Environmental Quality: Monitoring and Analysis
Prof. Ravi Krishna
Department of Chemical Engineering
Indian Institute of Technology, Madras

Lecture-40
Dispersion Model Parameters - Part 2

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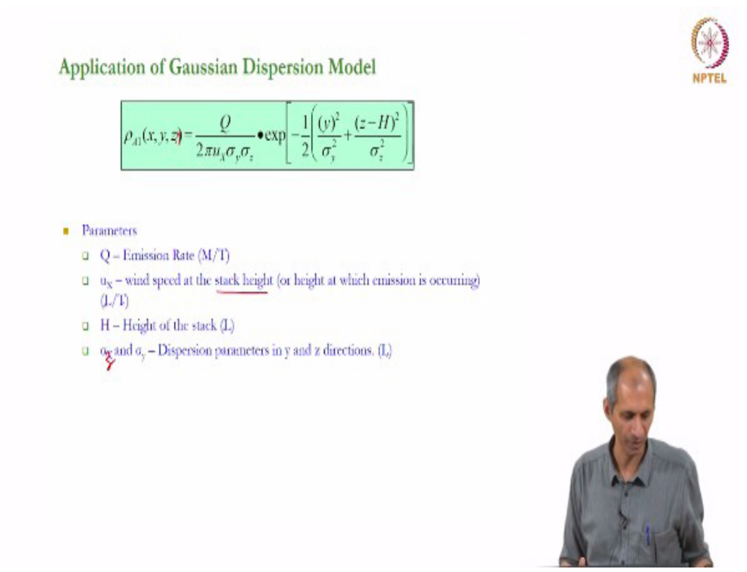

So these are the parameters that we are interested in, so in order to calculate $\rho_{A1}(x, y, z, H)$, four things are important: Q is emission rate, u_x is wind speed at the stack height. So this is the wind speed at stack height. So What we mean by that is, we will come off to each point separately. H is the height of the stack and $\sigma_y$and σ_z in y and z directions.

You also see dimensions of these things. Emission rate is mass per time, u_x is L/T. the height of the stack is length, dispersion is also length. So you can look at that the dimensions here within the exponential term, they will all cancel out.

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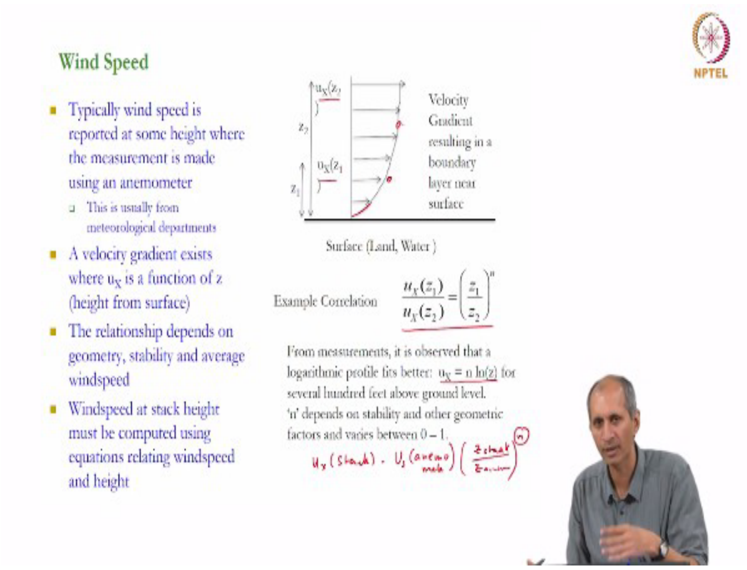

So the first parameter, wind speed. You need to calculate wind speed at the stack height, so stack height may be 50 meters, 50feet, 100feet or whatever it is. There is also the observation that typically wind speed if you look at wind speed. If I say I am looking at a stack in some place in Chennai, then what is the wind speed? Then you'll go to the nearest wind measurement? There is an anemometer in an airport or some place, somebody would have measured some value.

It will usually say at what height it was measured. Why is this important? Because typically we see that there is a velocity gradient of air as it flows on a surface. This velocity gradient itself is a function as we have discussed in some one of the earlier classes. That, there is friction on the ground, so the Earth surface is drawing energy from the air mass, and therefore the velocity that is present near the surface is smaller than something higher.

And this energy transmission is happening in this direction and it is being lost towards the ground. So velocity is decreasing towards the ground. So there is a velocity gradient that you expect. So as a result you find that the velocity at different heights is different. So if I make a measurement here if I have an anemometer here, but the stack is here (at different height) then you have to estimate what is the velocity here (at the stack) based on this so which means that if I know this gradient equation by some equation.

So this is an example, it could be different correlation could be linear almost never linear. It is non linear, it can be parabolic sometimes, sometimes its power law equation. This is power law equation.

$$\frac{u_x(z_1)}{u_x(z_2)} = \left(\frac{z_1}{z_2}\right)^n$$

Sometimes it is a logarithmic equation. logarithmic means it is Ux equals to n ln z, this is not the same, this is power law. So a lot of times this is the equation that will fit nicely. You have to measure the velocity gradient at a given location typically, you have to get multiple heights, velocities and then fit it to see what is the form of the velocity gradient? Whether it is logarithmic or power law or anything and that is the easiest way of doing it because the fluid dynamics is very complicated because in the place like in urban areas the velocity gradient will be something, because the friction offered by the surface here is different from the friction offered in an open ground or a forest or sea.

So velocity gradients all are changing within a city itself. So it is best to get measurement, but if you do not have measurement then whatever is the nearest measurement you have you make an estimate. So this is how it is done, so if you have the relationship of velocity as the function of height then you calculate the wind speed required for your Gaussian model, dispersion model, at that point.

So it is typically we do this, so if we use power law,

u_x¿

So this n now depends on whatever is the structure of wind, that depends on a lot of things, that depends again on the magnitude of wind, it also depends on stability. Stability its mixing is in a different direction, then you have different stability classes.

So the value of n depends on stability is, generally varies between 0 and 1, but actual values are very specific to what is the class, we will leave it at this for this time, I will give you other equations for that also. So this can get very complicated if you want because there is entire body of work that talks only about turbulence in the environment, velocity gradients and we will touch upon it a little bit later. What temperature profiles and all that.

But if you go there and you need a lot of data to resolve any of these issues. So there are simple ways of doing it. So people use simpler methods to get an estimate. So first of all people need quick ideas, where is this plume moving? And what will be the cost? So we need worst case scenarios quickly and for that;

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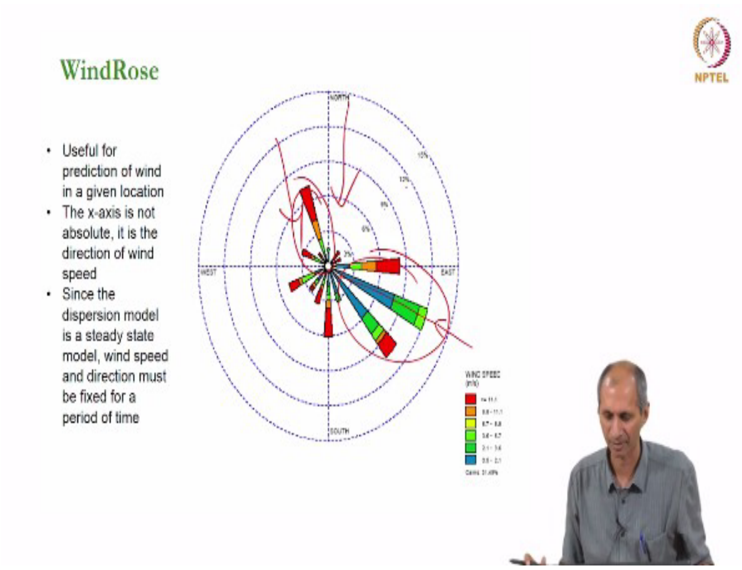

Typically, what people use is Windrose for average wind directions. This windrose is a compilation of wind speed in a given area. This is an example of how wind patterns in a given location, for example, this could be a windrose for a given city for a day, for a month, for a year. So this is an average windrose. So what the way this is read is, for example, there are different representations, you can go and search for windrose and it will give you different kinds of representation.

What this is is you can see this scale here, it is colour coded with wind speed. So the red is the highest, so greater than 11 meters per second and no color is 0. So the center most point is no color 0. The radius of this represents how much, what fraction of the time is this calm region 0. So the radius of this we can see number is 3%, 6%, 9%, 12, 15, please this is the indication magnitude of what particular value of wind speed, how long did it persist? For if you are taking for 1month I am collecting data every hour. I have that much data. I have 24 X 30 that many data points. What is the distribution? Some of them, suppose 10 of them are 11meters and higher. 20 of them are between 8 and 10 meter and so on. so we make a distribution and we represent this distribution. You can see that there is a certain length for the light green, dark green, blue and all that.

So this also gives you additional information, what is the direction of this wind? So you have plotted it on a polar graph north-south, east-south. So you have to be careful. So this wind direction usually is reported as from. When we say wind is north, northerly wind it means wind is coming from the north. Which means its direction is in this direction, it is coming like this.

So, but here (in the picture) this representation is the highest one, which means that wind is coming from the south east. But you have to be careful some people plot it the opposite way, this wind is going to direction. It is coming from the north and it is going to the south right. So they also represent it as to, wind-to direction, which is a very confusing way of doing it, but you have to watch if somebody is giving you data you have to find out whether it represents to direction or from direction, it exactly means the opposite right?

It will change by the Gaussian dispersion model. If I am saying to and from interchange my entire dispersion model will change. I am looking at concentrations in opposite directions rather than in this direction. So wind data meteorology is very important that determines the entire thing. So a lot of times if you are looking at say, for example, I am looking at estimating Gaussian dispersion for a given factory. I am setting up a factory and I know that this is going to be the emission I want to find out, what is going to be the impact? If I am locating the factory in Chennai ok and this is the Windrose for Chennai, by the predominant wind direction is in this south east or east south direction. For a large fraction of my time and there is some fraction of time wind that is coming in this direction right (north-west). So this will help me in finding out where I should put the factory, if a pollutant is released it goes in this direction or in this direction, one of these two direction which one? So I can determine whether I can locate the factory or where I should locate the factory and all that. The windrose is useful in doing that qualitatively. Quantitatively of course, you have to take the wind speed. and this also will give me an idea what is average wind speed over a period of time. Which is the most, for example what people normally do is they take monthly windrose, they will take January, February, March monthly wind, they will see how this wind is changing. If you are doing the estimate for this month and this month and this month everything will change. So you have to do it for one month. You can't do one year, year is useless, because it will give you an average picture. Especially in places like Chennai it will give you average. in places like Chennai you can do hourly also if you want but wind speed is reported every hour, if you go to meteorological this thing, they do not report they report every half hour every half an hour, so it is useless. But daily windrose is reasonably useful.

So as I said in the beginning you have to find out why you are doing this? And what is the objective of this? So it all goes back to our original plan of why you want to do this? That objective must be clear.

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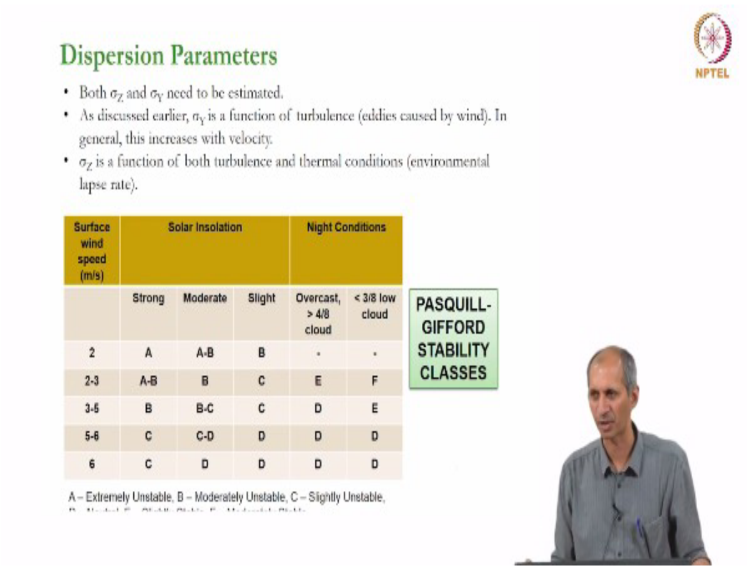

All these are only tools for doing it. The next thing the dispersion parameters sigma z and sigma y need to be estimated. So these are caused by two things one is eddies caused by turbulence in both directions y and z directions and the thermal stability class. So a very old classification in the system of what is called a stability classes. This is very old 50's or 60's by PASQUILL and GIFFORD popularly known as this.

This is not the current state of the art, but this is very useful and for the reasons that we have seen in the previous slide. To get the full information of dispersion you need thermal profiles. You need to calculate the adiabatic lapse rate and the environmental lapse rate. Lot of times this information is not available. Some people have just this, this is simpler as you can see this table you have surface wind speed there is no specification as to where, which height and all that.

It gives very simple instructions as solar insulation; insulation means solar radiation. Very strong solar radiation means it is a bright day, sunny day. You have very high winds, moderate winds, light winds. And some cloud cover, no cloud cover. And then at night conditions there is no solar radiation and you may have cloud cover or no cloud cover. See in the night when there is no cloud cover you can expect that cooling happens very rapidly the inversion will happen very nicely.

We do not have any cloud cover, if you have a cloud cover inversion will not happen because variation will be blocked. Cloud cover will stop and so the inversion will stop ok. So this is a very qualitative way of doing it based on data and so you can, people have defined stability classes based on this, so your A; is extremely unstable, B is moderately unstable and so on, F; is moderately stable slightly stable and so on.

As a classes increases you are going from unstable to very stable conditions, D is neutral and so on. How is this to be used? You get this stability class based on this observation, which means that from weather data you know, or it was very cloudy, the wind speed of this much across the sun day time, I am going to use stability class A or B or C or whatever.

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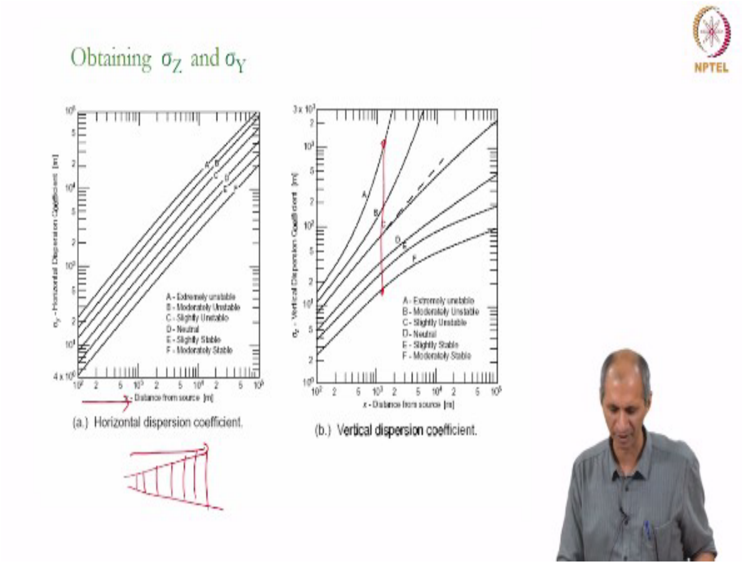

Then I use these charts, which is also given by them to give the value of sigma y and sigma z, so sigma y does not change a whole lot. So you can see stability A to B are very close to each other. It is on the y axis; x axis is the distance from the source. This exactly gives you the plume shape, as the distance from the source is increasing along the x axis, you see that the sigma y is increasing which means the plume is increasing if we are looking at sigma y is increasing.

So this distance (spread of plume) is what we are plotting versus the x axis distance. So it is kind of going nicely all of them are close to each other, irrespective of stability classes distance difference is not that much, but if you go to the other one, sigma z, the difference between the sigma z value for different stability class is several orders of magnitude, 2 orders are magnitude. F is very stable, moderately stable, so this is very low, the lowest dispersion and it is consistent with our physical model of what stability can do to this.

So this is a very simple way of doing it. It is a very old and so the data that you need for this is wind speed, average wind speed and data about qualitative information about whether it is sunny or cloudy and all that, that's all yeah but there is a current state of their model I will describe separately, we need little more discussion on fundamentals how it is done. And that is what is done in the current model which requires a lot more data, so what happens sometimes is you may have to go back to this method.

To get some preliminary estimate before you go and do it with the real model because if you do not have data you cannot just fold your hands and sit down you have to get some estimate this is this is very true with all modeling because you do not have data that is why you have simple models and more complicated models, the difference in estimation, there will be a difference but know that difference will exist and then you know how to correct for it based on their information you have about the system.

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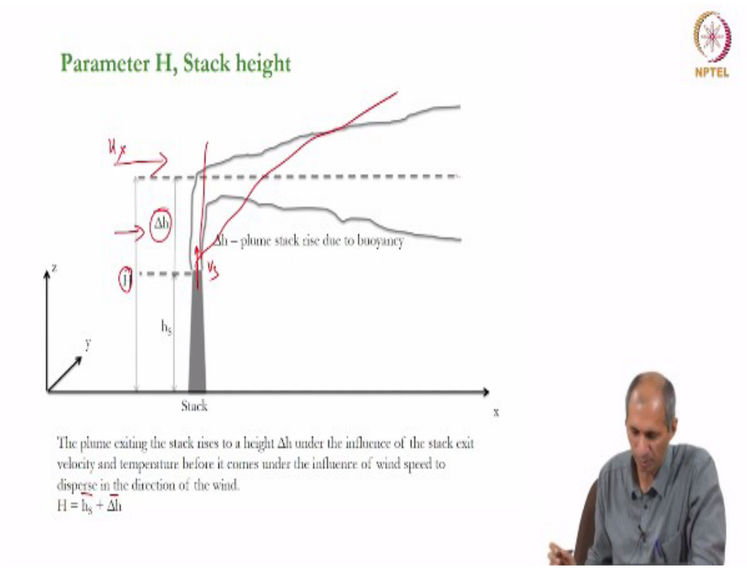

So the third the last parameter that we have is a parameter H ok, so this is simply as we see in this case it is not just the height of the stack, it is the height of this center point where you have the highest concentration. Which means that will happen for these things will happen. For example, in this example we are seeing that this plume is getting out and is going up to a certain height before it starts turning and going in the direction of the wind, why does this happen?

This is one scenario; why does this happen? What is this a function of? Why will it go up and then start moving? Two reasons why this can happen. There are only two reasons for all of this. One is density difference because of temperature, high temperature emission coming it will go up buoyancy will drive it up, but this buoyancy force of buoyancy also has to be accompanied by something else for it to go up. See it can go up like this, why is it going up straight?

It can go up like this and it will eventually it will affect the adiabatic lapse rate, and therefore it will affect the plume, shape and the sigma Z and all that will that will come there. Why is it going straight up? What else is there? Buoyancy is one which is the other force? Velocity, there is a stack velocity. If you are if you are in industry, industry is pumping these gases out and there is pumping there is velocity of pumping, they are sending it out in some flow rate and this is a velocity is very high it goes up, it shoots up it’s like a jet. It shoots up a lot of energy, a lot of buoyancy, it keeps going up and up before this, this Ux here takes over, it loses the energy and then it is just hanging there. You can see that if I light, if I burn something I am not sending any air or anything. I am just burning it. It just goes up, just raises up no wind and then I put a turn of fan and it will start getting carried away in the direction of the fan, so it is like that. This wind direction is there also but this force is so much that is energy is that it goes up to a certain height before it loses energy and then it gets carried.

So this is sigma H, delta H here is called as the stack rise, plume stack rise, stack rise of the plume and this is a function of two things both, so we calculate H the actual H is the sum of the physical height of the stack and the plume rise. The plume rise is a function of two things.

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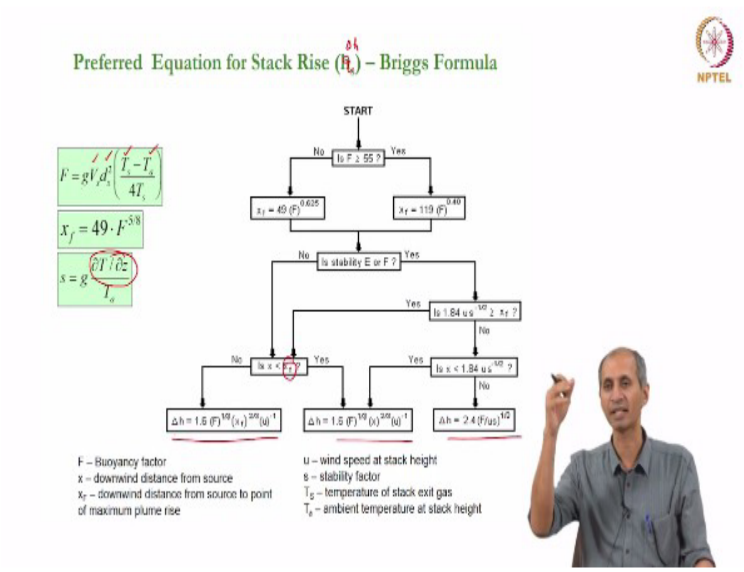

Something the velocity of the stack and the temperature is the formula that people have derived, so I am not going through this, we will just give you an idea of this several things. This is a preferred equation for calculating stack rise, Hs is delta h not Hs. So you are calculating all these parameters, F is given here, so here you can look at the parameters here this is velocity of stack, this is the diameter of the stack, this is the temperature of the gas coming out of the stack, this is the ambient temperature and this is the gradient $\frac{\partial T}{\partial z}$.

This is ambient temperature gradient ok, which will tell you if there is inversion or no inversion, stability class determination is done like this, which means you need a lot of data for this, at least in the near height. So based on this you calculate the delta h. There is some other parameter here X_f, the purpose of X_f here is this following. Sometimes what will happen is the plume moves a distance in the direction of the wind before it starts spreading. So there is a certain distance that is X_f, so that distance it moves the entire thing, it goes in a jet but the jet is moving like this it is not going up straight but it's moving inclined direction before it starts spreading and that is a starting point for this spreading plume spreading. So in this in the next equation, you see the term called X_f here.

The X_f is calculated using the buoyancy, so these are empirical equations. There are a lot of empirical equations this is not the only one. Which I have not given the other equations here but use this, this is the most comprehensive one. And this is also used in some of the regulatory models for this. This is also used in designing,

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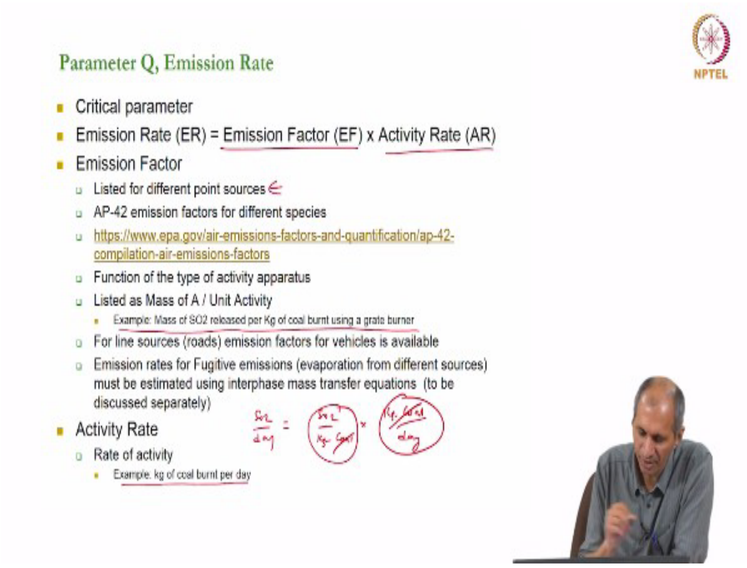

we will come back to that in a minute, so the last thing we have is what is called as emission rate, this is the most important parameter without this there is no Gaussian dispersion model, this is emission. You must know what the emission rate? So emission rate in general there are different types of way in which we estimate emission rate for different processes. But when you have things like point sources.

Point source is a different particular activity, it's a particular industry. Emission rate is calculated by the product of what is called as an emission factor and multiplied by an activity rate.

$$Emission\, rate = emission\, factor \times activity\, rate$$

Emission factor is for example, mass of sulphur dioxide released per kg of coal burnt using some kind of a burner. Kilogram of what coal, which coal everything comes here, kilogram of Indian coal, burnt using open stuff so it's the difference. I can burn coal, I can burn different kinds of coal, I can burn coal differently. In different types of burner combustion devices, I can burn coal in power plants. I can pulverize the coal and burn it, do all kinds of things right and then, what is the activity? Activity is how many kilograms of coal am I burning per day. So essentially the emission rate for SO_2 per day, this is the emission rate.

$$SO_2\, released\; per\; day = \frac{SO_2}{kilogram\; of\; coal} \times \frac{kilogram\; of\; coal}{day}.$$

These two are different numbers. Activity rate is independent of emission factor. I can burn one gram of coal, I can burn 50 tons of coal a day but emission factor should be the same more or else. Unless you are doing under different conditions, so the emission factor is listed for different sources, ok.