Environmental Quality: Monitoring and Analysis

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Lecture-42
Gaussian Dispersion Model - Example, Additional topics

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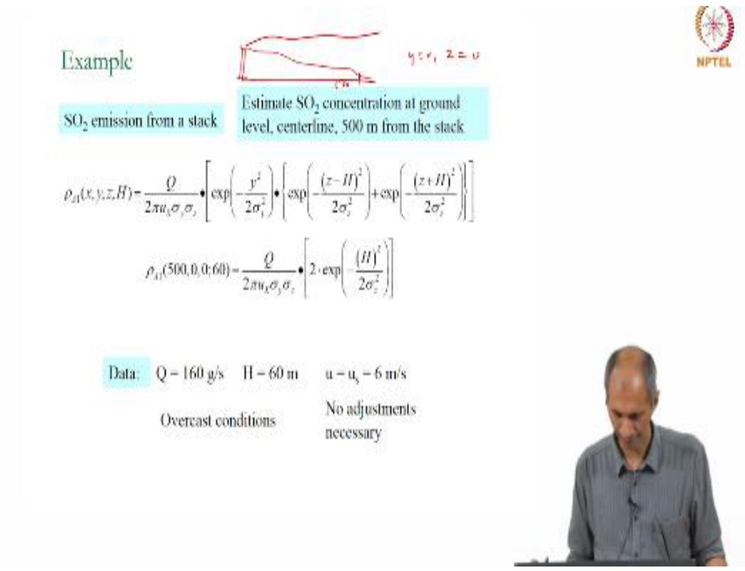

So we'll do a small example just to illustrate what we are doing. This is all there in the PPT you can go and look at it. So we want to look at SO_2 emission from a stack. So this is what we want, estimate SO_2 concentration at ground level center line 50 and 500 meters from the stack. So there is a stack here and we are looking at a distance 500 meters from the stack and we want to know, what is the concentration? Center line at ground level which means y equals to 0, z equals 0.

$$\rho_{A1}\,(500{,}0{,}0;60) = \frac{Q}{2\pi u_x \sigma_y \sigma_z} * \left[2.exp\left(-\frac{(H)^2}{2\sigma_z^2}\right)\right]$$

the height of the stack is 60 meters; it is already given to you. What do you mean by height on the stack is H.

$$H = H_s + \Delta$$

plume rise all of that is added given to you. You do not have it, you have to calculate all that and put it there. So data that we need is Q, that is given to you is 160 gram per second. If you do not know anything about this problem, you have to compute all of this individually including this u and we are given that this overcast conditions.

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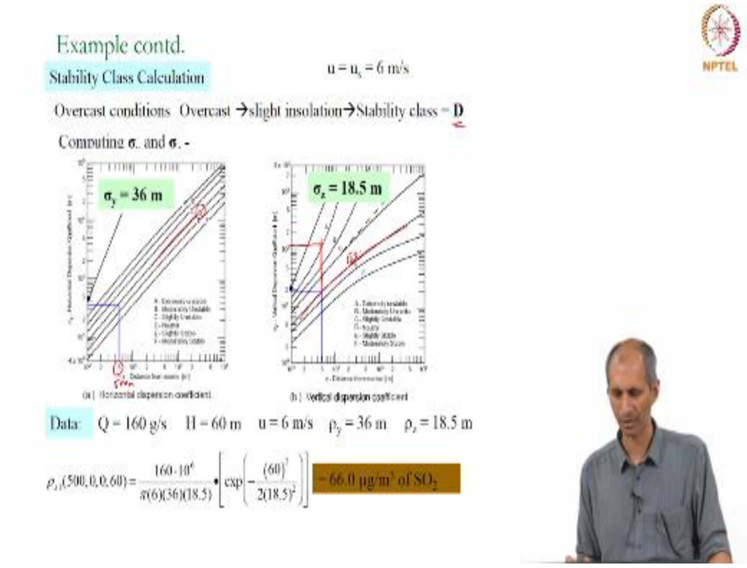

From the overcast conditions, we can select the stability class from the Pascal differs table so for slight insulation stability class is D. Now, this is a matter of judgment, so I think some of you may determine this as stability class C, some may be doing it as D, therefore your numbers will be different. So this is an estimate not the true value because a lot of other factors that will Gaussian dispersion model is the ideal model everything is very symmetrical and all that. There are non-idealities in system and transports that will occur which you have taken into account. Based on that. So we are looking at x equals 500, so it means that the computation of σ_y at x equals 500 will take this is 500 meters. We go to stability class D. This line is stability class D and then I pick my value for σ_y as 36 meters there and similarly I do this for σ_z also at the 500 and I am going through this line. And I get the value of the σ_z as 18.5, if the stability class where A then my value of σ_y would be around 150 or 120 something like that, so I have other this I put it in there and I get a value of 66 microgram meter cube of SO_2. This is the concentration at that point. This is the single computation for one coordinate, one point, one location, it could be anywhere around the source, hopefully it is in the direction of wind. So that you have to calculate that, you need to know which direction is going and there is in the direction of wind that should be implicit in the problem, it is not said anywhere in the problem as we mentioned yesterday.

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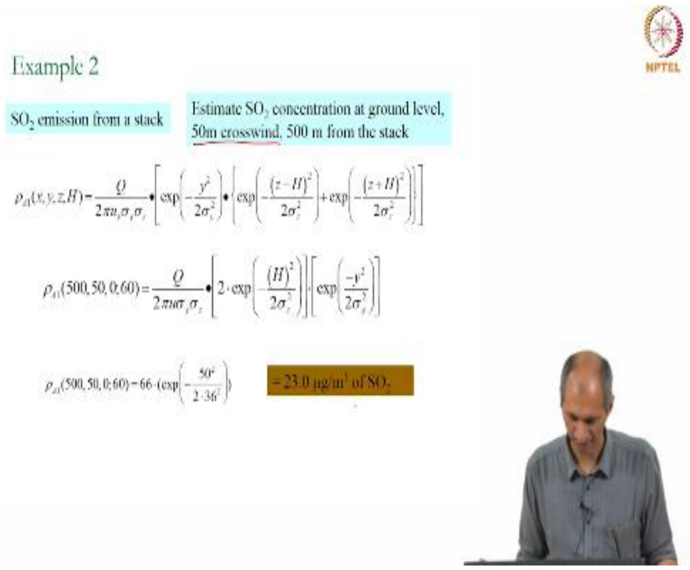

Second example; so here we set 50 meters crosswind, which means that y is not 0 anymore, y is off the x axis 50 meters away, so we put y equals to 50. See in some cases it is not clear so most of the time when you are doing the problem this is not important, this is only examination people will give crosswind and central line and all that, we will see what the real application is, we do not care about all of this things, we are interested finding out a lot of points.

We just calculate everywhere and find out what is, so this is just from a single, if you are writing an exam somebody will ask what is central line or what is crosswind, there it is important. Otherwise the real situations we do not use this for these kind of calculations; We are not just interested in central line.

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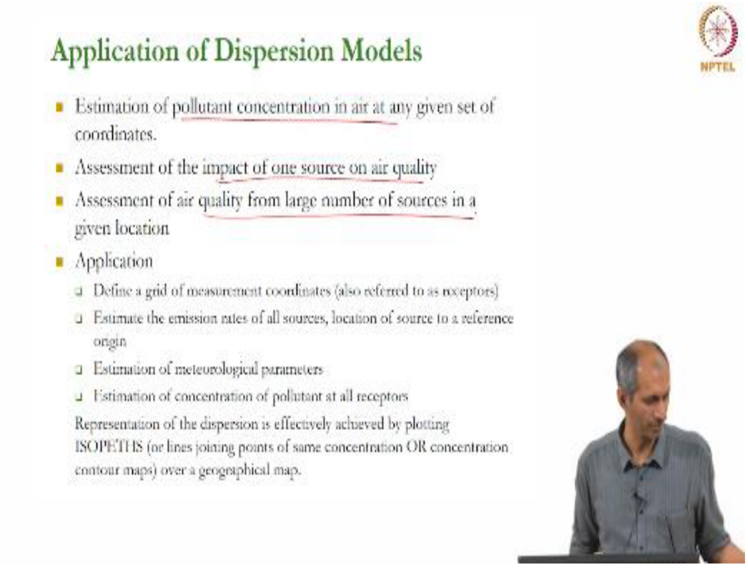

So how do we apply this dispersion model, what we are using it for is estimation of pollutant concentration of any given set of coordinates whatever it is, assess the impact of one source on air quality, you can also assess from a large number of sources you just add large number of sources.

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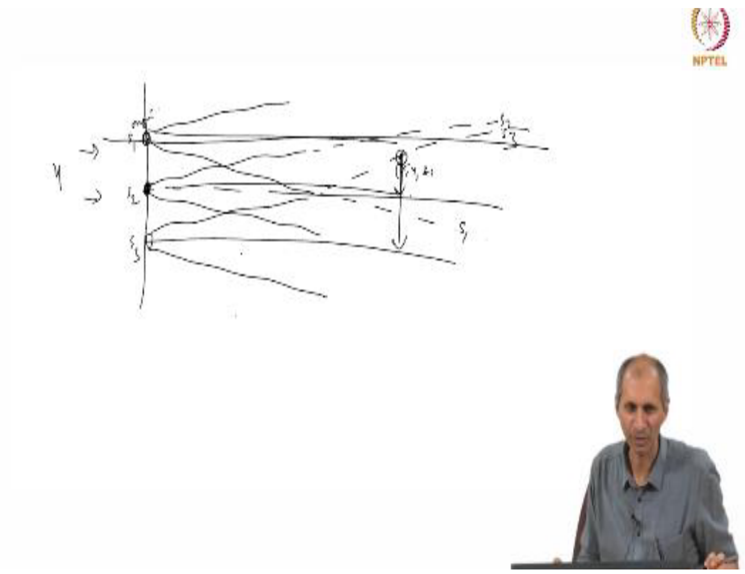

For example, if you are interested in doing a large number of sources, I am looking at a top view of a map there is a source here, we call it a source 1, the source 1 has plume. Source 2 somewhere nearby assuming that wind is in this direction source 2 also has plume, source 3 also has a plume it may have different q1, q2 what we are assuming in dispersion model is let us say if I want to measure the concentration at this point from location x, y and z, now there is a contribution from source 1 for this S1. There is also a contribution from source 2, there could also be contribution from source 3 all of these 3 will contribute to concentration here. In the models we just add all of them, that is it. Now we have a frame of reference if we assume this to be origin, x equals 0 or something. We will just take this as the point of reference and everything else will calculate from here, so in the dispersion model when we are assuming this we can transpose all of this. Even if we do the calculation for this we add this contribution to this based on a set of coordinates based on one of them when you are doing the calculation this is x, this is some y, this y is different for this one, this y is different for this one, this y is different for this one, each one of them this y is different. But in the real system y is y there is one fixed coordinate, but when you are doing calculate individual sources you have to transpose that, you have to adjust that y. So you take frame of reference, a fixed frame for the point and then this one you have to do separately like this. When you do 3 sources you will know what we are talking about contributions to this source from particular points.

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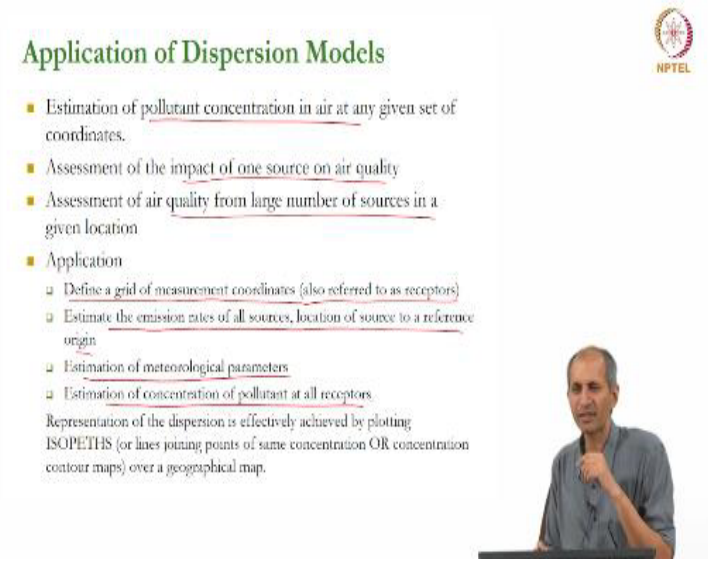

The application when we do this we define a grid of measurement coordinates also called as receptors. What we are doing is we are trying to measure concentration exposure which means there is a receptor there, so instead of receptor what we are doing is we are putting the coordinates x, y and z on the left hand side of the Gaussian dispersion model that is the receptor which means it’s a coordinate.

We define a grid of coordinates; we can calculate the concentration at the source and at those large set of coordinates. We estimate emission rates for all sources and location with reference to some origin as described earlier. We estimate meteorological parameters. We also estimate concentration of pollutants at all receptors. Once we do this we have to represent it somehow so there are large number of sources even if there is one source. I will show you the example of one source. How do we effectively represent this?

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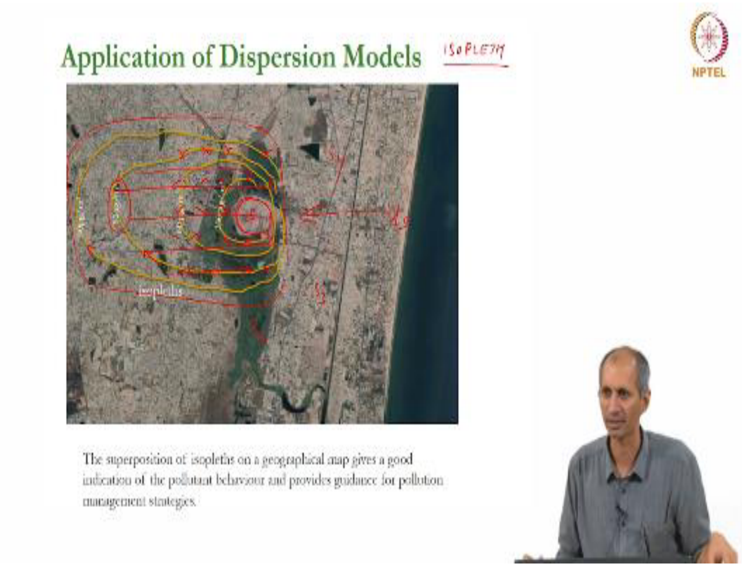

The way we do it is by mapping it. So this a very good way to doing it, say for example; this is a map of Chennai and this is a garbage dump in South Chennai. This is the source, I am assuming this is my one source. So if I plot, if I measure a large set of coordinates all around this. I am assuming that the wind is coming from this direction. If my wind is in this direction, I am defining that as my x axis and then I am measuring it in a wide set of coordinates. So I can have a Cartesian coordinates I can just define a bunch of this entire zone, I am measuring the concentration. Say at 100 locations. Then I get a table of concentration versus coordinates. Then there is what we do is this, we join the points, it is like an isobar. What is called an isopleth? An isopleth is the line joining points of equal concentration, so this gives you a contour map. So here I have written the contour map. This boundary of the source, this radius around source is 100 milligrams or micrograms of meter cube will concentration of some pollutant. They are going out you are expecting concentration will decrease. So this contour is 80, this contour is 50; this contour is 40, so on. So you get a map of where the pollutant is going. You get a visual map of where the pollutant is going. So this is the superposition of your Gaussian dispersion model calculation with reference to a real source. So, on a map this is how people apply this on a map you have different sources. This is only one source. Now, I can have multiple sources, I can have source 2 here, source 3 here, and whatever. And I do not have I can just put a contour map of one particular pollutant. So the contour map is a one pollutant because the pollutant concentration depends on the emission factor and emission rates.

So even if they are burning coal in all those four places the emission factor for Sulphur dioxide, if they are doing the same process, it should be the same but you still have to estimate it differently for all these four sources depending on the emission rate is estimated differently based on activity rates and all that. So each of these things have done separately and then you apply the Gaussian dispersion model and then plot. What is going to be the contour map?

So what this application gives you is; let us say that 50milligrams per meter cube is the ambient exposure level you cannot anything above 50 is supposed to be not safe. So then you can say that I will mark these regions in this radius to be seriously affected. So this is very useful in planning an emergency response. So say there is a factory and there is a leak then immediate response you want to say who are the people going to be affected immediately and you can say this is a radius worst case scenario, worst case scenario means, very high winds dispersion happens very fast, you have to find out what is the worst case scenario, run the dispersion model and find out which case is the lowest. So you have to map these things.

So there are companies that do this emergency response planning. So there are scenarios there are worst case scenarios. We know the windrose, we know the behavior of wind and we know extreme events they say there is a big cyclone or something happens. So for different events, they will have different plans. So if they know if something happen, they know exactly what to do. Which area should be targeted first and if you know that that area is going to be under high risk you give them some safety equipment, there is a leak this put on this mask or stay indoors or something whatever something do some remedial measure. If you are unable to evacuate from there, so this is emergency response measure, dispersion modeling can give you a great deal off.

The second type of application in sense how you can use this information is to plan this sighting of industry. This is a very, very common thing in the reason people used to do this very heuristically. So you have the industrial estates or what we call as this, in Tamil Nadu, we have the sipcot small industries, so they are all located in some locations some places which are far away from typically urban places and the idea behind that is given the wind patterns and all that even if there is an emission something there is nobody downwind that will get exposed to it. So t is essentially far away from all receptors. You do not take that into account this is why you see a lot of debates right where do you site the particular thing they say this is dangerous you cannot put it here, because it will cause groundwater pollution and the same thing what we are talking about air here applies to other media as well, you are talking about soil pollution, water pollution and all that. We don't want things to reach receptor or by the time it reaches, it should be concentration should be small enough because of dilution or dispersion, so the mathematical models give you a very good preliminary handle on this what we talk of preliminary handle is it's not accurate by no means it is accurate but it gives you a general idea that you know 5 kilometers is a region that some going to be great interest worst case scenario.

If it is better than this fine very good no problem, but it is worst case scenario what we have planning for dispersion models are reasonably good under these conditions. So you can also plan the way you apply the dispersion model depends on whatever you are trying to do your objective. A lot of companies which do this it is very common in the West; it is catching up here people are trying to find out scenarios in urban areas. For example, there are a lot of places in India right now there are industries in the middle of a large city, in Chennai itself, it supposed to be in the outskirts now around that there is a lot of residential areas it is happened in all cities in India. There is large amount of urban residential locations in the middle of that there is a cluster of industry. So therefore the regulation and the way they operate and all that comes under scrutiny.

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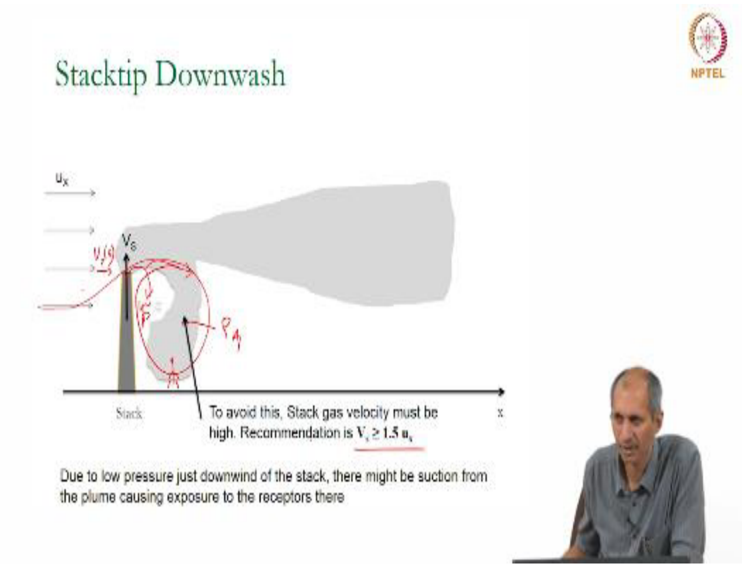

There are a couple of small Artifacts to this dispersion, these are the non-idealities one of them is called as stacktip downwash, now this is not important for ambient pollutions, this is important for in the place in the source, for example a factory and you have a stack you have a chimney which is releasing emissions. There is a possible scenario that this plume will not disperse but it will come back. Right below next to the stack, so the reason for this is the same reason why particles get adsorbed with it is, the wind is here. The streamline of the wind flows around the stack when that happens there is a low pressure region that is created here right behind the stack because its low pressure if anything comes in this region, it gets sucked into this low pressure region and circulates there.

Why does this happen? It happens when you do not the material coming out of the stack does not have enough momentum to clear out of this region, so it happens only when the velocity of the stack gas is smaller than the wind. So what happens is as soon as it comes pushed in you get pushed to the side and it can get into this slow pressure zone and it can recirculate there. So when this happens the concentration of $\rho A1$ can increase can accumulate over period of time, which means that for exposures of people standing here can be very high. So in plant exposure can be very high that is not very safe for the whoever is working there, so to avoid that people have a recommendation that the stack velocity the gas velocity coming from a stack must be at least 1.5 times greater than the wind speed at that point. The stack here, this is the Ux at the stack. The Ux must be 1.5 times greater than by this much.

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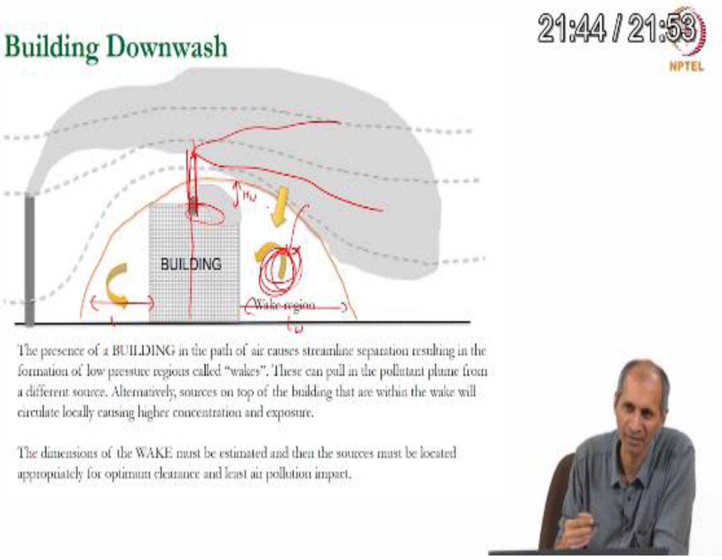

The other type of artifacts is called the Building Downwash. This is more serious, this affects people away from the source, so there is a streamline. This dotted lines are streamlines, we see a big building in the pathway this streamline move around it and they create this regions around the building are called as wakes, the same as the stacktip downwash but this is huge stack is as a small the reason we say stack means many of these industry stacks are huge. They are not like 20 centimeters, they are big several meters in diameter and all that, so at least at ground level. These buildings can be big, so these buildings the streamlines separation around buildings causes this low pressure regions called as the wake and now if there is a plume that is going here and this plume gets near the wake it can get sucked into this wake, so it can get pulled in and it will recirculate here.

Over a period of time, that is one second problem; suppose you have a stack on top of this building. Because this region mark by this red line the red curve is inside the wake which means it is not mixing very well with the outer this thing. There is no air circulation in this there is no air movement here, if your stack releases right on the roof of a building and there is a height of this wake there is this some distance is the length of the wake. Depending on the size of the building this dimensions form and the velocity of the air. So if this stack is below this height, it will not get out, it will stay there. This entire thing will accumulate in this region around the building. It can sink in, it will just accumulate there concentration will be very high which means exposure to people in the building or near the building can be high. The only way to do this you have to extend here. So that it gets carried by the general wind that is crosswind that is happening and so there then it will disperse nicely.

This can happen in a lot of building which are not planned. Can you give me an example of this? Stack on top of a building, which is not extending into the building. There a lot of examples you can go around see; Dispersion, stacktip downwash, building downwash, small sources. What is one of the major urban sources of emission combustion sources that you can think off? Not vehicles other stationary sources? Kitchen is one, second; there is one more source. So kitchen is one very good example. So lot of this big corporation offices, they have a food court or something and they have a long chimney that will be rising. Now it will go to the roof and stop here sometimes. And you can see in some other buildings nearby there will be a big black mark in the top part of the building, which is indication that is not gone up, it is there, it has to extend further up. That is a cost because you have to pump all its exhaust a few meters high pumping is expensive. You have to work against this thing. So that’s a cost so people do not plan it ahead. That is one second what is the second source.

Large buildings you can see it; you can see it next to research park here, the IT park. What is one common source of combustion that people use in current urban scenarios in India, is a generator. Diesel generator people have huge diesel generators, you can see in buildings lot of residential buildings have a lot of commercial buildings have it. The diesel engines have a very bad history with exhaust.

So it is improving now but a lot of fine particulate matter that comes out of it and this diesel exhaust supposed to go all the way. If you follow the rules of dispersion, proper dispersion you have to stack height has to be reasonably high. So but in the middle of an urban cluster, where will you send it, you have to send it out really high? There is building downwash it is not going anywhere everything is accumulating in the road, it will stay there. Lot of carbon dioxide and it will sink and it will road level pollution be very high. So it is supposed to go out all the way up into the region above the wake and get out, disperse. All of times, it is not done. So this design of these kind of devices, we use dispersion model and we use these kind of things to do this.