Environmental Air Pollution

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Lecture No. 34

Examples for Air Quality Modeling

I want to do an example so that we get used to doing and solving problems.

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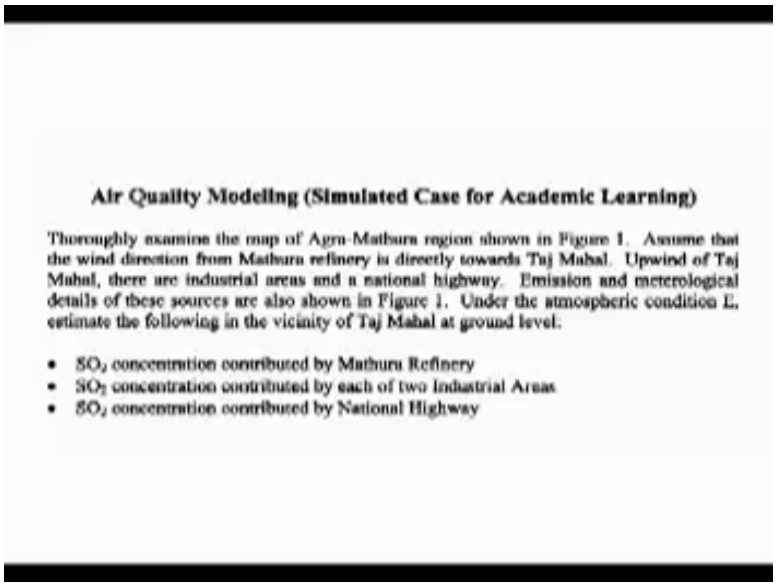

As you can read, this is a somewhat simulated problem – it is not an actual problem. Let me also say that it is not very far from reality, but we have to say that it is a simulated example. I will show you a picture of the Agra–Mathura region in figure 1. Assume that the wind direction is from the Mathura Refinery because we have talked so much in the country about emissions coming from Mathura Refinery and affecting the Taj Mahal – we will try to do some example on that. We are assuming that the wind direction from Mathura Refinery is directly towards Taj Mahal – that is generally true. Most of the time, the wind blows from the Mathura Refinery towards Agra. Upwind of the Taj Mahal, there are industrial areas and a national highway, which passes very close to the Taj Mahal. Emissions and meteorological details of these sources are shown in figure 1. Under the atmospheric condition E…. What is E? What condition is E? Stable

and F was highly stable. Under the condition E, estimate the following in the vicinity of the Taj Mahal at the ground level: SO_2 concentration contributed by Mathura Refinery, SO_2 concentration contributed by each of the two industrial areas and SO_2 concentration contributed by the national highway. You are very familiar with these things. So let us see if I can show you the figure 1. All this is information that you all understand very well. So the way I have things here, let us go to picture two.

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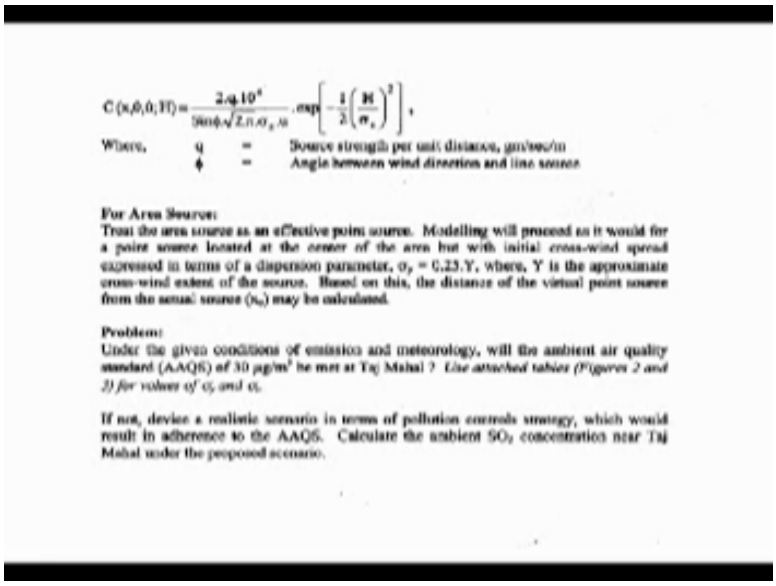

For highways, how we do this? The formula is given to you. What is to be done for the area source is also specified –we have covered that in the class. The area source can be an effective point source. Modeling will proceed as it would for a point source located at the center of the area but with the initial cross-wind spread (that is $sigma_y$) in terms of the dispersion parameter $sigma_y$ as 0.25. Do you remember we had said that $sigma_y$ was the distance of the area source divided by 4.2? You can take that as 0.25, where Y is the approximate cross-wind extent of the source. Based on this, the distance of the virtual point source from the actual source x_0 may be calculated – we discussed that.

Now, what is the problem? Under the given conditions of emissions and meteorology, will the ambient air quality standard of 30 microgram per meter cube be met at Taj Mahal? Use the attached tables that I will show you in a moment. Finally, what do we want to do? We want to do

some solution – we just do not want to stop with saying "There is a problem" or "There is no problem." Finally, if you are not meeting the standard, devise a realistic scenario in terms of a pollution control strategy that would result in adherence to the air quality standard and will attain the air quality standard. So what is the idea? To make what safe? To make Taj Mahal safe, right? Calculate the ambient SO_2 concentration near Taj Mahal under the proposed scenario. Now I want to change the things. After having changed the things, what would the picture look like?

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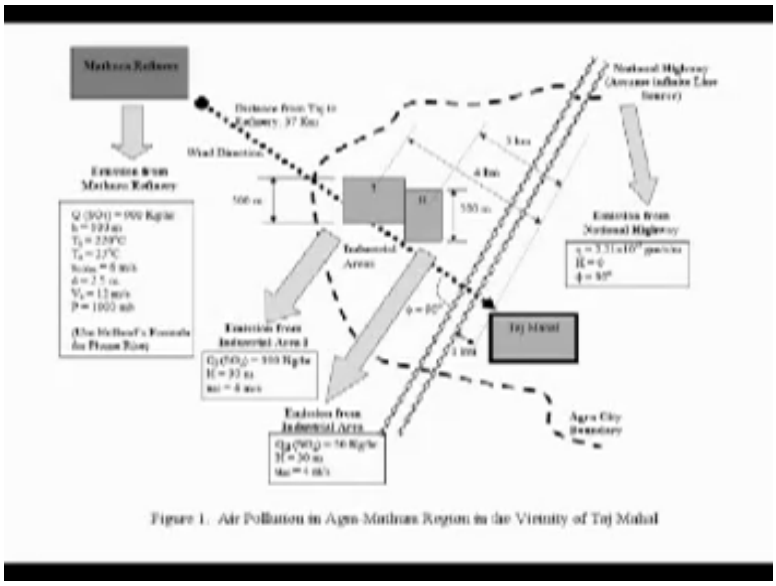

Figure 1. Air Pollution in Agra-Mathura Region in the Vicinity of Taj Mahal

Of course, the picture is not to scale as you can see. In the picture, suppose this is the Taj Mahal and somewhere here is the Mathura Refinery. How much is the aerial distance between Mathura Refinery and almost up to Agra, Taj Mahal? 37 kilometers. The details of the Mathura Refinery emissions are the following. SO_2 emission is 900 kg per hour, h is 100 meters, T_{stack} is 220, [05:17] is 20. I have already given you the speed at the height – 100 meters; if it was not given to you as 100 meters, you will use u1 by u2 equal to z1 by z2 into 2 to the power n, where n is a function of stability – that is already given. The diameter is given as 2.5, the exit velocity is given as 12 and the atmospheric pressure is 1,000 mb. Then, we have to find out the impact of the refinery on the Taj Mahal – that is idea number one.

Second thing: you have two sources and the center of the source is almost…. You see this. What are we saying? At the area source one, how much is the SO_2 emission? It is 100 kg per hour and

the effective stack height h is 30 meters. The wind speed is 4 meters per second and then here, this length was… does it show anywhere? Anyway, this is 500 meters. There is another source that is also 500 meters in size; this is located at 4 kilometers and this is located at 3 kilometers and what you see here is a national highway that is going like this.

Details of the national highways: the emission rate is 2.21 into 10 to the power of —2 grams per second per meter as you remember the units that will be the h = 0, we are assuming that the plume rise from the vehicles is 0 and phi is 90 degrees; as you see, the wind is like this, this angle is 90 degrees, this distance from the highway to Taj Mahal is 1 kilometer – this is the situation we have. In air pollution, what we do is we find out the concentration from the various sources and a simple summation of the concentration is the net impact, unlike water conditions – in water, you consider the concentration but you also consider the volume of the water that is being mixed. Here, what we see is everything is being mixed but then everything is meter cube, concentration per meter cube and meter cube is the same, so this is what you have to do. We can start from anything but let us start from the refinery. What is the condition we have?

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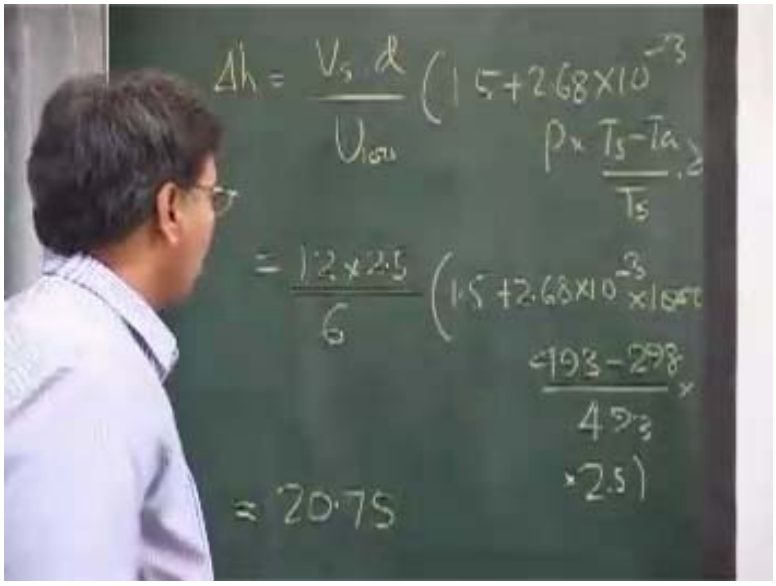

Stability is given to us as stability E. Let me ask you, suppose the day is very heavily overcast, what stability do you think it will be? Lots of clouds and of course the wind speed is moderate kind of thing three four. When you have lot of clouds, the normal stability you take is about D – the neutral conditions. The stability is E. Then what do I do? First of all, suppose I start with the Mathura Refinery, I find out the delta h. What was that? V_s d by U at what number? 100 meters. U at 100. What was that? 1.5… P times T_s minus T_a by T_a into d – do not forget that there is a diameter term also here (Refer Slide Time: 09:18).

I could not do the calculations. If you have the calculator, you may want to do very quickly or if you do not have it, we can take my calculator. Let us put the numbers here quickly. What is the V_s? 12. What is the diameter of the stack? Keep telling me. 2.5. 2.5. The wind speed at 100 meters is 6 into 1.5 plus 2.68 into 10 to the power of —3 times… what is the pressure? 1,000 mb. Then the other thing is T_s. T_{stack} is 220, 220 plus 273 makes 493 minus 225 plus 278 298. This should be T_{stack} (Refer Slide Time: 10:30), 493 times the diameter, which is 2.5.

[Conversation between student and professor - Not Audible (10:48 min)]

Something like that.

[Conversation between student and professor - Not Audible (10:52 min)]

20.75. All right. No question of aerodynamic downwash in this case. Do you remember the aerodynamic downwash we talked about? When the speed is high here – 12 and the horizontal wind is 6, do you expect any aerodynamic downwash? We do not expect it because the ratio of V_s to U is much more than 1.5. Otherwise, if that was the case, we will correct the height for aerodynamic downwash. The next thing you can write…

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This was our delta h. We generally correct this delta h for stability. We take this as 0.9 in case the conditions are stable; for neutral, we take it as it is. Then in that case, let us say I have multiplied with 0.9 – the correction for stability and let us say this is 20 meters approximately.

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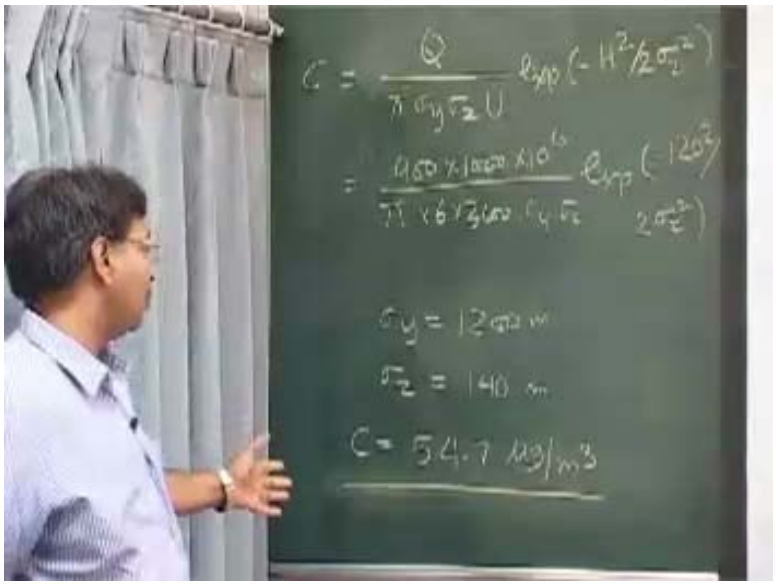

I will write the formula directly. What was that? Q upon 2. Was 2 there? Now what I have to find out is I have to find out y = 0 in this case; my x direction is always the wind direction, so this is my x direction. What is y at this point? 0. What about z? 0. If you recall, 2 will disappear from my general formula. Many times, students make a mistake and carry this 2 forward because of putting that equal to 0 and the 2 will come because E to the power 0 plus E to the power 0 will be equal to 2. So now, you say pi sigma$_y$ sigma$_z$ and now what U should I take?

[Conversation between student and professor - Not Audible (13:37 min)]

At height of…?

[Conversation between student and professor - Not Audible (13:42 min)]

h plus delta h, so height of 120 meters, right. What is my h finally? Effective stack height is… 100 is the…. Where is this? 100 plus 20, so this U will be at 120. Just to save some time, we will take this equal to the number we have – 6, because it stabilizes as we go higher. Just to save time, I will take the U as 6 only but ideally, you should correct it.

[Conversation between student and professor - Not Audible (14:24 min)]

n value is in the table we gave last time. You do not have to remember the n values – you can refer the book or if there is a question in the exam, it will be given to you. No one can remember the numbers, but you can modify the U if you like. Let us continue to have the figure here.

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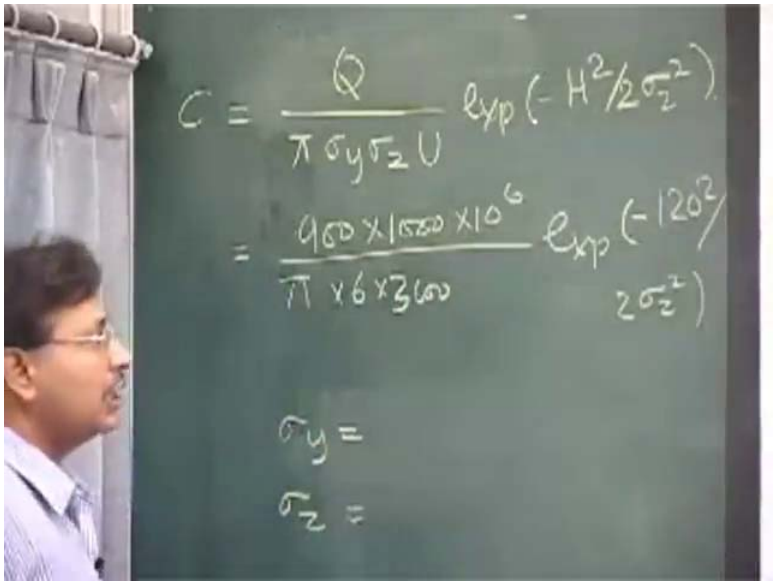

Exponential minus H square and Q I should be careful with the units, so 900 and I want to find out in micrograms per meter cube, so 900 times 1,000 is my grams, micrograms is 10 to the power of 6 upon (pi $sigma_y$ and $sigma_z$ I will write in a moment into 6) into exponential and this we have to find out per second – that was per hour, so… and my H is equal to —120 square by 2 $sigma_z$ square. Let us look for $sigma_y$ and $sigma_z$. Is there anything else I need? I do not need anything else.

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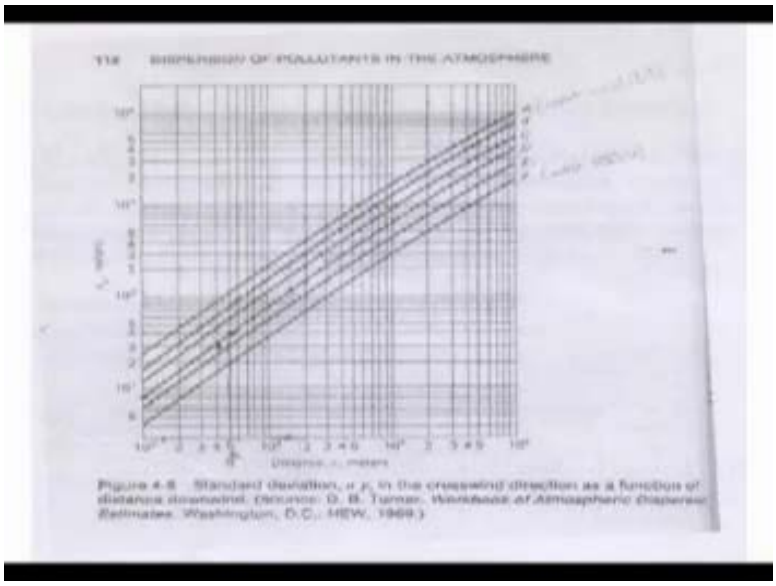

That is what is my sigma$_y$. It may not very bright for you, but I will try to read for you from here. Here, the distances are in meters. How much is this?

[Conversation between student and professor - Not Audible (16:31 min)]

10 to the power of 3. This is 10 to the power of 4. What distance is this one?

[Conversation between student and professor - Not Audible (16:40 min)]

I mean what is this distance here?

[Conversation between student and professor - Not Audible (14:43 min)]

10 kilometers, right? This is 100, right? 30, 37, go here, E here and how much is this value? About 1,000. About 1,000, is it? We will take that as 1,000. That is about 1,000 here.

[Conversation between student and professor - Not Audible (17:15 min)]

I will take 1200 or so.

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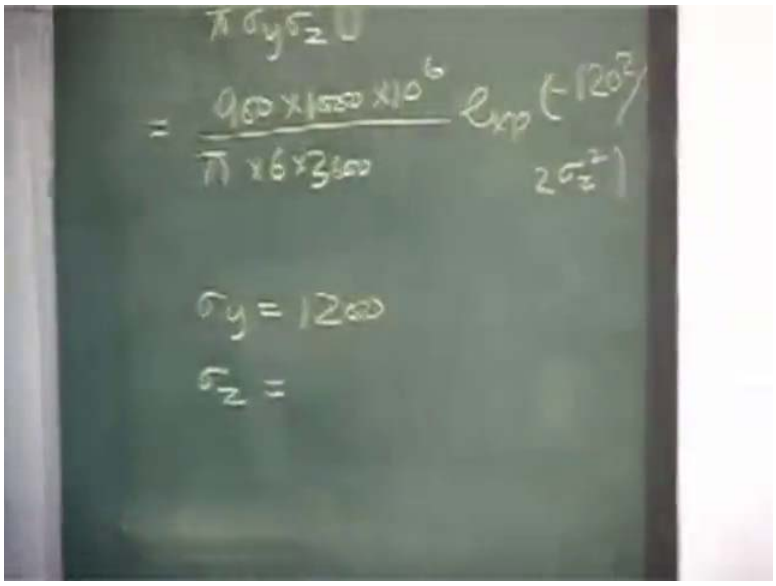

sigma$_y$ is 1,200.

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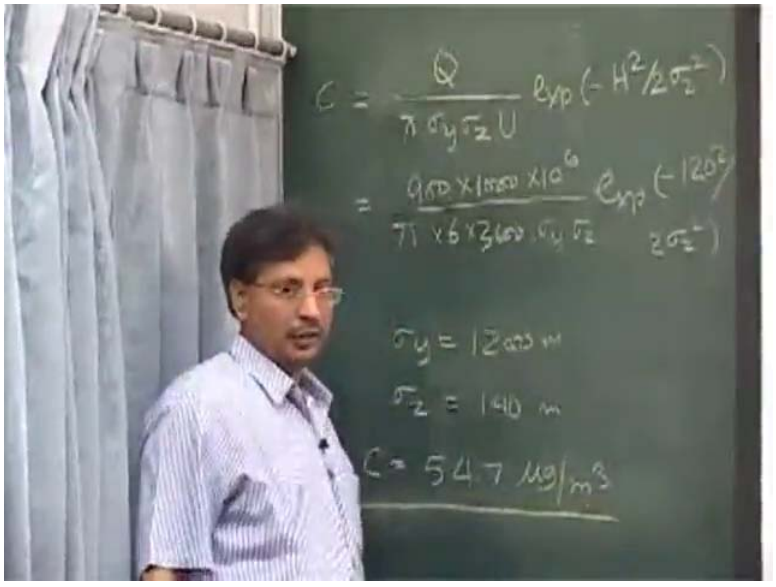

Same thing for sigma$_z$. How much is that? 37, stability E.

[Conversation between student and professor - Not Audible (17:50 min)]

120, 140. Can you please give me C because of the Mathura Refinery caused onto the …? We immediately compare this with 30 and then you obviously say that even the Mathura Refinery is contributing much more than what is the acceptable level at Taj Mahal. What was the acceptable level, do you recall? 30 micrograms. This we will keep somewhere as our point number one, so let us remove this.

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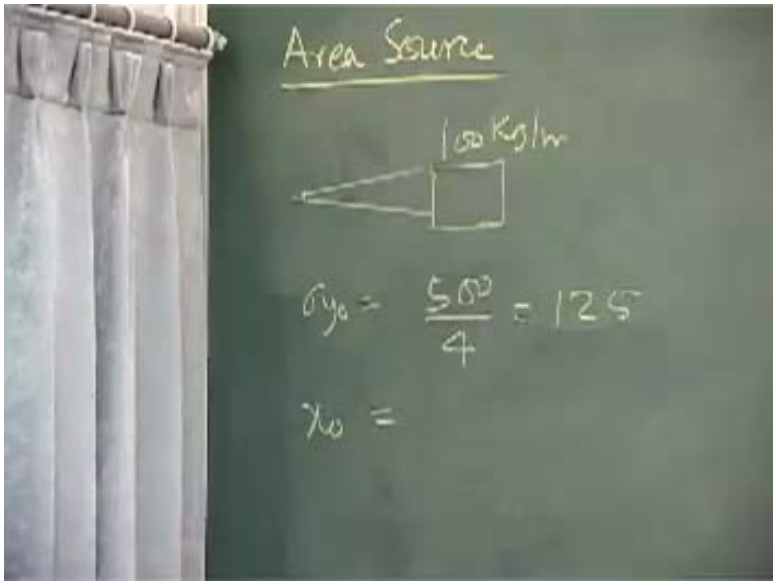

Area source. Let us take the area source number one. What is the quantity of the emission? 100 kg per hour. At this side, it is given as 500 meters, so $sigma_{y0}$ is 500 by 4. How much does that come out to be? 125. 125. Find out x_0, correct? Go back to the…. What is that we want? This was 125, this is 10, this is 100, this is your 200, 125 is here, go back here and somewhere here and then come here. What is this coming out to be? Approximately 250. I will just check with this figure, which is like accurate to me. What is that $sigma_y$? It is 125. You move here 125 and I am getting nearly 300 or so – you get 300. Should it be 3 kilometers or 3 meters, 3 this thing?

[Conversation between student and professor - Not Audible (21:07 min)]

It has to be 3 kilometers, so this is actually 10 to the power of 3 – it cannot be so small; it is just experience that tells you.

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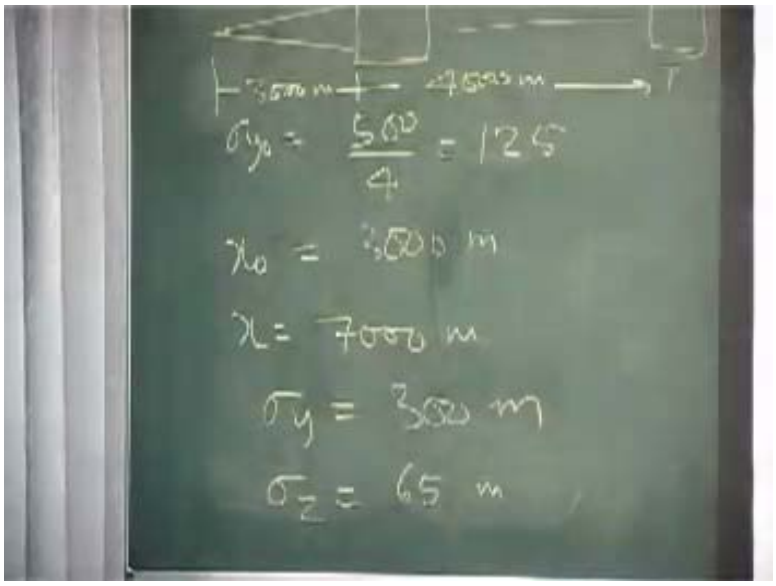

This is your Taj Mahal somewhere here. This distance is 300 meters and what is this distance from center to this? 4 kilometers. 4 kilometers, so 4,000 meters. So your x is equal to really 4,000 plus 3,000 or 7,000 meters. The $sigma_y$ spread by the time it goes to Taj Mahal will be equal to… I have to find out at 7 kilometers. All agreed? This is your 2, 3, 4, 5, 6, 7, 300; $sigma_z$ starts from 5, 6, 7, F, go back. How much?

[Conversation between student and professor - Not Audible (22:52 min)]

No, no, no. 60.

[Conversation between student and professor - Not Audible (22:57 min)]

60 or so; 1, 10, 100, so I am somewhere here, so 650 or something, right? Now can you quickly calculate the concentration? 65 sir. All right, I agree with you. What was the h? 30 meters and U_{30} is given to you as 4 meters per second, so you apply the same formula – identical to what we did for the Mathura Refinery. How much does that come out to be? That was area source one, so I remove this. I will take the number you give me.

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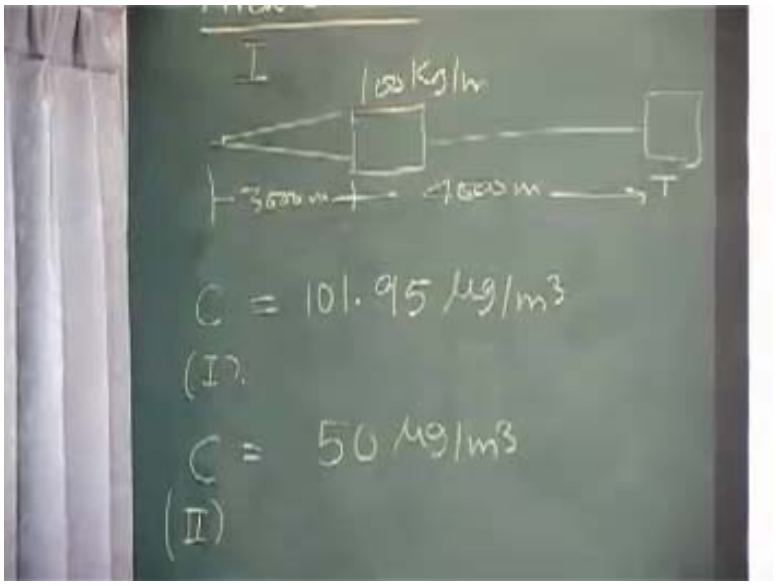

Now, we have to do the same thing for area source two. If you want, you can quickly do it or else we assume – just to save time. You know how to do it for the area source two, right? I can assume this to be nearly 50 percent of source one, because the concentration is always proportional to Q and h is more or less the same and the difference you will see is the difference of 1 kilometer distance. That will have some impact but then if you agree, for saving time, we can say it is 50 percent of area source one, because Q is 50 percent. This is C for area source one and we assume C for area source two to be…. Now comes the national highway business, but let us keep writing somewhere here so that we do not forget.

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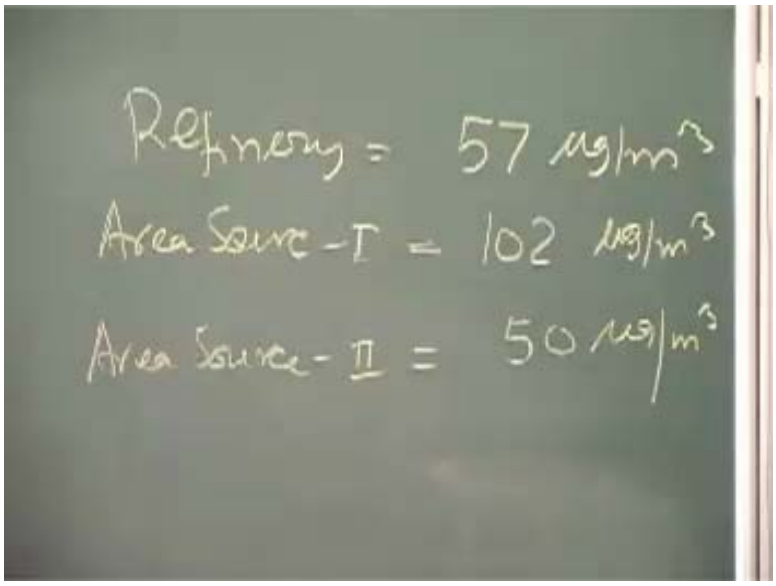

Refinery was about 57, then area source one was 102, this is about 50. I am not going to talk about the highway business.

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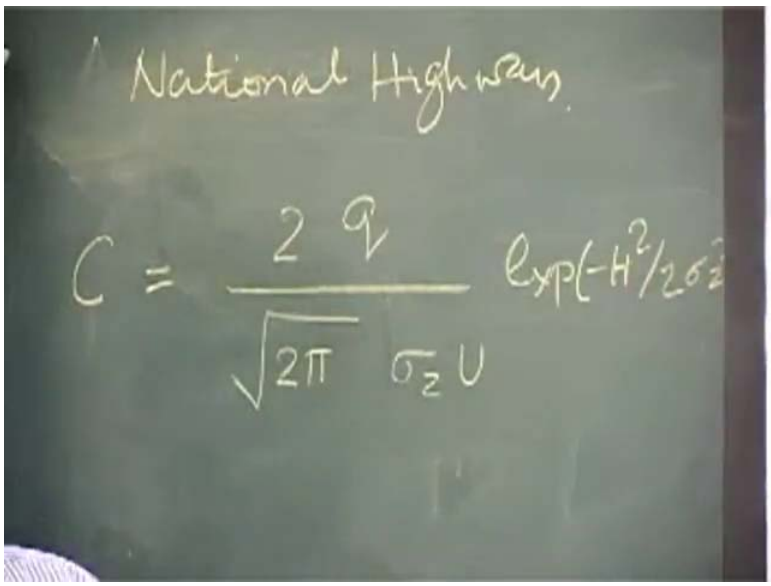

The source is your national highway. C was 2 q by root of 2 pi, something like this and of course sine phi is 1.

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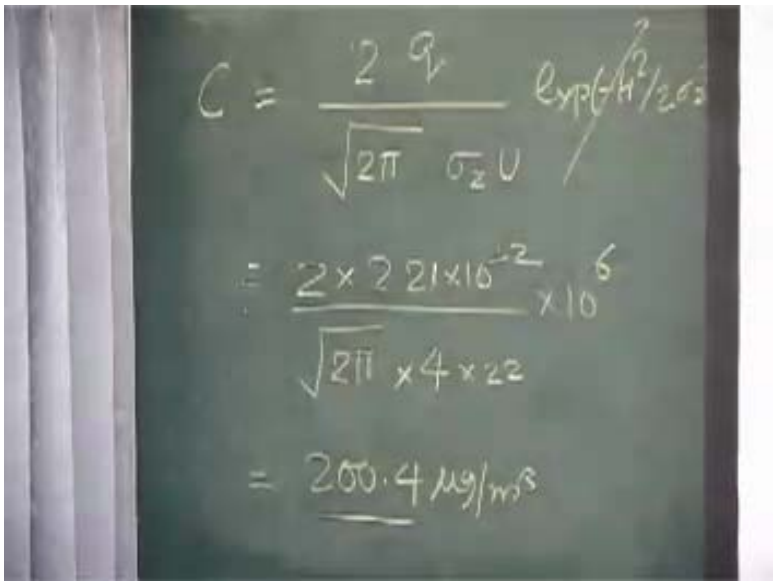

This will be my… 2 times what is the q? 2.21 into 10 to the power…? —2. 10 to the power —2. U we will take the same as 4 meters per second and we must find out sigma$_z$. How far is it from the….? 1 kilometer. Distance is… take this… 22 or so. This is in grams but I want in micrograms.

[Conversation between student and professor - Not Audible (28:13 min)]

10 to the power of 6. Let us see what number you get.

[Conversation between student and professor - Not Audible (28:22 min)]

200.4. I am going by the numbers you are giving me.

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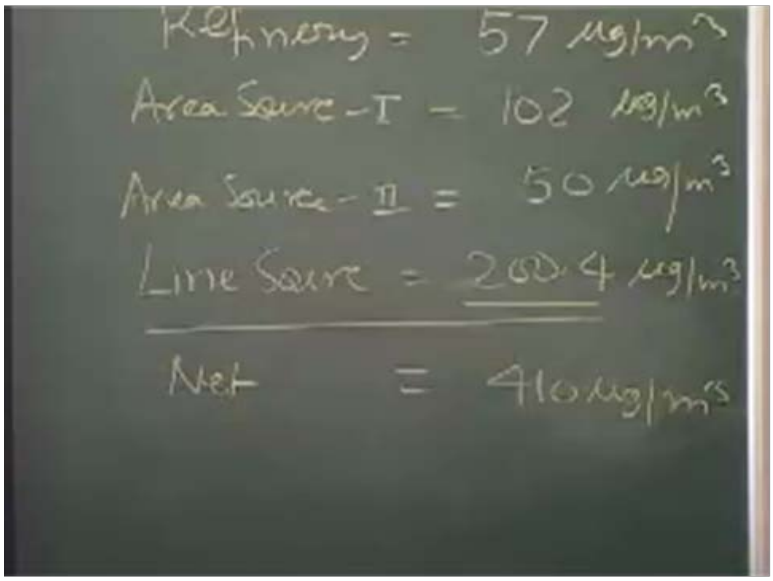

Line source. Most of you have got this 102, right? You have accounted for the microgram per second emission rate – then we will assume that everything is fine. What do you want to say? There is a serious problem. It is a hypothetical case – more for learning and the situation may be very different on the ground, but then what do you need to say? Every source needs to be controlled. Now, what do you do? The net concentration is… What it tells you is that of course the Mathura Refinery is causing a problem, but then again the larger problem comes from the national highway, which may also be true in some cases. So what are the options you have? What can you do? Close the refinery. Close the refinery, but that is of no use at all.

[Conversation between student and professor - Not Audible (30:15 min)]

This is the situation we have – we are just talking about this situation; whatever the calculations we have done, we are talking about this situation only.

[Conversation between student and professor - Not Audible (30:31 min)]

That again will not help much because you cannot bring this down to 300 with artificial means. So immediately, you should think as a planner, as an engineer and realign the national highway – make an outer ring road or something like this. Many of you are civil engineers, so you have to think – no matter how good the cars and trucks are, the emission is not going to be 0. So one of

the solutions that you would immediately think of is to get rid of this source. These are the just the options that you think of and the final decisions are taken with other considerations and what you can and cannot do. But then, suppose this highway is going like this, suppose it goes something like this in the already in the downwind of this one, then automatically the contribution is 0 from there. I am not saying this is the final answer but we still have to make some sense from our example. Of course, we just make it for our learning – the realistic thing will be different, realistic models will be different and we can use more complicated models.

[Conversation between student and professor - Not Audible (31:48 min)]

You have the experimental results here but then, with the measurement alone, you cannot say that it is contributed by this or this or that – you cannot say that. The model can give to only some extent what is contributing to what extent. One of the other ways is to use a tracer gas. Along with the emissions here, you release a tracer gas from the refinery and then you release another tracer gas or the tracer gas at some other time from these things and to measure the tracer gas because the tracer gas will not be contributed by anything else. Then, you can really establish how much is the contribution in the measurement terms. Then you can take the ratio of the emission of this thing to the ratio of the tracer gas and that same ratio will be maintained more or less as it travels through. Then you can find out how much is the contribution in realistic terms from the Mathura Refinery.

Provided these numbers you have given to me are correct, one would immediately think that the alignment of the highway should be done. If we can do something about this thing, the emission is brought down, convert… the processes here we are using coal and oil with more like CNG – sulfur content in CNG is 0. The moment you say you have mostly the… because sulfur dioxide will come from the combustion processes, you say use CNG. If you make them CNG or 50 percent change them to CNG, this is gone and you ask Mathura Refinery to control the emissions to let us say one-third. In fact, this emission I am talking about was in 1980 or so – they had this kind of this emission in 1984. Do you know what is the emission right now from Mathura Refinery? It is about 150 kg per hour – tremendously controlled, whereas the quantity of production has increased nearly about one-and-a-half times to two times. They have really controlled it – they have controlled it to the extent that it is nearly about 150 or so. Automatically

if you think that our calculations are correct, you can almost say it is reduced by one-fourth (Refer Slide Time: 34:31), whereas this source will continue to increase – the number of vehicles will increase and we cannot stop that. For this thing, people are trying to do something – supply CNG and at least make sure there is no more increase in the industrial units coming up. So as a field engineer, as a practical engineer, you have to take decisions and decisions are based on your modeling work and the experience you have. Once you do this thing, then you can find out the this thing. The other way, which is even more scientific, is to develop a cost function.

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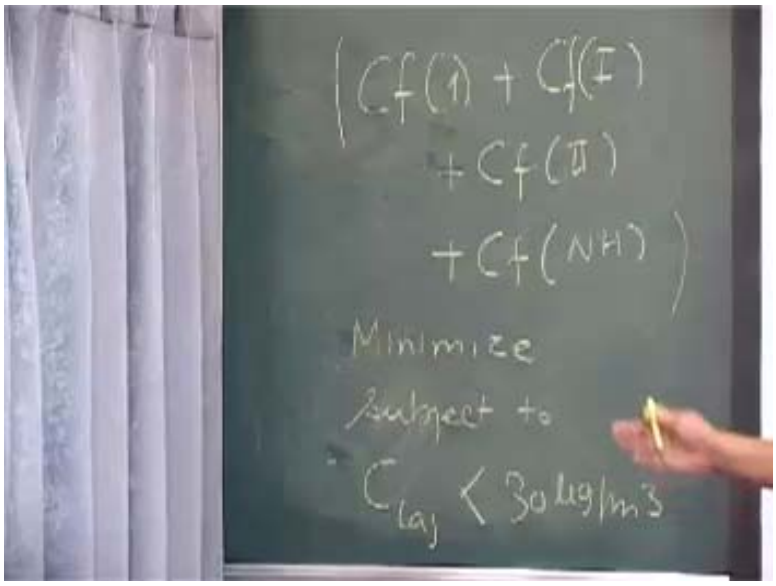

The cost function will be something like…. Cost function for source one and that will be a cost function depending on how much you want to reduce the value of q – it will not be a linear function. If you want to reduce some emission, some emission can be very quickly reduced and certain emission you just cannot reduce. The Mathura Refinery cannot have zero emissions. So plus cost function for area source one plus cost function for area source two plus cost function for national highway – that may even include realigning the highway. Then you want to minimize this function – minimize it subject to what?

[Conversation between student and professor - Not Audible (36:24 min)]

Concentration at Taj Mahal is less than… That is our objective – that is what we want to do. This cost [36:42] is after all national money and you want to plan something for your area and then you develop the cost function – we are not getting into this but you minimize this cost function subject to concentration Taj Mahal is less than 30 micrograms per meter cube. This is how we do things.