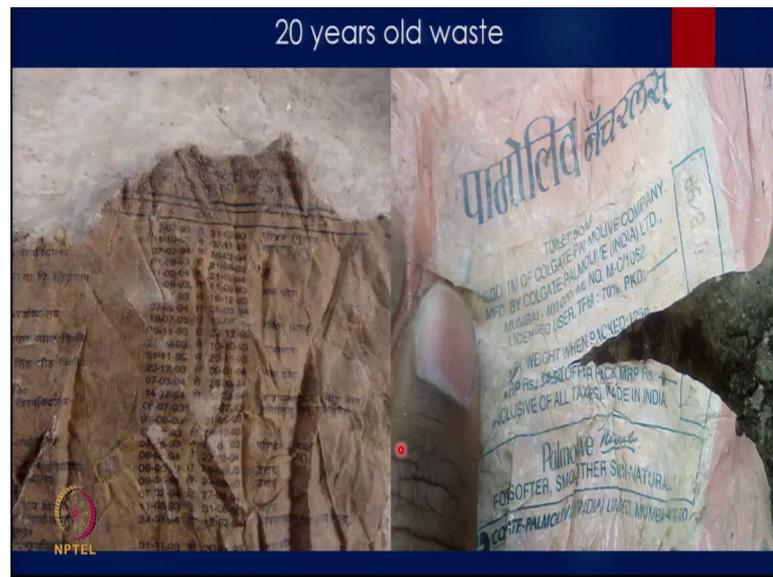


And this is at Delhi landfill excavator being used you can see this dark material this is another material and here there were no trommel. So, these sews have been made specially soil is put on it and this is something and this is ok.

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And Mohith was able to retract the dates from the newspaper cuttings which are still there and he could prove it that this was man in 98. So, that is almost 20 years ago.

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Compositional Analysis

Components	Percentage		
	Kadapa landfill	Hyderabad landfill	Delhi landfill
Soil	75.21	64.95	68.21
Inert (C & D waste)	15.09	7.56	24.12
Plastic	6.71	11.6	2.5
Paper	0	0.65	0.50
Textiles	0.87	2.18	1.2
Metal	0	1.48	0.2
Leather	0.73	1.41	0.60
Glass	1.01	1.65	1.25
Wood	0.16	3.34	1.2
Others	0.18	0.50	0.22
Total	100	100	100

So, he could anyways; so, when you look at the material in terms of its compositional individual components most of the material is soil size ranged, this is the oversize range this is the big large construction indium when you say inert you mean the large size material.

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Results of on-site grain size distribution for 4 months aerated waste from Kadapa landfill

S.No.	Date of excavation	Quantity of material (tonnes)	Material retained (%)						
			Rejected waste (> 30 mm)	30-8 mm	8-4 mm	4-0 mm	Inert (C&D)	Losses	Total
1	17-10-2016	455.3	26.7	33.1	12.7	22.2	1.8	3.3	100
2	11-11-2017	1078.84	30.3	15.6	13.9	26.5	1.8	11.6	100
3	16-11-2017	1168.51	32.0	22.1	13.1	16.6	2.1	13.7	100



But you have plastics here in Kadapa, you have plastics and your plastics and the others a little bit of textiles you know cloth rags leather wood all these are burnable these are energy recovery materials please remember when I do grain size distribution I am interested in how much is soil like material soil like means gravel sand silt clay.

So, sand range is less than 4.75 mm and gravel is 4.75 to 20; probably fine, gravel, but there is also coarse gravel. So, in anyways here is the material which is less than 4, 20 percent, 16 percent, here is the material which is 8 to 4, if you go up to 30, then it is 33 plus 12 plus 22. So, about 60 percent material is soil like.

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Results of on-site grain size distribution for air dried waste from Delhi landfill

Age of waste	Date of excavation	Time for drying	Total material excavated	Material retained (%)							
				Above 200 mm	200-80 mm	80-35 mm	35-16 mm	16-4 mm	4-0 mm	Losses	Total
20-22 years	14-01-2017	7 days	2050 kg	3	11	10	14	20.4	33.2	7.7	100
10-12 years	21-01-2017	7 days	3000 kg	2.1	9.6	8.6	10.6	20.7	40.6	7.6	100
2-3 years	28-01-2017	15 days	2460 kg	-	7.6	6.6	10.3	18.1	40.4	16.7	100



So, this is from Kadapa 60 percent material is soil like from Delhi also if I go 35 down 14, 35 to 16, 16 to 4, 4 to 0, 14 plus 20, 34 plus 33; 67, 10, 30, 70. So, 60 to 70 percent material is in the soil sized range.

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Organic content results

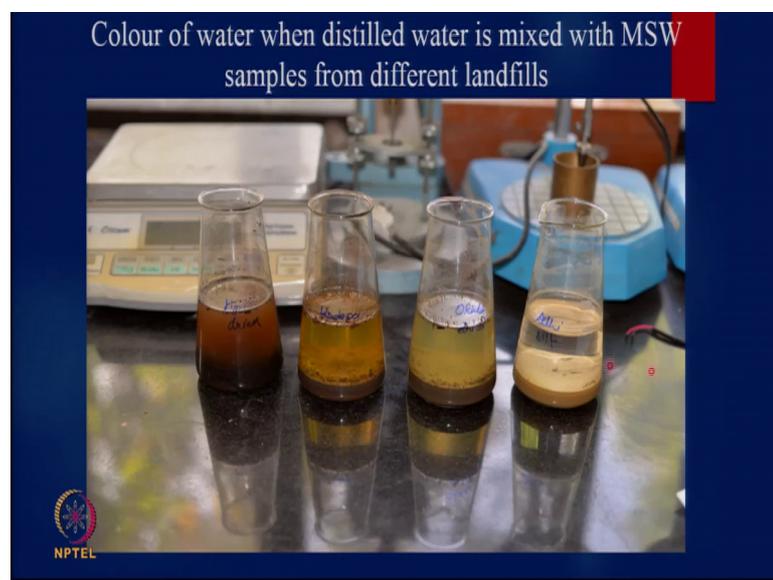
S.No.	Age of waste	Name of site	Organic content			
			0-4 mm	4-8 mm	4-16 mm	4-20 mm
1	20-22 years	Delhi landfill (20 years old)	6.8-7.4		7.9-9.1	
2	10-12 years	Delhi landfill (12 years old)	6.9-9.0			
3	3-4 years	Delhi landfill (3 years old)	6.5-7.0			
4	8-10 years	Hyderabad landfill (12 years old)	11-12			19.2-19.8
5	3-4 years	Hyderabad landfill (3 years old)	15-16			
6	-	Kadapa landfill	6.5-6.7	5.7-6.9		
7	-	Yamuna sand	0.6-0.65			
8	-	Delhi silt	1.1-1.2			



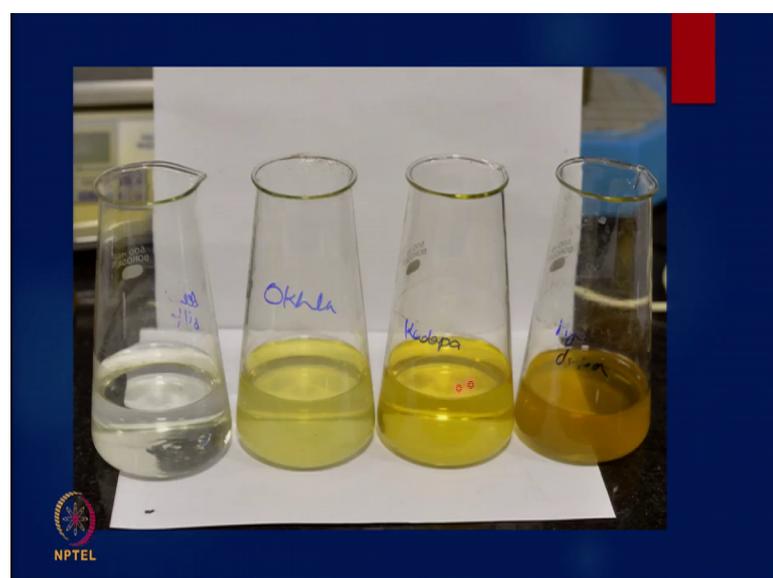
Then let us look at organic content because that is something which is important to us. So, from 20 year old Delhi landfill 12 years old Delhi landfill, we are having 6 to 10 percent, but this is only the very fine range please see the wood, wood fragments and the other will not go the moment you go to a higher range it goes up Hyderabad landfill

eleven to 12 in the very fine range, but if you go to the higher range 20 percent Kadapa landfill 6 to 7, if I take Yamuna sand point 6, if I take Delhi silt one they less than 3 percent and these are all above 3 percent and still the full has to be done because this materials has only been done in this side when you fill these up maybe the values will go up because this piece only 20 percent of the material if you are only going to take out 20 percent of the material you are not going to be able to use much of the material, but when you mix water with them because you saw black Leachate at the scientist said let us mix water with the soil.

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So, we get these kind of suspensions and when you decant it through filter paper this is silt this is Delhi this is Kadapa, this is Hyderabad.

So, there is some color which is coming out and the other thing is the Leachate.

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Total Dissolved solids in water coming out from MSW samples

S.No.	Location	Total Dissolved Solids (ppm)
1.	Delhi samples after 7 days aeration (1:3 dilution)	5100-5300
2.	Delhi sample without aeration but oven drying (1: 3 dilution)	4500-4800
3.	Kadapa (1:4 dilution)	750-800
4.	Hyderabad (1:4 dilution)	3500-3600
	Delhi silt (1:4 dilution)	150-200



That you analyze, they do not have very high heavy metals maybe a 1 or 2 mean exceeding the limits, but the lot of total dissolved salts. So, we just mixed up 1 is to 3 dilution or 1 is to 4 dilution, this is just initial works and we are getting very high values of total dissolved we see Delhi silt is 100 to 200 in drinking water, 600 is acceptable desirable, but here these are all in thousands. So, that is a problem.

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Odour coming from MSW samples

S.No.	Landfill site	Duration	Level of odour
1.	Delhi	Immediate	High odour
		After 4 days aeration	Nominal odour
		After 1 month	Nominal odour
2.	Hyderabad	Immediate	High odour
		After 1 month	Medium odour
3.	Kadapa	At the time of collection	Very less odour



And does it smell bad when you excavate it smells very bad, but within a month there is very little order after aeration for a month you can it is like soil you feel it is like soil high order when you excavate it.

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Permissible limit of organic content in soils to be used in subgrade and backfill

S.No.	Name of country	Maximum limit for organic content (%)	Regulatory organization	
1.	USA	Louisiana	5	Louisiana Department of Transportation
		Texas	1	Texas Department of transportation
		California	If organic content is up to 1 then soil can be used without any treatment. Maximum limit is 5 .	Department of Transportation, California (Jones et al., 2012)
2.	Australia	1	Department of Transport and Main roads	
3.	India	3	Ministry of Road Transport and Highway (MORTH)	
4.	UK	2	UK Department of Transportation (UKDOT)	



And if you look at the permissible or organic contents in the various literature this is about up to 5 percent is allowed maybe sometimes 7 percent is also mentioned, but 5 percent is allowed.

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Landfill mining project summary						
Name of landfill site	Operation started	Area mined	Reclaimed soil (%)	Sieve size used (mm)	Use of reclaimed soil	Lab test investigation
Perdido landfill	2009	20 acre	60	75	Daily, intermediate cover	Not reported
Perdido landfill	2006	50 acre	70.4	25, 75	Daily cover, reuse is also possible	Organic content= 5-15 %
Naples landfill	1986	33 acre	40-60	75	Cover material	Heavy metals were found below the limits
Edinburg landfill	1990	1 acre	75	100, 50 and 25	Cover and off-site use	Not reported
Edinburg Landfill	1992	1.6 acre	Not reported	100, 50 and 25	Construction fill	Not reported
Frey farm landfill	1991	3-4 lakh yd ³	41	25	Cover material	Not reported
Maung Pathum Dumpsite, Thailand	N.A.	15000 cubic meter	69-75	2-10	Not reported	Organic Content= 0.3-2.7 % TCLP indicated it was not hazardous
Burghof landfill, Germany	1993	Not reported	70.5	N.A.	Fine material was reused at landfill site	Not reported

Then you look at case studies that all these landfill mining projects how much of the soil has been used as an earth fill and this is all these landfills abroad and you are using about 60 to 70 percent soil, but all of them are reusing it at the landfill as intermediate cover daily cover intermediate cover daily cover, nobody is using it as an earth fill except one place it is written, but the details are not mentioned. So, even today because of the organic content and associated salts there is a slight thinking that it cannot be used, but one thing is clear maybe it requires some pretreatment and if you can find a cost effective way of pretreatment then I can use it in the earthworks.

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Metal concentrations in aged MSW reported in literature									
Landfill location	Conc. (mg/kg on dry basis)								
	Hg	As	Cd	Ni	Pb	Cu	Cr	Zn	Mn
Shanghai, China (Zhang et al., 2008)	-	-	1.5-2.8	30-51	98-173	78-221	143-229	228-323	-
Matuati, Bangladesh (Karim et al., 2014)	-	-	N.D.	0.84-9.89	5.66-87.89	14.41-137.7	10.10-81.19	19.41-163.80	9.66-82.89
Alachua, Florida (P. Jain et al., 2005)	0.1	1.5	0.6	5	9	16.9	8.6	140	47.8
Khulna, Bangladesh (Karim et al., 2014)	-	-	N.D.	0.42-0.90	11.18-69.6	4.72-14.66	1.72-2.96	12.46-29.4	16.28-24.26
Kano, Nigeria (Anake et al., 2009)	-	-	22.3±19.3	6.0±8.72	2917±538	-	81.2±61.3	-	-
Kaduna, Nigeria (Anake et al., 2009)	-	-	1.17±0.71	0.67±0.3	84.3±41.3	-	10.8±1.15	-	-
Gboko dump site, Nigeria (Anhwage and Kaana, 2013)	-	0.145	0.499	0.445	1.063	-	0.278	-	-
Fiborna landfill, Sweden	-	-	1.6	12	88	53	0.39	500	-
Shanghai landfill, China (C. Xiaoli et al., 2007)	-	-	1-3	44-61	280-440	300-540	110-160	970-1360	-
Screening level (Canadian standards)	6	12	1.4	50	70	63	64	200	-
Response level (Dutch standards)	36	50	13	100	530	190	-	720	-
Contaminant level (Hans, 1995)	0.08	1.8	0.1	5.59	15.1	14.5	25.42	30.5	105

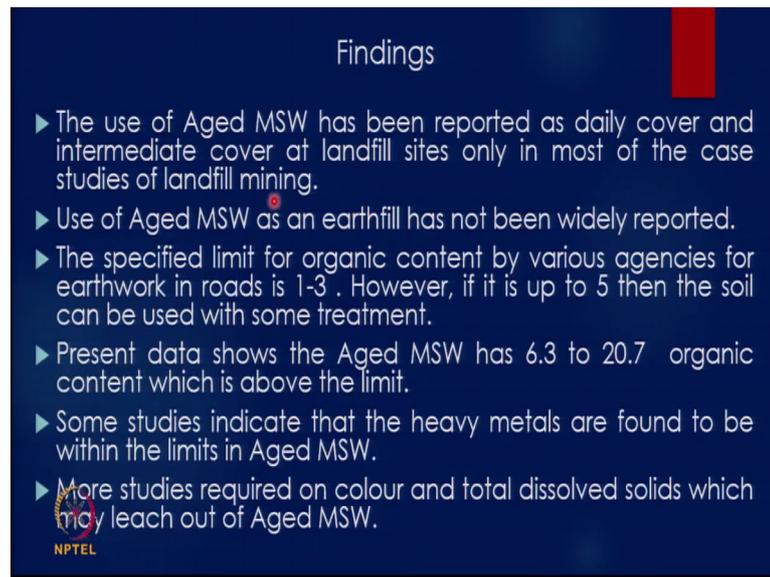
If we look at the heavy metal concentrations reported in literature with respect to aged municipal solid waste and if we compare these concentrations with respect to some standard levels reported from the Canadian standards that Dutch standards and also the continental crust, we find that in some of the aged waste the heavy metals are higher or elevated for example, if you look at chromium then the screening level as per Canadian standards is 64 and the continental crust value is 25, but we are seeing that at least in 3 landfills the chromium values are more than these values similarly copper lead and cadmium have also been reported to be higher than the acceptable values or at least elevated in comparison to the soil.

We look at metal concentrations in aged municipal solid waste from Indian landfills and here also we are using the Canadian standards and the Dutch standards along with the continental crust values and if you look at this table where we have determined all these heavy metals we find that in bulk of the landfills the chromium is high in some of the landfills copper is at an elevated level and in one of the landfills cadmium is at an elevated level, it is interesting see that the Okhla landfill at Delhi, what are the heavy metal concentrations in comparison to the local soil adjacent to the Okhla landfill and if I compare you will see cadmium is similar, but nickel is a higher, lead is higher, copper is higher, chromium is 10 times higher, zinc is elevated, manganese is elevated and so is iron.

So, the issue is that in aged municipal solid waste sometimes the heavy metal metals can be higher this is another interesting comparison, we are looking at the heavy metals at Okhla, Hyderabad and Kadapa and we are compare comparing this with the composed standards; that means, can the waste that we have taken out from these landfills how do the heavy metals compared with the composed standards as per Indian MSW rules and we find that if we look at cadmium it is higher in Hyderabad in Kadapa, if you look at chromium the acceptable values 50, but in all the 3 aged waste it is higher and. So, is copper in 2 of the landfills.

So, in this way what we see is that in some landfills the heavy metals may be within limits, but in other landfills heavy metals may be at an elevated level.

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- ▶ The use of Aged MSW has been reported as daily cover and intermediate cover at landfill sites only in most of the case studies of landfill mining.
- ▶ Use of Aged MSW as an earthfill has not been widely reported.
- ▶ The specified limit for organic content by various agencies for earthwork in roads is 1-3 . However, if it is up to 5 then the soil can be used with some treatment.
- ▶ Present data shows the Aged MSW has 6.3 to 20.7 organic content which is above the limit.
- ▶ Some studies indicate that the heavy metals are found to be within the limits in Aged MSW.
- ▶ More studies required on colour and total dissolved solids which may leach out of Aged MSW.

So, use of aged municipal solid waste has been basically as cover and intermediate covered in most cases and in earth works. It is not been widely reported of the issues about organic content because aged waste is reported to have 6 to said 20 percent in some of the studies, heavy metals have been reported within limits. So, often they will say they are higher, but issues about color and total dissolved solids have still to be resolved, but I do expect over the next 5 years, the technologies will now be there where we can start reusing it we do some aeration we do some burning, we do some pretreatment to make it workable any thoughts on your mind before we go forward because the next one is incinerated ash.

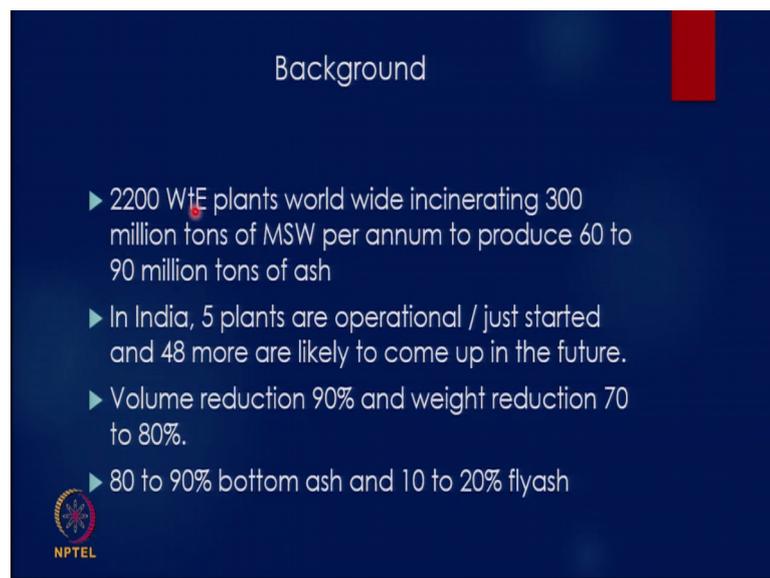
So, as far as aged municipal solid waste is concerned one thing that does come out is it degrades very rapidly in 10 years that 35-40 percent is down to 10-12 percent and whether that limit of 5 can be taken to 10 is the jury still out, but remember that if you want to use more and more of the waste you have to take the higher fractions. So, as you go to course or fractions the organic content seems to be going up. So, if you want to do 70 percent then you have to use 30 mm down and the test for doing organic content is a muffle furnace test where the crucible in which you put the sample is very small.

So, if you want to take a lot of soil then you have to have a big muffle furnace which is required for at representative organic content any questions then let us look at some data on waste to energy ash. So, one of the thoughts which one has is that if you take the

waste and burn it, it will vanish. So, let me remind you nothing vanishes if you do mass burning in India and abroad a lot of mass burn incinerators are there; that means, they put everything in it including the soil mix a little bit of pre segregation, but you mass burn the whole thing 30 percent to 35 percent of the material is still going to come out as ash because that is the amount of soil and in hertz which were there originally. So, nothing vanishes volume reduction is 90 percent because plastics and paper and cloth will burn and wood will burn. So, volume reduction is 90 percent, but weight reduction is only 70 percent.

So, we have a 3 waste to energy plants in Delhi, but one is in one has been working for the last 3 to 4 years other 2 have just started this year. So, we will not look at data from there we will look at the waste reaching the landfill from this one plant and we also looked at data the remise done this literature as to what data regarding this ash.

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Background

- ▶ 2200 WtE plants world wide incinerating 300 million tons of MSW per annum to produce 60 to 90 million tons of ash
- ▶ In India, 5 plants are operational / just started and 48 more are likely to come up in the future.
- ▶ Volume reduction 90% and weight reduction 70 to 80%.
- ▶ 80 to 90% bottom ash and 10 to 20% flyash

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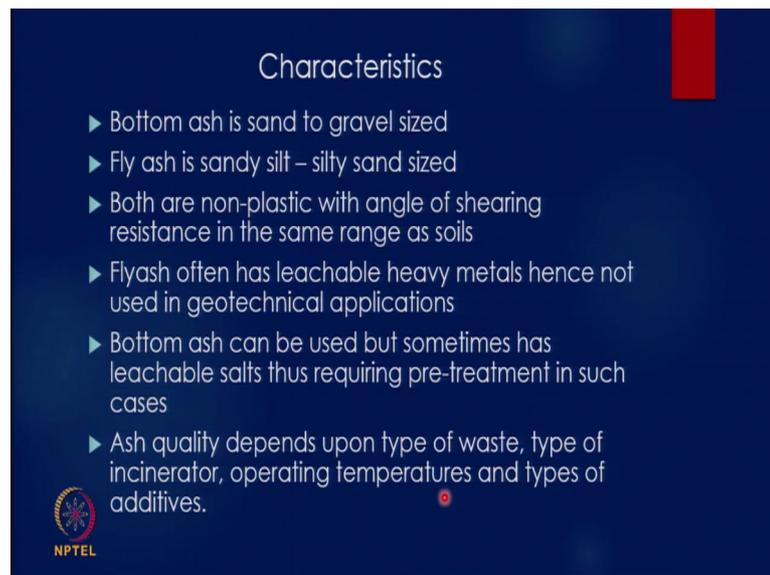
So, there are more than 2000 waste to energy plants which are burning 300 million tons of municipal solid waste every year and they produce 60 to 90 million tons of ash and this ash has also to be reused or they go into landfills. In India 5 plants are now operational or they have just started under the Swacch Bharat mission 48 more are likely to come up in the new future that is a huge number of waste to energy plants, but I do expect in all the major cities in the one million plus cities which is what 53 cities are all about because we have no land and the next city or the next village will not allow you to

dump the waste near there and they near the backyard we are going to have to use these waste to energy.

Volume reduction is 90 percent, weight reduction is 70 to 80 percent do you remember in coal fired boilers, how much was bottom ash and how much was fly ash in our coal, coal fire thermal power plants when you did the there anybody remember how what percentage of the ash which comes out in coal plants is fly ash and what is bottom ash well it was 20 percent bottom ash and 80 percent fly ash. So, 80 percent of the ash fly ash here it is opposite 80 to 90 percent of the ash is bottom ash and 10 to 20 percent is fly ash.

So, that is a big difference number one.

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Characteristics

- ▶ Bottom ash is sand to gravel sized
- ▶ Fly ash is sandy silt – silty sand sized
- ▶ Both are non-plastic with angle of shearing resistance in the same range as soils
- ▶ Flyash often has leachable heavy metals hence not used in geotechnical applications
- ▶ Bottom ash can be used but sometimes has leachable salts thus requiring pre-treatment in such cases
- ▶ Ash quality depends upon type of waste, type of incinerator, operating temperatures and types of additives.

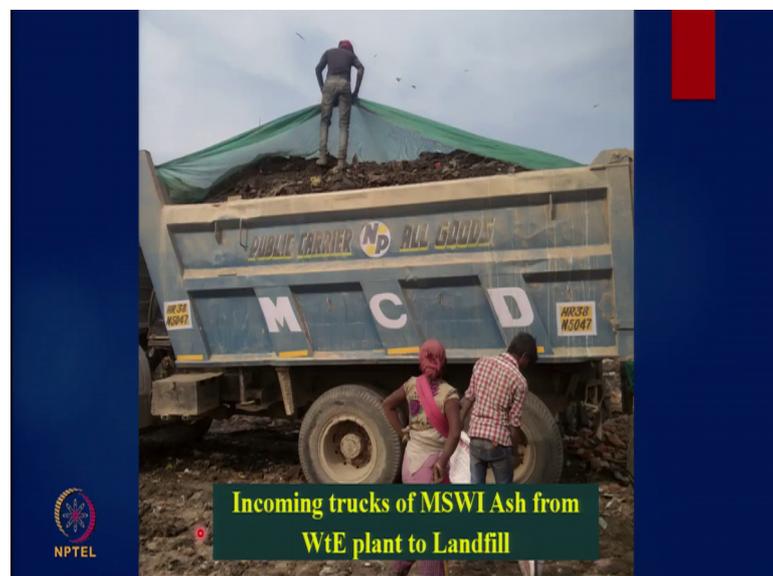
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So, when you look at literature bottom ash is sand to gravel size very good can be of great use to us fly ash is basically sandy silt silty sand. So, it is a much finer material both are not non plastic and their angle of shearing resistance is in the same range of soils 30, 35, 40, 45 sand and gravels, but the problem is fly ash has leachable heavy metals that is clear that is a clear message coming out in coal ash it is still not 100 percent clear that all fly ashes have leachable heavy metals though America is now saying that from the ash bond some unusual heavy metals are leaching out. But here in MSW ash in the fly ash which is a low percentage; that means, the metals get volatilized in the furnace they go with the flue gases and when the flue gases are caught with the ash

they deposit themselves on the fly ash bottom ash can be used in geotechnical applications, but sometimes has leachable soils and therefore, you may need some treatment or dosing of the bottom ash for earthworks, but the bulk of the cases bottom ash is reusable with some nominal pretreatment.

Now the ash quality depends on the type of waste how much energy you are sending in the type of incinerator what is the process what is the operating temperature you are expected to be above 800 to 900 degree centigrade and all these. So, that dioxins are not created and what are the types of additives that have been used in the processes of burning.

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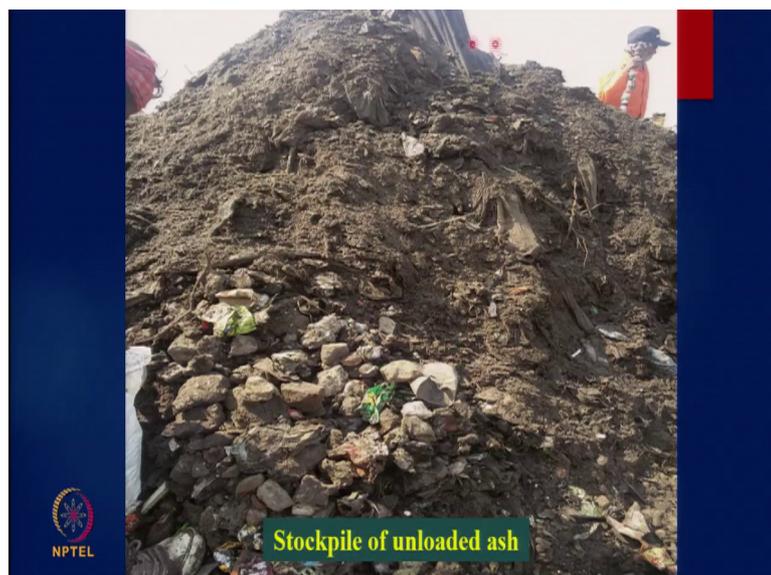


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So, if you look at what is happening in Delhi ash is coming in the form of in trucks we are not sure whether it is mixed or are unmixed, but no separate truck comes for fly ash and bottom ash. So, maybe its mixed maybe, trucks will be of bottom ash and 2 will be a fly ash the ash does not look like coal ash, it is dark, it is not like the light gray fly ash that you saw and you can see large sized particles because it is a mass burn of plant.

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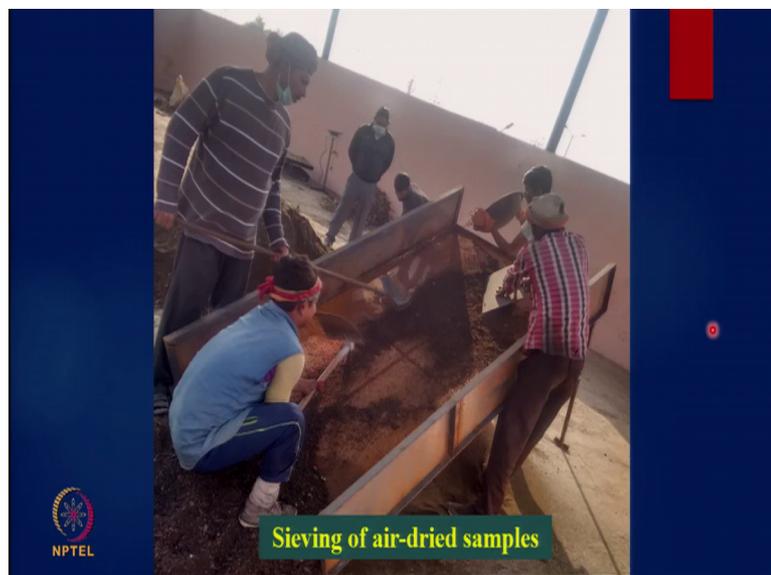


Then you stockpile it, this is one truckload you can see some of these large sized stones or you could sample it using a loader and this is the material which has reached the ceiling station and this is after drying and now you can use the sieves of different sizes.

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Sieving operations going on so that is less than 4 mm looks like soil sandy material comfortable grayish Yamuna sand like that is 4 to 16 mm, but you see some non soil like material. So, everything does not seem to have burnt right we would expect at 900. This should have burnt, but anyway still its gravelly material what we expected that is 16 to 35. So, mostly gravelly material C and D waste aggregate some ceramics some glass. So, this should have burnt and that is 35 to 80 cloth you can see lot of cloth and of course, large size material and not to miss this greater than 80 mm; 80 mm; 8 centimeters, 3

inches; the size of your tri axial sample that is the sieve size a lot of cloth in plastics, but some bricks and other materials as well.

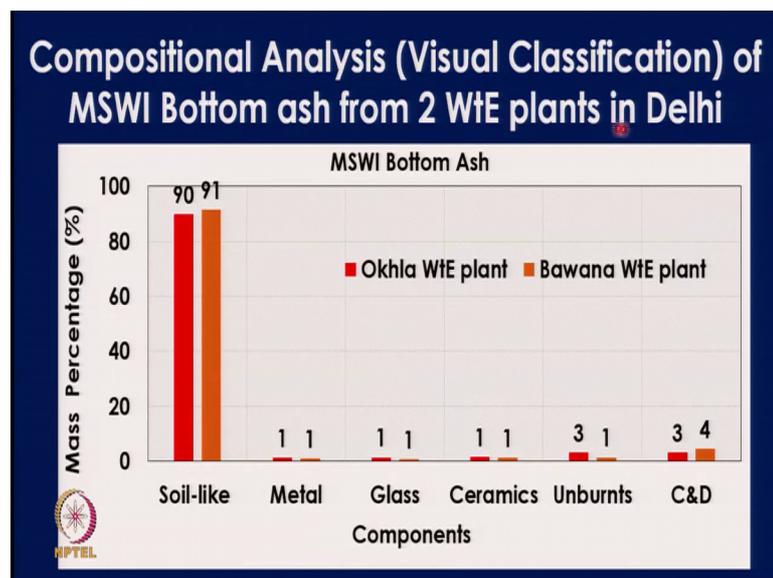
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Sieve Analysis

	Truck 1		Truck 2		Truck 3		Truck 4		All trucks	
	Weight retained (kg)	% wt. retained								
> 80 mm	47	9	36	7	44	8	144	14	270	10
35-80 mm	46	9	34	7	69	13	191	18	340	13
16-35 mm	77	15	73	15	96	18	219	21	464	18
4-16 mm	140	27	137	28	140	26	241	23	659	25
< 4 mm	205	40	215	43	192	36	247	24	858	33
Total	514		494		541		1041		2591	

So, if you look at the grain size distribution 90 percent in the gravel to sand silt size range 93 percent, 90 percent, 86 percent.

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If you look at the compositional analysis of the incinerator bottom ash from 2 waste to energy plants in Delhi, we see that the soil like material is 90 percent of the total and the

other minor components are metal glass ceramics some un-burnt organics and C and D waste.

Loss on Ignition (Organic Content)

Reference, Country	Material	LOI, %
Alhassan and Tanko (2012), Nigeria	BA	6.78
Bayuseno and Schmahi (2011), Germany	FA	8.5
Zhang et al. (2009), USA	BA	7.5
Forteza et al. (2004), Spain	BA	2
Arm (2004), Sweden	BA	3.2-7.7
Li et al. (2004), China	BA, FA	BA:11-15, FA: 3
Izquierdo et al. (2001), Spain	BA	2-9
Tay and Goh (1991), Singapore	BA, FA	BA: 2.7, FA: 15

If you look at the data reported in literature on loss of ignition in the muffle furnace then in the incinerator ash the LOI can be as low as 2 percent, but it can be as high as 15 percent; that means, all the organics are not completely burnt in the incineration process some values are.

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Loss on Ignition (Organic Content)

Material	LOI (%)
Okhla Fly ash, WtE plant (Mar)	0.9 – 1.1 %
Okhla Bottom ash, trucks (Feb)	6.5 – 8.1 %
Okhla Bottom ash, WtE plant (Mar and Jun)	5.0 – 6.0 %
Bawana Bottom ash, WtE plant (Jun)	2.5 – 3.0 %
Yamuna Sand	0.3 – 0.7 %
Coal Bottom ash	0.3 – 0.5 %

Now coming in from the 2 waste to energy plants in Delhi and what we observe is that the LOI can be as low as 0.9 percent, but can be as high as 8.1 percent, this also seems to

be dependent on the weather conditions during the cold months the winter months like in February, burning of the organics may not be as efficient. Whereas, in the in the summer months will say June, the burning of the organics may be more efficient in comparison to the local soil of Delhi which is Yamuna sand you find that Yamuna sand has much lower loss on ignition and organic content and similarly in the ash which is coming from a local thermal power station in Delhi the organic content of the loss on ignition at this site was much lower.

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Contaminants (heavy metals & soluble salts) in Incinerated MSW Bottom ash and Fly ash

Reference, Country	Contaminants in Fly ash
Yu et al. (2013), China	Pb, Zn
Chang and Wey (2006), Taiwan	Pb
De Boom and Degrez, (2012), Belgium	Cd, Pb, Sb, Cr, Chlorides
Li et al. (2004), China	Pb, Cd, Cr

Reference, Country	Contaminants in Bottom ash
Travar et al. (2009), Sweden	Chlorides and sulfates, Cu
Dabo et al. (2009), France	Chlorides and sulfates, Cu, Pb
Aberg et al. (2006), Sweden	Cd, Cr, Cu, Chlorides
Bruder-Hubscher et al. (2001), France	As, Chlorides and sulfates

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The other issue regarding incinerated ash is the presence of heavy metals and soluble salts. So, if you look at data emanating from different countries fly ash has more abundance of heavy metals and lead zinc cadmium chromium has been have been the metals of concern, whereas, in bottom ash its more the salts. So, there has been a reporting of a high amount of chlorides and sulfates in many bottom ash samples and heavy metals have not always reported have not always been reported to be of very high values, but we do see copper coming up again and again.

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Total Dissolved Solids

Type	TDS (mg/kg)
Okhla Bottom ash, WtE plant (June)	20,000
Bawana bottom ash, WtE plant (June)	20,000
Yamuna Sand	3400
Coal Bottom ash	2700



If we look at the total dissolved solids data just emanating from the bottom ash of the to waste energy plants in Delhi we find that the values are extremely high in comparison to the local Yamuna sand and local bottom ash of a coal fired thermal power station.

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Case Studies: MSWI Bottom ash

Project/Country	Application	Remarks	Environmental Control
Aveley Landfills site, Essex, UK	for production of secondary aggregates		
Netherend Lane, Dudley, UK	Road reconstruction; BA used in the base course layer of a half mile stretch of road.	Ash was processed to produce a bituminous material called ASHphalt: 50% of primary aggregate was replaced by ash.	
Caland Wind Barrier, The Netherlands (1985)	Embankment (L= 700 m, H= 15 m)	BA utilization: 650,000 tons;	Ash is covered by primary cover layer of 0.5 m compacted clay with a sand drainage layer (0.5 m) and top soil (1 m) overlaying clay layer. Groundwater quality is measured on both sides of the embankment.
Highway A-15 Rotterdam, The Netherlands	Embankment for roadway construction	BA utilization: 400,000 tons;	Ash is covered with sand-bentonite mixture with minimum thickness of 20 cm to reduce water infiltration
Canada	BA from Burnby incinerator facility to construct access roads within landfills	Only Fe removal; then later compacted	
USA (1994)	An asphalt access road built at site using 30% boiler aggregate substitution	Fe and Non Fe metal recovered; The state of Massachusetts later approved the use of Boiler Aggregate in asphaltic paving.	



(Source: Management of Residues from Thermal Processes, IEA Bioenergy: Task 36, Dec. 2001)

If one looks at case studies for reutilization of incinerated bottom ash, we find that often it has been used for production of secondary aggregates or as part of the base course in road construction, 2 examples of embankment construction in Netherlands reported in the eighties talk about large utilization of bottom ash, but it is important to note that

wherever bottom ash was used a compacted clay liner was put over it and also a sand drainage layer in an attempt to keep the water out of the bottom ash which had been placed in the embankment and groundwater quality was measured intensively on both sides of the embankment.

And so is the case in the second example where a sand bentonite mixture was used on top to minimize the infiltration of the rainwater everything the bottom ash in other examples; bottom ash has been used within the landfill for construction of access roads and also as 30 percent substitute in aggregate for the asphalt access road in the us. So, these are some examples of how MSW bottom ash after incineration has been used in different applications in roads and embankments well that is all the testing that is been done so far data emanating from the world is that bottom ash in many cases can be utilized in geotechnical applications.

So, this is a front running area because you have 30 percent of the material which has to be taken care of landfills may become one third their size, but they are not going to vanish if you can take all this one third material which is coming out in ash and put it in building blocks put it in the building materials put it in the roads the inert matrix of life if everything is burned off and put it in earthworks then you can vanish the landfill then the landfill will vanish is that right, but you cannot hide it if it has got heavy metals you have to report it because you cannot just say ok I will take a little bit and you know; I will spread it overall the area and I will make the landfill vanish.

So, that is the information about geotechnical reuse of incinerated ash and aged municipal solid waste I hope one of you will be working in this area in the future to solve the countries. So, that all them lovely mountains that we have of waste disappear in the future. So, I will be happy to answer any questions if you have something which bothers you or something some thought some alternate thought as to what we should do with all this, but quite clearly once you do the sieving and the fractionation it is clear that the soil like fraction is towards the finer size and the larger size material. You can actually pick it up; pick out the boulders, it can be treated like construction and demolition waste and the balance of it can go into producing energy; that means, all these clots and plastics and paper can be re sent back, but for that you have to do all this sieving again and that is something which costs cost money any.

Student: (Refer Time: 43:50) what you kind plastic and paper. So, because when I see the fires 60 (Refer Time: 43:56). So, I see that might plastic and paper (Refer Time: 44:01) on the on one (Refer Time: 44:03) pass through that.

Yeah. So, this issue about sieving is an equivalent size, remember. So, if you have a laminated if you have a laminar element that is a plane like element then you can always say that the smaller dimension can pass through, but the longer dimension may not, but just like equivalent overall things.

So, the thing is once you have sieved it then you can only do compositional analysis which is visual I mean you have sieved it you got the big particles. Now keep the cloths weight separately, keep the stone weight separately and keep the plastics and weight separately and do you remember that cloth and plastics look like too much, but their weight is very little. So, in that large size material that you are going to have bulk of it will be the weight of the brickbats and the stones and very little weight is going to be there of the plastics and the cloth 1 percent or 2 percent only of the entire material. So, compositional analysis has to be done and I am saying if this material goes into the geotechnical application then over a period of time it is going to detail.

So, we have to be very careful what is the organic content of the finer fraction where visually you cannot you know see once you have sand size material you can look at the sand grain, but you cannot visually look at the pore size of the sand and say no this has got fiber this is got wood pieces. So, that will come out from the organic content any other thought which comes to your mind, but as earth becomes more and more expensive remember local soil used to be 50 rupees per cubic meter several years ago then it became 100 and 50, then it has become 500 now. So, as local soil becomes 500 rupees per cubic meter or even more the economics of reusing these materials after sieving, what it says is if you have got ash the cost of sieving sending in a truck fractionating putting it in a truck bringing it to side must be cheaper than the cost of digging up soil from nearby area.

So, as these 2 will come on par, soon or later all you have to do is underwrite it will not pollute the soil and the environment around it, it should not smell bad, it should be no colored water coming out of it, we have done the colored water test on this, we could

also check that out and there should be no salts which should be coming out in a big way.
So, we will stop here have a good day.