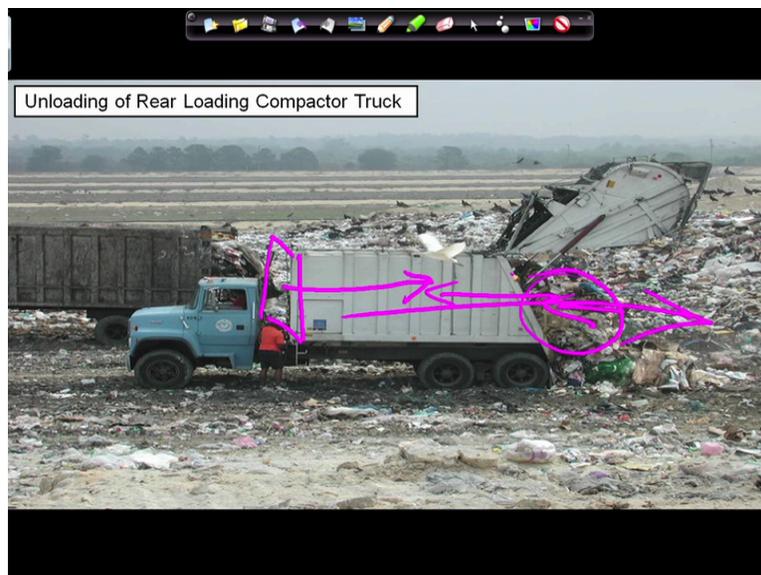


Integrated Waste Management for a Smart City
Professor Brajesh Kumar Dubey
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Module-04 Lecture-20
MSW Collection System

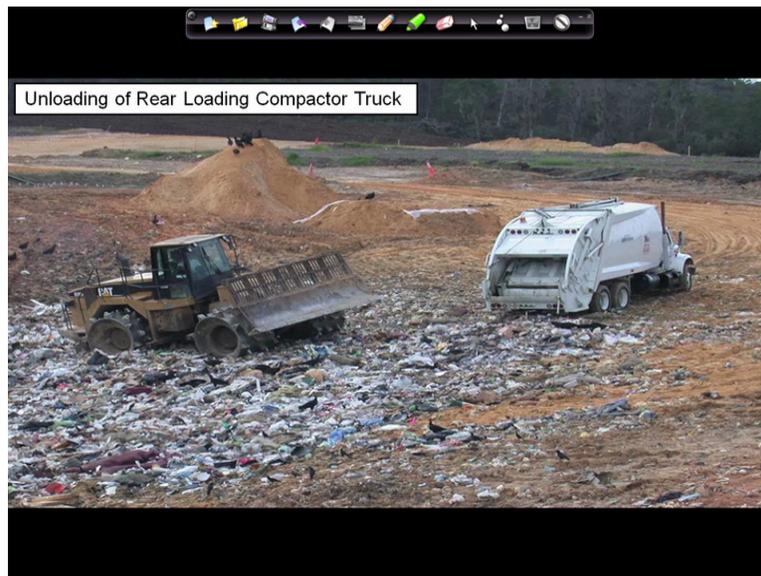
Okay. Welcome back. So we will continue our discussion on the different types of collection equipment that is used typically for the waste, in terms of the waste collection for both municipal solid waste, C&D waste. So let us continue for that.

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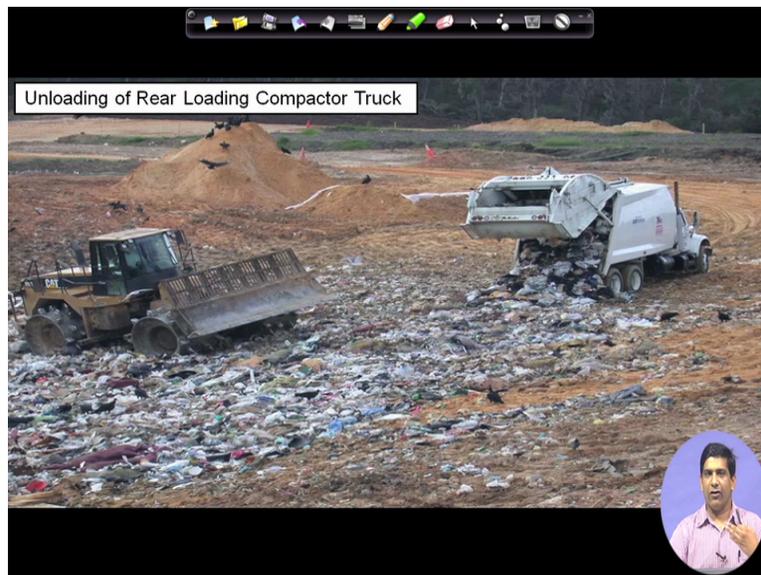


This was the last picture we were looking at in the previous module. So in terms of this rear loading compactor truck, if you remember from the previous module, we talked about that. When it, when the garbage gets collected, it is thing gets loaded up from the back, from here and then things gets compacted into this truck. So now at this disposal site, since we cannot, we have to uncompact it, we have to bring it back, so there is actually a, usually there is a plate here. There is a plate which is into like this, into the truck and these plates move along the length. And then as it moves, it basically gets this garbage out. So as we can see, the garbage is coming out from that. So this is how these trucks work in terms of waste disposal.

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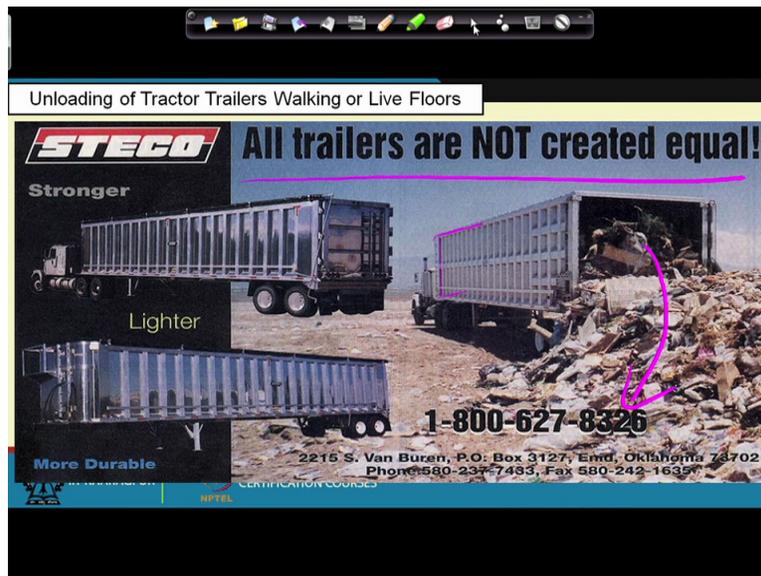


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And then this is another, I will show you (typic), I will show you how it works. So if you watch the pictures carefully, so the truck came in at the disposal site, it got lifted up. Now the plate inside is moving and then it, whereas the plate inside is moving, the garbage is coming out. So that is how it is rear loading compactor truck works.

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Then here again in this type of truck as well, you will have a plate here along like if you look at, if you go and look at that. So there is a plate and that plate is actually moving and bringing this garbage out. So all, as it says all trailers are not created equal, there are different types of trailer trucks. And the trailer trucks are, this is some are lighter, some are more durable, heavy-duty. So different types of trucks are there. And these are typically, these trailers are used when the garbage is taken first to a transfer station and then from the transfer station to a disposal site. We will talk about, we will look at that as well like the use of transfer station.

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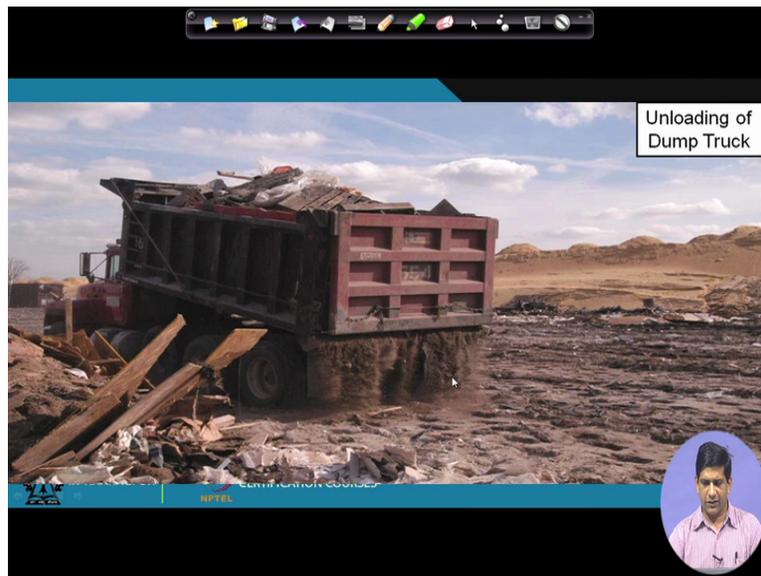


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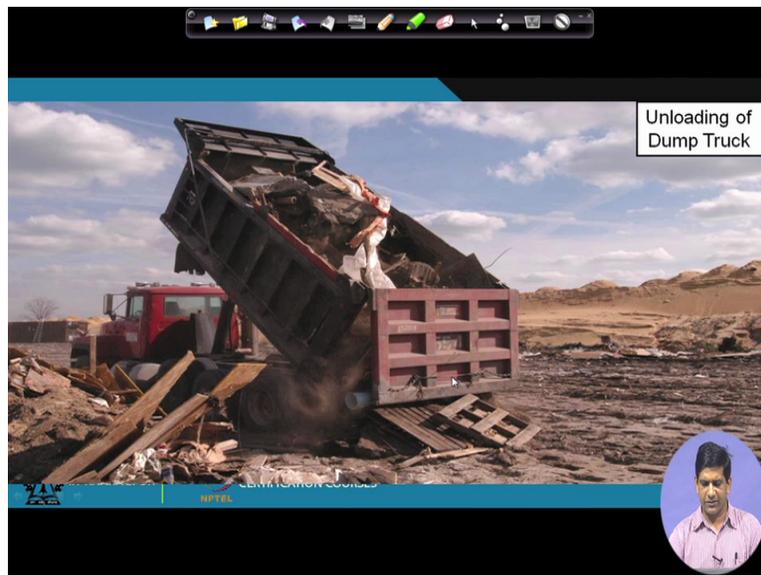


Then another, some unloading of the tractor trailer. As you can see this is a tractor trailer came in. Now it is lifted up and then it is gets, the back is opened up and then the garbage is coming out.

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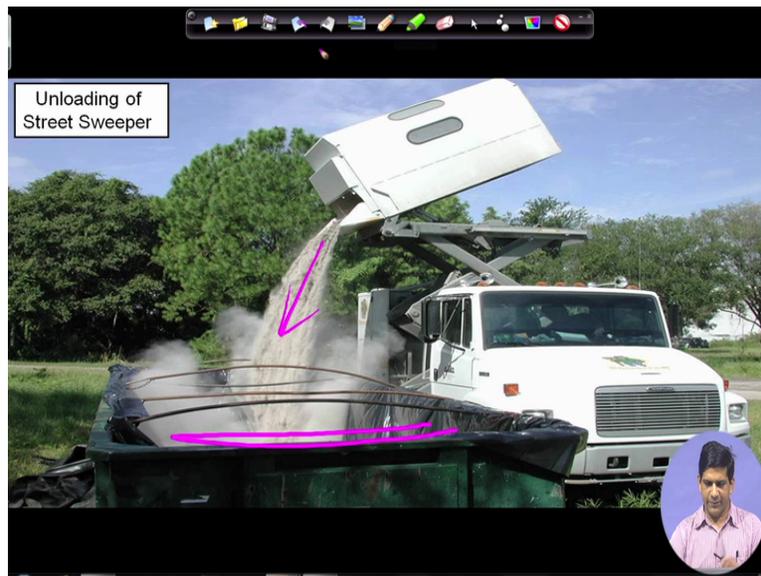


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So there are some pictures, again unloading of the dump truck, similar stuff.

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This street sweeping, that street sweeper what is going around, it will unload it in this roll-off box. This roll-off box as you can see is lined. The reason for this it is lined is so that if there is any moisture coming in from here after any event or a snowstorm event, it does not leak into the surface while it is being taken away to the disposal point.

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A slide titled "Residential Collection Systems" with a bullet point: "Funding Collection Services Property Taxes vs Utility Bills Flat Fees vs Variable-rate Fees". The text "Property Taxes vs Utility Bills" is circled in pink. The slide includes logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES at the bottom.

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Residential Collection Systems

- Funding Collection Services
 - Property Taxes vs Utility Bills
 - Flat Fees vs Variable-rate Fees

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So that is, this is how typically a resident like collection system works. And then we will talk about this transfer station in a minute but before that we go to the transfer station, like how this collection, as I said earlier the collection is one of the most costliest component. So how this collection system gets funding?

So there are funding is, there are as I said, probably I mentioned earlier as well, there is sometimes the funding is through the property tax. So some places, some ULBs what they do, they have a certain amount of property tax that you need to pay. And then as part of the property tax, a part of money is built into for waste management. But some places they also go for what is known as the utility bills.

So as you get a bill for water, you get a water bill, you get a waste water bill and similarly you get a solid waste collection bill. And that is, this is actually becoming more common these days. Most of the ULBs try to go for that if they can. Of course, it is all in the democracy, everything is decided through a democratic process. So you will have ward commissioner, municipal commissioner and then they have, they will get down, they will look at whether this is okay.

And then of course, what is the practice that state is telling? It is, so the state, throughout the state they go for property tax, then a particular ULB going for utility bill may not work. So if they, it is left on the state, on the ULB level. Then they can decide whether they want to get as part of property tax or through the utility bill. But most common these days is trying to go for

this. Because what, why go for this? Because here the money is coming directly for the waste management.

When it goes to the property tax, there are lots of things happening with that money. And depending on who the commissioner is and how efficient or how I would say the lobby, in terms of the lobby of the waste management engineer or the waste management, who is waste in-charge of the city, depending on his caliber, some years you may get more money, some years you may get less money. But if it is directly built for the waste management, the money will come to waste management. So that is why it is looked at that particular way.

And then there is also a concept of whether we should go for a flat fee or a variable-rate fee. Now what is the flat fee and the variable-rate fee? Flat fee means you have a one rate for entire city, that is one option. You can have one rate based on certain area. This area will have this rate, this area will have that rate based on number of like a type of area, like whether the area has typically lot of wealthy people.

So if you have a flat fee, there is no incentive to reduce the amount of garbage. So it is but if you go for what is known as the variable-rate fee, in the variable-rate fee essentially you are forcing people to think about the amount of garbage they are producing. So you are encouraging people to produce less garbage because more the garbage you produce, more money you have to pay. And that is what is known as the pay as you throw.

So more waste you produce, more charges are there for the waste. So what you saw in the previous, in couple of videos earlier that the prepared bags. So prepared bag is your variable-rate fee where the you have, based on the number of bags you need to purchase, more and more money you are paying. If you produce less garbage, you will need less bag. If you produce more garbage, you will need more bags. So that is the variable-rate fee.

So there is incentive to reduce the amount of garbage that we are producing. Ultimately, see, as we are talking about sustainable development and we are talking about sustainable development goal, all this talk about this climate change and all those things that is going on, these days there are lot of debate going on, along that line including that like a Paris Declaration which happened few years back and like some of the world power is thinking of withdrawing from this Paris Declaration or they have withdrawn from the Paris Declaration.

But this is, again this whole debate is where we, it kind of comes down to, from a waste management perspective, it comes down to how can we reduce the environmental impact from this waste that we are producing. As the society is, kind of society is growing, more urbanization is coming, we are getting more and more into mall like culture, lot of packaging material. Earlier what used to happen is you will go to a village, you will go to village or semi-urban town. Even in big cities there will be vegetable markets, you go there with your own bag and you collect, get the food, vegetables and whatever in that bag and you bring it. There will not be even a single polyethylene bag throughout your shopping.

Now if you go for, even for vegetables and fruits, many times you do not carry your bag because you think that, you know that they will provide you a polyethylene bag anyway. And even if you carry own bag, you try to get in different polyethylene bag, so the things does not mix with each other because that is, this is all convenience. And because of we can afford to have those polyethylene bags, they are inexpensive, they are not expensive at all.

So that is why it is, we are collecting, creating lot and lot of these plastic bags for example or if you buy things from Amazon or Flipkart in or any other like what other, ShopClues, there are lots of online shopping these days. And you buy anything from there, you get lots and lots of packaging material. So, we are producing more and more garbage. In fact, if you look at, there is a very nice, in fact, I showed you in the very first week that as the GDP of the country increases, the amount of waste produced is also increasing.

So because as we become more and more so called developed and I say it is so called developed because I do not know whether that is the development. Because where we have four, now every like in terms of the development, everybody has their own cellphone, everybody will have their, possibly many houses every bedroom has a TV but the enjoyment that you, that we got as children while watching TV together, even that was a black-and-white TV. And then watching with like 10, 20, 50 people, watching that Ramayana or Mahabharat serial in one tiny room, that fun is no more. Even when we are watching in a 50 inch or 60 inch TV, so that is I do not know what is development. So anyway, we will not go to that debate.

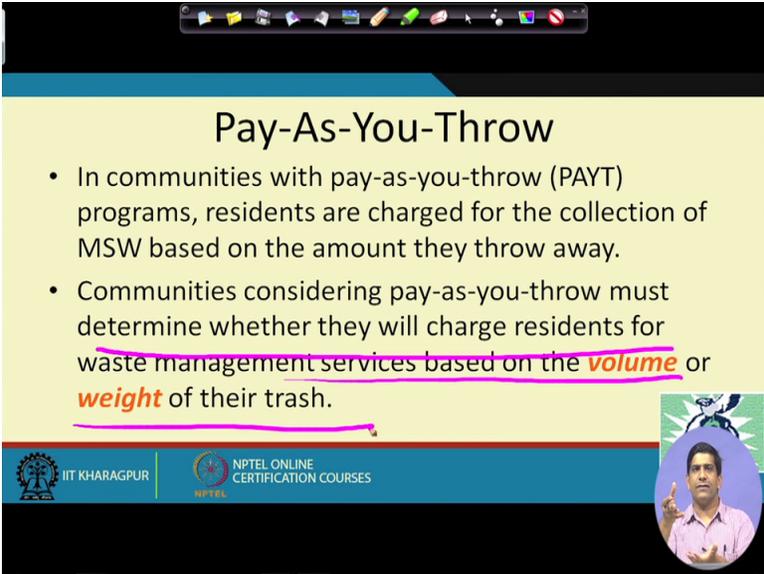
But so coming back to the solid waste side, since we want to, in terms of the sustainability and all that, we are trying to reduce the amount of impact from the solid waste sector. So and which

includes trying to reduce the amount of garbage that is being produced at the first place. But since our lifestyle is changing, we are producing more and more garbage, more plastic, more stuff.

But introducing something like this in terms of the variable-rate fee, at least we will start thinking again trying to go back, trying to say no, we do not want to produce more because people look at money. It is, if you find something and if you have, when people will say oh, if I have one bag, I can save rather than two bags that I am throwing every week. If I have, throw one bag, I am going to save this much amount of rupees.

So that hits the person like, and then there will be some incentive to reduce the amount of garbage. That may work, that may not work. That may work for some section of society, they may not work for some section of society. But at least it will be, at least it will work partially for sure. And there are other ways to try to reduce the amount of garbage that is being produced. So that is, and we will discuss this little bit more in detail.

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Pay-As-You-Throw

- In communities with pay-as-you-throw (PAYT) programs, residents are charged for the collection of MSW based on the amount they throw away.
- Communities considering pay-as-you-throw must determine whether they will charge residents for waste management services based on the **volume** or **weight** of their trash.

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So in terms of what are say variable-rate fee, there is a concept of what is known as pay-as-you-throw. So this pay-as-you-throw is, it is a program, it is where the residents are charged for the collection of MSW based on the amount they throw away. So it is based on if you throw more, you are paying more. If you are throwing less, you are paying less. And that seems fair. The communities that must, now when do that, when the communities when they are doing that, there

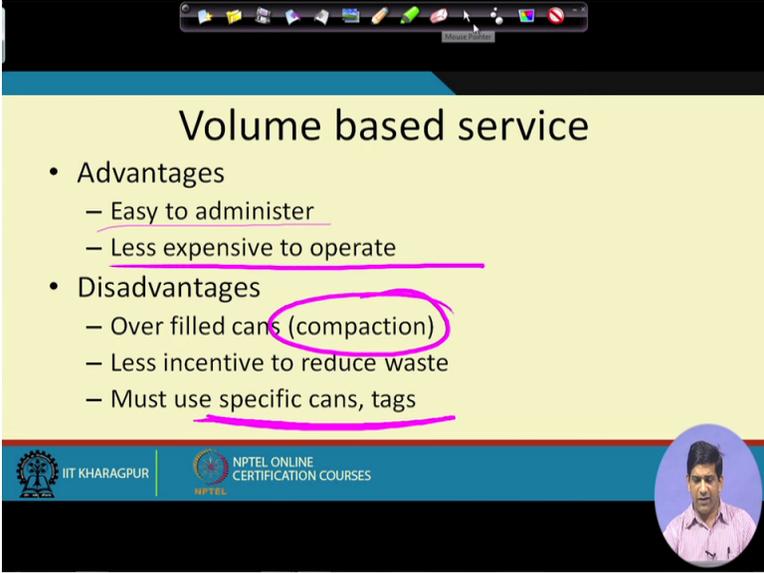
is always a question of whether they should charge the residents for based on the volume or weight of the trash.

Typically you see volume because you have a bag or you have a trash can. Remember like you may, that based on your house requirement, you can get a certain size of the trash can and that trash can if you have a smaller trash can, you pay less fee. If you have a bigger trash can, you pay more fee. So but, or same thing with the bags. So those are all based on volume. So what will happen is those trash cans if you have more garbage, you try to compact it in. You try to push it in as much as possible.

So then if you go for the weight, there is a benefit there. But that weight, you can weigh the garbage. But when you are trying to weigh the garbage, that means you are adding another layer of sophistication. So at every household, you need to have some sort of mechanism either in the truck itself.

So when the truck, if it is a mechanized truck, when the truck is going and lifting this garbage can, it should be able to weigh the garbage can while lifting it or you can have some sort of scale arrangement. So that adds little bit of more complexity there and that means more money. So you need to weigh pros and cons of both weight based as well as the volume based and then decide which one we will go for. But pay-as-you-throw is kind of getting a popular concept now, so that more the waste you produce, more money you pay for that.

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Volume based service

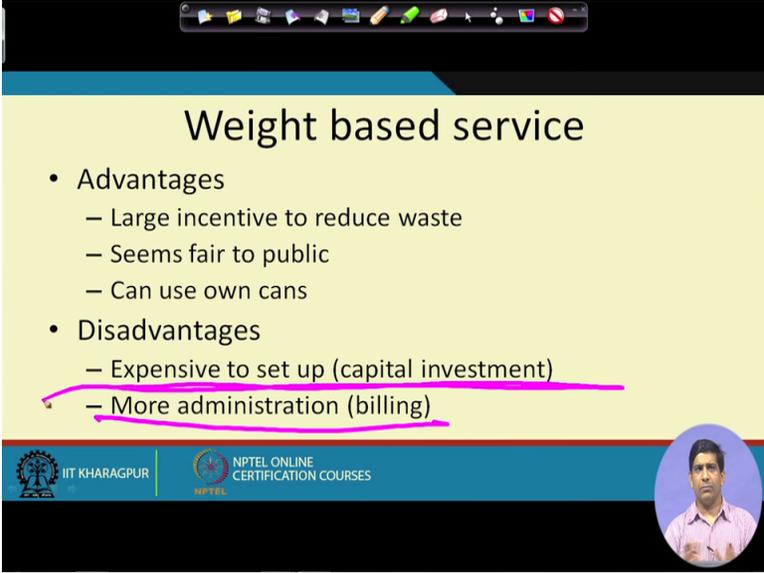
- Advantages
 - Easy to administer
 - Less expensive to operate
- Disadvantages
 - Over filled cans (compaction)
 - Less incentive to reduce waste
 - Must use specific cans, tags

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So if you go for either for volume based, volume based is easy to administer. So you have given this, you saw those prepared bags or the trash can's typical size and then based on that, you have put a flat, you pay a fee that if you use this bag, this much amount of rupees. If you have this size of trash can, this much is your monthly fee and then that is one way of doing it. Smaller trash can, less pay, less money you pay. So it is easy to administer, less expensive to operate.

So it is you can do it easily like there is, once you decide something and then you can just keep on following that. Disadvantages, many times you will try to, people will try to compact in their garbage can, try to compact it so that less incentive to reduce waste. So because they will try to compact it in a same can, so it will not be, the incentive is less in terms of reducing the waste. And then for that, you need to use a specific can, a specific tag or specific bag for that in terms of the volume based service.

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Weight based service

- Advantages
 - Large incentive to reduce waste
 - Seems fair to public
 - Can use own cans
- Disadvantages
 - Expensive to set up (capital investment)
 - More administration (billing)

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For the weight based, although it seems more fair, because there you have large incentive to reduce the waste. Because it is based on the weight, it seems fair and people can use their own cans too. So you can, for the every household, you know the tare weight, you know the empty weight of the can. And if they use the same can all the time, so you will have that, you know the empty weight and every time you weigh the garbage, the difference, things are automated these days, so difference will give you the weight of the garbage. And based on that, how much weight of the garbage they produce, you can have a spreadsheet setup, Microsoft Excel spreadsheet setup where it will calculate how much will be the charge.

And those, that can be done but somebody has to be, you need a person to look after all that in the office and that means an additional manpower requirement as well. So that is why there is, they are expensive. More administration is needed in terms of the billing and also it is expensive to set up in terms of the capital investment. So you need to have those kind of truck which can weigh those trash cans. So that is again more money is required. But there are benefits of doing this weight based service as well.

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Volume-based PAYT

- Options
 - Variable Cans
 - Prepaid Bags
 - Stickers

An example system. Residents decide on what size of cart that they want to use; the larger the cart, the more that they pay. If they have more waste than the cart will hold, they must purchase prepaid bags.

monthly fee

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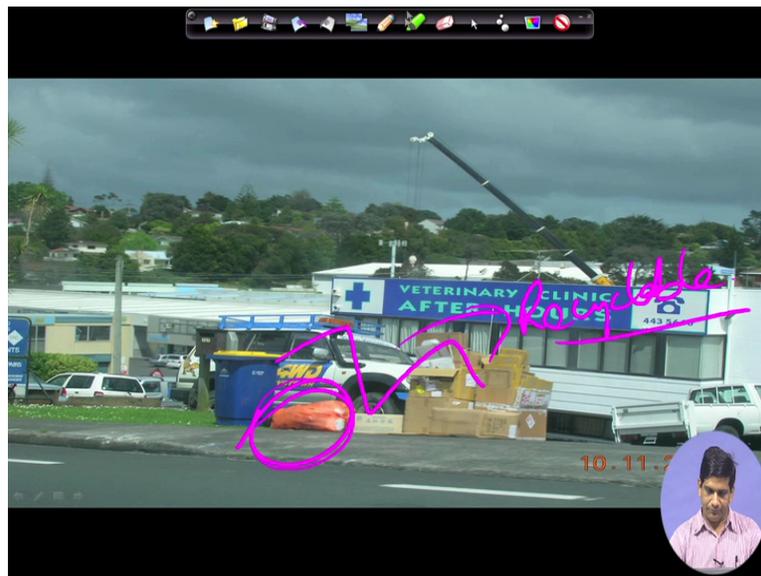
NPTEL

(A red circle highlights a black trash can and a yellow prepaid bag next to it. The text 'monthly fee' is written in pink above the trash can.)

So volume based pay-as-you-throw, we already talked about that. You have variable cans, prepaid bags, stickers. You already saw this example system where residents can decide on what size of can they want, what should be the size of the can. So they pay monthly fee based on this. There is a monthly charge, based on monthly fee based on this. And then if you have extra weight, extra garbage, you put it in this prepared bag. So that is your volume based pay-as-you-throw.

So this is more common as of today. You see whenever they have a pay-as-you-throw system, it is mostly volume based. I do not know of any weight based pay-as-you-throw system as of today. There might be some out there in some cities in western European country or maybe one or two cities in North America but could be there. I am not sure, I am not saying that it is not there but I have not seen any yet.

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So just for, and this is another like just kind of reminder of the way the thing is collected. Here again, it is pay-as-you-throw kind of system for bag that you have. You have bought this bag and they charge you for this bag. This is recyclable, these are recyclables, so this is for these recyclables, they do not charge you anything, it is collected for free. And so there will be two trucks coming in here. One truck will take these things which is needs to go to the landfill or go to the, yeah this is a landfill waste. And then the once the recyclables will go to a recycling center and since the city will make money out of that, they do not charge you anything for that.

So that is kind of some idea about how the waste is like collected and there are different how the collection system is funded.

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Solid Waste Generation Rates

- knowledge of the quantities of solid waste generated, separated and collected for further processing is fundamental to the design of a solid waste management system
- we estimate the quantity of waste generated using available data:
 - load-count analysis
 - weight-volume analysis } weighing scales are critical
 - material balances
- these are based on amount collected, which is different from the amount generated
- people divert waste before it gets collected
 - backyard composting
 - re-use programs (outside of public collection and disposal)
 - transport between municipalities
 - taking stuff on trips, to the cottage, disposal in other jurisdictions, ...

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Now we will talk about that since you have to design a collection system, ultimately we have to, say for different smart cities that we are talking about whether we are in NDMC or whether we are in Kolkata, new town (Bhub) like Bhubaneswar, Bhopal, Indore, whichever city you talked about, so we have to, even we are trying to develop a solid waste collection system.

For designing anything, first of all, we need to know the data, is not it? So we need to know the data. So data means, in terms of collection system means we have to collect the garbage. So we have to collect the garbage. The number one is question is, how much garbage? So we have to find out how much garbage is there to be collected. That will decide how many trucks we will require. So that is, we will look at that aspect, the solid waste generation rate.

So what is the solid waste generation rate? As if in Indian context, there is a CPHEEO manual which is out there which is on solid waste management. Again that manual was also revised recently and you can Google that. And I will try to put that manual also on the website. So you can probably, as a reading material, you can see that manual as well. So this is, this has been published, newer version has been published now which is as under the Swachh Bharat Mission program.

And we have to know the waste generation rate, so CPHEEO manual from the Indian context, they have come up with around 0.4 to 0.6 kg per person per day. So around 400 gram to 600 gram kg per person per day is that typical waste produced in the urban areas of India. Of course,

different, this is a general average rate. With depending on the type, the city you are in, the numbers may change a little bit. And the numbers are actually going up because of more and more packaging material, more Big Bazar kind of a store, more mall.

Earlier you used to go and buy say any vegetable, you will just buy the vegetable. These days, they will be in a tray and then the tray will have lot of parafilm. And that parafilm, so when you come home, take this parafilm off, take the tray off and then you take the vegetables and the rest all these things goes to the trash can. So this is a lot of waste is being generated. So the numbers are, will go up. Typical number for like developed countries is, varies from few like around few kgs per person per day. So we are on one-third of that number. So our numbers will also go up.

And there is also, and in India we still have some tendency of not wasting some things too much. So that is we have paper, plastics, we are still selling. Otherwise, that number will go up, already crossed more than 1 kg per person per day. So here, so in terms of coming back to this thing that we have to first know the data, the basic data in terms of how, what collection system we need to design for. So how much waste we need, this collection system will handle, so for that what we, first of all, we need to find out what is the generation rate.

Of course, we need to know the knowledge of the quantity of solid waste generated. So how much waste is generated and then separated and collected for further processing, that is a fundamental to the design of solid waste management system. So anything we design from this point, we put those trash cans, people have disposed the garbage, now we need to know kind of garbage. We talked about that already how to characterize it in the previous week, that different ways of characterization, biological characterization, thermal characterization that we need to do.

And the second thing we need to do is for different types of garbage what is the quantity. Like if I have to design a compost plant or anaerobic digestion plant, how many tons per day, how many tons per day waste I am expecting? Waste-to-energy plant, how many tons per day waste I am expecting from this particular area? So we estimate that quantity of waste generated using the available data.

So what we do? We do a load-count analysis or weight-volume analysis. We use weighing scales. Most of these waste disposal facility, waste treatment facility will have a weighing scale these days. Weighing scale is very, very similar to, as you drive on the highway in India, you see what,

many places you see a dharamkata. That dharamkata is actually the weighing because I think after this GST, that dharamkata business I am not sure whether the dharamkata business will still go on or not.

I have no idea but essentially when a truck enters a particular state for the state tax, if I am wrong let me know but that is my understanding is that based on the weight of the truck, weight of the amount that is coming into that state, state will charge a certain amount of tax. So for that, those dharamkatas are there along the highway. So similar kind of, that is a weighing balance actually. That is, similar weighing balance are there in most of the waste disposal and treatment facilities. It is, it should be part of that. If it is not there, it should be there.

And then these trucks when they come in, we weigh them. We weigh the empty weight of the truck. So we kind of, or once the waste is dumped, when the truck is going back, we can weigh them again. So the difference will give us what is the amount of waste that came into the disposal facility or the treatment facility. So that way we can do what is known as the load-count analysis. And I will walk you through a problem and that will help you understand that.

And then the weight-volume like based on the weight, how much is the volume. The material balance, the material balance is also done for that. So these are based on the amount collected which is different from the amount generated. So because not everything is wasted, so whatever is the amount generated if not the waste, this is the amount collected in terms of, in the disposal stream. Amount generated could be part of it, it could be recycle. Part of it could be taken away by the rag-pickers, kabadiwalas. So those are different things.

And then people do divert the waste before it gets collected. You can do backyard composting. These days the home composting is getting popular. If you do a small home garden, you can do a home composting. And you can do a reuse program. You can, outside of the public collection, so you can do a reuse. You can say transport between municipalities. So if you had some waste in a transfer, maybe you work in one area but you live in the other area, so that could be, that you are, it can happen that part of the waste, not much a fraction but little bit of waste in a travel between the municipalities.

And sometimes you are traveling around and then you, some of the waste that should, may have gone in your local city may go into some other city because you carried some of the material

with you. So those things does happen. So that is, so we can take some of those factors into account.

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Load Count Analysis

- in this method, the number of individual loads are counted, and the waste characteristics are estimated (type of waste, estimated volume)
- weight is estimated, or, if scales are available, weight data are also recorded
- unit generation rates are determined using the field data:
 - residential area = 1500 homes, average of 3 people per home
 - observations at the scales (transfer station) per week:
 - 11 truck loads, each 20 m³, total = 40,500 kg/wk
 - 40 private loads, each 300 cm³, total = 900 kg/wk

$$\text{S.W.} = \frac{40,500}{20(11)} = 184 \text{ kg/m}^3$$

$$\text{S.W.} = \frac{900}{40(0.3)} = 75 \text{ kg/m}^3$$

$$\text{unit rate} = \frac{(40,500 + 900) \text{ kg/wk}}{(1,500 \times 3) \text{ person}} = 9.2 \text{ kg/capita/ wk} = 1.31 \text{ kg/capita/ day}$$

note the impact of compaction

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So in terms of the load-count analysis, here small example has been given. In this method, what we do is we try to take, individual loads are counted. So we count the individual loads and then the waste, we estimate the type of waste and estimated volume. Then the weight is taken in the scale or the weight is also estimated based on the typical density. So if you take one and then collecting this field data, we can calculate the rate.

So if you look at here, there is a residential area. One example has been given here where we have a residential area. There are 1,500 homes, average 3 people per home. And then when it comes to the transfer station which is the waste like treatment center or material recycling facility as well, it got 11 truckloads each with 20 meter cube. So each truck was around 20 meter cube and total weight coming in was 40,500 kg per week from those truckloads. And then 40 private loads. Private loads means the individuals like you and me came and drop off in their cars or they may have a pickup truck especially from this urban, semi-urban area.

And then each of these private load was around 300 centimeter cube. The volume may change but again it is an approximation and they got 900 kg per week. So if you look at in terms of like unit rate, it is we can calculate the unit rate here. This part, we will look at, let us look at the unit rate first and then we will come and talk about this in a minute.

So in terms of the unit rate, we have 40,500 from 11 truckloads. We have 900 coming from the private load, so this is the total waste that is produced in a week from that particular area. And total we have 1,500 homes, average 3 people per home. So we have 1,500 times 3, so that is the number of people, that is the number of, that is the amount of waste that is being produced. So amount of waste being produced per week divided by the number of people gives you the unit rate, which we typically express as kg per capita per week or kg per capita per day.

Actually, this should actually go there. So this is kg per capita per day, let us see, so this is the yeah, this should be like this. So it is a kg per capita per day is what we are, it is a unit of waste generation. Or kg, you can also have kg per capita per week, I do not know why this week and day kind of got little bit that side. So here, so 40,500 plus 900, that is the amount of waste produced per week. This is the total number of people. So if you do this math, you get 9.2. But this is per week, so divided by 7 further and we get 1.31 kg per capita per day.

So it is in this particular area, 1.3 kg of waste is being produced. When we say per capita, means per person. So every one person on an average is producing 1.3 kg of waste per day. Why this number is important? As we said earlier, at the very like that individual, in the previous slide, I think it was in the previous slide we said that having this data because this is the basic data we need.

And as accurate this data we can get, better it will be in our later calculation because once we know this number, once we know with this number, we know how much is the population. We can find out how much is the waste produced per day. And then based on that, we know how much waste will come to my compost plant, how much waste can come to my waste-to-energy plant, how much waste will come to my landfill. And if I am designing this compost plant or waste-to-energy plant or landfill say for a period of 20 years, 25 years, I know how much waste will come over that particular period.

Of course, that generation rate will change and we have to factor that in. Population will change, we have to factor that also in. And that is you typically you will see. If you have not seen any DPRs of waste management system, go and look for one. Like if you Google one, there are several, there are few DPRs available on Google for the Indian ULBs and from especially from the smart cities.

And you can look at how the this population forecasting is done, how people have looked, try to look into how to like the present generation rate is 1.31, how the generation rate will change over the years because we have added some fact like every 5 years maybe 10 percent will go up. Those, some of those will be your estimate as well because we do not know what will happen in future.

Population, based on the past population data, we can predict what will be the future population data. And of course, that is again assuming that the way the population has increased in the past few decades, same trend will continue in future decades which may not be true depending on, if the city is already saturated may be not, we will may not have same population growth. If there is a big industry coming into the city, the population growth will be much faster. So those problem, those factors sometimes we can consider, sometimes it is beyond our consideration. But we try to be as accurate as possible.

And then the other part is in terms of which I said that I will talk to you later. So it is looking at the density of the garbage in the truck. So as you can see the private load, the density was only 75 kg per meter cube because 900 kg divided by 40 loads and 300 centimeter cube. So this is mass upon volume, so the density is, in the private load is 75 kg. But when you go to the compactor truck, it is 184 kg. So compaction, so since those compactor trucks they do increase,

they help in carrying, so what in terms of compacting the garbage, we have increased the density by almost what? Nearly 2.5 times.

So if no compaction is done, we will need 2.5 truck, which the amount of garbage that can be collected in one truck. So we are saving, by compaction we are saving the number of trucks. And as I said earlier, more the number of trucks, more the cost. Each truck is almost like a quarter million dollar, good one, so sophisticated ones that has been used in developed countries today. So these are kind of the calculation we need to do. Again, as I said in the, in some point of time, these solid waste problems are not difficult ones, it is just you need to do it properly. You just do the like a regular math.

And so with that, let us stop here and we will continue this discussion, some of this discussion we will continue in the next week as well. We have few more things in terms of the collection that we wanted to talk about. So maybe in next video of week, so the first video of week 5, we will finish off that discussion. So with that, again thank you very much for watching these videos and trying to learn something.

I really hope this will help in achieving our mission in terms of the Swachh Bharat Mission and other things that we want to do in the country. So if you have any questions, put it in your (discuss) put it on the discussion board, we will be more than happy to answer. We are always waiting for your feedback and questions there. Let us make it a two-way conversation and again thank you and keep watching and keep learning.