Urban Services Planning
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Lecture 16
Waste Generation Part I

Welcome back. In module 4, we will talk about waste generation storage and minimization. And in lecture 16, we will start with Waste Generation.

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The different concepts that we will cover is on municipal solid waste generation. Waste generation, we will give a global outlook. Key drivers for municipal solid waste generation and projections, how to project municipal solid waste generation.

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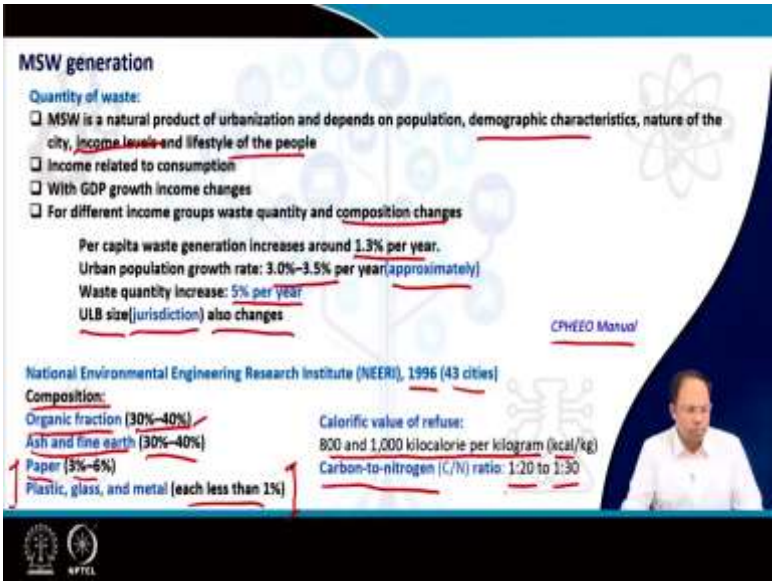

So, when we talk about municipal solid waste generation, there are usually two aspects that needs to be considered. One is what sort of waste we are considering within the municipal waste stream and as that we have earlier discussed that certain kinds of waste like the construction and demolition waste or hazardous waste this could be kept out of consideration whereas, we are mostly concerned with the organic waste, the combustible waste, the non-combustible waste and the different other fractions of waste from where we can recover some amount of recyclable materials and the inert waste like we gather from street sweeping or cleaning upgrades and so on. So, this is the general this is what municipal waste is all about. And when we talk about municipal per capita waste generation, this is usually what we are referring to.

Now, when we talk about this municipal solid waste, there are again two parts to it. One is how much it is generated in an urban area and how much it is collected in an urban area. So, sometimes the figures that we get from literature or from documents there is a overlap between these two. Sometimes it is as per the amount of waste generated by different households or sometimes it is as per what is recorded and usually that is based on the amount of municipal waste which is collected. So, in many cities, there is a significant difference between the amount of municipal waste which is generated and amount of municipal waste collected. But anyway, we will try to sort those values as we go along and then you can understand the difference between what is the amount which is generated and what is the amount which is collected.

So, municipal solid waste, it is a natural product of urbanization. So, with more urbanization, more amount of waste would be generated. And usually the amount of waste that is generated in urban areas is much higher than what is the amount of waste generated in rural areas. There are two reasons. There are many reasons for it, but the primary reason being the consumption pattern is different in urban and rural areas and there is a significant amount of reuse in the rural areas. For example, organic waste and even lot of liquid waste gets reused in the form of fertilizer for the urban fields and all which is sometimes not possible or which is sometimes not practiced in urban areas.

So, there is significant difference in the amount of waste which is finally generated or which comes to the waste stream outside. So, municipal solid waste it is a product of urbanization mostly because we are dealing with municipalities and it depends on population of that particular urban area, it depends on the demographic characteristics of that population, the type of city it is, the nature of city for example, if it is a large city, then it will have in addition to lot of residences, it will have lot of commercial areas, institutional areas and so on. Whereas, in case of a small city, there may be some commercial area, but there may not be too much of institutions and other kinds of industries and so on. So, these are the differences in the cities characteristics or cities nature.

Then the income levels of the population. So, one is the demographic pattern a correct socio economic characteristics, but within that we can also talk about the income variation among the population. So, the income levels how or if we talk in the terms of an urban area, how rich that urban area is, overall the affluence in the turbine area and the lifestyle of the people that means, it depends as per different cultures, as per different society, as per affluence the lifestyle of people also changes. So, different lifestyles, different income levels leads to different quantity of waste that is being produced in urban area.

So, why this happens? Because income is related with consumption that is, with more income usually you consume more. It is not always the case, but usually higher income countries or higher income households usually is tend to consume more and if you consume more automatically you will generate more waste.

Now, how we can determine the income or change in income? So, in that case, the GDP growth is a indicator of change in income that means, with GDP growth, income level of the country also changes. We will come we will explain that in detail later. So, that is if I can predict the GDP of a country automatically we would be able to determine what sort of waste

increase in waste generation will also happen. For different income groups, waste quantity and composition also changes.

Now, why it is so, because we have already said that as per demographic characteristics as per income levels, the total amount of waste that is generated changes, but the composition also changes. Why? Because of the change in the lifestyle, different people with different levels of affluence consume different kinds of good. So, automatically the waste that is generated is a different nature. For example, if you can afford you will by a poor household will probably not buy packaged food, whereas, a rich household usually buy a lot of packaged food or they will order a lot from the restaurants. So, that will generate a lot of plastic waste. So, that is how composition of waste also changes as per the affluence or the lifestyle of the people.

So, usually, so, these are the basic fundamental characteristics of waste generation, waste in urban area you can say, and usually we say that, in a particular urban area, we have to assume certain growth rates for both the growth in population, growth in the amount of waste that is generated, so, that we can project the waste generated in future. So, CPHEEO Manual suggests some figures for example, per capita waste generation is increases around 1.3 percent per year. That means, because we can assume that you say households grow in sizes, household income changes, so, with a change in income, change in lifestyle, gradually there will be increase in the amount of waste that is generated by the household. So, that is considered as around 1.3 percent per year.

Then, one is part is the urban waste generation rate per capita waste generation rate, the other is how much is the urban population change that is because total quantity of is depends on the total population multiplied by the waste generation rate. So, urban population growth rate is around 3 to 3.5 percent per year approximately considering Indian conditions, but it is not necessarily that this would be true for most urban areas, neither it is necessarily be true for different urban areas in different countries. In some places, the urban areas also shrink. So, we have to be careful about these values.

So, then, so, overall if I say in case of an urban area, overall waste quantity increases by 5 percent per year, and not only that, not only number of people change in an urban area sometimes what happens the urban area also grow in size, grow in size physically that means, the jurisdiction or the boundary of the urban area is extended. So, in that case the ULB size will also change. So, the municipal bodies boundary will also change and that also leads to

change in the total waste that the municipal body has to handle. So, municipal solid waste is a function of population, the rate of waste generation and also the size of the urban area.

Now, the National Environmental Research Institute in the year of 1996 conducted a study on 43 cities and they found that in most Indian cities, roughly the composition of waste that is what are the things that is what is the type of material that is available inside the municipal waste stream, they found that organic fraction is around 30 to 40 percent. So, that is biodegradable fraction is around 30 to 40 percent whereas, Ash and fine earth, these are mostly inert material and all this is comes to around 30 to 40 percent and finally, the waste paper comes from 3 to 6 percent and plastic glass and metal each is around 1 percent. Now, you can see that that means all these are more or less recyclable materials. So, around 6, 7 percent of recyclable materials is generated.

Now, the problem is, even though it is generated municipalities in many cases do not end up collecting this. Why? Because sometimes people do sell this directly to some informal groups, informal waste collector groups who sell them via the kabadi system to the different or the recyclers to the local level recyclers. And so, that does not enters into the municipal stream directly, but it do is it is generated at the household level, but at the collection level it does not reaches the collection part. So, that also needs to be considered.

Similarly, calorific value of refuse was found to be around 800 to 1000 kilocalories per kilogram. So, calorific value is important as we have discussed earlier that this determines if the waste is can be incinerated or not or is it feasible to be it to consider incineration as a disposal mechanism or final treatment mechanism for this kind of waste and also the carbon to nitrogen ratio in waste was found to be around in the range of 1 is to 20 and or to 1 is to 30.

Now, carbon to nitrogen is actually the content of carbon matter and nitrogen matter, nitrogen mass and carbon mass in the organic waste. Now, why it is important? It is important for the success of the composting process. So, there are some ratios which are ideal for the composting process. We will discuss that in detail when we do composting.

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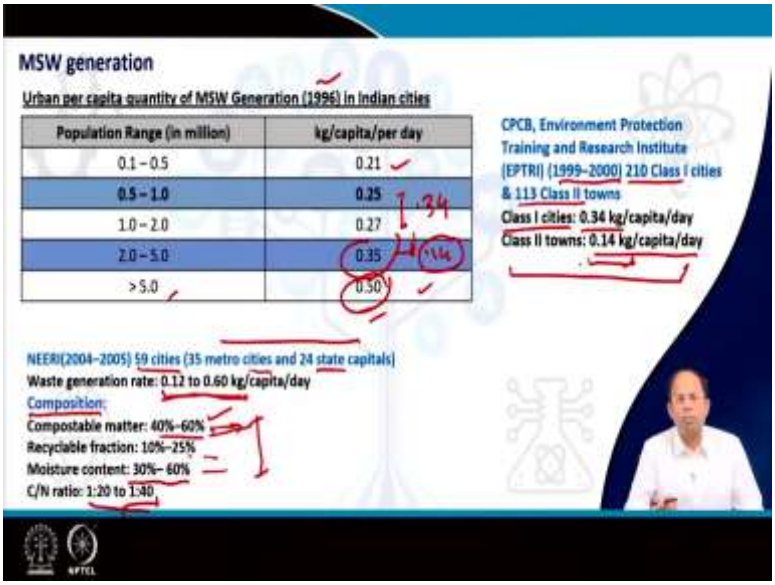

So, now, what we have discussed is as per the nature of the city also the amount of waste that is generated also changes. Over here you can see in this table cities with different population ranges and this is again data from 1996. It was found that with smallest cities where population ranges around 0.1 to 0.5 million. So, in that case, the rate of waste generation was found to be around 0.2 kilograms per capita per day. Whereas, for cities which are larger size around more than 50 lakhs, so, in that case the waste generated was found to be around 50 kilograms per capita per day. This does not mean that everybody in the city produces this amount of waste, what it means is that average of waste that is generated in a city of this size which includes residential area, commercial area, institutional areas and all the different kinds of generators both small generators and bulk generators, all things included this is the average value of is that is being generated.

Now, CPCB conducted another study during the year 1999 to 2000 and they found that and they did study on 210 class 1 cities and 113 class 2 towns. So, class 1 cities are small cities, class 2 towns and even smaller cities, so, roughly 1 lakh population and even less than 1 lakh 50,000, 50,000 to 1 lakh for class 2. So, in that case you can see that they found that in class 1 cities the value of waste generated is 134 kg per capita. So, if I put it in this particular table class 1 cities roughly comes around somewhere in between these two, so, we can say that the value was around 3-4, whereas, class 2 cities come somewhere between here or maybe somewhere in between here. So, it was coming around 1-4, so, which was a little bit lesser compared to what that previous study has found.

But anyway, so, that what it means is waste generation varies as per different cities, it also varies for many other purposes. So, we have to be very careful about these particular rates, why, because, when you multiply this by the total number of population, we can also multiply it with the number of days in the year, you get a huge amount that has to be dealt with the waste. So, in that case, if I am not careful with this rates, you will end up with designing facilities which are either over designed or under design. So, that is the reason we have to be very, very careful about these values.

So, in subsequently nearly in the year 2004 and 2005, they again conducted another study on 59 cities including 35 metro cities and 24 state capitals, they found the rate, the waste generation rate varies from 0.12 to 0.60 kg per capita per day. So, you can see the difference in the change or the change in the waste generation rate in different cities. And these are done mostly in the major cities either 35 metro cities as well as state capitals. So, when in the large cities, we can see the difference ranging from 0.12 to 0.6 kg per capita per day. So, just adopting a value like 0.5 or 0.35 for a city without doing any kind of surveys doing any kind of check will result in wrong estimates for the entire solid waste management plan.

So, similarly, in terms of composition, what they found was compostable matter was 40 to 60 percent. So, this value is more than what we found earlier, which was roughly 30 to 40 percent. So, now, we found it to be much more. Then recyclable fraction also increased to 10 to 20 by person. The moisture content of the bass was found to be around 30 to 60 percent. So, this was not found earlier, but now, it was found that out of the overall weight of the waste, that 30 to 60 percent is moisture this is also very important, because when you are carrying this waste, this weight will matter in the transportation system that you will design. C N ratio was found to be more or less same 1 is to 20 to 1 is to 40. So, obviously, this has increased a weight. So, that means, there is a lot of variety of the kind of organic waste that we are also getting.

So, this indicate that with more affluence in the Indian scenario, we are finding that more people or the percentage of compostable matter the organic fraction is actually increasing in the waste and there is not and the recycling fraction is also increasing. So, but in other developed nations and all we have found that the compostable matter organic matter is much less, why, because in India, the affluence level, at the lower levels, usually we find that the consumption is very low that because people are poor, they cannot waste items or waste food. So, organic waste is very less, but with affluence, the amount of organic waste increases. So,

that is what we are saying, but again, when the income changes further, then instead of buying food from markets and cooking it daily people will start buying packaged material and then it will again come down.

So, that means the composition wise the organic matter increases gradually with the change in income and then again it falls back.

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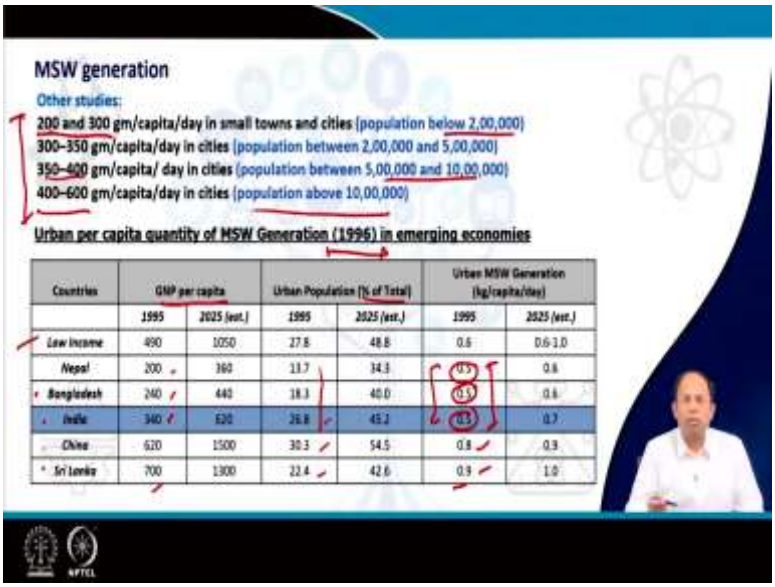

Now, some other studies this we can, actually, in case of absence of data, absolutely no chance of doing any kind of service or not. So, these are some of the values that you can adopt for population above 10 lakhs for a city we can go for 400 to 600 grams per capita per day. For population between 5 to 10 lakhs, 350 to 400 grams and in small towns and cities below 22 lakhs we can go for 200 to 300 grams per capita per day. To give you a comparison with other similar countries in the region or low or you can say emerging economies, this is data from the year 1986.

We can see that the different income categories low income countries, which include Nepal, Bangladesh, India, China, Sri Lanka, these are all most more or less South Asian countries. So, here you see that the waste generation is more or less same with little bit increase for China and Sri Lanka. Now, why is that increase? You can see, now let us check the GNP per capita. This is gross national product per capita. So this is a indicator of the affluence of that particular country or society. So, here you can see that Sri Lanka's GNP is higher than China's GNP in the year 1996. So, accordingly, their waste generation rate is also higher.

Now, India, Bangladesh, Nepal, there is some difference in the GNP, but in the waste generation levels, we are not finding so much amount of difference in waste generated. So, these values can be considered in conjunction with GNP weight in order to make sense that what sort of affluence reside in what kind of waste generation. So, the other thing that plays a role is of course, the urbanization rate. So, we will talk about that in details. So, you see, the urbanization rate is also different for this particular countries over China's urbanization rate is a little bit higher than India in 1996 of course, now, it is further different. Sri Lanka, it is a little bit lower.

So, urbanization rate may also influence the overall waste generation rate for a particular city. So, that we will check later.

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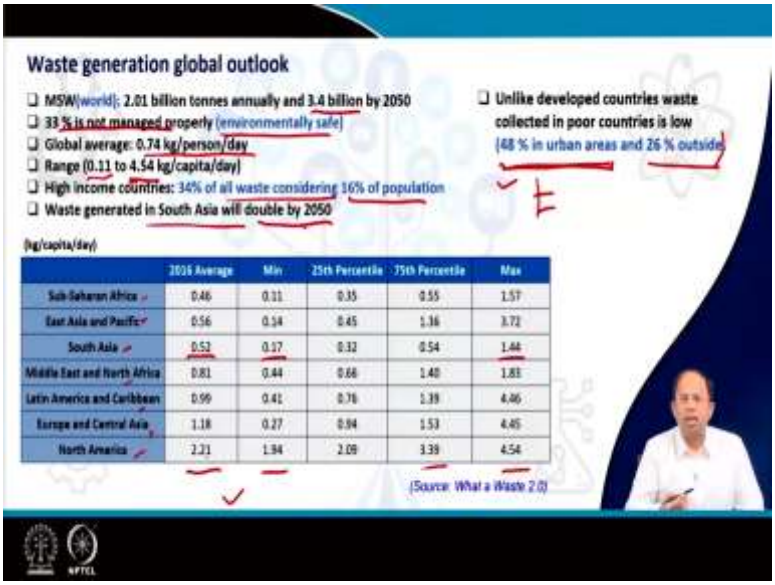

So, now, considering a global, the scenario, recent studies say that, around 2.1 billion tonnes of waste is generated annually and around 3.4 billion of waste to be generated by the year 2000. So, that means this is the quantum of waste that we have to deal with together in the overall world. And out of all this 33 percent of waste is managed properly. That means it is managed in an environmentally safe way.

Now, you can say that, in developed countries or rich countries, probably this person is something around 90 percent whereas in poor countries this value is something around 10 percent. So, there is a significant difference among the countries as well. Global average waste generation is 0.74 per kg per person per day. It is higher than the Indian average. The range is from 0.11. You remember this 0.11 we saw it in the some in Indian study as well to

maximum value of 4.5 per kg per capita day. So, it is a huge amount of is that a person generates per day.

So, high income countries we see that around 34 percent of all waste is overall in the world is generated in high income countries whereas, they have only 16 percent of the population and waste generated in South Asia particularly India, Pakistan, Sri Lanka, Nepal and all this country Bangladesh there the waste generation is supposed to double by the year 2050. So, rich countries are probably the growth would not be that high, but in poor countries the growth is very very high. And in our country, we estimate that roughly the total waste generated would be double by the year 2050.

Now, unlike developed countries waste collected in poorer countries is low. For example, 48 percent in urban areas, that means, out of all the waste generated around 50 percent of the waste is collected in urban areas. And the rest 26 percent is for outside areas that is areas outside the urban areas area, semi-rural areas, rural areas and so on. So, you can estimate that only 50 percent of waste is collected. So, where does the rest go? The waste goes to unauthorized dump sites, unauthorized, people throw garbage in the drains, people throw garbage in the streets, people throw garbage in open plots and so on. So, that is where all this waste ended up with. That is why we see a lot of litter in Indian cities.

So, if we can improve the waste collection process of the waste, and we can reduce the generation as well as the waste collection process automatically we will not see so much litter in Indian cities. Now, let us look at some data. So, if I divide the world into different regions, starting with North America, the one of the most affluent regions, Europe and Central Asia, Latin America, Middle East, North Africa, South Asia, this is where we are East Asia and Pacific, Japan and other places and then Africa. So, you see that North America, the average waste generate is 2.21. Whereas the range is starts from minimum of 2 kilograms approximately to around 3.5 sorry, 4.5 kilograms. So, that is the range.

In India, we are at average at around 0.5 kilograms per capita, whereas minimum is 0.17, and the maximum is 1.4. So, that is the difference in range of waste generation in different parts of India or for different groups of people, different population groups in India. So, similarly, you can see the values for the other countries and obviously the it shows that the more affluent a country is, or it is not only a question of affluence, there are other things lifestyle and lot of other things, the culture all these things plays a role.

For example, Europe is equally or more or less similarly affluent as America, but the waste generation it is less compared to US. Whereas, if you go to Japan and all it is also the GDP rate is more or less, the per capita is more or less similar, or a little less, but the waste generation rate is much significantly lower.

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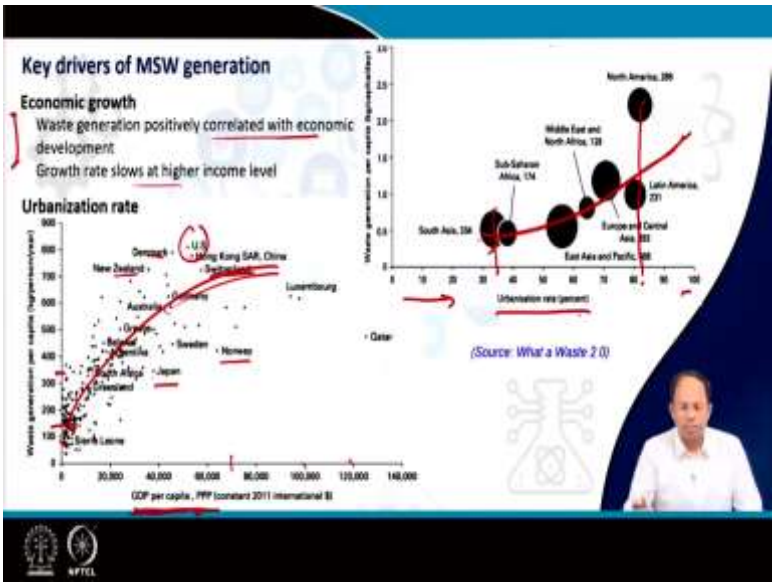

So, let us take a look at some other data points. So over here, we see two graphs. One graph shows the, this waste generation per capita kg per person per year. And on the other side, we have GDP per capita. So, this GDP calculation is done on PPP terms that is in as per the parity terms. So, this GDP per capita is the amount of income for the country divided by the population. And when we plot the amount of waste that is generated, you can see this scatterplot we can see that the poorest countries in Africa like Sierra Leone, and all is somewhere around here, whereas Japan is somewhere over here, it is affluent country, but still it is at a value of around 350 kg per person per year, so, that comes to around 1 kilograms per day roughly or 0.9 kilograms per day.

Norway, Norwegian countries a little bit higher. They are more affluent, but still their amount of waste genertae is higher, but not that high. Whereas US, they are affluent than Japan but less affluent than Norway, but they generate a lot of waste. Same happens in Hong Kong, New Zealand, Denmark and Switzerland and in other places. So, there is not there is a trend of course, but it does not mean that it is same for all countries, but roughly we can have a find a trend where we can say that well GDP per capita in terms of purchasing power parity, it is similar it is as per that is, we can say that that increases with increase in GDP per capita, but

at the same time, it is not uniform for all countries and our country is somewhere is around over here. So, that means we generate around 100, 100, 20, 30 kilograms of waste per year.

So, the other way to look at it or waste generation rate is the urbanization rate. So, we can say that waste generation is positively correlated with economic development from this particular graph. And growth rate slows at higher income level. We can see that the growth rate at hiring, so, with the increase in the GDP growth rate, we are not seeing a similar increase in the waste generation rate. So, the increase is the growth rate slows at higher income level. So, that means if I have a curve, if I can plot this, so, the growth rate is gradually coming down when GDP increases. So, this is what economic growth, so, this is one of the key drivers for municipal solid waste generation and the other driver is the urbanization, let us check the data on urbanization rate.

So, over you see that with different levels of urbanization that is percentage of people living in urban areas. So, we see that this is urbanization rate is in this direction, it is in percentage 0 to 100 percent. So, certain cities are very very urbanized, certain countries or certain regions are very, very urbanized for example, North America region is very urbanized around 80 percent urbanized. So, same goes for Latin America, then Middle East is over here, South Africa is somewhere around here, whereas Asia is even lower somewhere around here. So, there is difference in Asia of course, South Asia of course, some are higher, some are lower than Africa, but overall we are somewhere around here.

So, you see that with lower urbanization rate, somehow there is also a trend, which shows that with higher urbanization, the rate of this generation per capita also changes. So, that means that with increase in urbanization, more area is urban automatically the waste generation rate is also different or it will increase because as we have discussed earlier that rural areas the waste generate is less compared to urban areas. Similarly, with GNP, GDP per capita increase, we will also see a higher this waste generation rate in those countries with higher GDP per capita.

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Now, how do I project this the waste generated for coming years that means, today I know what is the waste generated, but in future how do I do that. So, to do that we need to total waste we say that its population the total population for which we are estimating it multiplied by the waste generation rate. So, our job is to determine how the population changes over time and how the waste generation rate changes over time. So, if I am predicting the waste generation for the year 2050, I have to first predict what would be the population in the year 2050. So, we have already discussed how to project population and what are the factors that has to be considered while protecting population.

So, we should consider the migration to a particular city, we have to consider the birth rate, death rate and many other factors. Similarly, the waste generation rate also needs to be predicted. And in the last slide, we have already showed you that with GDP per capita increase, we can also see a increase in waste generation per capita. So, that means, if we can find the relationship with increase in GDP, how much of waste is generated, then automatically I can predict that by 2050 we can estimate based on other things, what is the GDP of that particular country or GDP per capita for that country and accordingly we can predict the waste generation rate.

So, over here you can see that a regression model has been performed the curve fitting exercise has been undertaken, and this is the curve that is generated. So, this curve is actually predicts the waste per capita. This is curve means its equation. So, this equation actually predicts waste per capita based on log of GDP per capita, that means we take a log of GDP values per capita and we are able to predict the waste generated per capita. So, this is a

regression which has been conducted by World Bank and they have projected GDP for different countries accordingly.

So, over here you can see that 2016 average values are given for waste generation rate per capita, 2030 projected values are given and then 2050 projected values, this is short term projection, this is long term projection, as you understand short term projections are more accurate, long term projections are less accurate because the more the time passes, there is other very variabilities other lot of things can influence a prediction. So, we can see that in Sub Saharan Africa, all the areas or all the zones of the world is growing. But particularly you see in South Asia from 0.5 to we are supposed to grow 2.62 by 2030 and point around 80 grams per capita, 80 kilograms per capita per day sorry, 0.8 kilograms per capita per day during the year 2050.

And if you can see that North America the grow right now there are 2.21 and they would probably become 2.5. And similarly, this has been predicted for different regions of the world. Now, that means, using this equation we can do this kind of prediction. So, that is we have to generate this kind of equations for our country as well or for different cities or we can take the GDP of different urban areas and accordingly using that we can also do some predictions. Now, how do I predict, so, we can conclude by saying that waste generation rate is a function of GDP per capita as per this particular digression, but we can also say that as we have just seen in the last slide that it could be a function of urbanization as well. So, it is a function of both urbanization rate and GDP. So, I can have another regression where I can include also the urbanization values of different countries and we can also do a more accurate prediction.

So, coming to my country, how do I predict, GDP changes in an urban area. So, city level GDP is basically estimated as a share of the district level GDP. And usually, the State Directorates of directorates of Economics and Statistics in India estimates the state domestic product and the district domestic product. So, within once these two things are predicted, we can predict that what is the share of the GDP for this particular urban area that we are talking about, and from there, based on the prediction of this state district diversity product for future we can also predict the share of that for the city level for future years as well.

Now, how is GDP predicted? There are different ways to predict GDP that is income approach, production approach, expenditure approach, but in our country in India, we usually follow the production approach and the expenditure approach. Now, production approach of

GDP calculation means, we have to add all the values of all economic activities in a particular area or in an urban area in some particular territory. What are these economic activities that means, amount of production in different sectors construction and transportation and so on. So, we have to add all the year of production that happens in each of these sector, how much amount of production happens and plus the sum of outputs, all this minus intermediate consumption that is what is the amount of resources required to do this kind of production. So, that has to be taken out, plus indirect taxes minus subsidies on products.

So, when we do this, that is total income generated from different products and sorry, total production of different products and all. So, in monetary terms, how much amount value of products has been created, from there we can actually predict GDP.

Similarly, we can also predict GDP using the expenditure approach, where we determine the final consumption expenditure for households, nonprofit institutions, then the government and along with that, we add gross fixed capital formation, acquisition less disposal of valuables, changes in inventories, which are already there, and exports and minus inputs. So, when all these are added, we can also predict the GDP following the expenditure approach. So, usually this is not urban planners do not need to do that, but there are departments which actually conduct this kind of experiments. So, it is this type of estimations. And as you can understand these sort of calculations could be also done at the district level or the state level or even for some matters if a large urban areas we can also do this kind of calculations.

So, from there we can estimate city levels GDP and how the city level GDP changes over time can give an indicator of how the waste generation rate will change over time. So, GDP minus depreciation is the net domestic product of a country which is actually what we consider.

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So, these are some of the references you can consider. To conclude, MSW generation depends on urbanization, demographic characteristics, nature of the city, income levels and lifestyle of the people and MSW generation is likely to double by 2050 in South Asia. Thank you.