Course on Integrated Waste Management for a Smart City
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Module 5
Lecture No 24
Waste Collection and Transport (Contd.)

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Okay so welcome back and we will continue our problem solving in this particular video as well if you remember from the previous module we looked at the transfer station economics problem and I hope that you are working on that problem I really want you to work on it and then we also did that load count analysis part. So we will do some more math in this particular to just illustrate how the different things that we have learned can we apply in a practical scenario is very important because ultimately you should be able to use the knowledge when trying to solve problems for any particular ULB.

Specially for when you talking about all this smart cities and the initiatives and without having a Smart waste management system like smart when I say smart means real working waste management system unfortunately as you know we have been trying the waste management system is still kind of struggling in the country we have to improve that so that is the reason this course is being offered.

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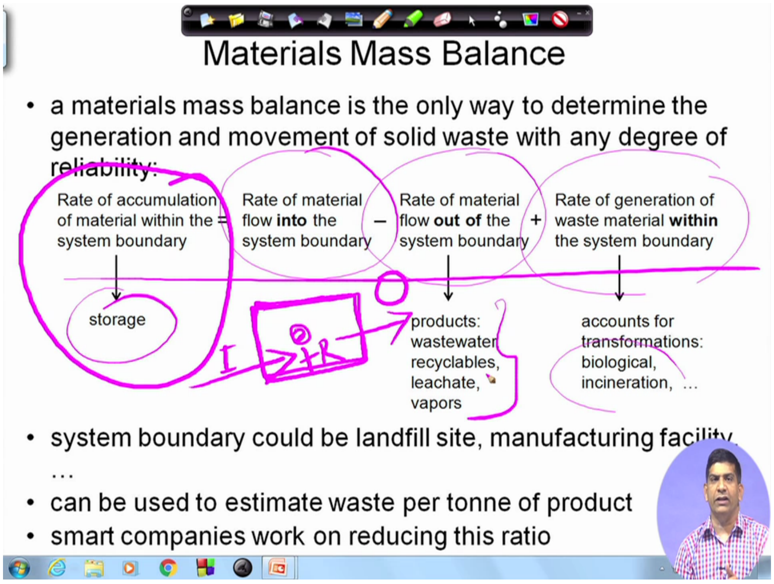

So we are trying to we will look at some other math, so lets get started in terms of like how to do this is if you remember the last problem was on how to come up with waste generation rate, so one way that was of load count analysis which we covered in the last problem of the last video. Now the next option you can also have is you can do a mass balance, it is you can do a material mass balance.

Now when we say material mass balance what does that mean, you are trying to take a boundary that boundary could be a city, that boundary could be a state or a particular boundary you are taking and then you doing a what is the rate of accumulation of material within the boundary which is being stored in the boundary is how will you find out? So if this is this is the boundary we have, so how much is the rate of accumulation is particular boundary, how much things are being accumulated? How will you find that out?

We have input to the boundary we have an output to the boundary, so this we have input, we have output and then we could have some generation rate like there is some plus R or minus R within that as well. Some waste materials could be produced within the system, so input minus output plus R will give us what is the waste that is being accumulated or material that is being accumulated within this particular area.

So that is what have been explain over here, so you have the rate of material flow into the system boundary, rate of the materials flow out of the system boundary and rate of the generation of waste material within the system boundary. So using that you can find out the storage in a particular area. So now when we say flow out flow out could be products like the waste water, recyclables, leachate, vapors and rate of generation could be some biological incineration and all those transformation that is happening within the system.

Now the system boundary could be a landfill site, could be a manufacturing facility, so where it is used say if you are a company for example Tata steel or any particular company they want to know how much waste they are producing per unit or per tonne of the product or per unit say if you say Telco or Maruti they will say per car that I am per Maruti Alto or per Maruti Zen or whatever the vehicle they choose Celerio. What is the amount of waste that I am producing, so but why this value is important for them?

This value is important for them so that they can work on reducing this ratio, so they can reduce this ratio further and in that what they will do is they will try to come up. They will try to reduce this ratio than what it helps, if lowered the waste lower the amount spent to manage that waste and lower the amount is spent to manage that waste that means better is the profitability or they have more competitiveness.

2 brands same products one company produces less waste, less money is spent to manage that waste means they have less capital cost going for that particular product, so that helps them to be competitive. Like I said earlier Smart companies works on reducing the ratio, which ratio? The ratio of waste per tonne of product or waste per unit of product whatever they try to reduce that and that is one of the goals they want to do.

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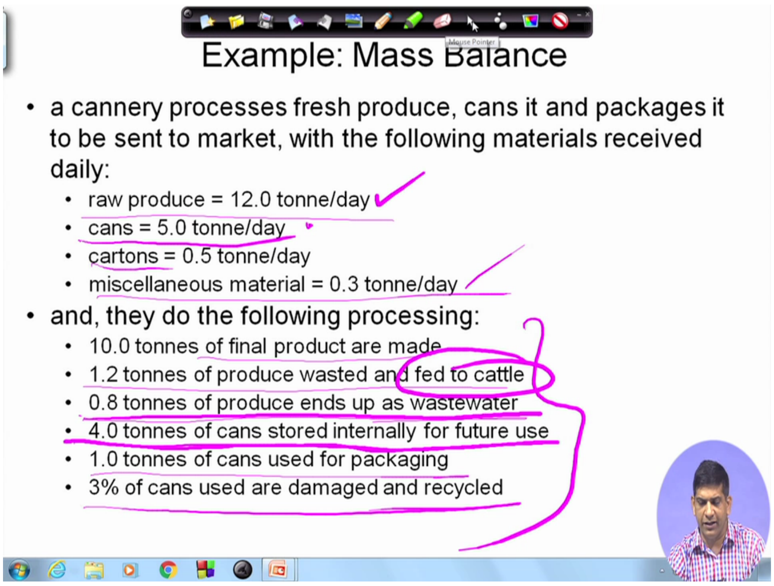

So in that particular aspect if you look at some of this examples mass balance problem here if you can try to do some of this say this is one agricultural processing waste that is cannery, it processes fresh produce, can set and packages it and sends it to the market and they have following materials received daily, they have some raw produce as you probably produce means the vegetables and all those kind of stuffs.

So they get a raw produce, so this is I think it is a cannery so they cannery means it will make cans. Nowadays if you go to Big Bazaar or Reliance Fresh and other places you will start getting things in cans so it is like you even have a tomato soup sorry tomato juice or even pulp those things are coming up in cans, different things are showing up in cans. So they are basically getting this raw produced and they are making the canned products and they are selling it back up so raw produced they get around 12 tonnes per day, that is the raw produced they are getting.

Then they have they are putting it into cans so they get around cans of 5 tonnes per day, then the cans has to be packaged, so you need certain cartons to package it, so that is your point 5 tonnes per day what that, then you have some miscellaneous materials that could be some packaging material, some tapes, some stickers are some labels so that is around 0.3 tonne per day.

So these are the stuffs that is coming they particular facility then they are doing certain processes there and that processes 10 tonnes of final products, they are producing final product which is around 10 tonnes. 1.2 tonnes of produce gets wasted because this produce has got some problem, maybe many times when you go and buy a vegetable we find that when you come home and then you try to put it in to the fridge and then you find out that maybe this one particular tomato is not that good so you do not basically you may have to throw it away depends on how.

So since this company they have the quality control, quality assurance, they have to maintain certain food standards, so many a times there are certain produce which does get wasted and so they have this wasted but they are not throwing it away, they are basically feeding it to cattle so they are feeding it to cattle over there, so then this is not going out of the system actually. Then you have 0.8 tonne of produced which ends up in the waste water if you remember in the very beginning we also talk about food that waste is the water waste, so even if you waste the food because there are lots of embedded water, there are lot of embedded water in the food.

So if you are wasting the food you are also testing the water, so even water goes 0.8 tonne of the produced it ends up into the waste water because of the moisture there. Then 4 tonnes of cans stored internally for future use, so they are just on that particular day they got 5 tonnes per day but they only need one tonnes this 4 tonnes are actually just stored internally for future use. 1 tonne of the cans is used for packaging because of who is 4 plus one is 5 and that is what we have, 3 percent of can used are damaged and recycled, so when they found out the 3 percent of the cancer actually cannot use causes already damaged but they are being recycled they are not being thrown away.

So these of the data provided to us, it may seems too much information but for any problem like this or in fact in general for any problem my suggestion or my advice to you is to always you try to put these things in a pictorial description, pictorial means made a sketch make a small sketch and you do not have to be an expert artist to do that, just simple boxes then say these other inputs these are the outputs because essentially these are the mass balance problem and any mass balance that you do it is a good idea to do that so we will try to do that as well in this particular stuff.

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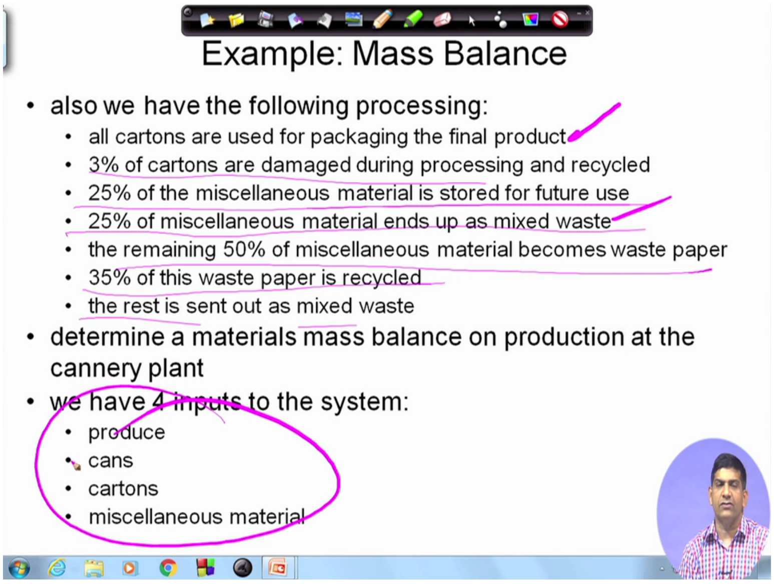

So here and then we have some other stuffs there too, like we have some more data, all cartons are used for packaging, so basically all the cartons are used for packaging of the product. 3 percent of the cartons are damaged during the processing has to be recycled, 25 percent of the miscellaneous material is stored for future use so close so those were the stationary materials, stickers and all those kind of stuff 25 percent is stored for future use, 25 percent of this miscellaneous materials ends up as mixed waste.

So it is because of even we use those tapes stickers made time stickers will have other paper attached to it, so you took those stickers off you put that on the box but the other paper becomes the waste, so those things do end up as mixed waste. Remaining 50 percent of miscellaneous material becomes waste paper so you have some they become waste paper as well, 35 percent of this waste paper is recycled the rest is sent out as mixed waste. So determine a material mass balance on production of this cannery plant, so we have for input to the system produced, cans, cartons and the miscellaneous material.

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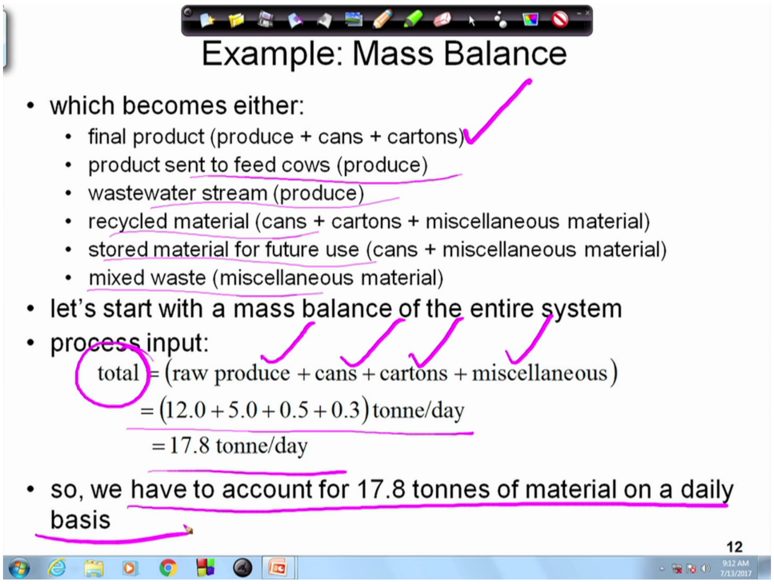

So what we will do is well tried to set up our like a problem in terms of the input output and whatever things are happening, so we have this 4 input to the system, so whatever is coming into the system they either become a final product, they either go into as a final product or send it to feed cows or they become part of the waste water or they could be recycled, they could be stored for future use or they can become mixed wastes so these are where they are ending up.

So let us answer the mass balance of the entire system so if you look at the total mass balance, so the total process input is whatever is the raw produced, cans, cartons and miscellaneous which was data has provided to us so we can add them up, so it is around 17.8 tonnes per day, so that is the amount of material coming into the system, so we have to accounts for, so in terms of mass balance we have to for 17.8 tonnes of materials on a daily basis so that much amount of material that we are getting, so now in terms of the accounting, how we will try to find out is where they end up.

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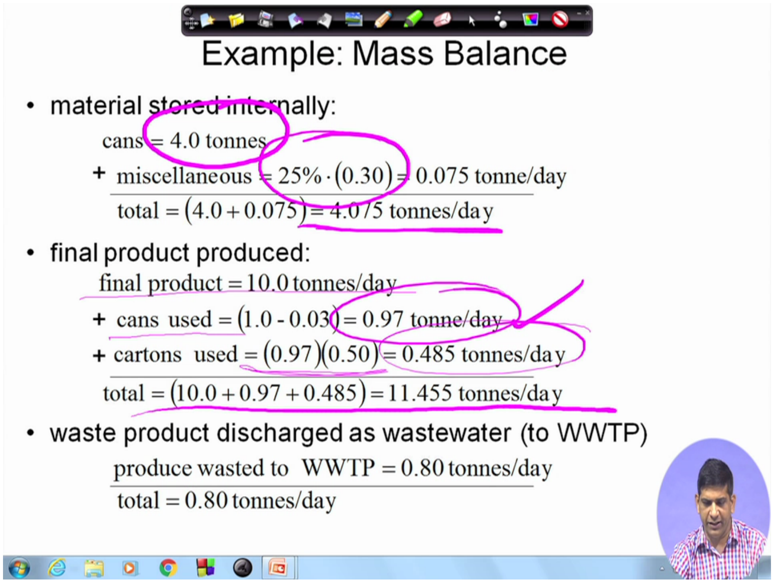

So there are some materials which is stored internally, so cans has 4 tonnes and then miscellaneous 25 percent, so 25 percent of the 0.3 tonne is 0.75 tone, so if you add them up so this is the amount of material which is stored internally and again these are all information sorry this all information is what we have is from the previous slide. So again there are several slides since this is a this seems to be a much bigger problem but it is not that difficult, it is a simple mass balance problem what we have to do is, is to go step-by-step. I have shown you each and every step in detail this particular example just to walk you through.

My advice to you in my strong suggestion to you is to if you want have the solution you take that problem and then you walk out by you own then you match your solution with the solution that I am providing and to see whether you got everything okay or not because again this is not very difficult, it is just that will bit of time consuming, you have to go step-by-step make sure you have the same units and then it is all fine. So in terms of the material stored internally, 4 tonnes we have been given that information and then 25 percent of the miscellaneous materials so if you add them up, so this much is actually just goes into the storage.

Final product we have been given 10 tonnes per day that is that is produced plus the cans also goes out because the cans are used to store this final products and there we have been told that nearly only point what only 3 percent of the cans were damaged or something the rest cans are used in terms of 1 tonne which is used per day, so which around 0.97 tonnes per day that is being used in the cans then this cans goes into the carton, so this whatever the tomato juice or whatever is this particular product from the produced things goes into those cans.

Now these cans go into the cardboard boxes, so this cans are also going out of the system cardboard boxes also going out of the system. So in terms of the cans we figured it out its around 0.97 tonne per day, for the cartons again you need nearly it says you need half of that so 0.97 with 50 percent is you get 0.485 tonne per day and that is the amount of carton is used, so if you add them up so this is the amount going out.

Remember we had amount coming in was 17.8 if you remember from the previous slide they are on 17. something things which is going out is around 11.5, so there is a difference of around 6 tonnes, when 6 tonnes are ending up we need to find that out. So waste product discharged as waste water 0.8 tonnes per day, we know that so that is the total coming out to be 0.8 tonnes per day that is going into discharge into the waste water.

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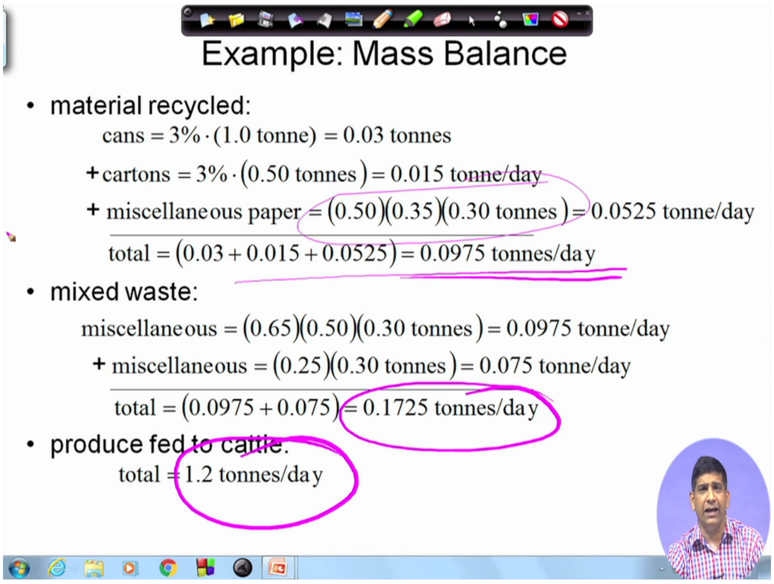

Then material is recycled so that if you 3 percent of the cans is recycle, cartons 3 percent of the cartons is recycle, miscellaneous papers part of it is recycle as well so you find out that particular value and these are again based on the data that we had sorry based on the data that you we have been provided you can come up with this details, so total we have material recycled is 0.0975 tonne per day.

Then we have some mixed waste it is again part of the miscellaneous paper and then some other materials which is there so you have this coming up as 0.1725 tonnes per day, there is something which is fed to the cattle which is around 1.2 tonnes per day, so there are different things that is being happening into the plant and everything has to be accounted so that is the kind of beauty this particular problem is it is not difficult but you need to be really diligent in terms of going step-by-step and including everything from there.

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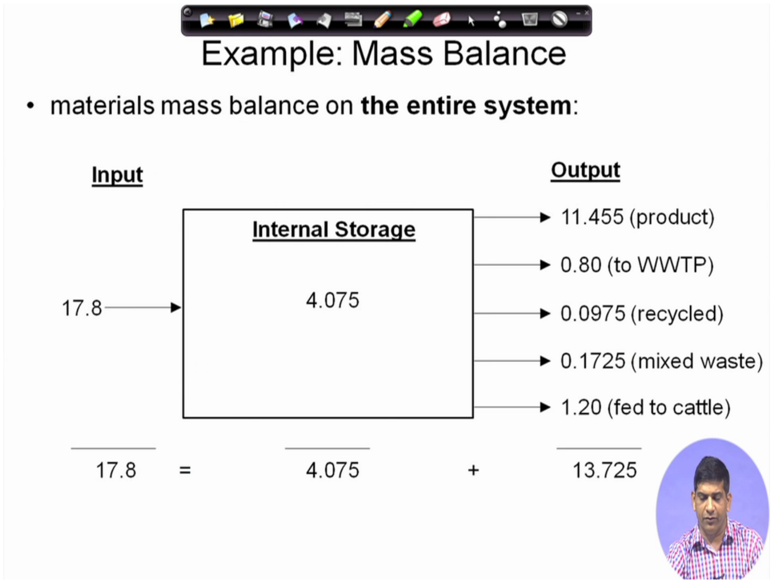

So once you have some of this data what you can do is you can come up with this I would say sketch where you have this input to the system, so this is our system this is the cannery process system, so the input was 17.8 this much tonnes per day internal storage we have been told that 4 tonnes of cans and then some paper sorry cardboard, so waste on that comes 4.075 and so the remaining one has to be and then we have the output in terms of 11.455 is product, this much as waste water treatment plant, this is recycle, this is mixed waste, this is fed to cattle so if we add them up you will get 13.725.

So if you add this plus this it comes to 17.8, so that means we have account for everything that is how we should look at your mass balance problem where you account for all these different and then you cross checked by having a sketch like that, so that helps you to find out this is again as if you have like it is pretty simple but again that has to be done, has to be followed up and you go step-by-step.

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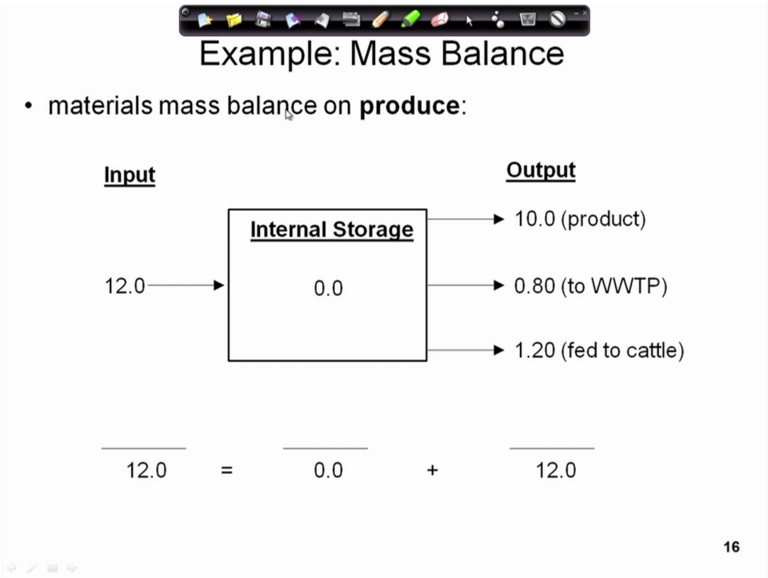

And then once you have this is the overall for the entire system then we can do it for individually as well, so if you just want to do it for the produced for the produced 12 tonnes was the input there is no storage. Some goes as products, some goes to waste water treatment, some is fed to cattle so you look at that 12 tonnes coming in 12 tonnes going out. So that is input and output is equal it should be for this like mass balance.

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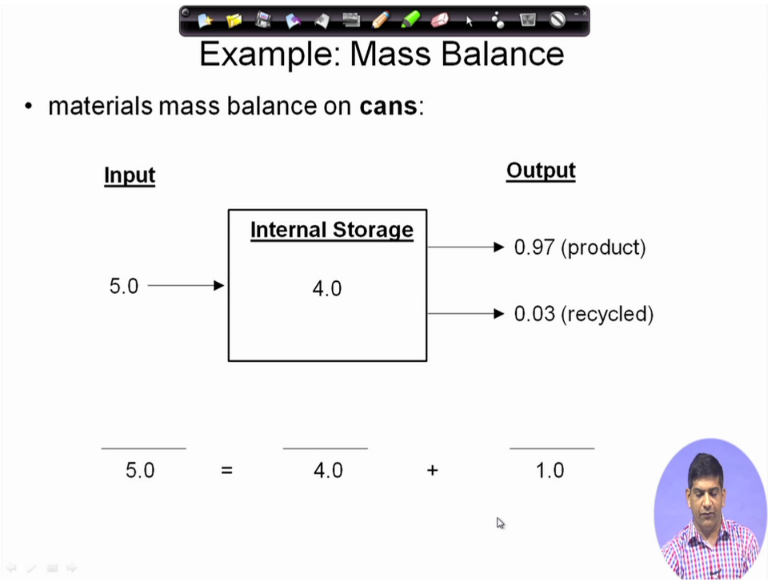

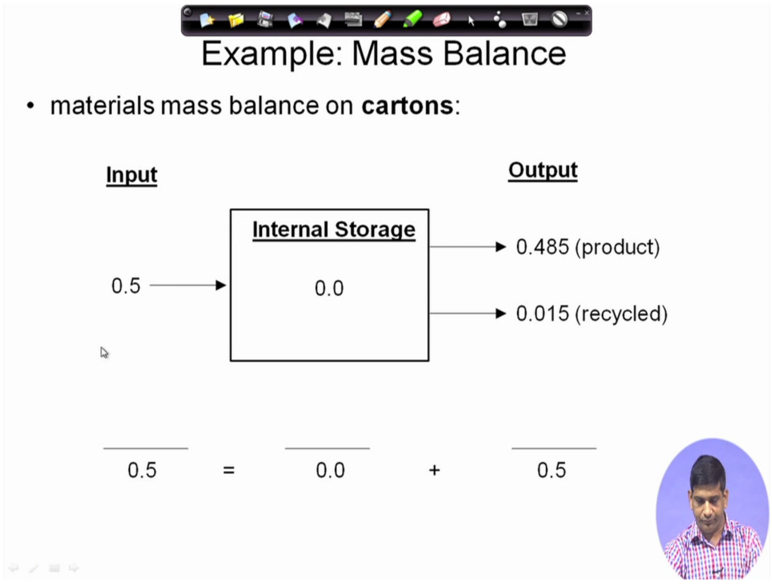

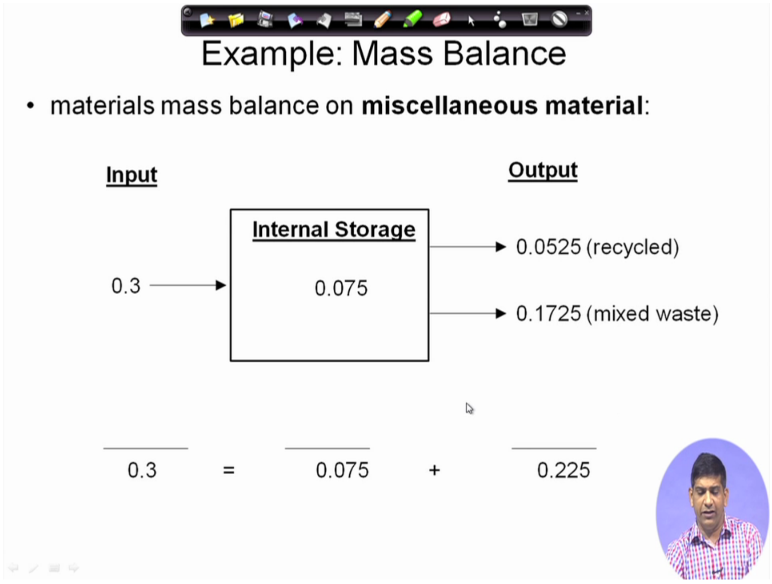

For the cans 5 tonnes coming in 4 is internal storage 0.97 goes for product and 0.3 is recycle so again 5 tonnes 4 plus 1, so it adds up there, then cartons 0.5 tonnes comes in there is some no internal storage there is no sum to the products some gets recycled so that is again they do add up 2.5 coming in 0.5 (())(18:15) as an output. Miscellaneous materials we had 0.3 comes in there is some internal storage, is there is some recycle there is some goes to a mixed waste again you can do the math associated with that and they do add up.

So what I was trying to illustrate by doing this problem is that again this is the very simple mass balance concept and you may have views this mass balance concept other classes as well, so you can very well account for different waste that is out and then based on how much waste is being produced you can come up with your waste collection system for this particular plant you can come up with if you want to have an on-site treatment system.

So all those things can be done by first of all we need to know how much waste because unless we know the waste quantity and waste quality we cannot design the system and the waste quantity and quality should be collected in very thorough manner especially say we were talking just recently in a meeting that many times what happens is these vendors and other companies they come over and they submit a proposal some made projects saying that we can do this, this will be viable but the amount of the type of data that we collect all the calculation that is based on certain type of data and the data itself is not that reliable.

So if the data is not reliable that is kind of the building block, so it is data is like a foundation, it is like foundation of a big building so if your data is not good, if the foundation is not good the building will collapse, so similarly if the data is not whatever design calculation you do, we not sure whether is going to work or may not going to work. So waste collection data, waste generation data and waste composition data and we have talked about all these things in our class over last 4 and half weeks these are very important, this is like first thing we need to do or any smart waste management system or any good waste management system.

We need to have waste quality, quantity data and when I say quantity data is not only the data that is although it is such a good idea to get the data what the households are producing but we are all also have to understand that there is the waste quality keep on changing, even the quantity keeps on changing because things are being taken away, so if you have some recyclables showing up in those primary collection centre there will be people rag pickers who will take out those recyclables and then later on at the landfill site as well you see people trying to pick some of those valuable materials out.

So if you want set up a waste-to-energy plant or some other plant you need to find out okay what they had I should collect? Should be collected from the individual houses? Or should collect data at the primary collection centre or secondary collection centre or at the existing dumpsite? So we really need to think very hard to have this relevant data which is representative as well of the real scenario so that is very critical. And once you have this data like in terms of these kinds of problems you can do certain mass balance and all that.

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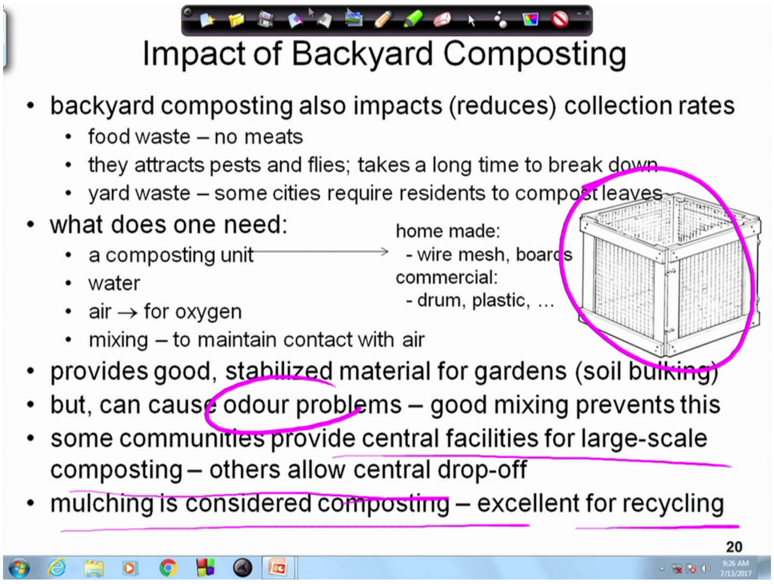

So let us look at some more problems so this was one example let us look at some more examples here it say in the other example, so if we start doing some backyard compositing. So if you backyard composting it also will impact the collection rate, why it will imply the collection rate? Just think logically what will he will do, certain waste that was putting on the curbside we are giving into the waste collectors, if we are doing our compost in our backyard you want those food waste they will probably not give those food waste away.

So we will like to use that food waste, so the amount of waste going to go those trucks will go down, so if the amount of waste going to the trucks go down that means the same truck can probably service more houses could mean that we need less number of trucks so this kind of all related all related so, so in terms of if you are somebody starts doing this backyard composting we are encouraging people like are many cities in India where we are (())(22:40) household to do the compost and use it for their own garden they are balcony garden or wherever is there is a subdivision, if they have a gated community they have lots of landscaping and other stuffs so they can use those things over there.

So in terms of backyard composting or as I said it will also impact to reduce the it will impact or potentially reduce the collection rates. Food waste water are the things that we use we try to avoid using the meat because it does not degrade it does not degrade very quickly so you try to reduce the amount of meat going into this backyard composter. They do attract pest and flies also and take long time to break down, then yard waste some cities require residents to compost leafs, so you can do the composting of leafs as well.

So what does one need for the composting for the home garden the different things out there, if you go on Google and try to search or a home composter, you will probably come up with several 40 50 may be more than 100 of different varieties just within India and will people are selling different types of composter. So basically you need composting unit, you need some water, you need some air you need to mix it. So water you can add, air we can do it by turning of the garbage sorry turning of the compost vessel so that can be done and that is how the air can be injected or we can make the air injection through some other way as well or you can have some home-made wire mesh, boards commercial – drum, plastic we can even use something like this to do this compost stuff.

So there are different types of things we use what it does it provides goods stabilised materials for soil, for the garden it use the soil bulking but if the composting not done properly so that is the odour problem it is where you have the smell problem is there. So good mixing prevent this and then some communities they provide central facility for large-scale composting, so you can have a huge center facility you can bring your garbage you can dump off or if it is not collected in your house and then that can be used in the compost plant. Mulching is considered composting for recycling, mulching is that you cut the grass you leave the grass there itself and it mulches and then it adds basically it composes and add itself it becomes part of the soil, so it is also used quite a bit.

So the thing is that lets see so in terms of we will look at some of this examples of different types of problem, so this problem we are trying to see the impact of compaction, so if you do some compaction what is the impact of compaction of the garbage? So it at source compaction, it will impact collection rate, so if you can compact the garbage a little bit so all the air volumes are gone most of it, waste gets compacted, so even 1 KG may take this space after compaction if it is not compacted it may take this space.

So when from here to here when you go, you are saving some space and for the landfill industry the landfill space is very costly like a million dollar per acre so is a big number, so if we can save some landfill space that is actually a huge saving, so at source compaction and then if it is compacted that means less space the trucks that means more houses can be served on trucks so that means less number of trucks that means some save of money there as well, so you have to think in that way like again always for any subject matter will you think that it will be applied and how potentially can be applied.

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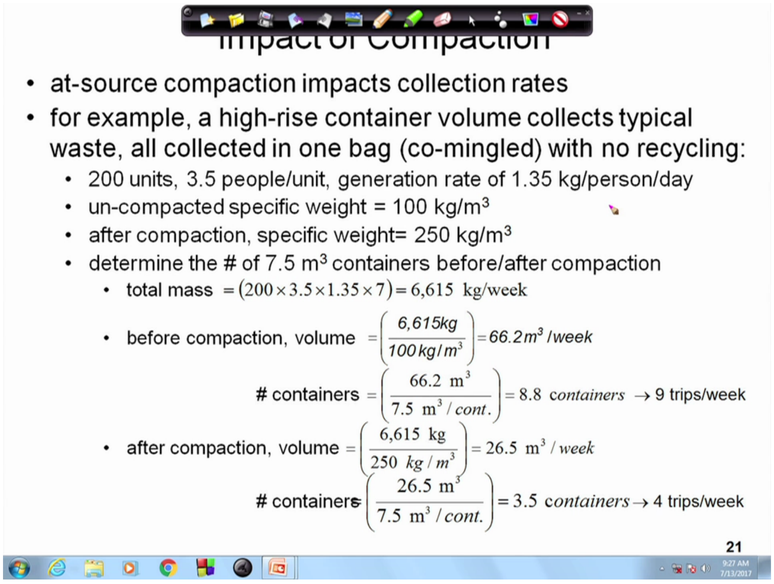

So for example if here we are looking at some of this compaction impact in terms of collection rate for example if you have a high rise container volume and typically the waste all collected in one bag co-mingled with no recycling you have 200 units of high-rise buildings, 3.5 people per unit hash generation rate of 1.35 KG per person per day, un-compacted specific weight is 100 KG per metre cube whether compaction it is around 250 KG per metre cube. So if you want to compacted we get around 250 KG.

So determine how much number of 7.5 meter cube container you need before and after compaction, we know the containers volume, we know the amount of waste that is produced you also know the specific weight so before compaction volume find out we know the total mass how much KG is there and then we can find out the what is if we have before compaction, it comes out to be around 66.2 meter cube per week that means around 9 trips, 9 trips per week.

Now if we use this compacted compactor we are reducing, we are increasing the density so reducing the volume, so volume goes down then that means the number of container goes down as well and that means less number of trips. So if you have the less number of trips that means you have you can save the number of trucks that you need to buy and as I was saying these trucks are very expensive, so if we can save the number of trucks that we need to buy that means more money with municipality to other things, so those are we need to think about in this kind of problem.

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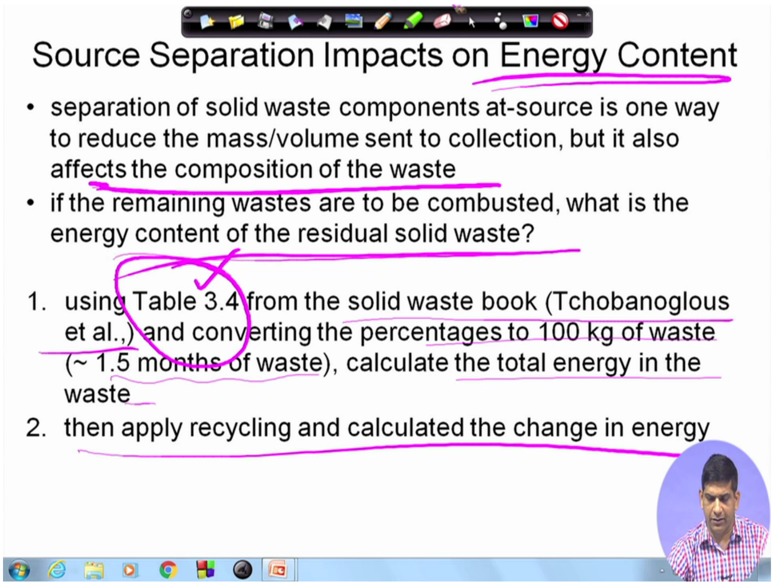

So and the other thing is that when you if you do the we always talk about the source separation is good so if you want to do a source separation, suppression of solid waste component at source is like one way to reduce the mass volume which is sent to the landfill but it also impact composition of the waste, so if you look at if you do the source separation, it does affect the composition especially if you trying to do a waste-to-energy plant so we will look at the energy content, how the energy content changes when we do the source separation.

So these are very practical application oriented problem where if you are doing the source separation at how to impact your waste-to-energy plants, so and if you are putting too much recycling effort very are trying to get all the plastics and papers out, how it will affect your recycling plant sorry how will it affect your waste-to-energy plant because waste-to-energy plant requires good calorific value. Good calorific value, materials plastic, papers and some other materials are out there but plastic paper is one of the major components of that, so if you can take all the plastics and papers away from the waste stream in the form of recycling our calorific value will goes down.

So that is what is been illustrated this particular problem and the thing is that will talk about it not saying that do not go for recycling, recycling is a good way of managing waste but you should realize that if you because we all different technologies different plants are basically targeting same material, the pool of material is the same so if you are doing a very good job of recycling that means the calorific value has to go down and there is no other way and if the remaining waste is composted what is the energy content of the residual solid waste will talk about that will do some maths.

So here I have used I think this is for the first time you are seeing it set a table 3.4. Now what is a stable 3.4 is coming from the solid waste book, so this book is very old now unfortunately this gentleman Dr Tchobanoglous is also very old and I do not think he is going to revise this book any further but some other people may take up this book and do it but there are some of the basic stuff and this book I would encourage you those of you who have some time to at least spend some time flipping this book and tried to read some of those materials.

So this butler table is coming from there but you do not have to get the book for this table because I have reproduced the table in the next slide. So using this particular table from the solid waste book and converting the percentage 100 KG of waste which is around 1.5 months of waste, calculate the total energy in the waste and then apply recycling and calculate the change in energy, so if you do the recycling and what would be the change in energy, so let us to this particular math and I think then probably we will be towards the end of this video, so we have the data lets see will go to the next slide.

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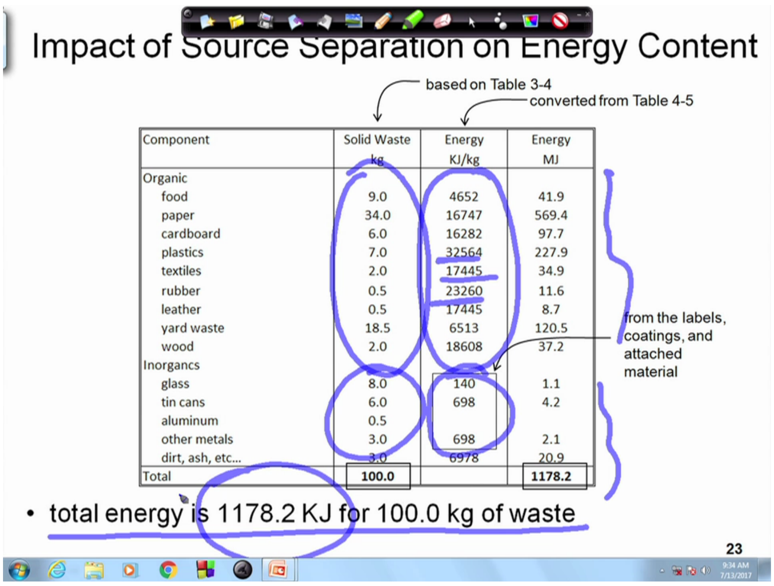

Component	Solid Waste kg	Energy KJ/kg	Energy MJ
Organic			
food	9.0	4652	41.9
paper	34.0	16747	569.4
cardboard	6.0	16282	97.7
plastics	7.0	32564	227.9
textiles	2.0	17445	34.9
rubber	0.5	23260	11.6
leather	0.5	17445	8.7
yard waste	18.5	6513	120.5
wood	2.0	18608	37.2
Inorgancs			
glass	8.0	140	1.1
tin cans	6.0	698	4.2
aluminum	0.5		
other metals	3.0	698	2.1
dirt, ash, etc...	3.0	6978	20.9
Total	100.0		1178.2

So here is the table from the book where we have this solid waste different components food, paper, cardboard and all those things components have been provided to us sorry this has been provided to us. Then for inorganic also it has been given us in terms of KG for each of these components we know the energy content we have idea about the energy content, so we know how much energy each of these can produce and so from kilojoule to kilogram we can go to megajoule we know the, we know the weight so we can calculate the megajoule for this is how much is the energy and for the other as well, so those energy is 1178.2 kilojoule for 100 kg of waste.

So that is the amount of energy which is there and so this is without having any recyclables, you have 34 percent paper, cardboard, plastics although is with high calorific value. If you can look at the here the calorific value part let's see which one is the highest. Of course we see the plastic is the highest one then you have textile sorry in between we have rubber as well and then we have which one is this one leather and textile pretty much the same, then we have cardboard, paper, so as you can see most of the stuff which could be recycle have a little bit of higher energy content. So based on that we can calculate this much amount of energy that is being produced from there, so this is without doing the recycling.

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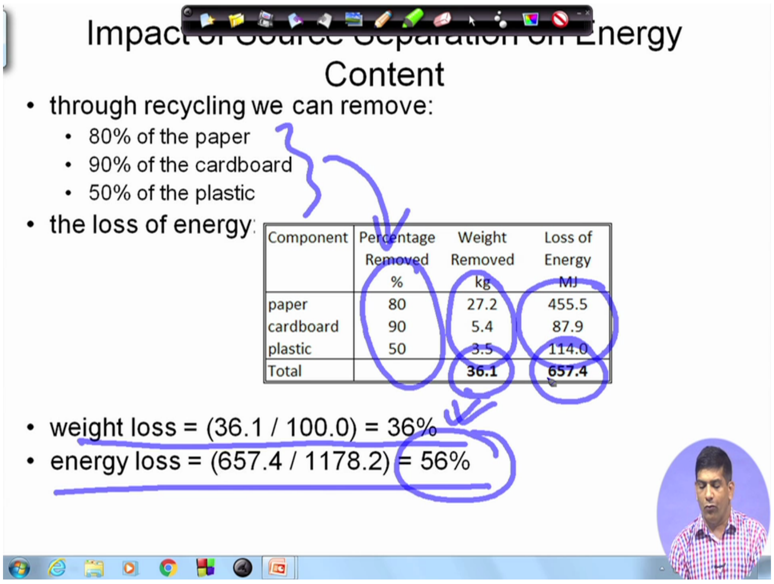

Now let us see if we do the recycling part how the energy changes, so if we recycle 80 percent of the paper, 90 percent of the cardboard, 50 percent of the plastic, so if your recycling this you have 80 percent of the paper is recycled, 90 percent of the cardboard is recycled and 50 percent of the plastic is recycled, so we can find out how was the percentage removed that is basically the data coming from here and then based on the weight we have earlier we can find out what is the weight that is removed from the system and based on the calorific value which is again given the previous slide we can find out what is the loss of energy.

So I would encourage you to do this like these math has been done for you but cross check this numbers I can also make mistakes, so crosscheck this number and if there is any mistake let us know. So this is the how much we weight that is removed from the system, this is how much the energy there is removed from the system, so if you look at the weight loss weight losses is out of hundred kg 36.1 kg is removed, so 36 percent is the weight loss but in terms of the energy lost 657.4, initially it was 1178.2 in the previous slide, so if you look at the energy loss is nearly 56 percent, so with the waste lost is only 36 percent but energy losses 56 percent, why?

Typically would expect it to be the same if the waste was uniform, if all the different components of the waste had the same calorific value in that case probably yes here it is not that case, here you have the calorific value is different for different components as was shown in the previous slide, so that is why with only 36 percent of the reducing the weight you have a 56 percent reduction and this waste to energy plant or there and they have to be if we start setting up a very good recycling system.

We should not get surprise that once you have a very good recycling system your calorific value add the waste-to-energy plant will go down because you can see from here because there will be reduction the energy will lost, it is energy loss from a incineration point of view but recycling again am not saying recycling is bad recycling but when you recycle certain components which has high calorific value your calorific value at the waste-to-energy plant will also go down, so in terms of when we do this integrated waste management framework, we have to look at all these in components and try to see which one will work best, which combination will work best that particular smart city or for the particular city.

So with this let us conclude this particular video and then we will go into the next video where we will continue some of this math problem and then as we wanted to little bit of discussion on landfill. There are 3 major things that we will talk about in terms of treatment and disposal site, will talk about the composting anaerobic digestive that is on the biological side, will talk about the thermal treatment which is on thermal incineration and all and then of course we will talk about the disposal in a landfill before we move to other like construction and demolition waste and e-waste which will be on the last 4 weeks, so let us stop here and I will again see you in the next video, thank you.