Environmental Quality: Monitoring and Analysis
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Lecture – 43
Regulatory Models

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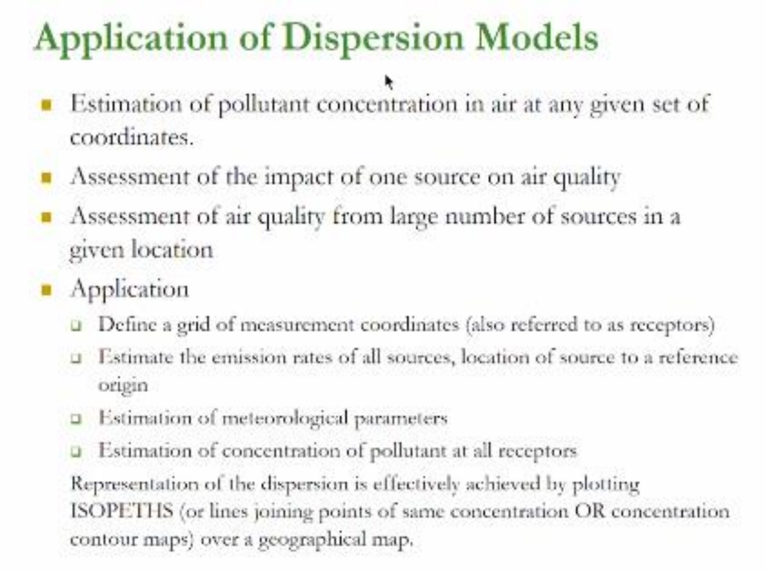

So last class, we were discussing the application of dispersion models. We will just recap from that little bit.

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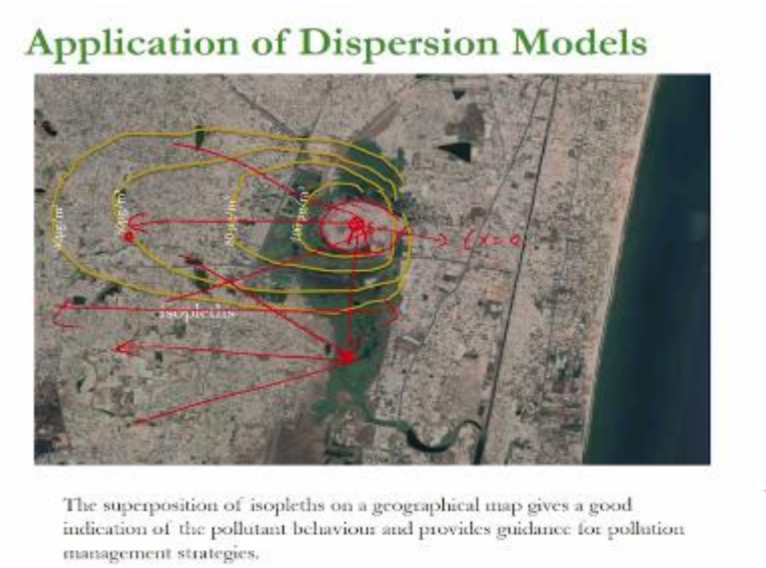

So, one of the applications where we apply this superimpose calculation of dispersion models over a given geographical location. So here, what we usually do is in the dispersion model x, y, and z, this is with reference to an origin. So the origin is the source, we have a source. So in this particular example, let us say the source is here. This is the source, it could be an area source. For now I am considering it as a point source. If the way I apply this dispersion model is if this is the source, then this source will be the x = 0.

Now, this is a problem, I think yesterday's class we discussed that. So this one source is x = 0. For another source, there is an x = 0 corresponding to that okay, axis is that. However, when you are looking at concentrations at a given point is the contribution from different source, then you have to adjust the coordinates accordingly. So for example, if I have another source here, there is an x = 0 axis going here and a plume that is probably going out like this, right? This point is, there is an x = 0 is the same, but the y distance is different compared to this plume.

So if you know the distance between this, then you have to adjust this point. So at that point, you have to adjust what is x, so which reference are you taking. So you have to add accordingly okay, where the contribution from different sources is additive, there is no assumption that one source interferes with the other, which is not true in reality. If you mix 2 air masses, they do not mix nicely. There will be collision and there will be a local circulation there and all that, all those issues are there, it will neglect all that.

So it assumes that we are just adding, but there are some corrections to that people do, that is a different issue, it is a little more advanced that needs more information about the air mass and all that, but here we are just looking at simple velocity in the x direction. We are not even doing any turbulent components and all that, we are not. So it is theoretically possible since we know that we model, see we have the full model, it is possible for us to go and do a proper fluid dynamic calculation if you want.

The people have done that with the estimation of dispersion parameters, not using Pasquill-Gifford and all that, using something else, some other correlations. There is a technique to do that, just out of scope of this course, people can do that if you want accurate modeling. The problem is all environmental modeling is which all depends on the amount of data you have. If I have real time, velocity measurements changing, I can apply it as and when it is happening, it is like weather forecasting.

This becomes like weather forecasting because weather prediction you are predicting wind speed and temperatures and all that. This you are doing that and on top of it you are adding one chemical component in the same model, people do that. There is modeling that people work with, in conjunction with weather, they add a chemical model interact that is how they do prediction of pollutants across global scale. There are lot of different software that will do that in which dispersion is one component okay.

But here, we are talking about a very specific dispersion model Gaussian dispersion model application and this is a first step, very quick screening tool, approximately it gives you what can happen. So, if you have an additive component, it is usually the worst case scenario. So, that is what it is done. So, any questions on this, this particular this thing, so one of the other point that I would like to make in this slide is when we superimpose this on a map like this okay, depending on the scale of the map, you can consider this as an area source.

See, for example, this particular thing, I am considering the entire thing. This is a garbage dump in South Chennai, this is Perungudi garbage dump. Let us say that there is a lot of emission occurring from this entire thing. This is about close to a kilometer in dimension across. Now, if I am interested in this, now I cannot take this as a point source, this is reasonably big okay. So, I have considered it as an area source and I will assume uniform emission per this entire area and then I can model it that way, but if I zoom out, this entire thing will become a dot on the map and then I cannot use it like an area.

So, that is a point source from a point of view of the scale at which you are looking at. For example, I am only looking at the scale is 1 kilometer, so I am looking at perhaps this is the maximum extent of this is few kilometers, 3 kilometers or 4 kilometers, but I am looking at a large forest which is extending 10-15 kilometers or annex, I am looking at the impact of this when I zoom out on the entire city of Chennai, this is 1 kilometer extended to scale of 50 kilometers, this will be a dot and this is essentially a point source okay.

These are some of the things you have to, depending on what you are calculating, you have to adjust the model parameters. We will come to the exercise that the regulatory models that we generally use, at that point you will know what we were talking about.

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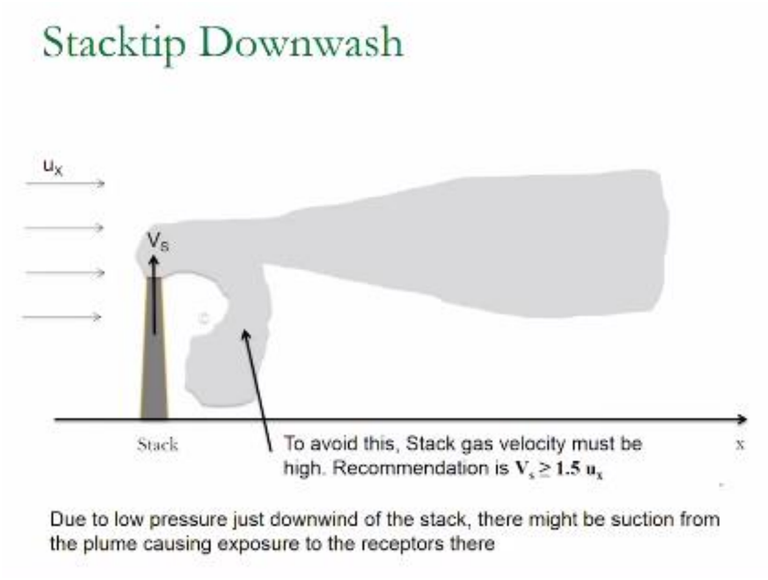

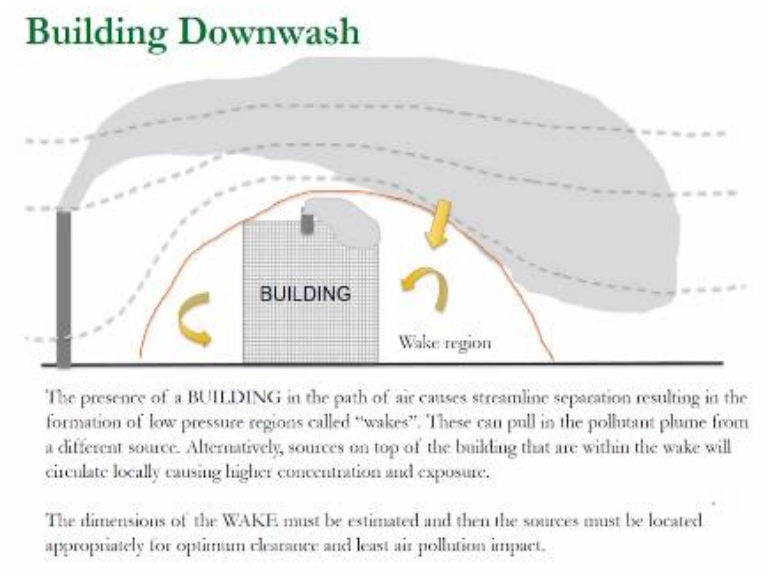

So, we talked about stacktip downwash, building downwash and all that last time.

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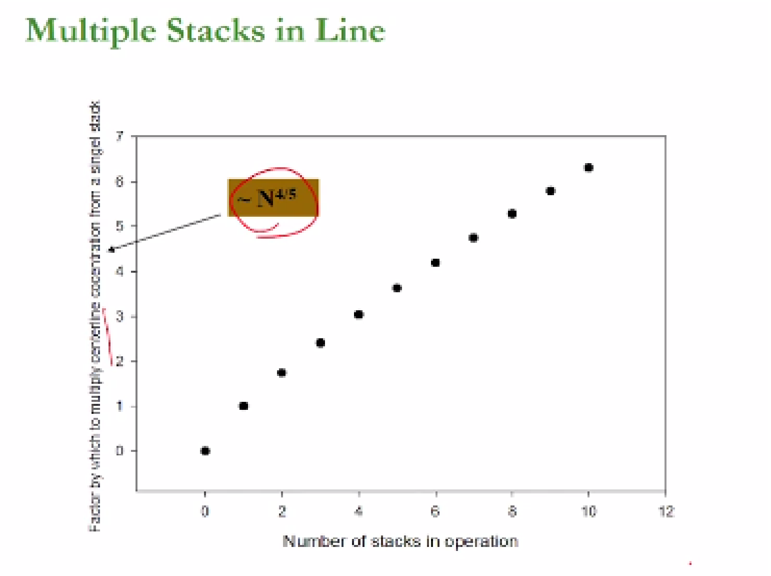

So, this is the multiple stacks. So, you have several stacks. All of them contributing to this thing, so it is usually additive, but here you are seeing that it is not just additive, it is slightly lower than the, it is N raised to 1. What we mean is the contribution factor by which multiply centerline concentration from a single stack. So you have multiple stacks in line. So what it means is that the contribution, the additive contribution is not exactly additive, experimentally it is found that it is about N raised to 4 by 5.

So, number of stacks is not straight additive, it is lesser than that, which means that there is some loss in the process of doing this. **“Professor - student conversations starts.”** Sir what is the reason for that 4 by 5? What the, what is the reason for 4 by 5? It is an experimentally found. **“Professor – Student conversation ends.”** You find out that it is not adding, there will be some loss as I said, it does not reach this receptor, it goes somewhere else, maybe there is mixing, it goes up and down.

Usually there is conservation of mass means that if there is a reduction somewhere, there has been an addition somewhere else. So which means it is not simply adding, some inequalities are there. You cannot make mass disappear somewhere, it is just to go somewhere else, so unless it is reacting. For what it means is it is not simply adding that its non-interacting plumes is the assumption which is not true.

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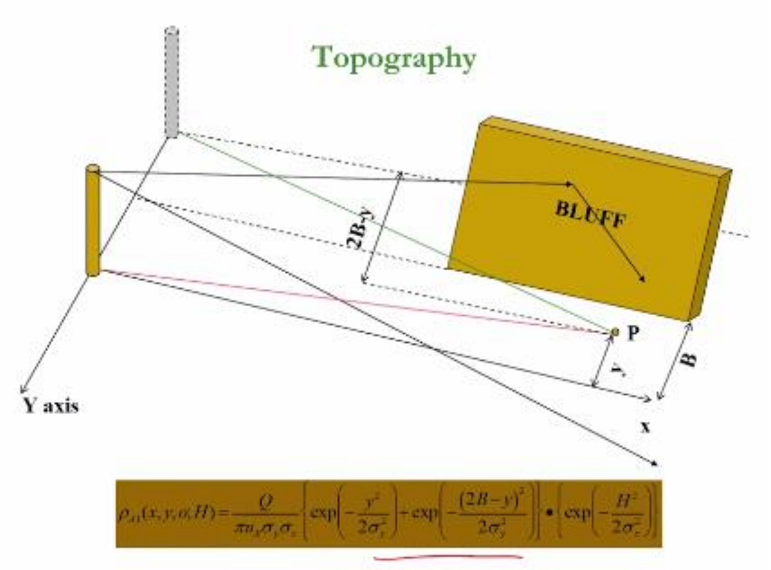

Generally, when you are talking about plumes, air masses they mix, there is other secondary effect to that, which is still not very clear. In order to quantify them, you have to go and do a fluid mechanic model because see all the models that we are talking about assumes very nice uniform these things, uniform flow, nice boundary layers and all that, good in turbulent flow is chaotic, you cannot really predict very well, so one has to do. This is the same kind of thing that we talked about in the reflection.

Suppose there is what we call a bluff means, this is like either a mountain or a building or something in the path in the y direction. The ground reflection we talked about is a z direction reflection, so there can also be y direction reflection if there is a big building or a big mountain and there is a source, so it is there is constriction for the plume to expand on both directions. So, then you can see that you are adding another term just like what we did for the z direction, we are adding another term here. The geometry of that is all given here in this.

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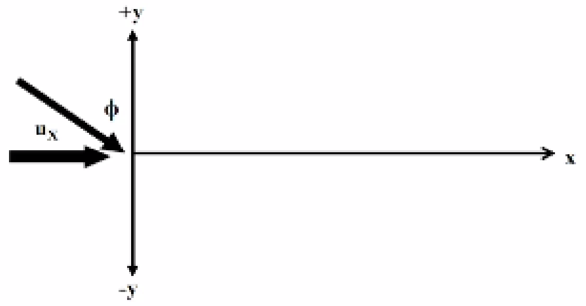
Line Sources



For wind at an angle $\phi > 45°$, and continuous line source

$$\rho_{A1}(x,y,0;H) = \frac{2q}{\sin(\varphi)\cdot(2\pi)^{1/2}\,\sigma_z u_X} \bullet \exp\left[-\frac{H^2}{2\sigma_z^2}\right]$$

q = rate per unit length (g/m-s)

There are some line sources. So this line source equation, this q is different, q here you can see that the equation is slightly different because sigma y is considered negligible if the first case is where this is both infinite y okay. So, here this is considered as the road. This is the line source. This is a continuous road extending infinitely and your wind is coming here, so it is a crosswind, yeah. Emission is occurring this direction, all the vehicles are traveling on this road, this crosswind.

So you will have one plume like this, the next plume like this, next plume like this, next plume like this, that is what crosswind compensation is equivalent to having the same thing. So, there is no y term here, the white term is neglected because it will compensate for, whatever is originating from here is going here, but whatever originating is appearing here. So, essentially, it is not a factor, it is almost uniforms as there is uniform in the y direction, only the z direction is changing and the axis change.

So the y term is vanished, goes away from here, but this term q here if you look at the dimensions of this equation here, this is L L by T and so this has to be M by L cube. So, this one, the numerator here has to be M by L. So, this is mass, normally in the other model, the point source model, q is mass by time, here this is mass by, no this has to be mass by time as well. This is mass by time, yeah, but mass by length, the length appears there. So, it is the emission, the rate per length of the road.

“Professor - student conversation starts.” Small q is the big Q by L, yeah big Q by L for given length, in this formulation. So, the T will cancel it, M by L cube will appear here.

“Professor – Student conversation ends.” So, for a given section of the road, you can. Then of course q you have to calculate by doing you need to know what are the vehicles on the road and the emission factor based on composition of vehicles.

So people do count the number of vehicles of each category, so you have and it is a bit complicated to do the emission for vehicles because it also depends on the speed of the vehicles, it also depends on the type of vehicle and all that. So, if a vehicle travels at a certain speed certain distance, then the emission is certain amount for that distance of travel. So, when they consider this emission factor estimation, we need to know what is the speed of the vehicle also, how much they travel and so it is not straightforward.

Collection of that data is fairly laborious to do and you have to keep doing it again and again because these things will change with time, where in the morning time vehicles will travel fast and peak time vehicles will travel slowly and so on, all these issues are there. So interpretation and the calculation of this varies. This is an extension of this again when you have an angle. The wind speed is not at right angles, it is an angle to the road, this can happen. So there is another term here called sigma sign phi here. It is all there in your PPT, you do not have to write it down.

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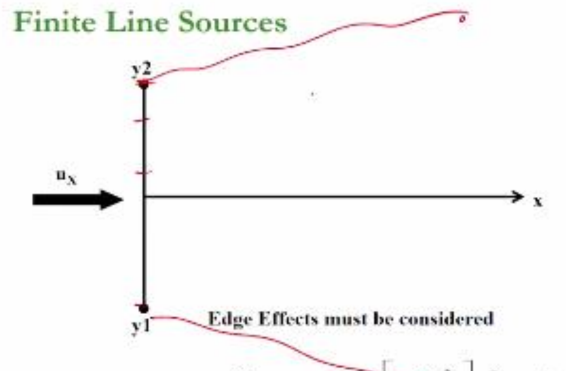

$$\rho_{A1}(x,y,0;H)=\frac{2q}{(2\pi)^{1/2}\sigma_z u_x}\bullet\exp\left[-\frac{H^2}{2\sigma_z^2}\right]\int_{p_1}^{p_2}\frac{1}{(2\pi)^{1/2}}e^{.5p^2}\,dp$$

$$p_1=\frac{y_1}{\sigma_y}\qquad p_2=\frac{y_2}{\sigma_y}$$

But, there is also some cases where there is a finite road, it does not extend all the way and then the end effects the sigma, sigma y appears as an end effect in one of the edges of this. So here we have this will appear like this, the end, the concentration up to y here because this stops here, the road stops here. So, we are measuring concentration at this point somewhere, then you have to calculate the dispersion in the y direction. There is no crosswind compensation in this case. This is a suggested equation for that.

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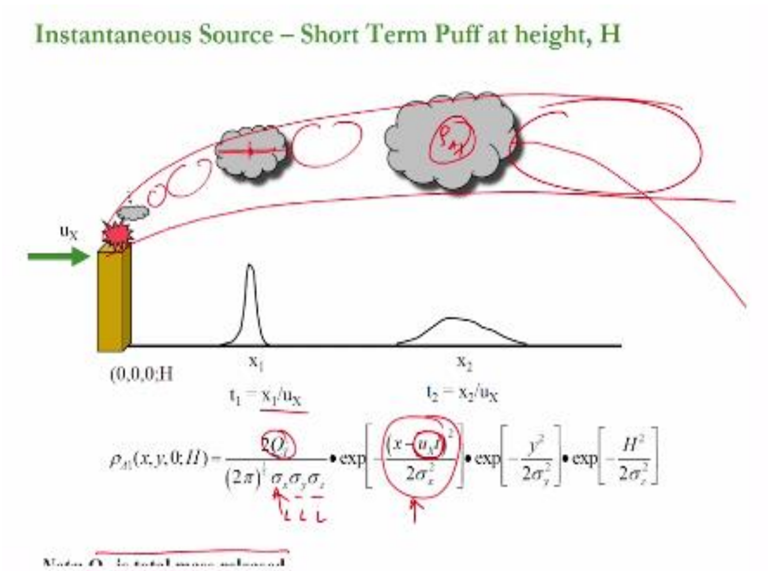

So what we considered till now is the Gaussian dispersion model which is a steady state model, but lot of times you may not have a steady state emission. So steady state emission, some say that you just have a finite, for example is an explosion, it is a large amount of material that is now just released because of one shot explosion. This is very common in air pollution accidents. You have a big tank that has exploded and one big say one ton of chemical has gone up and it is going somewhere.

So we need to find out where it is going, how fast will it go, what is the concentration, this is a very nice classic representation of this Lagrangian model that we are talking about. This is one small volume and this volume is expanding, means concentration in the volume is decreasing as it is going. So when this goes up and this puff reaches, it becomes big or it is carried up and down. It will reach the ground sometime at some point okay and that point whatever will be the concentration inside the puff will be the exposure of that particular thing okay.

So, to do this, this is the puff model, the steady state model is modified by this by including another term here which is x, in the x direction, so it is no longer steady state. So, you need to consider the full volume of the puff here. So, there is a third term here that appears and use sigma y, sigma z, and sigma y all of the, there is a sigma x term also that appears in this case because it is finite puff, this volume. So, here and because there are3 Ls here, this is no longer Qt, it is no longer a rate term.

This Qt is really is M, total mass released, we have retained the term Q because it is the same as the previous one, but it is not rate mass, so there is this term here that is x-ux into t. So, this is a Lagrangian model where we are looking only at the distribution, here the x starts in here, the actual value of x that we are talking about is this t1 equals the time that we are considering in here is calculated like this by the velocity. There is also another methodology by which people use the puff model to simulate a continuous steady state source.

What they assume is continuously there are puffs that are released, which means then the plume, steady state room can be considered as a series of puff being released one after the other, okay. So, the advantage of the puff model is you can stop it whenever you want, you can control at what rate the puff is being released, and then so for example, intermittent release, it is released for some time, then it stops, and it comes for some time and stops.

Steady state model you have to stop the entire model and restart it when it starts again, and if it is unsteady state, it is difficult. So, here there is possibility for you to change those things by assuming that it is a puff and you consider each puff as it is going and where it is going. So, that is one way of doing the model.

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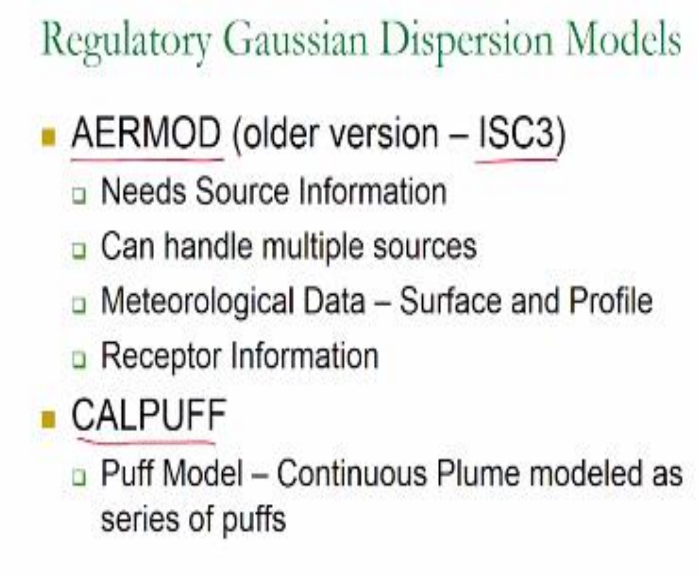

So, in the current regulatory framework, there are 2 models that are used. One is called AERMOD. AERMOD is the current regulatory model that is used. There is an older version called ISC3 okay and there is a second model which is now currently used called CALPUFF, the CALPUFF uses the puff model. So, if you give it a rate term, it will convert that into some volume of the puff and what volume of puff depends on where the emission is occurring. These occurring through a chimney or what it does is it generally convert your steady state thing into a puff based model, but AERMOD is a steady state model.

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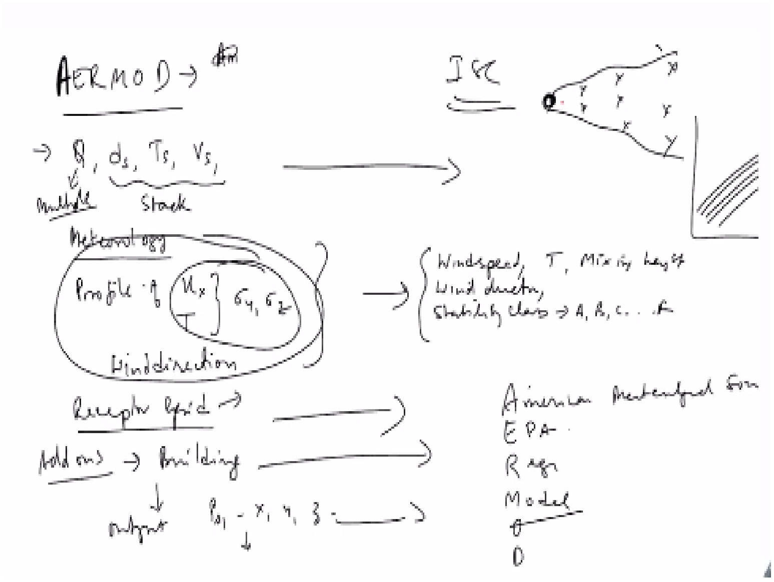

The big difference between ISC and AEROMOD, the ISC is the older version and they are both similar. So here again, you need same kind of information, the information that you need is the Q the rate, you need the diameter of the source, you need temperature of the source, you need velocity of the source, these are all stack; stack diameter, stack temperature, stack velocity. Then you need meteorological conditions.

Meteorology that you need here is the profiles of wind and the profile of temperature, two things you need because it calculates the dispersion parameter sigma y and sigma z based on the profiles. We will look at it later. When we are looking at emission from surfaces, we will look at this again, we will revisit this topic again that is relevant at that point, right now it is a bit this thing, at that point we will do that. So, it needs data of profiles of wind and temperature in addition to a few other things.

You also need wind direction. So, the wind profiles, the temperature profile automatically what they do is they will allow you to calculate the mixing heights and those kind of things in the stability class. There is no stability class in this case. This directly computes the sigma y, sigma z based on these things directly. It is a slightly more advanced model in that way, yeah.

Then you need a receptor grid. You need to specify where you want to measure and you can also add-ons.

You can input here is for building, effects of building, a building downwash, you can say where are some buildings and what is the dimension of the buildings with reference to the source. You can put multiple sources, you can add multiple sources, many sources, you can have a point source, you can have area source, you can have all that okay. In the receptor grid, you can specify where you want, what height do you want measurements and everything can be done and the output is usually rhoA1 versus x, y, and z, the calculation is done at each point you want specified.

From this, you have to calculate the contour map or whatever you want to use it for to superimpose on source. The AERMOD is this. ISC is the same, this is the same, this is all the same, you can also do buildings. The big difference in ISC model is the meteorology that it uses is very much like the equations we had, what we showed as in the example yesterday last class we had, how to calculate concentration using the Pasquill-Gifford stability classes.

So, the met data that we need is very small, you need the wind speed, we need wind direction and we need a stability class which means that stability class you have to give it, you have to give an hourly stability class or whatever stability class that it should use. Based on that, you give A, B, C or D or whatever till F, it will take sigma x, y and sigma z correspondingly using those graphs. So, you see those graphs that we saw with all this sigma y as the different stability classes, those graphs you can convert them to equations.

So you can convert them equation, use those equations in the program here and calculate the value of the sigma y and sigma z. So it is far more easier when you have temperature and mixing height, you have to give mixing height. You have to provide the mixing height from externally. What you are doing is you are calculating all that based on some estimate for the temperature profile in that given area. It does not do it itself, you have to give everything. In a way, this is easier to do when you do not have this data.

This profile data is not very easy to get, very few places it is measured. Indian metrological department measures this in several places, so you can buy it from them or you can request from them, they will give it to you and it may not be available for all the sites that you want, maybe available for some places. So you have the data, then this is the model that you should use. If you do not have it, ISC it can be used but you have to mention that you have used ISC. So, there will be a difference between ISC and AERMOD mode, okay.

AERMOD stands for the American Meteorological Society. You do not have to write this down also, it is there in the website and the US EPA Regulatory Model. So, imagine the amount of work that has gone through, the theory behind lot of this section alone is huge because it deals with turbulence in the environment and it is very unlike turbulence in flow in a pipe or in a channel, it is huge. The scales are big and it is very unpredictable. There is a lot of work that has gone into it.

So, when these models are developed, people verify these with experiments. How do you do an experiment for dispersion? Anytime when somebody develops a model, you are using it to predict something, right, so which means you have to test if the model is correct. **"Professor – Student conversation starts."** How will you test? Wind tunnel, but wind tunnel is not disclosed. You can test the dispersion model using a wind tunnel and all that, but in the field you have test it, otherwise nobody will use it for risk assessment. **"Professor – Student conversation ends."**

We are using it for risk assessment, so nobody will use it for risk assessment unless you test it. You tell people that this is happening, so one has to use it in a field. So, these experiments are large scale experiments, somebody has to release something, right. So, you have to release some component which is not present in the atmosphere and then verify its concentrations, predict the model, and compare. So, basically what you will do is you will release a certain chemical and you will predict concentrations at different locations.

You will also measure concentrations at those locations, and if it matches, how closely it matches, then you adjust the model to that. So you have made some assumptions in the model, those assumptions you have to justify or say that these assumptions are not valid under these conditions. So, there are a lot of experiments conducted long back for these kinds of verification of these models. You can also do it in a wind tunnel as he says, but the wind tunnel is an idealized system, again you will get an ideal behavior.

You can test several things in a wind tunnel. You can test what happens if I put a building what happens, so people do all these things, people study it using what is called a tracer, you must be able to visualize it. There are a lot of classic studies. You go to the EPA's AERMOD development studies, you will see. So right now, people use CFD, computational fluid dynamics to do all these, but you have to still study a physical model. CFD is an equation based model right, whatever equation I put, it will use that equation, but the equation is based on observation.

Whether a particular equation is valid or not you have to test it again by experiment. So, people use tracers. They use a smoke and to see how the plumes are going and how it is dispersing, those kinds of things are done. There is a lot of, it is a very elaborate science AERMOD is not to take the dispersion modeling and it is fairly complex if you get into it. So, AERMOD has its limitations, the regulatory models have their limitations, but that is if you go and read the document, this is the third project that I am going to give you.

If you read their document, you can see it is very big document. So, what are the limitations and what are the assumptions, some of them we have discussed in class, some of them we have not discussed in class, so you can see that also.