Environmental Air Pollution

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Air Quality Standards
Lecture 3

If you recall, we just talked about air pollution systems last time. Take a look at this slide. I have borrowed this slide from my friend in Norway. I thought I will share this slide with you.

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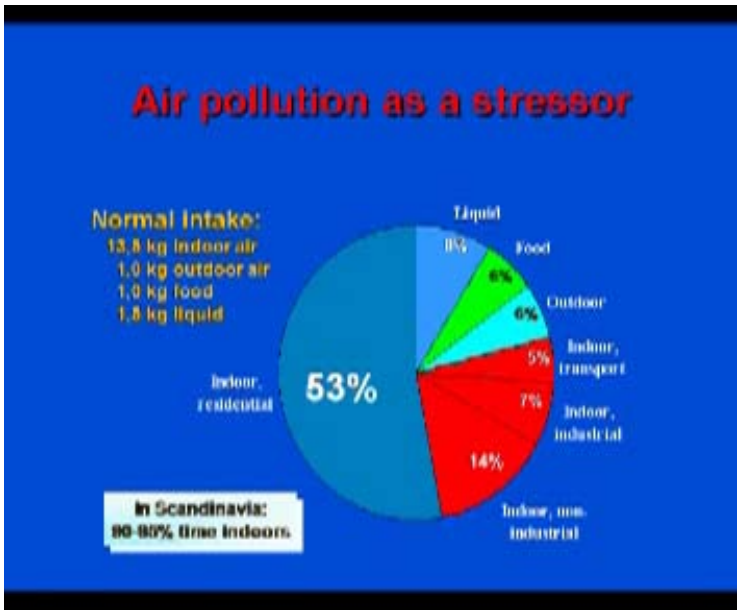

Air pollution is a bigger stressor than most things where you get exposed to environmental factors which can cause the ill effects. What you see here is a very interesting thing; when it comes to the doses or the quantity, what could be contaminated? The air could be contaminated, the food could be contaminated and the water could be contaminated. Look at the amount of the things which you take; it is almost per day [kind of stuff] which you see here; 13.5 kg of indoor air. We see interesting things. Very quickly, tell me do you have any idea as to how much air we breathe in every day? It depends on certain factors: it depends on the body weight; it depends on the age and things like that. You see, you will be surprised that we almost take about 20 meter cube of air per day approximately but it depends on many things;

children will take less. You see the air is so important because the major environmental stressor could be air. I will pass on these slides to you. You should be able to highlight why the [quality] of air is important.

The little pollution in air, that dose, becomes more because volume is high. So even if the concentrations are in micro grams per meter cube or even in nano grams per meter cube, when you talk in terms of the doses, and what really effects is the dose sometimes, not the concentration. When you multipy by this meter cube this quantity in dose becomes quite significant. Air pollution is important and sometimes this may not be quite true, that you see the indoor air…. In India, the indoor air is important especially, in the villages, in the kitchen areas, but our houses are very airy; we have lots of windows. So, the difference on a [on the side of] not so much about the indoor air and outdoor air because of these things. If you move to Europe and colder countries, you see, many people spend lot of time indoors; going outside is very little. So, the indoor air is also important, the external air or outdoor air is also important and of course, so you see that how important is the air is.

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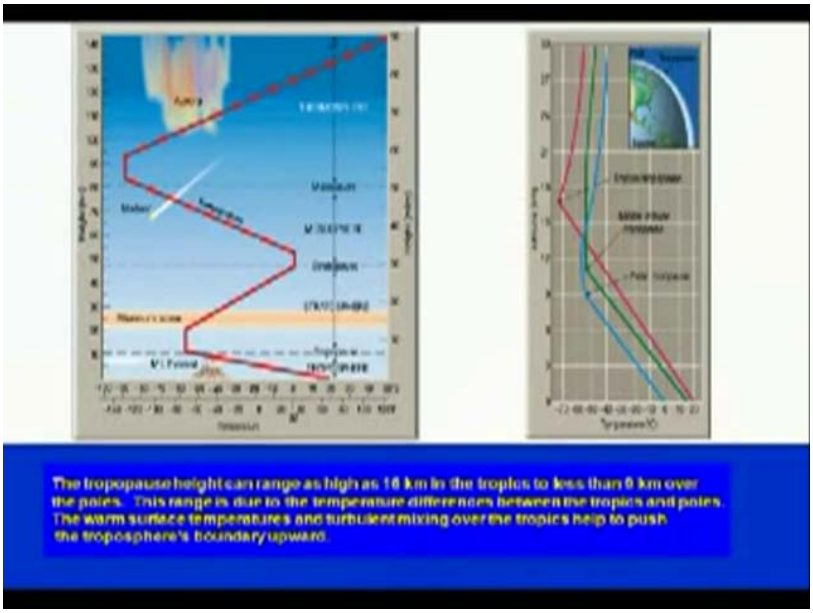

We have discussed this part briefly, but for now, we will slightly highlight one point which we had somehow not focused on.

What you see here is when you look at the troposphere and the temperature is changing, we said why the temperature is changing. Look at that picture on top and that little white band that you see around the earth, this band is narrowing as you go to the poles. You see when you look at the temperature profile, the temperature profile in terms of the gradient, it is the same but the height of the troposphere will be different at poles and it will be different on the equator or tropics. This is clearly seen here, as you see here the graph, this is what it is being shown in the troposphere; this is more here and this is less here (Refer Slide Time: 00:04:31 min).

The reason is that this range is due to the temperature between the tropics and the poles. The temperature at the poles is much lower, nearly 0 degrees or —5 or —10; at the equator, the temperature is high, so heating is more. This kind of gradient you see is largely because of the influence of the earth; because earth gets heated up. When the earth gets heated up, the surrounding air gets heated up but the upper air is still cold.

You see the influence at the equator because of the difference in the temperature, this is more and the tropospheric part of the atmosphere, we consider it almost going up to about 18 to 20 kilometers at the equator; while it could be about 9 to 10 kilometers at the poles. So, that is a little subtle thing which we should know. So that is why I wanted to put the slide and to make the picture very clear and the reason is now there.

We also have seen this thing and we have discussed as to why there is a temperature profile. This, of course, was made very clear to you, why temperature decreases as you go up and then why the temperature increases in the stratosphere; as most of you had pointed out that it is the ozone absorbs the UV radiations and as a result the temperature increases. As you go still go further up from the stratosphere, sometimes we also call this as ozonosphere; as we go further up, the ozone is not there and once the ozone is not there, the temperature starts and that is what we call exosphere. It goes almost up to 90 to 100 kilometers and the temperature would start decreasing once again. If you go up to 500 kilometers or so the temperature starts increasing because largely oxygen is present and oxygen absorbs lot of UV radiation in the lower range; so that is why the temperature goes up. That was the reason that we discussed.

If you recall very quickly, this is definition that I gave you last time. I did write it on the board as the computer was not working. You will also recall that we had identified some key words in the definition.

The key words were - such a concentration. Then all the discussion that we had in last class was focused on this. In fact, this word, concentration - such a concentration - is the crux of the air pollution problem.

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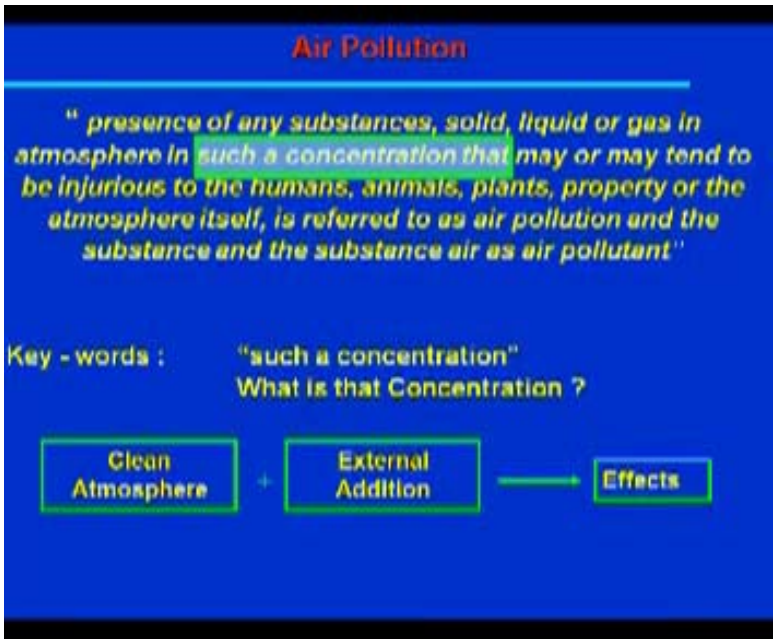

It is important to find out: what is the concentration that is not problematic? We could be very happy even if some pollution level is certain; we must still say this is not pollution. In fact, we do not even call this pollution; simply saying that SO_2 is there in the atmosphere, does not constitute a problem of air pollution, unless it exceeds a certain concentration. We are trying to say what that concentration is since that concentration decides everything. It decides what kind of car you should have, that will decide what kind of power plant you should have, that may decide what kind of LPG should burnt at the home. So everything is decided by that number and that is what your goal, objective is. We also said that this can also be a standard. When I use the standard, the moment I use the term standard in terms of air quality, it has legal connotations. It means it is legally binding that is in fact, how people can demand cleaner air. They can go and shout at the government, they can go and shout at the regulator agencies, saying this is that standard, we are not able to provide that kind of level of good quality air, so there is a problem. In this lecture, we will try to some how, at least in some brief sense, how to arrive at such an important number. It is very important.

Usually, apart from science and engineering, we should also understand the implications. What it means you know if number is fine, the equations are fine, but then you are not just dealing with the equations or you are simply not the mathematicians who will sit and write the equations or solve the equations. You are engineers, you are out there, you have to solve many problems and you have to give the solutions.

For a clean atmosphere, you need some external addition, but that addition has to be to the level that it causes an effect which is not acceptable and that is what we call as the air pollution. The philosophy, that I repeat from the last class, is not to make zero pollution; the philosophy is not to make the emissions zero; we do not want to close the power plant. What we are saying is that we are not talking about the zero pollution; we are not taking about the absolutely pristine time pollution.

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We have to find out; we have to reduce the emission only to the extent that there is no noticeable adverse effect on the pollution scene. We have to determine the extent of the reduction and this is the philosophy. The engineers have to understand and establish the linkage between the source and the receptor. The linkage will, provided by the atmosphere or the meteorology that should be able to give you how much control is to be done to make the receptors safe guard. So, that is what we need to see. This will give rise to what we call - such a concentration - or air quality standards to protect the receptor. We had discussed this last time; this time, do you think there is anything else you need to discuss here?

Let us go to the next slide. With these slides, we can go a little faster. We also discussed as to what are the little challenges that we face when we talk about the air pollution control. Air pollution problem or any problem for that matter is always an inverse problem. You start with the problem, at the receptor, and try to see where the changes need to be made. It is always an inverse problem. We do not start from the source but we start from the facts and then look to do the changes in the source.

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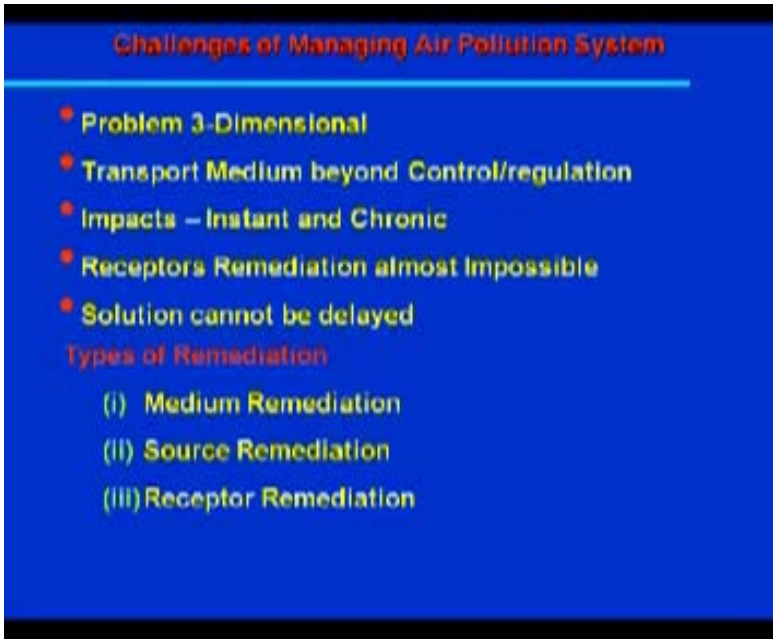

We also talked about source remediation, medium remediation and the receptor remediation. I gave you a little example of how the receptor can be remediated; the way the Taj Mahal is being protected with the plantation, and trees, and the development of the forest in that area; so the pollutant somehow escapes and does not go there.

Now we come to an important question. Having said that, we also need to say: why control the pollution? That we have specified in some sense. Then a question also may come: which pollutant we should control? So, we have to know, not only that we have to control the pollutant, but also which pollutant to control. There may be so many pollutants and sometimes we need to fix the priority as to what we can do or what we cannot do. How much? That also we have to answer; that answer will come from our inverse problem. Do we have the money to do that? Is the society ready to spend the money? What are the short-term and long-term gains? You sit down with the economist. Economists and

engineers will always fight. [Or say scientists they will fight; it is a fact] If we are economists, we will say the cost-benefit analysis; what is that you are gaining out of this and what you are spending for this one; there will always be some cost-benefit analysis. Let me tell you with my experience, between the scientists and the economists, the scientists because of their knowledge, the argument they can always win.

Can it be sustained? You can talk about high-fi technologies, but can it be sustained? Once we have a system in place there must be someone over-seeing the system, whether the system is working or not, that is very important. If you do not oversee the system, you might put in place lots of thing through the documentation and reports and they are lying just like that. This is how we handle air pollution. In this course, we will some how touch upon these points but let us go on to something more important.

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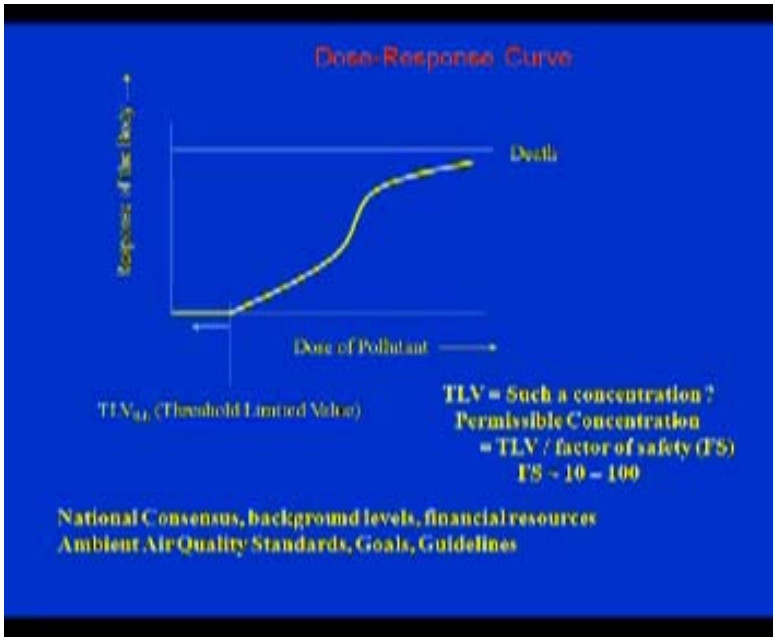

This figure is hypothetical but very important. This is little more like a hypothetical thing. Why is it so important? You see here the dose of pollutant is on one side and what it can cause in terms of the effect on the body. Whenever the body is stressed because of anything - including there is stress that you have to do well in the exams and there is a pressure for the examination - the body responds. There are a lot of chemical and biochemical reactions going on in the body and the body will first try to stabilize itself.

There is a dose of the pollutant here and you can see there is some response in the body. You keep on increasing this; the body will try to adjust as far as it can. Eventually, if you increase so much of pollution, it could lead to death also. So people have observed that there is some kind of the relationship with the response to the dose, but this also has been seen that up to certain levels the response is not seen. There could be many reasons: either the body can resist this kind of pollution level as you see here the dose, or your instruments for the measurement of the blood response may not be so sensitive. It could be possible that the body is responding but you are not able to measure it. You are not able to see it but with science getting better, many people have come out that, well, it is not quite as simple as that. With this you are not observing, many people say that, well, the effects are there and things with time as your analytical capability, as your instrumentation quality improves, people are able to say these things.

So such kind of dose that shows no effect; if we look at this dose level, these levels are called as threshold limiting value or TLV. This is called TLV. In fact, the terminology, TLV, first came from the people who were working in occupational health. The first ever effects of air pollution were seen in the occupational areas, where the people exposed to higher concentration would have the illness, which other people in the society will not have. They died early; they will suffer from cancer more frequently than the normal population and so on.

People in the toxicological group and occupational health and safety, did a study and then they came up with these numbers called TLV. They also used to write little thing here which is very important. Can you see it is written 8 dash H (Refer Slide Time: 00:17:00 min). Why do call it 8H? It is because mostly the shifts in the factory would be the eight-hour shifts. They say this is the eight-hour exposure. So time is also important.

Apart from this in the occupational area, the people in toxicology or the research people started doing lot of research and they called it… some of this research is called - epidemiology. The experts on epidemiology study and they started doing studies on rats, on other animals and also people. Some people came forward and said we are ready to be exposed to higher concentration, please examine us.

This science has been going on for last hundred years. It is important that you know that some people come forward, some of the animals studies are there. Then what the people have done is they can and go study some area that is polluted or let us say could be very clean. I was showing a picture to a class in

the morning for Delhi versus Himachal Pradesh. So some of the studies can be done and the people can largely be in a statistical sense, then what kind of responses do they have.

A lot science that has gone into that one but I am just showing you, that you get the feel, but do not forget at the back of mind, where we have to go from here, to that concentration because that is the crux of the whole problem.

Having said that, if I ask you a question…it is mostly a hypothetical pollutant that we are looking at; having given you this information, can you say something about what the concentration should be? Suppose this curve, for example, this is for sulphur dioxide. We have to establish that concentration, so that people could be exposed to this and could still be living very happily. What would that concentration be? TLV. That is what I have written here. Can there be such a concentration? That looks like reasonable answer to the problem. Having said that, do you when you design something… many of you are civil engineers, you have the bearing capacity of the soil. Do you take that as a design capacity or something else?

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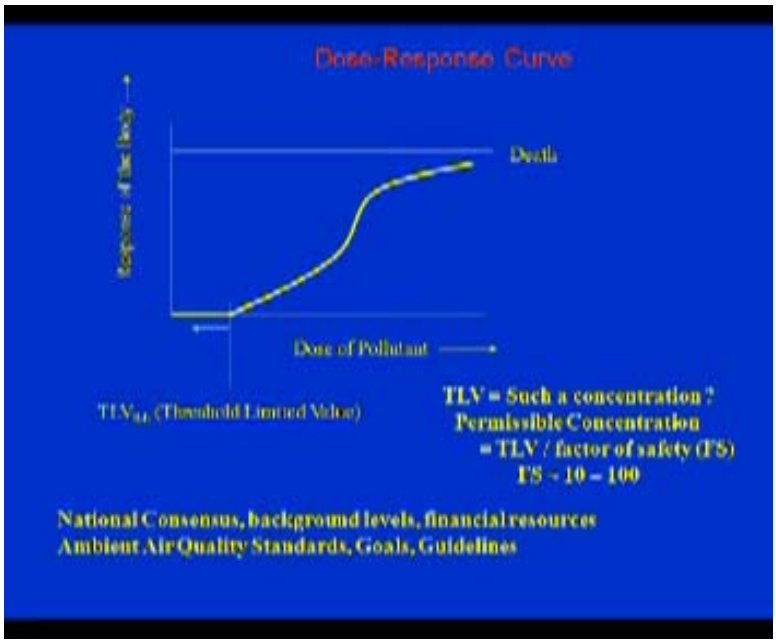

Factor of safety - that is extremely important. We know there is a problem that about to happen. We cannot start from here. As engineers, we see the capacity or strength of the material; these are the

strengths of your body. You put the factor of safety because you do not know how instruments are treated here; was the person or the animal that was tested could they be resistant to that kind of pollution? So we always provide a factor of safety. Factor of safety is in fact not a factor of safety, but it is a factor of uncertainty or a factor of ignorance. Our knowledge is poor, so we sometimes take the factor of safety. We will give it a better name; I will not say factor or ignorance but factor to account for the ignorance, let us put it this way.

When your knowledge is good, your instruments are very good, the factor of safety can be smaller; when your instruments are very crude we do not know, so let us be safe and then the factor of safety will be large. So that is something similar to that we do. Normally the TLV, which is available, we divide by some factor of safety, and is not uncommon to take the factor of safety because we are dealing with the human health, is sometimes taken in the range of 10 to 100. This how we try to define as to how we can arrive at those concentrations. Do you have any questions?

Let us move further then. Now the question comes apart from… this is fine, you know 10 and 100 but again since the standards are country specific, there should be national consensus. What do I mean by national consensus? There should be national consensus between the regulator agency, between the scientific community, between the industry because see we cannot put this some were here and then if you put this some were here, well somebody might come and argue let us take the factor of safety as 1000 and then you probably will have to close down all the industry in the country.

There has to be a solution, it may not be the perfect solution, but something which you agree upon through the various meetings, discussions, arguments, fights because the implication of this number, as I have been repeating all the time, is very important. It means a lot; it means lot to the country; it means lot to the people; so there has to be a national consensus on this. Apart from that, we should also look at what is the background concentration of the pollutants that we are considering. When we are not doing any of the human activity and background pollution level itself is very high, we cannot bring down the concentration to lower than what the background pollution is.

Let us say I go to a very clean area and measure something; of course, your health might say there may be a little trouble here but then background level itself is very high because this also leads to a planning for the pollution control.

The background level is high but we look at what are the sources of the background level. The background level could be because of some other thing happening somewhere, may be in some other country for that matter. So we have to see the background level. We have to refurnish the resources we have and then that is how we come up with the [embedded] quality standards for something which we are not very sure; we call it as goals and the guidelines, because, something we want to give as that standard; you are pretty firm about it; that this what the number is. Sometimes otherwise we give the goals and guidelines that we have discussed in the last class.

You have some idea as to how this number can be such a concentration I am trying to over emphasize again and again this is so important. We also will also see some more interesting things about making the standards. The science that develops the dose response is called the criteria; it is the basis is the knowledge. So always, remember that the criteria are not the standards. Criteria is the knowledge, criteria is the basis on which standards are built. Sometimes there is a lot of confusion between criteria and standards. So, you might see something more here. So this criteria is basically to develop the dose response. The dose response needs to [be developed] to the general people too, to the sensitive population; we want to save or safe guard our children, our infants, our elderly people also. So, you have to look at which is the sensitive population and derive from there your standards.

This knowledge of the dose effect or the cause effect or the causal relationship, if you like, that all depends on the science and the criteria that is to be developed. So a lot of people work on this area, then there are the publications. Then your when you are fixing on standard, you should look for all the science that has been that developed. What I will do is this; this is a very important slide; I borrowed it from the net from someone.

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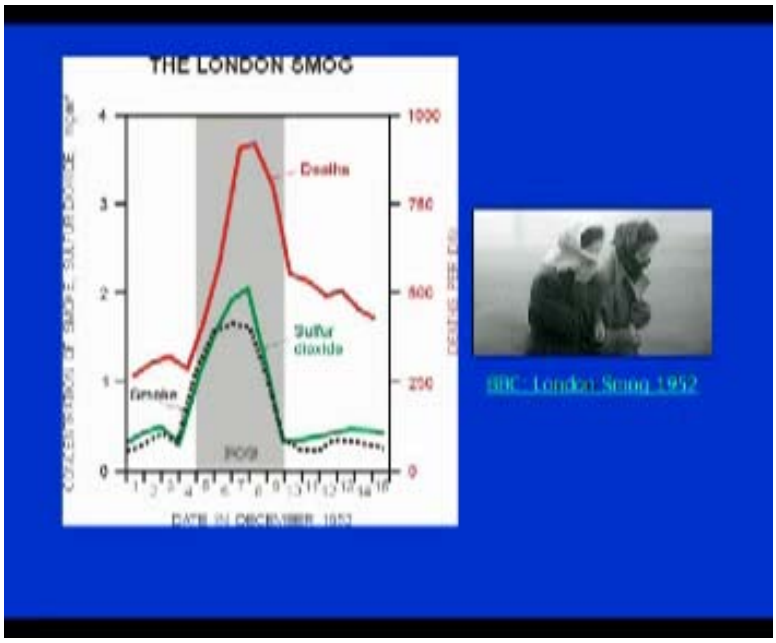

This episode happened in 1952 and that kind of you know caused a lot of these things and sometimes until lot of data that became available, people were using this as the dose response or the criteria. In 1952, the episode was the London smog. There are a lot of things that one can talk about: as to how it happened? Why it happened? And so on. As you can see from this picture is from the BBC.

You see here this side gives you the concentration of the smoke and the sulphur dioxide in terms of milligram per meter cube. This concentration is very high. What happened was because of some metrological condition, and no wind. Normally the level of this, you see here dash line (Refer Slide Time: 00:26:10 min), this is the smoke. Smoke levels are normally around 200 microgram per meter cube. This is 1 milligram, that is 1000 micrograms. So, some level around 200 micrograms. It was almost like normal life was going on. Somehow, due to some reason, the pollution started increasing. You can see here (Refer Slide Time: 00:26:39 min), this was the smoke and we have to see SO_2 levels, that was, increasing. They had some of the measurements and some of the measurements were reconstructed. This is the fact, as to suddenly when a number of deaths, which you see on this side about 250 per day, which were normal, shot up due to high pollution level.

Death is a serious thing. We cannot even protect the people even from the ill effects in terms of the hospital admission, in terms of the feeling uncomfortable and that sort of thing, having sore throat as

you walk through the city and so on. Death is a serious thing; it is not a joke. What you see here, is that the level is going up and then as the pollution started receding, things tend to be become normal but it takes a while before things become normal. This was one of the major incidents. People started talking about lot of air pollution control after this and some of the people even used to take this as the initial dose response path. The moment the level is slightly going up in terms of 300 or 400, look there could be rise in death or mortality, even in one day's exposure. We are not talking about long-term exposure.

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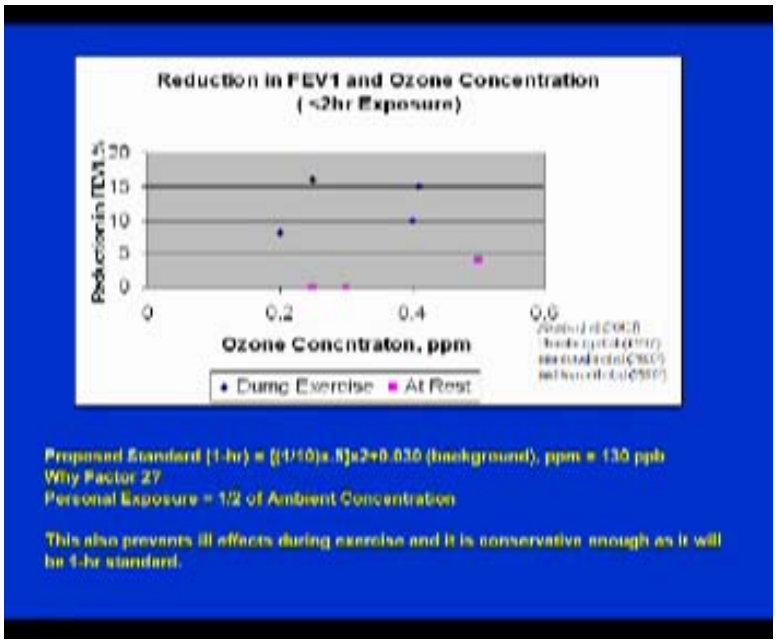

Now science has changed enormously; somehow that science that is available to us now, that we will see now. This is the data we collected from literature. What we see here is the response; do not worry if you do not understand this FEV_1. This $FEV_{1,}$ let me explain FEV_1: it is forced expiratory volume one, that is in one second. This is one thing which shows about healthy people, you should have certain amount of volume, you should able to exhale out with the huge intensity.

If you are not able to exhale, it means that your lungs are not that strong. We will discuss it later on when we talk about the health effects. Here we are talking about the reduction. Here this is the ozone concentration. Look at these dots here (Refer Slide Time: 00:28:53 min), ozone concentration is 0.2, 0.3 or 0.5. You see it begins to show in terms of the lung function parameter because there were reductions. The same thing with people who are just like sitting in hall but people if they are doing some exercise,

see here even at lower levels like 0.2, the effects can be seen, even this one. So below this of course the measurement was not there so we do not know. One may construct a graph like this.

We not only want to save the people at rest but we also want to save the people during exercise. In fact, the air pollution forecasting just tell to the people that the pollutions are going to be high and not a very good idea for elderly people go outside and do the exercise, because these are the effects. I am just giving you an example. This not quite the way you do the standard. What is interesting here is that the exposure period is also very important. Just in two hours, you can see the effects. So you propose the standard, you can do one-tenth of the 0.5. This is the for this people one-tenth of the .5. That is the factor of safety. This 2 was taken because there is a difference between the emend air and the exposures, because exposures can be sometimes…these are based on the actual exposures but the concentration sometimes is not equivalent to the exposure. Exposure can be less because you are all the time moving, you are not all the time in the polluted area, so sometime you go to clean area, you go to the city you are polluted and come back.

Here you see… where are we? Here, so then it can be factor too. This could be the background concentration that we cannot do anything about. This is what it is in terms of the ppm and then pvv it could be [ ] standard can be 130 pm, just giving the idea, these standards are not fixed the way we are talking.

We have to generate the science, knowledge and argument but there are many levels of discussion that goes on. I want to just give you the feel, just not talk about the equation. You should understand what all goes behind making the decisions as well.

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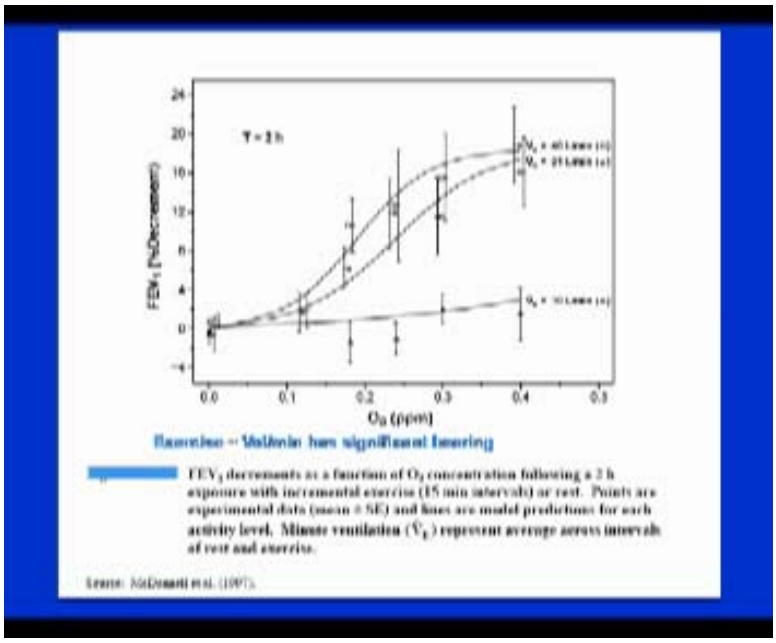

Let us see, apart from this, this is another picture. Here, again, we are staying with the ozone, FEV_1 decrement or reduction, you see here, this is the called the volume per minute. This is the normal volume which you and me will take; this is what we found. What we found was that when the people are at the rest, sitting comfortably, not so much effect is seen here, even with the higher concentration. But the people, if they are doing exercise… when you do the exercise what do you do? You exhale, you inhale more air and volume is much more. What you see with this picture, here is that 40 liters per minute, you are doing exercise 31 liters per minute.

Here you see the effect is very pronounced, the change percentage, change of 16% is really causing problem to the persons. So when we design the standards, we not only design the standards for these people, but also for these people (Refer Slide Time: 00:32:34). You have to look for the sensitive population. So that is what it is. This is the source and lot of work there, so you see the differences here. Again, it just tells you that there is a effect depending on what levels you have; in fact, slightly drifting but that is okay.

Looking at one study the Chinese are trying to do because they are going to have the Olympics. They are looking at: what could be the pollution levels, what could be the pollution levels in Beijing or where ever there are going to have the games, can it affect the athletes performance? Yes, a very important

point; a person is working in for 4 years, 10 years, all the entire life to do very well in some international event. If the place where he is, because of the environmental problem, he is not able to perform to the level he is capable of, I think we have deprived him of his hard work, the results of his hard work; so these things also play a role. The implication of these things is very huge. What I am trying to say again here is that you try to cover the people other than the normal people. See here, again this for the short-term exposure, 15 minutes interval, 2 hours (Refer Slide Time: 00:33:54 min). So just in 2 hours sometimes, you can have the effect.

Another picture again from the ozone. I am just focusing on the ozone; similar things are done for the other things also.

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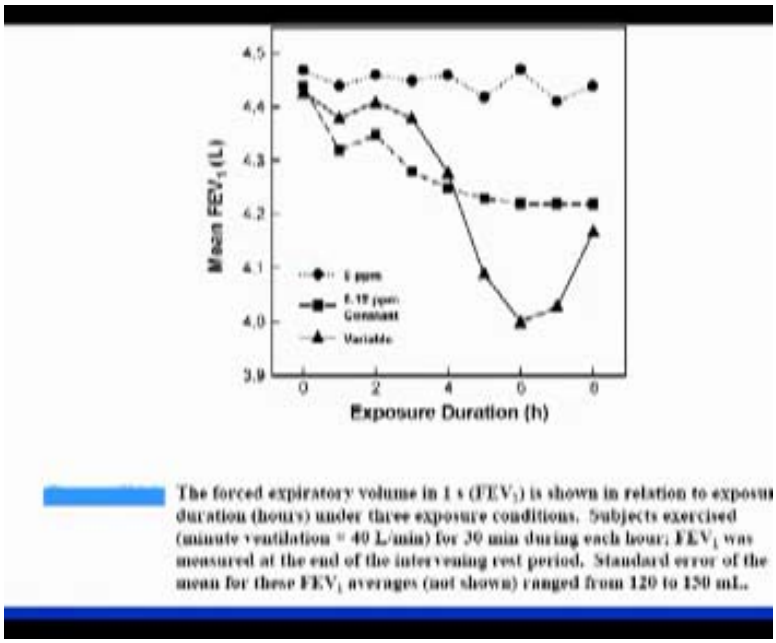

The forced expiratory volume in 1 s (FEV_1) is shown in relation to exposure duration (hours) under three exposure conditions. Subjects exercised (minute ventilation = 40 L/min) for 30 min during each hour; FEV_1 was measured at the end of the intervening rest period. Standard error of the mean for these FEV_1 averages (not shown) ranged from 120 to 150 mL.

Here you see again mean FEV_1 value. I am not talking about the reduction, but I am talking about real value in terms of the volume you see in the liters. Not only that exposure was there, suppose you continue to expose that person for a longer duration; short-term we have seen the changes. Suppose the person is exposed for a longer time what happens? This person is exposed to the 0 concentration, no change; it means his lung function is normal. Look at this person, he is being exposed for a longer period, his lung function is decreasing (Refer Slide Time: 00:34:49 min). The other curve was reverse of this one. Earlier we were talking about the reduction; here we are talking about the FEV_1.

Look at this person, the concentration are variable though here, that has decreased very sharply. Then he tried to start some kind of equilibrium. Then maybe we see a slight improvement because the body also adjusts itself; in a constantly polluted environment, the body adjusts. Why I am showing you this graph is while there is an effect for the shorter exposure, can you see there is an effect with longer exposure also. I showed you graph with 2 hour or 1 hour; here the impact is seen even if the person is exposed to 6 hours. After 6 hours, probably it stabilizes; so when it comes to making the standard, so what the time has to do with the standard. You tell me.

There should be a standard for shorter duration and there has to be a standard for longer duration because this person can be affected when he is exposed constantly. So the averaging time for the standard can be shorter depending on the pollutant that we are talking about or it should be standard.

So the averaging time… here the averaging time will be little lower and the concentration will lower as you have this thing. So many times, for many of the pollutants, we do not have the standard just for one averaging time but we have for many averaging times.

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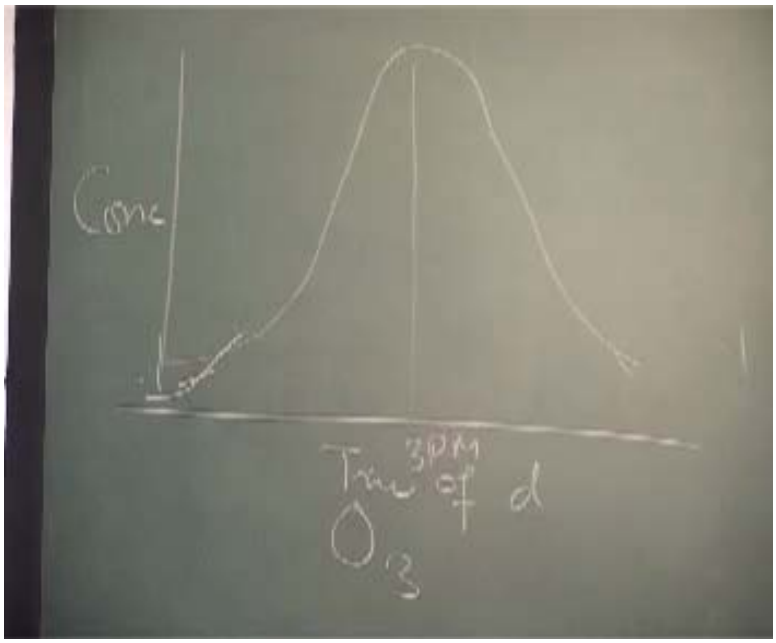

Why I am saying is if I show you the ozone concentration and this the time of day, and this is like say 3.00 p.m; if you look at the profile of ozone, you will learn that but that just for the time being see; this is the concentration it becomes, it varies something like this.

If I give a standard of 24 hours, the average of 24 hours it almost like 0 because this is the peak for a certain period but the point I am trying to make is, the person, if you give the standard for the 24 hours average; 24 hour average will be actual concentration observed; it will be very low and everything will be fine. Healthy people are enjoying healthy life but damage is done just for the short period of peak concentration. As we have seen that, the ozone can effect even at the shorter period. So it is erroneous, it is a mistake, it is an error on your part if you make a standard which is averaging time, for this particular pollutant I am talking about for 24 hours. If you do not have the knowledge, you have made a terrible mistake. What I am trying to say here is, when you talk about the standard, you are trying to fix the standard. I told you how the standard is fixed, very important thing is the exposure time or in normal terms we call the averaging time. Specify the averaging time depending on what pollutant that you are talking about. There were more studies again staying with ozone, I just took ozone as an example.

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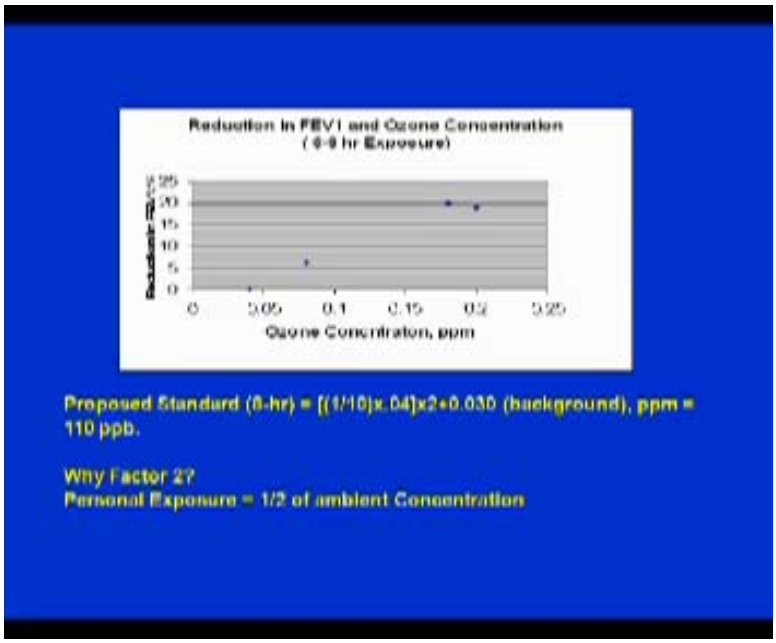

You see here for a longer duration, so longer duration has no effect but as pollution level increases, it does. So you can propose the standard even for 8 hours. So both the standards are important; 1 hour as

well, as the 8 hour. 0.04 is the level where you are going to have the effect, 0.04 decibel, this is the beginning point. Take one-tenth exposure and the background, and then you can change the volume. So you can say 8 hours standard should be 110. So which standard will be lower 8 hour standard or the 1 hour standard?

8 hour standard will be lower because the exposure time is more, so the averaging time is more, so the level here is suppose you have to fix here, 8 hour average, 8 hour factor, 8 hour concentration can be fixed at here (Refer Slide Time: 00:39:11). But for 1 hour, I probably will fix this standard here. So it is important to understand how we deal with the problem.

If there are no questions, let us go further. Now the same thing, but now I am talking about the particulate matters.

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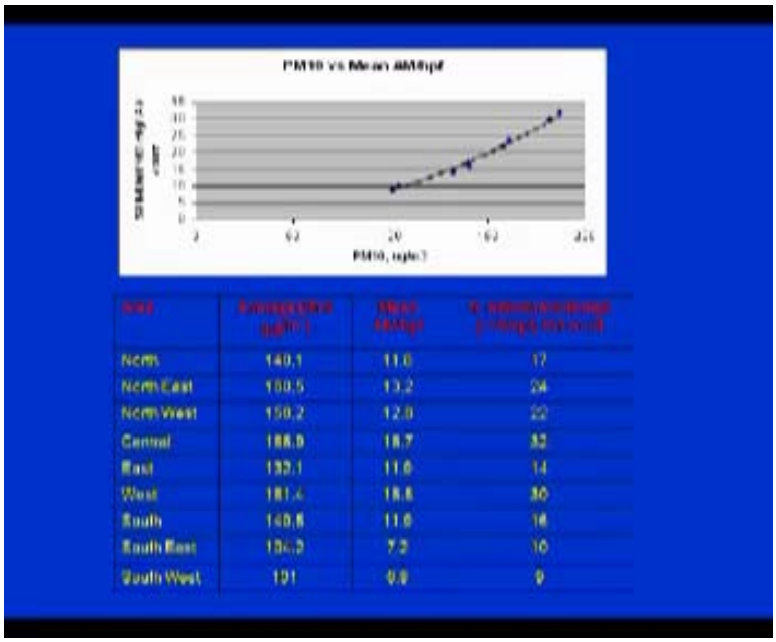

What we see here is the particulate matter PM_{10}. We will define the PM_{10} at some stage but what you can understand from PM_{10} is particles of size less than 10 microns.

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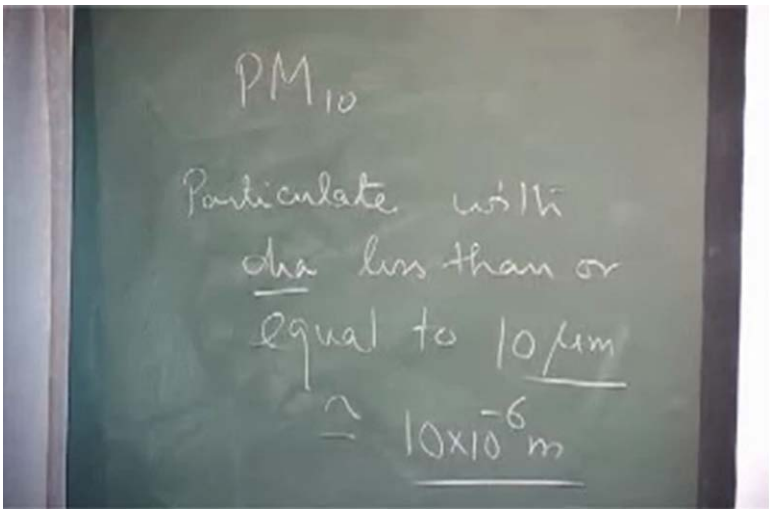

Let us write this. We will discuss this a great deal in this course PM_{10}; this means particulate matter or particulate with diameter, this diameter is a special diameter that we will define later, less than or equal to 10 micron meter. Let us, just to give a little feel of that what kind of tiny particles we are talking about, the particles are smaller than this just to give a little feel, the diameter of the hair, one single hair of course, is about 50 micron. We are really talking about very small particles, just to give a physical feel of how big or small 10 micron really is.

There has been a study, an Indian study in fact, done by Chittaranjan National Cancer Research Institute. They did in some part of Delhi that the measurement part of the particulate matter, as you see here in different ranges (Refer Slide Time: 00:41:25 min) and then you say mean AM. AM is a measure of a body response called alular macro phases. If you cannot remember this name, that is fine - alular macro phases. What happens is the body response, the moment the body is attacked by the external thing, so the body thinks this is the bacteria that has come, so it kind of produces some kind of another body which angles this bacteria and kills them there. If you add more polluted the particles the body does not know whether this is bacteria or particles, it just produces more of macro phases and then it tries to engulf those things and then they think that the body can destroy that one.

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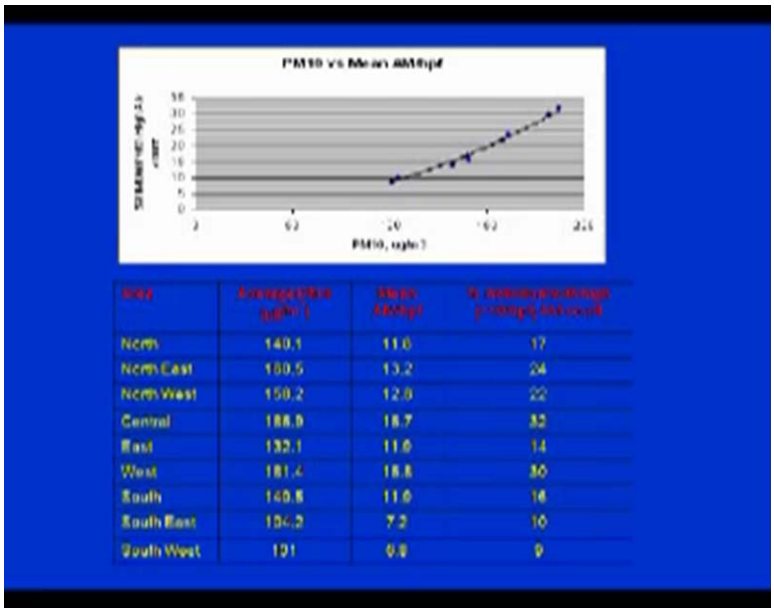

You see here, in the area where the pollution levels are high, the body responses in terms of the number of macro phases this is the for ((hphs)) more for magnifying terms. You see here if the pollution level is high, it should be high. If the pollution level is low, the macro phases is… body is happily sitting, it does not need to do anything but the moment the pollution level changes, body is responding. This kind of plot can be made and you see that what levels you want to fix to the people, so that you can, something close to 100 or so we can fix because after that you know like these is a kind of background level. You see with this knowledge that we should use and try to fix a standard.

Again, we are defining the criteria. Criteria are complete knowledge about those response-relationships for the pollutants. It is just not only what happens is the various doses, depending upon on the time concentration depending on the averaging time, depending on the exposure time and it also accounts for the people who might be at the larger distress, it can be the children, the infant, the elderly people, the adult people; so this is the complete knowledge. This is what we use to develop the science or the standards and the standards are legally binding concentration in the country right from the criteria.

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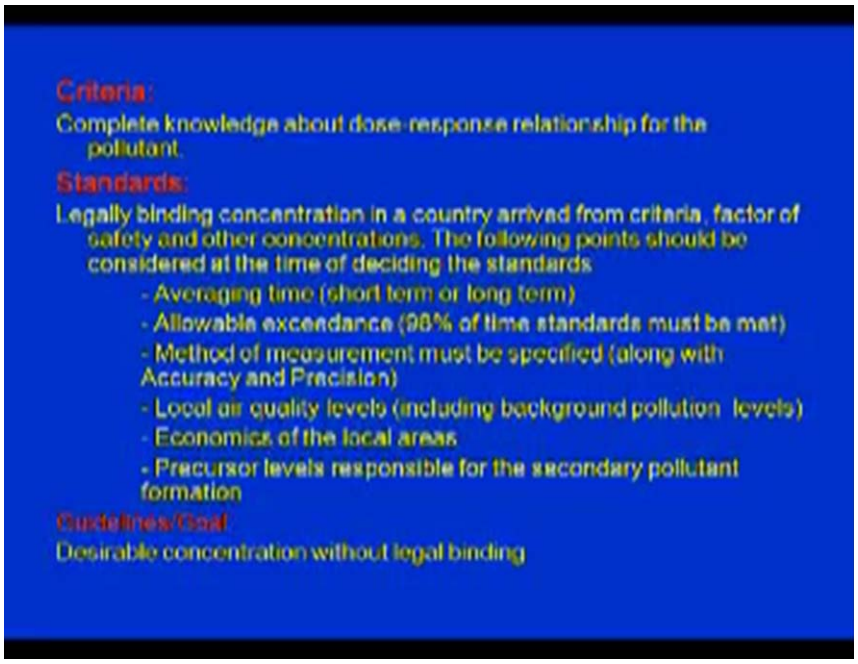

So that is the basis, that is the knowledge and that is the science. Standard is a more subjective thing which we all sit down and try to figure it out what should be a standard. Factor of safety and the other concentration the following point should be considered at the time of deciding the standards. This is very important.

Averaging time is very important. I have given you a little feel of how the averaging time is important. We cannot say that well that is a deadline, it should never exceed. Sometimes things are beyond your control, so some accidents you should allow. For example, it could be 98 percentile; it could be 95 percentile and things like that. It should be specified; it should be mentioned. You should also specify the method as to how you will do, because different methods can have different precision and accuracy. They might give you different accuracy. So you should also specify because we are talking law here, and law is not kind of fuzzy. You know that is something very clear and lucent; so here say you that the measurement is specified along with accuracy and precision.

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Local air quantity levels should be considered as to what are local or background levels, as we done in the past; economics of the local area it is very important. So some times the standard, you may have the national standard, but local area standards can again change. We are only making it as we want the people to be and it is a trade-off. You may say well I do not care whether the industries is there or not, I want a better environment, cleaner environment and if the society agrees on that, who stops you.

So these are the consideration that should go in. This is something which we will discuss later on, but you see here, many of the pollutants are changed through the chemical transformation they become while they are emitting they are something else; while they are come out in the atmosphere, undergo some chemical reactions, transformation and they change. If they are changing, so that changed thing can be another pollutant and the standard for the pollutant will decide as to what the standard for the other pollutants are. From the parent compounds, we will see that later that on. Then we are have the guidelines, that is, a desirable level or we do not want to put the legalistic term, so we say our goals are that sort of thing. This process what people have done is for better management of air pollution, certain pollutants are called as criteria pollutants.

Criteria pollutants are those pollutants for which are very common pollutants found in the atmosphere and for which criteria have been developed fully. More or less we know what happens and how it has

happens. Also, the criteria pollutants generally show a threshold. Most of the criteria pollutants, as you see… dose, response, they will show some kind of threshold before picking up.

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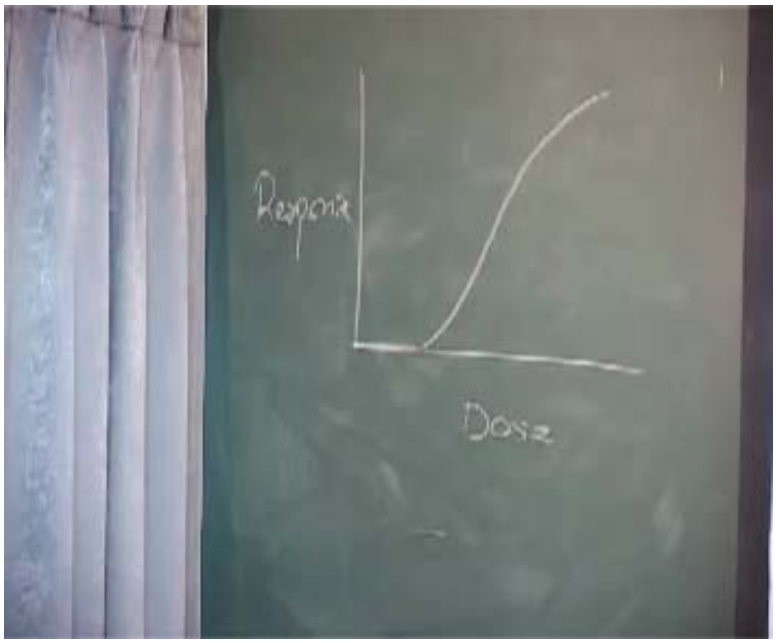

Many of the compounds and many of the pollutants do not even show any dose. So, when you look into any air pollution, suddenly you will find criteria pollutants and non-criteria pollutants. So these are the pollutants for which the criteria are available and fully developed industry; omnipresent, therefore, they pose the greatest over all threat to the human health.

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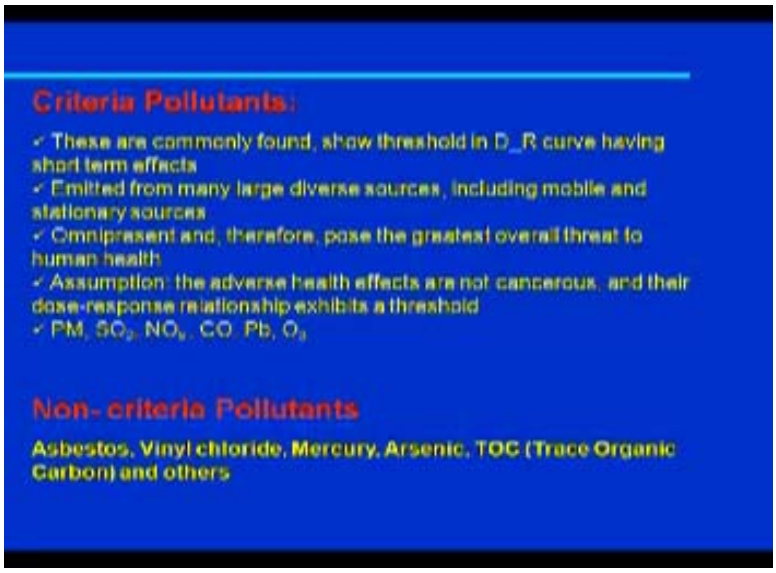

For example, supposing I want to fix something for some standard, for some compound, which likely to be never in the atmosphere, what is use of putting so much of efforts and energy? But particulate matter you will always find dust in the atmosphere, sulphur dioxide will always there, so will NO_X. NO_X is defined as NO_X. I shall define NO_X now.

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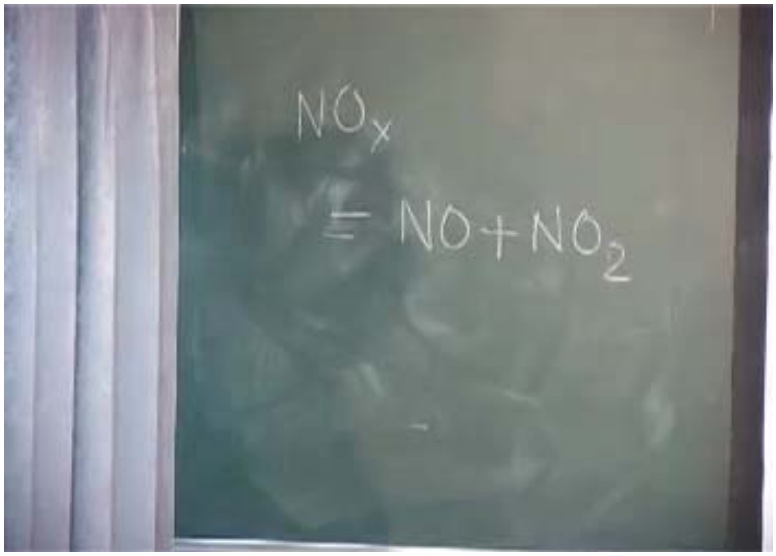

NO_X is a general terminology; this is a simply a linear sum of NO plus NO_2. This is what we call as NO_X and it includes carbon monoxide, lead and ozone.

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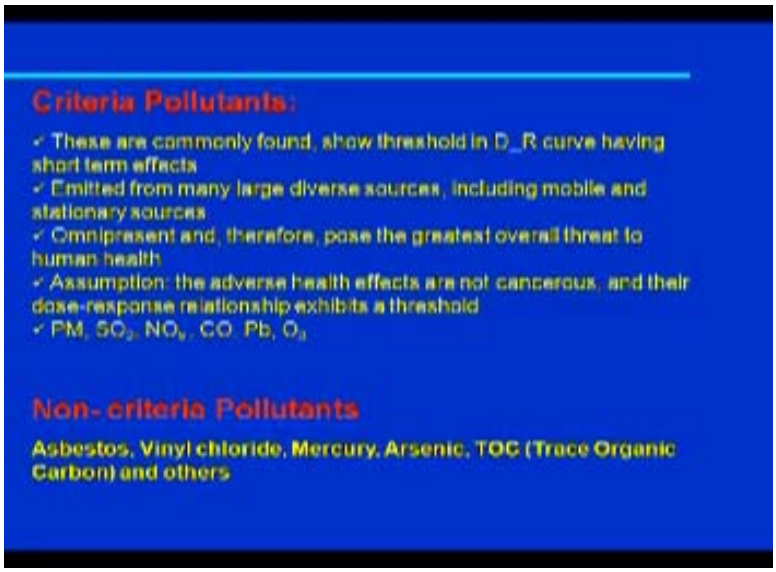

There are many non-criteria pollutants in this list because rest all will be always non-criteria pollutants. They could be asbestos, they could be vinyl chloride, mercury, arsenic, TOC which should be read as trace organic compound not like carbon and others for which we can fix guidelines, we can have the program to reduce them, but these are thing which are so much there, they need a very special standard.

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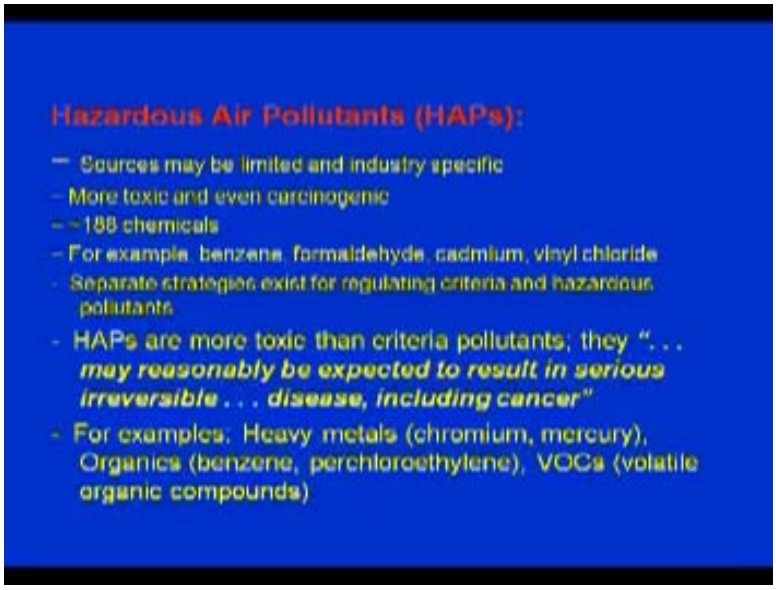

Another category is called HAPs about hazardous air pollutants. Their sources may be limited in the center certain area. You go to a refinery and then you can find a lot organic compounds. They are more toxic and carcinogenic; about 188 such chemicals have been identified. To give an example, benzene, formaldehyde, cadmium. HAPs are more toxic than the criteria pollutants because they may reasonably be expected to result in serious irreversible damages, including cancers. Heavy metals like chromium, mercury, benzene are the VOCs or volatile organic compounds.

For these, we may not have standards, we may have goals, we may have guidelines or we may simply have the plans to reduce their emission. Now this topic is becoming is very hot because criteria pollutants, people understand, and if not in our country, but in most of the countries criteria pollutants have been controlled well below the concentration, that we are trying to arrive at.

Lot of efforts are now put on the reduction and understanding the HAPs because we all are somehow dealing with this one. I will give you a little feel of how various countries can react to the problem differently; we are talking about NO_2.

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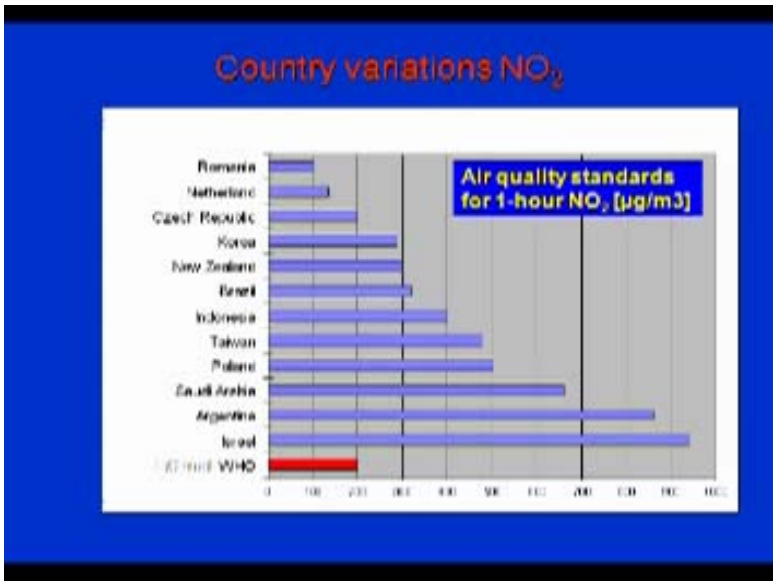

You see here Israel, Poland, Saudi Arabia, Argentina and WHO. We cannot call it WHO standard but is a recommended true value. Sometimes you see many countries may have the standard but they may not very aggressively implement those. What I am trying to say is it is very much a state subject. So what levels you want to fix. Then you see, what is important is always specify the averaging time, otherwise the standard without averaging time, it has no value. This OPM time you see here, the WHO in 1987 recommended this. I do not know why these people have very high standard.

We have the Indian standard OPM time, 24 hours, the Indian standard is 100. So somewhere here is this Indian standard but this is under revision right now and probably will change. All the countries will keep revising these numbers because more and more knowledge, more and more science is available, so you try to improve upon the standards.

This is what the national standard in India is as of now, that may change. I will give you 1 minute at least to see … and are these standards fulfilling at least the description part. Forget about how the numbers have been arrived upon… but the way these standards… because these are legal things.

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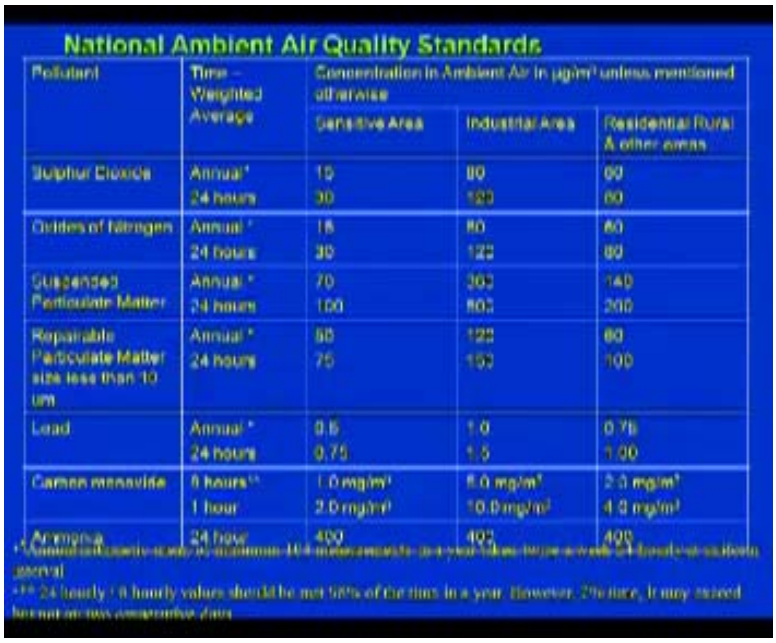

Here in India have the three areas. There are three standards for three areas: very sensitive area, the industrial area and the residential area. Sensitive area can be very special national park or ecological park or something very special which you want to protect, for example, Taj Mahal, you want to protect so that can become a sensitive area. In the Western Ghats and Eastern Ghats you have very fragile ecology; so that can be sensitive area, but the government declared as notified that area. You have a pollutant here, the averaging time, so important to specify the averaging time and then put the levels where are the units and the one-dimensional units here. There is the summation.

((that is the summation can give)) a micro amphometer give the summation otherwise .

You have standard for suspended particulate matter, you have finer particles, you have the lead and then you see when it comes for the average standard, the levels are lower or higher. Then you have the carbon monoxide. Carbon monoxide concentrations are still very stringent; it has a very stringent standard. You have ammonia which is again followed by the micro amphometer. This is for what higher and then it will go and specify what sample will constitute as an annual sample? So you cannot say I have taken the 20 measurement sir, this is my annual standard, it is exceeding it.

We are talking law, we are talking legal terms and arithmetic mean or minimum, 104 measurements in a year. Not the measurements you have taken in January, February, March but in a year taken twice a week, 24 hourly, at a uniform rule, you can do more than this; that is no problem. But then we have to be very clear that 24 hourly, 8 hourly should be met 98% of the time. 2% it may exceed but again there is a rider on that exceed but not on 2 consecutive days. So that you know, people demand that compliance with these numbers and the industry when they do the planning and still they will restrict their emissions, so that these levels are still attained. There is a lot of meaning are attached to these numbers; therefore a lot of energy goes into fixing these numbers; simply, it is not ordinary thing, sit down across the table, let me write some numbers. It does not happen that way.

This is the last slide.

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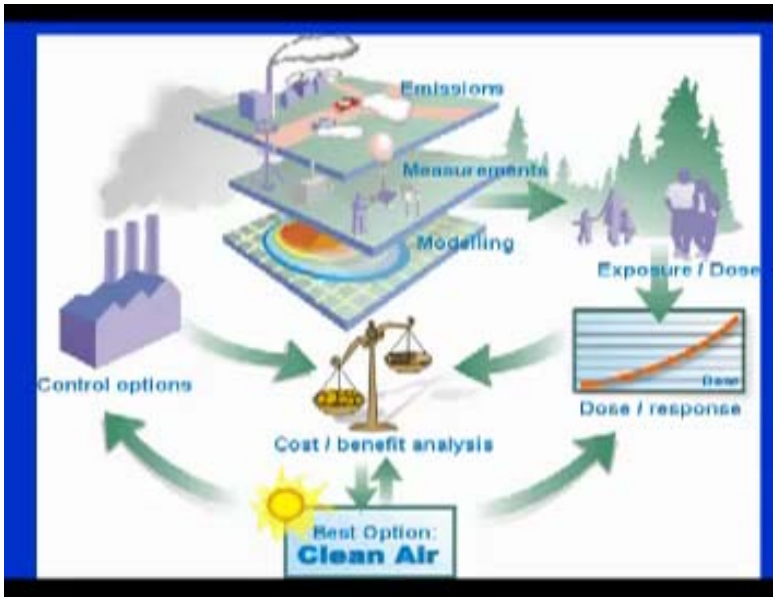

Summary of everything; before we get in to the more technical stuff in the slide. Let us see the system. There are the emissions; you can have many emissions. So when you are trying to manage air quality you have to understand I am doing on GIS, and there can be map overlay of the emissions.

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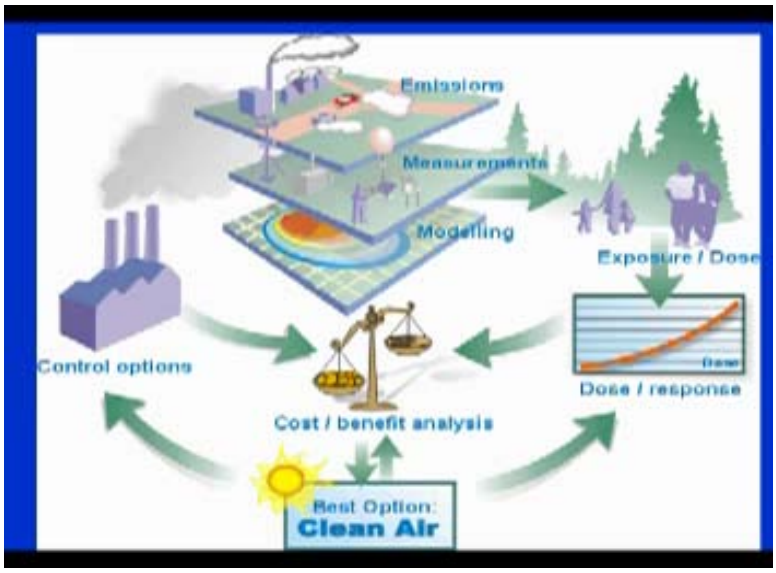

What will happen to emissions? It will be transported. So I must have metrological measurements. Most have the metrological measurements are here, you see the metrological measurement is the wind speed, wind directions and rainfall. Then you do this interconnectivity between these things to be able to say what will be the exposure. This is the exposure to people, plant, children; exposure not only in terms, you can do some measurements as well, you can model, because if you know the science so well, you can model and then look at what is happening in terms of dose response they way I did it.

There might be some effect or there might not be some effect, then you do like what economists do. Do some kind of cost-benefit analysis, if I reduce from here to here, what I will gain in the health improvement and how much of money I need to spend. We do some kind of cost-benefit analysis and come up with the best clean air options or strategies or plan whatever you like to call. Then you go on to the industry or to the pollutant. This is what we have come up with, you bring down your emissions, this, that or even you can tell the people to change your habits. This is what to you need to do. All looks very good hypothetically but when we implement this one on that field there are lots of challenges; especially in a country like ours where the lots of poor people are there and some decisions can effect poor people more than the rich people. Sometimes we have to take care of that, bearing in mind that in the process you might make them suffer or lose their livelihoods and things like that. This is the general approach and in the next class we will talk about more engineering. So I will stop here. Thank you.