**Fundamentals of Environmental Pollution and Control**
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**Lecture No. # 32**
**Air Pollutants and Meteorology Contd.**

It's okay, we were discussing about this stability in the atmosphere and so we can, were just discussed about one important thing that is I say that if we consider that you know the two situations that we have explained here say if is as you can see this is if the parcel as I have said that parcel begins to move, the parcel begins to move and then at one point of time the parcel begins to sink down.

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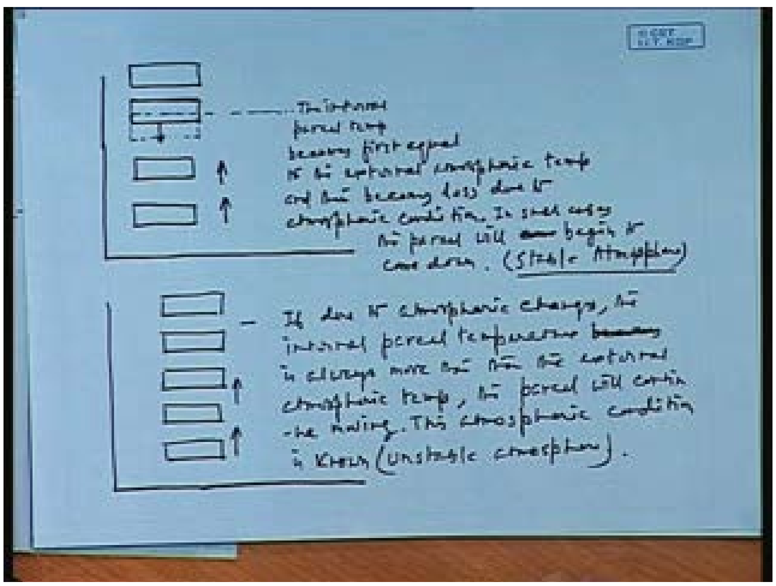

So, if the sinking down as we can observe here this is how it would look like, the parcel would begin to sink, the parcel would begin to sink. So, you know you can see this instead of say having to go up there, so this, this is how the parcel is moving up, the parcel is moving on. At this point of time, at this point of time as you can see here at this point of time this, the, the internal parcel temperature, internal parcel temperature becomes first equal to the external atmosphere, to the external atmosphere. The internal parcel temperature becomes first equal to the external atmosphere and less due to the atmospheric condition, becomes less due to atmospheric condition. In such cases, in such cases parcel will come, will begin to come down, will begin to come down with the parcel will begin to come down. So, this is what is known as the stable atmosphere. This would be what is known as the stable atmosphere. When the parcel, the internal parcel temperature becomes first equal to the external atmospheric, atmospheric temperature and then it becomes less due to atmospheric condition, a typical change in the atmospheric condition. This leads to the, this in such cases the parcel will begin to come down, this is known as the stable atmosphere.

On the other hand, on the other hand, on the other hand if this situation is like this, the parcel continuously the temperature reduces in the parcel. Remember one thing what I have said both these parcel and the external environment constitutes of air and nothing but air. Is it clear? Parcel is an imaginary, parcel imaginary object. The contents in the parcel and the external environment are same, there is no difference the same air is here in cases like this. Only in a situation we have considered that in this process there is no exchange of heat between the internal parcel environment to the external atmospheric environment, all right.

So, here if this is, if this parcel continuously even if you see here the situation begins like this, the parcel goes up and up, the parcel goes up and up and here you know in such a cases as you can see the situation is this that if due to atmospheric, due to atmospheric changes, due to atmospheric changes the internal parcel temperature, temperature becomes internal parcel temperature is always, if due to atmospheric changes, the internal parcel temperature is always more than external temperature. The parcel will continue moving, this continues moving, the parcel will continue moving, the parcel will continue moving. This atmospheric condition is known as unstable, unstable atmosphere will be known as unstable atmosphere, will be known as unstable atmosphere.

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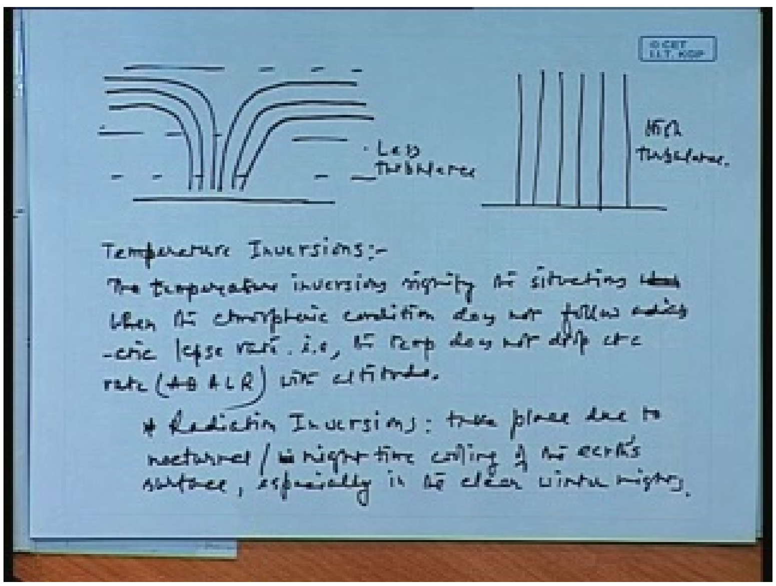


What is the significance? Physical significance is this, the physical significance is this you know you suppose, suppose here say if you just try to observe the surface of the earth, if the surface of the earth here in case if you just observe the air, the hot air beginning to go like this, this is where the hot air would begin to, depending on, depending on how hot the substances are the, how hot the substances are, they will form a pattern like this, this is, this should can be thought of in three dimension. This is what is then this is what would be known as a stable environment, this would be known as the stable environment. So, you know you can see here, this is the stable environmental, a stable atmospheric condition, the stable atmospheric.

On the other hand if this is like this, if it is continuously moving like if it is continuously moving this the, the particularly the air parcels or the, the, the column of air or whatever you think of the air current will continuously begin to move like this. This should be, this should be you know this would create a greater amount of turbulence. You can see this particular, this particular environment is less turbulent in nature because of this is, this is where it would come to equilibrium very soon whereas in these atmospheric condition, the equilibrium is not being reached ideally with a, within certain time, within certain altitude. So, this one would remain as an unstable environment, unstable environment.

So, this atmospheric you know this the, the particles of the gasses that would be dispersed here, the gasses would continuously beginning to disperse and they would continuously begin to move so it would be, it would just begin to in the, within the atmospheric column itself it will be continuously begin to move and as a result of, also result of due to wind direction or things like that this would be much more spread you know it will be a further more turbulence. So, here you can see less turbulence, high turbulence. So, this is less turbulence, high turbulence. So, this as you can see this has, this has a great implication in terms of, this has great implication in terms of, this has great these are importance in terms of the particularly the stability of the air as well as in, in understanding, in understanding the dispersion of the pollutant because you can see you know if it is a less turbulent situation our estimation would be it is in a position to be more correct than, than that of the estimation in case of unstable environment. So, this is stable and unstable environment meteorologically when you call see thus this is what actually it means, all right.

Now, here is this having gone from that there are many more things to discuss on this but you know we go to a new topic. Now, I would ask you to further read on this. There are new topics that we can say is the temperature, temperature, temperature inversions, temperature inversions, temperature inversions is essentially as you will see that you know the temperature inversion signify the situations, signify the situations, signify the situation when the temperature inversion signify the situation when the, the atmospheric condition does not adiabatic lapse rate, does not follow adiabatic lapse rate. That is the temperature, temperature does not drop, does not drop at a rate, at a rate that is adiabatics lapse rate, adiabatic lapse rate, the temperature does not drop at a rate with, with altitude, with altitude, temperature does not drop at a rate with altitude.

Let me explain this adiabatic rate, it does not or at a, at an altitude like this. What we, what we see now is this you know in a situation like this, what is, what is particularly there are two types of temperature inversions we are generally famously commonly known. One is the radiation inversion, radiation inversions take place, take place due to nocturnal or the night time, night time cooling, night time cooling of the earth surface, of the earth surface, of the earth surface especially, especially in the, in the, a clear winter nights. What is, what happens is I will come back to this, I will come back to this but you know just to mention the difference here that take place due to nocturnal or night time cooling of the earth surface especially in the clear winter nights, in the clear winter nights, this is radiation inversion and this and the second one is…

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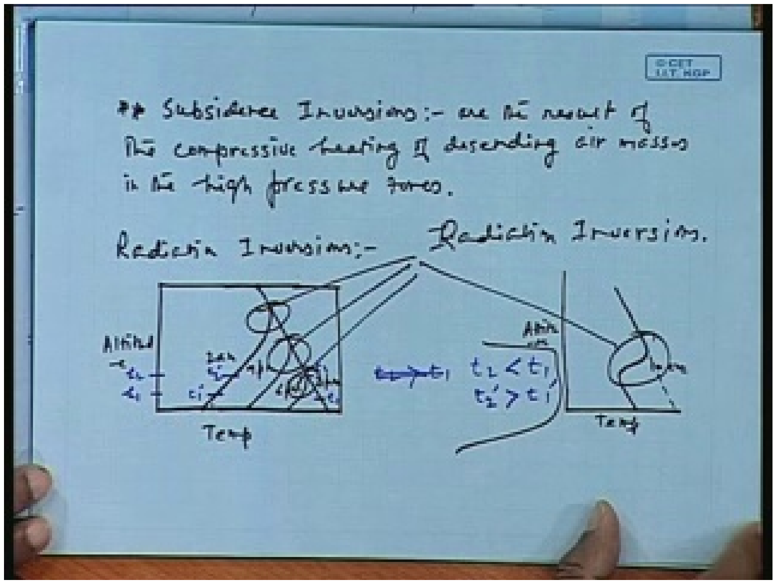


I will come back to this again, the second one is subsidence, subsidence, subsidence inversions, subsidence inversions. The subsidence inversions are, are the result of, are the result of, of the compressive, compressive heating, compressive heating of descending air masses in the high pressure zones, in the high pressure zones. Subsidence are the result of compressive heating, I will explain this compressive heating. Let me go back to radiation inversion first, radiation inversion. What is, what is happening in the radiation inversion like this we know if you remember the way I have said this you know adiabatic lapse rate this is something like this, this is what okay say considering this.

See, this if you are just say height say altitude, altitude and temperature, altitude and temperature. Suppose, this is what is the adiabatic lapse rate or say you know is a close to adiabatic lapse rate. You know this is what is a closed to adiabatic lapse rate, this is adiabatic lapse rate. If you remember the drawing that I have made, this is the adiabatic lapse rate which is like this. If this is the adiabatic lapse rate, what you observe this is as you can see that with altitude as we are closer to the atmosphere, as we are closer to the atmosphere, the temperature is generally higher than the, than that of at the height, okay.

What happens here is particularly during radiation inversion you know during the night time, this is during the night time you can see here this particular inversion takes place. This is how it would take place. The inversion this is instead of, instead of following this adiabatic lapse rate curve, the curve would change like this. What it means is let me explain this first. This one is you know at about 9 pm, at about 9 pm, at about 6 pm it would be further closer 6 pm and about 3 pm we will find something very close to adiabatic lapse rate which is very close to adiabatic lapse rate. What is happening here you try to understand this. If you just observe this now earlier in the case, earlier in this case suppose this altitude here suppose you know you just see the two cases here. This is, this is the time, this is the, these are the two points, these are the two points. At 3 pm, at 3 pm you observe them to be at this point. Isn't it? Say about this point right, at this point this is the temperature say the temperature as you can see with the temperature is decreasing with altitude as you can observe now.

On the other hand just try to think of this here if it is coming crossing at 2 pm, on at about 2 am, at about 2 am what we observe is something different. Here, here the temperature is essentially increasing with height up to a certain elevation and then again it would, it would be following the adiabatic lapse rate. You see these two points here, at the same height this is say this is say h 1, this is say h 2. Here, we can find say this one is t 1 dashed say t 2 dashed, t 1 dashed, this one is t, t 1, this one is t 2. What we observe here is you here is observe here is t 2 is more than, t 2 is, t 2 is less than t 1. See, t 2 is sorry t 2 is less than, t 2 is less than t 1 whereas on the other hand, whereas on the other hand we observe that yes… Isn't it? This is the, this is what is called the inversion. This particular the change from the adiabatic lapse rate, the change that takes place is known as the inversion.

So, what we are observing is just like this for about 2 am in the morning, at about 2 am in the morning since there will be a, as if there will be an effective way a nocturnal cooling takes place on the surface of the earth, on the surface of the earth. The earth surface becomes cooler than that of the air on top of it okay but this one, this reduction, this particularly this characteristics begins to change after 2, 2 pm, 2 am it becomes the most pronounced effect. After 2 am, about 9 pm you know 9 pm, 6 pm, 3 pm we can observe this would remain, this would remain like this but on the other hand in the 3 pm side is you can see we will observe that it would almost be close to adiabatic lapse rate. This is known as the radiation inversion. This radiation inversion there is another kind of radiation inversion that we generally observe you know for your example here that you know is particularly in the situation of, in the case of say height, this is altitude, this is altitude and temperature. If you see altitude and temperature we observe that at about 10 am, at about 10 am the inversion is like this, is about 10 am, at about 10 am whereas the adiabatic lapse rate, adiabatic lapse rate is essentially this one. This is what is, this are, these are the things, these are the things you know these are the things that take place if the, is the these are the things that are known as the inversions. These are known as radiation, radiation inversions. These are known as radiation inversions.

These are quite prominent you know these are provide prominent and as a result of this you know you can see this you know the temperature, the comfort level increases. So, in the about this time you can see this the temperature inversion taking place like this and particularly, particularly it is most prominent during the day time 2 am, say about 2 am in the morning, 2 am in the morning, we can find that the most pronounced effect of radiation inversion and as a result of which is this is perhaps the time when it is most very comfortable for all of us to I mean the temperature essentially on the surface of the earth, on a particular day becomes coolest during 2 am in the morning okay. So, this is called the radiation inversions, these are called the radiation inversions, these are called the radiation of inversion.

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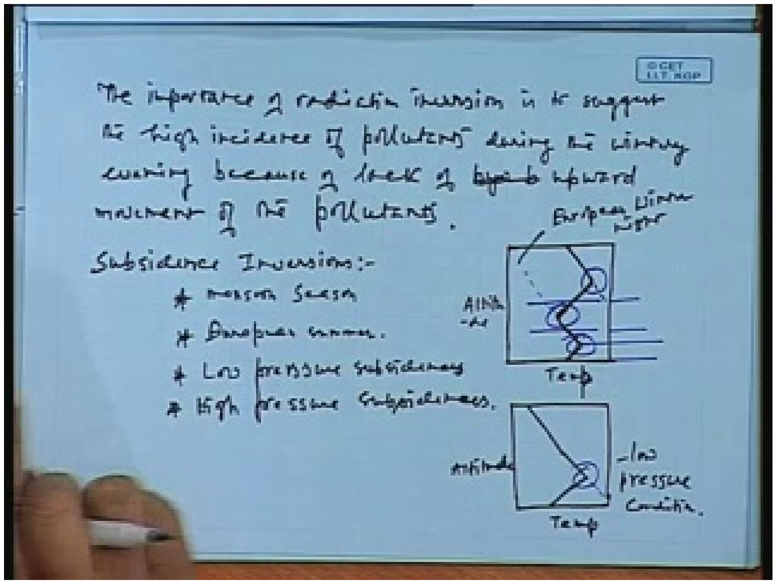


They, the importance of radiation inversion is the importance, the importance of radiation inversion is to suggest, is to suggest during the winter evening, during the winter evening because of the importance of radiation inversion is to suggest the high incidence of pollutants during the winter evening because of lack of upward movement of the pollutants, the pollutants do not move because of you says you can see during that particular time or during that particular time the temperature, the surface temperature, surface temperature becoming low, the surface temperature becoming low, the parcels would lose their heat content within a very short distance in the atmosphere. And as a result of which this will not be able to move up and this would remain confined in the atmospheric, near to the atmosphere.

At the same time the same situation does not take place during the case of, during the summer situation, summer condition, when the summer, in the summer condition, particularly as the temperature, as the temperature you know from the surface of the earth, on the surface of the earth becomes generally hotter than that of in the, on the on top of it, so there would be this, there would be a generally a gradual rise of the parcels in the higher atmosphere, there would be pollutants but the, the most important thing is to a understand this is that near the surface of the earth most of the, most of the plant kingdom, most of the animals and men all exists. So, you know it is important that if the, if the pollutants after their discharge disperse into the higher atmosphere they would not the, this would not expose, this would not expose the people and the population below near the surface.

So, we would always want that the pollutants take a travel instead of remaining fixed at one position, they take a travel particularly during the wintery time when the temperature is very cold near the surface of the earth, the parcels containing their pollutants cannot move up because much of the heat would be lost there itself and they would begin to settle down there itself. So, this is what is the importance of this radiation inversions; this can result in to result in different kinds of, different kinds of situations particularly related to the pollution.

So, this is so is, so the, this is, another is the subsidence, subsidence inversions, the subsidence inversions, the subsidence inversions as they have already said the are result of compressive heating of the descending air masses in the high pressure zone, in the high pressure zones. Here you know is basically a particularly this situation exist, exist during a particular time of the year. You see radiation inversion is quite common you know in throughout the season, throughout the season you know throughout, throughout the year but this subsidence inversions essentially takes place during a particularly, a particular time of the year.

Particularly, you see this subsidence inversions are quite common, particularly during the, during the monsoon, monsoon season, monsoon season and particularly also you know in particularly in a European region or Europe or America it is particularly during the summer this is, this subsidence inversions are quite common. In the subsidence inversions the examples of subsidence inversions you know is a particularly a this is, this say European summer, European summer. There are many this is low pressures, low pressure subsidences are, low pressure subsidences and high pressure subsidences those two things two, two things take place.

Low pressure subsidence, high pressure subsidences, low pressure subsidences are particularly that you know the, the temperature changes that is taking place during say particularly low pressure condition is you know say it a 4 or 5 days you know during which time you know in the part of in the thick summer in the hot summer due to the formation of the clouds due to different say typical is a non a what should I say random a environmental change that takes place and causes the clouds together at difference positions you know and to remain to, to rain for over the day, rain for throughout the day is days in the weeks and things like that. These are the particular situations which are low pressure subsidence takes place that means the here in the also the inversion would take place, the inversion would take place means the, the ground level temperature would be less than the atmospheric, higher atmospheric level temperature at certain positions.

So, this whereas it should be other way round, if it is, it has to follow the adiabatic lapse rate. So, this are the, there are typical situations that take place this you know the monsoon season in India, European summer also this is high, high pressure subsidence take place, low pressure subsidences, high pressure subsidences just like that you know they take place under this kinds of condition. You say particularly if you just see this, observe these subsidences, these subsidence’s are quite like this say is altitude, temperature, altitude and temperature we can observe this you know this is the subsidence inversions taking place you know subsidence inversions taking place.

European winter nights you know particularly high pressure subsidence, high pressure subsidence takes place and the subsidence you can see the changes that are taking place. This is, this is the adiabatic lapse rate, this is the adiabatic lapse rate curve, this is adiabatic lapse rate. We can observe say you know in night times say particularly you know is a low pressure condition, particularly in the low pressure condition you can observe in the low pressure conditions like this so you can see this is altitude and temperature low pressure, low pressure condition. So, you can see this inversions taking place at regular intervals, at different points inversions are taking place at different points say here as this is, this may be say here this is, if this is say this is the adiabatic lapse rate, this is the adiabatic lapse rate, this is the adiabatic lapse rate and the inversion is taking place here. These are the inversions that generally take place due to this kind of, this kind of situation, this kind of changes in the environment, this kind of changes in the environment.

There are few other things there are few other things on this, I would encourage you to read something from the books also more details on this but the basic phenomenon is this. The basic phenomenon is wherever the adiabatic lapse rate is becoming breached, the adiabatic lapse rate the which should remain exist this adiabatic lapse rate is either being violated due to different situation, different conditions in the different changes in the atmosphere. This atmospheric changes are take place because of say diurnal variation, the daily temperature variation, night time temperature variation, atmospheric, other short term atmospheric changes like you know wintery, clear sky absolutely clear sky.

Similarly, on the other hand in situation where this is the, the, the environment is the atmosphere is completely cloudy, cloudy and rainfall clouds are exist. So, in such situations what we observe is that you know the in most cases either in the column of the atmosphere there would be the, the difference in this, there would be changes in the, there will be changes in the temperature at different columns in the atmosphere as you can see here or this should be in the surface here also this changes can take place. Here, you can see this is essentially if it has to follow an adiabatic lapse rate, this should have followed like this. Isn’t it? But it has changed within the column of the higher column in the atmosphere it has taken place. So, it has not, so here in such cases here this inversion is taking place within the higher, too higher, too higher atmospheric columns, too higher atmospheric columns. On the other hand here this is as you can see at the ground level the, the inversions are taking place, the ground levels the inversions are taking place.

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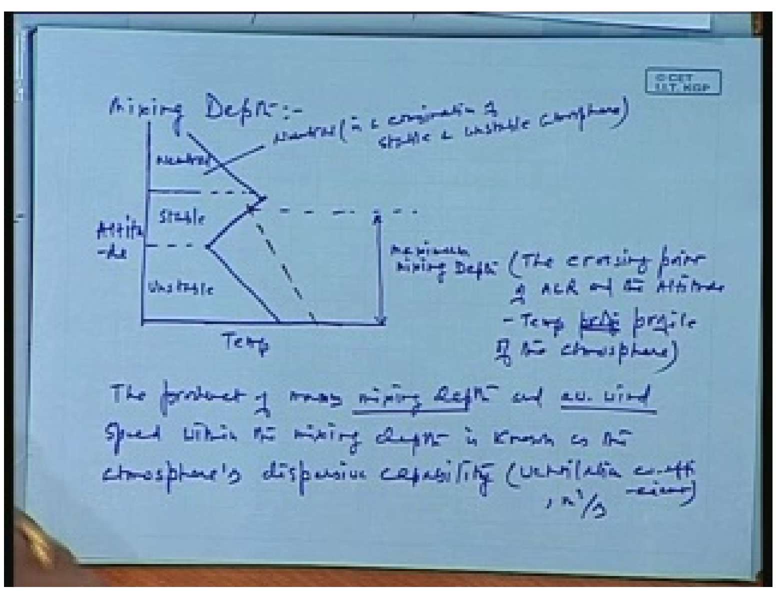


In this count just a one simple thing that I would explain here is the mixing depth. So, what is this mixing depth as such is you can see this you know if you see a, if you see a particular environmental atmospheric condition prevailing like this, atmospheric condition prevailing like this, this is a particular you know atmospheric condition that is existing remember this. At any time of the day or at any point of time you know this is what it is existing like this. What we observe here is particularly this one is the unstable, this one is stable for a brief while and this is what is they call is neutral, this is what is known as the neutral. The neutral is you know neutral is a combination of, is a combination of, combination of stable and unstable atmosphere. In such a case if we just see this, this is the adiabatics lapse rate, if say they this is the adiabatic lapse rate that is, this is the adiabatic lapse rate, this particular point, this particular point maximum mixing, maximum mixing depth. The crossing point of adiabatics lapse rate and this is altitude and this is temperature and the crossing point of, a crossing point of adiabatic lapse rate and the altitude temperature profile of the atmosphere is known as the mixing depth, this is the crossing point well is called the mixing depth.

The elevation means the maximum mixing depth. The product of, the product of maximum, product of maximum mixing depth and average wind speed, average wind speed, the maximum depth, mixing depth is the product of maximum mixing depth and average wind speed, average wind speed within the maximum depth is known as atmospheres dispersive. The product of maximum mixing depth and average wind speed within the maximum, within the mixing depth, within the mixing depth is known as the atmosphere dispersive capability, dispersive capability or also known as ventilation coefficient, ventilation coefficient that is maximum this is given in terms of meter square per second, meter square per second. So, here what is this? Okay, we will come back to this but before I close this lecture what I want to say is the mixing depth ideally you just write down.

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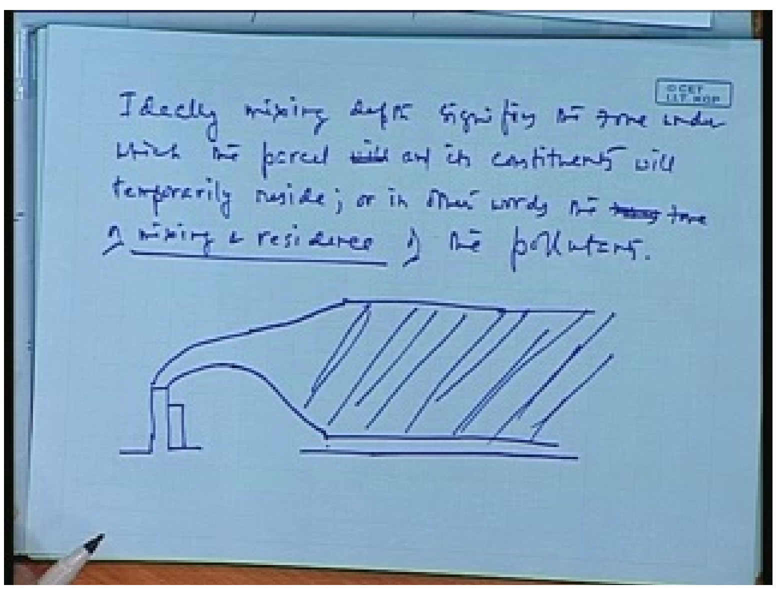

Ideally mixing depth signifies, signifies the zone under which the parcel and its constituents, the parcel and its constituents will temporarily reside signifies the zone under which the parcel and its constituents will temporarily reside that is or in other words the zone of mixing and residence, zone of mixing and residence of the pollutants.

Ideally mixing depth signifies the zone under which the parcel and its constituents will temporarily reside, is temporarily residing because all of them can settle, all of them can travel otherwise also. So, this is temporarily reside or in other words the zone of mixing and residence of the pollutants. So, if you are just trying to say you know if, if we are just trying to observe say you know for a power plant or power plant a, this particularly, this emissions are taking place, the mixing zone here would, would mean is the mixing zone would mean here till this point, till this point up to which, this is up to which the pollutants would reside, up to which the pollutants would reside. So, this is these zone, this zone is also the maximum mixing depth, the maximum mixing depth all right, okay.

So, this is what is you know this particularly the characteristics of most of this metrological aspects of air pollutants related studies you know so this would see you know what we have learnt today is to observe the, this is how what is the ideal atmospheric condition that is to follow the adiabatic lapse rate and non-ideal cases like when there will be changes taking place. Ideals, ideal means or you know when a particularly adiabatically ideal case where you know this temperature would go down with the elevation but this would be violated because of different situations like you know daily changes, diurnal changes, night time changes then seasonal changes, winters, summer, rainy season all these would lead to and as a result of which you know particularly related to this is since in most cases the pollutants whenever they are being dispersed either this they are being discharged with a, with a heat contained in them. Say particularly you know a thermal pollutants when they are leaving the stack their, there they have a temperature with them. So, these increase temperature would give them the buoyancy.

So, this buoyancy and the atmospheric condition together would allow the particulates or the gaseous substances to gaseous matter to reside in a particular zone. This zone is what we lastly known as the mixing depth where they would reside. So, we would now try to see in the next class we will try to see how it will travel, how long it would travel that is what we would know as dispersion okay.

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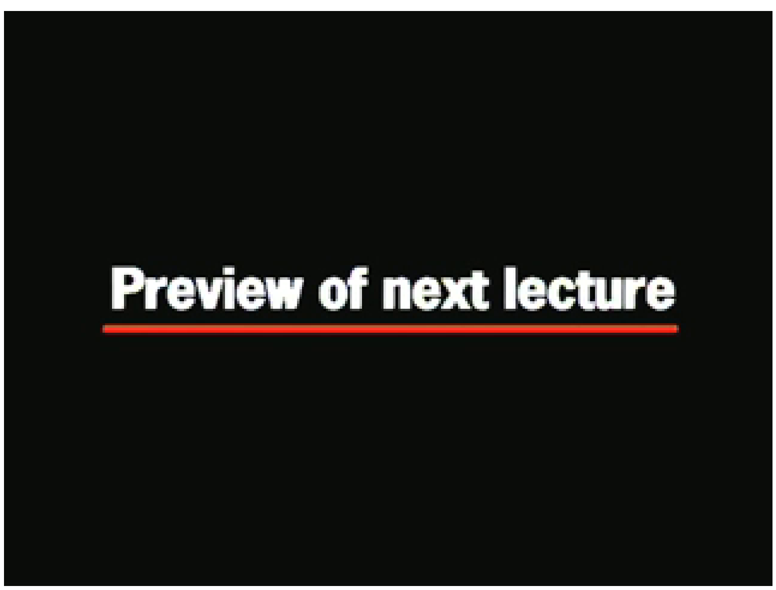

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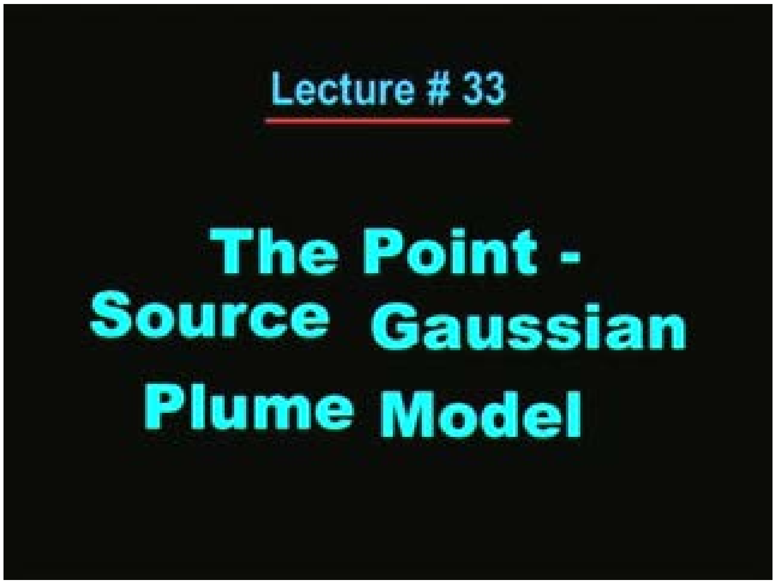


We were discussing about this mostly the, the dispersion of pollutants in the atmosphere and particularly today we will discuss about a very popular model which is used throughout the world and you know in very research establishments, many research establishments where this the dispersion models of dust another things are generally carried out. So, we will see that you know in a, in a, in this lecture today how this, this distribution or the dispersion model is worked out and what are its assumptions. As we know that you know any, any kind of, any kind of model should have to have some kind of assumptions. We will also greatly I mean in detailed discuss about the assumptions that essentially are linked with in a model air pollution model similar to Gaussian plume distribution here. So, so we begin with you know the mostly you know there are few important thing that we would just begin to discuss with before we actually come to this model.

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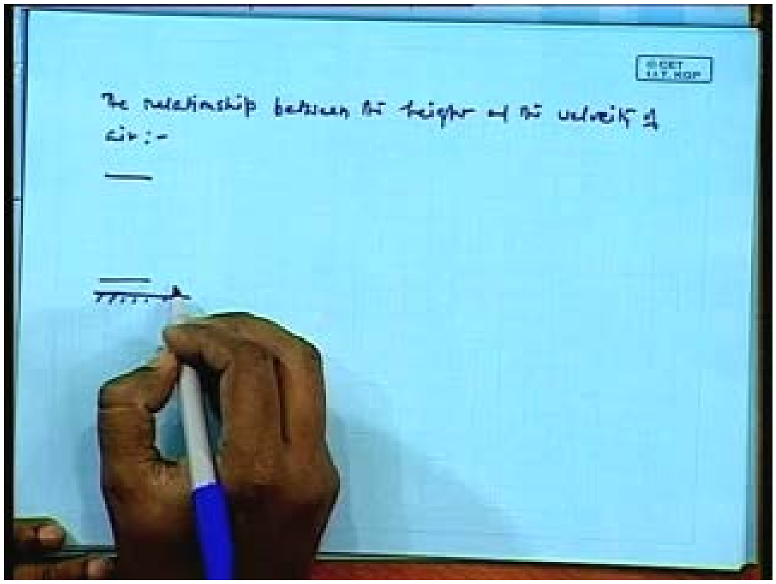

The first and foremost important thing here is the relationship, the relationship between, the relationship between the height and velocity of air, the relationship between the height and the velocity of air. See, here this is what would be quite important for of all of us. See, you know if you are just trying to understand the situation mostly all our velocity measurements, air velocity measurements are essentially at the ground level, are essentially at the ground level. Say you know at a, at a height almost, at most of the times at a height within 10 meters from the surface of the earth, from the surface of the earth, so you know in such cases it is necessary to sometimes estimate what is the velocity at this height, 100 meters and the reducing the temperature by one degree, so you find the plot.

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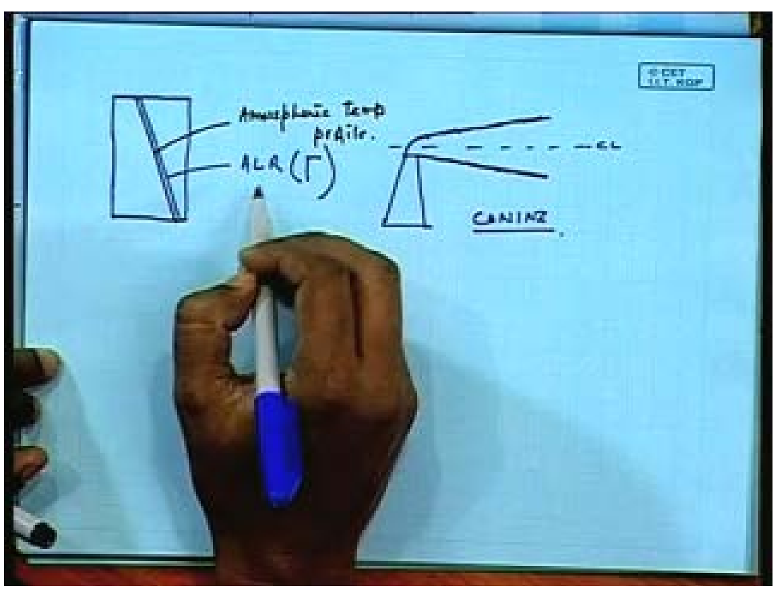

So, if it is say 25 degree centigrade here and another point would be at say 24 degree centigrade at 100 meter. Isn't it? So, this is, this is you say this would provide you, this would provide you the, this adiabatic lapse rate. This, this adiabatic lapse rate if you just consider this you know with this adiabatic lapse rate if you just try to find out this the value of, the value here just like this you know there, if it is the atmospheric temperature profile this is atmospheric temperature which is actually available at the atmospheric say this is the atmospheric temperature profile, this is the atmospheric temperature profile which is almost closely resembling to this adiabatic lapse rate in a situation like this.

This is adiabatic lapse rate which is an ideal condition, this is the atmospheric condition okay. This is called atmospheric, atmospheric temperature profile, atmospheric temperature profile. If this is so, if this is so we can find this, this the plume model that we can observe here, the plume would show a characteristic like this. A plume would show irrespective of the height of the stack irrespective of the height of the stack it would show a characteristics of the plume would be like this. It would be, it would be like this you know forming a, forming a clearly distributed pattern, clearly distributed pattern of you see this one would be, there would be some changes in this. So, but this would be according to this one is along the center line, it would be, it would be symmetrically distributed along a central line, this is central line okay.

This is along, distributed along the center line this is, this particularly would in you know situation like this is known as coning, this is known as coning, atmospheric temperature profile you know is connected with this ALR and atmospheric temperature profile when they are like this in a particular time of the day or you know particular season when ALR and ALR and say atmospheric temperature profile are quite similar or quite close to each other, in such cases we will find the plume which would be discharge from the smokestack would have an identical distribution.

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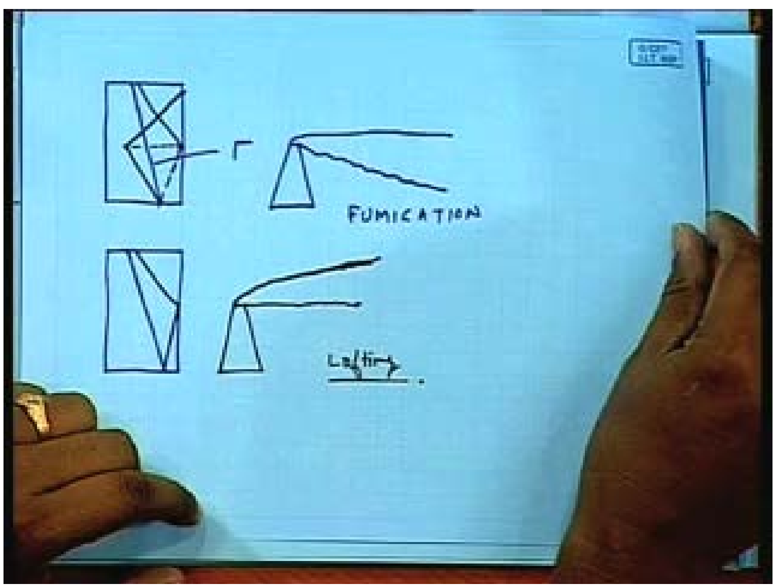

In such cases we observe that you know this the, the particularly there is the smokestack pollution this, the smokestack emission would form a plume which would be like this, which would be like this. Since, it would be, since it would be just the other way round, it would form, it will find lighter. Here, it was denser which was being discharged from the atmospheric air, here it is lighter than the atmospheric air at present at that point of time present at that place. So, here it would be, it would be rising so it is generally called as lofting, is known as lofting, is known as lofting, okay.

Now, having to say this I mean these are the typical characteristics of, typical characteristics that we observe in cases in cases like you know the dispersion of this air pollutants across you know from emanating, emanating from a smokestack, emanating from a, from a say the, there the power plant discharges that you observe. Next time when you, you know take a travel you know wherever you find a power plant you start to observe you know how this plumes actually behave but you will find some interesting observations in that you know many of this cases you'll find this is being this patterns are being followed, this patterns are being followed. So, what we begin to say some from this now onwards is that you know as we can find out we have found out that you know the different profiles that it would have, see the mostly this coning, looping, fanning, fumigation and lofting. So, having to understood from here that we can go into this the Gaussian plume distribution model which is, which is goes like this. This particularly you know beginning to understand this you know it would require a certain amount of drawing here, we just you know as you can see this one would be okay let me draw it from here.

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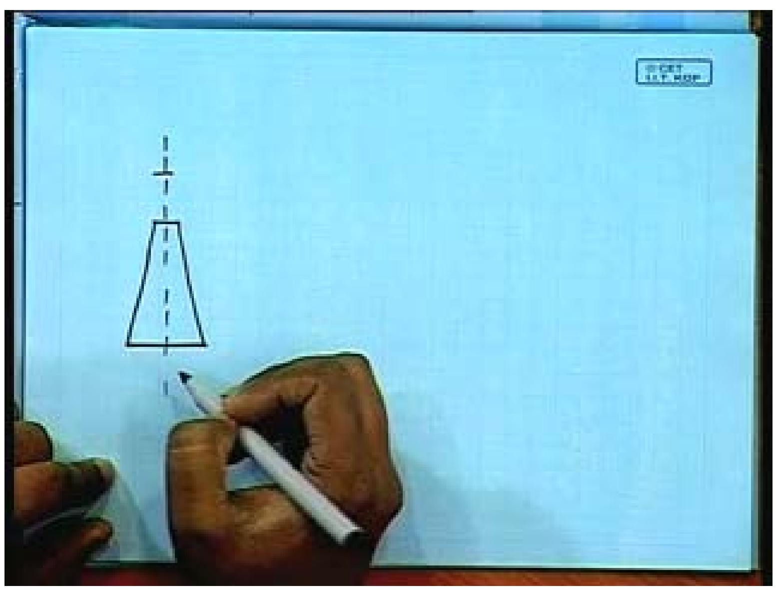

This is what is a say is smokestack. This Gaussian plume distribution you says basically following the normal distribution.