Environmental Air Pollution

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Lecture No. 38
Receptor Source Modeling

Today, we will learn a new technique for the apportionment of the sources. It is often a matter interest to know where the pollution is coming from.

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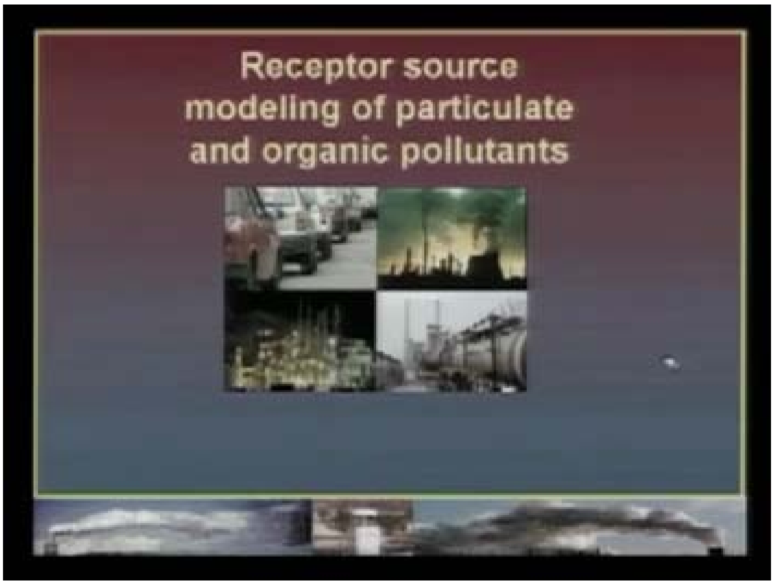

Receptor source modeling of particulate and organic pollutants

You might be staying at one location – in a residential area and you would like to know how much is the contribution from the petrol vehicles, how much is the contribution of diesel vehicles, how much is the contribution of let us say there is a power plant close by, so you would like to know about these sources and once you know about these sources, you can certainly control those sources. There are many techniques to find out the contribution of various air-polluting sources to the ambient air that people breathe. This contribution of these sources will be variable depending on what location the person is in or in what location is the measurements are being done. One of the techniques is called receptor source modeling and it can be used for particulate matter, it can be also be used for organic pollutants to clearly say what are the sources and how much is their contribution.

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Apportioning the contributions to monitored Ambient Levels of pollutants among various sources

If we move to the first slide, in terms of what you are seeing here in the circle in the middle, suppose you are doing some measurement, this is the instrument that measures the particulate pollution and this instrument is measuring. We want to see how much is the contribution let us say from the cars at this location, how much it the contribution from let us say this is a this is a refinery, for example, let us say this is some power plant and this some iron and steel industry, iron and steel industry. Now, what ideally we want to know, and if we can, is the apportioning of the contribution to the monitoring ambient air levels of pollutants among the various sources.

This is just a picture; we want to understand what is the contribution of the various sources at the place where I am doing the measurements. Once I know which source is contributing and how much it is contributing, it is up to me to decide the pollution control strategies and to prepare the pollution control plan. But how do we accomplish this and how do we know what is the contribution from the various sources? This technique we will learn.

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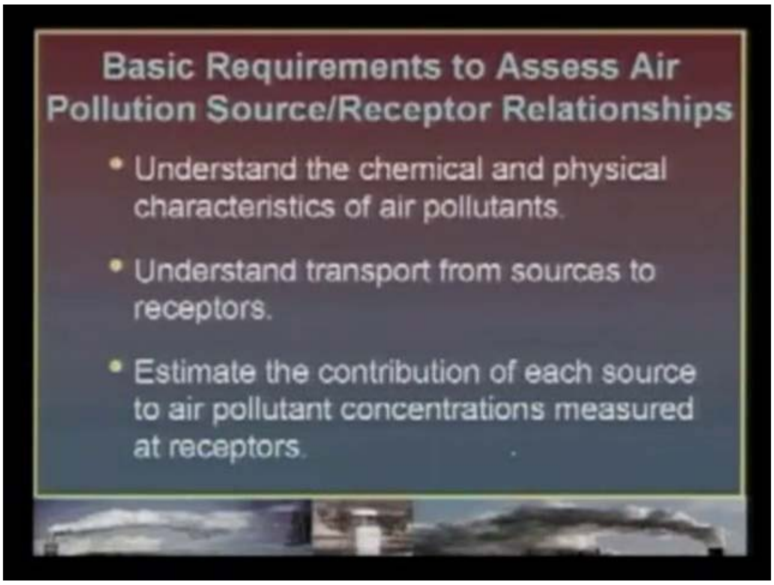

Basic Requirements to Assess Air Pollution Source/Receptor Relationships

- Understand the chemical and physical characteristics of air pollutants.
- Understand transport from sources to receptors.
- Estimate the contribution of each source to air pollutant concentrations measured at receptors.

One of the techniques you already know is using the dispersion modeling but we here will talk about a little different kind of modeling. The basic requirements to assess the air pollution sources and receptor relationship, we want to know the linkage between the receptor and the source. What is the receptor? It is the place where we are doing the measurements or the place of interest where we want to maintain certain levels of air quality. The receptor can be a residential colony, it can be the people, it can be let us say an ecological park where you want to control the air quality for a particular reason, it can be very important buildings like the Taj Mahal where you want to control certain air quality. But in order to control, in order to plan, in order to prevent pollution, you want to know how much is the pollution that is coming from the different sources.

Essentially, what we are looking at is to develop and understand the linkage between the source and the receptor impacts. As you see in the slide now, we want to understand the chemical and physical characteristics of the air pollutants, understand the transport from source to receptor – how it is transporting and finally estimate the contribution of each source of air pollution concentration measured at the receptor. If we can answer the key question, that is, again I repeat: contribution of each source to air pollution concentration measured at the receptor, if I know this, I think I have got very good information and I can plan and design my air pollution control systems.

To further elaborate on what I said, suppose you know the sources and you know the source contribution to the ambient air quality, then it can immensely help pollution control planning.

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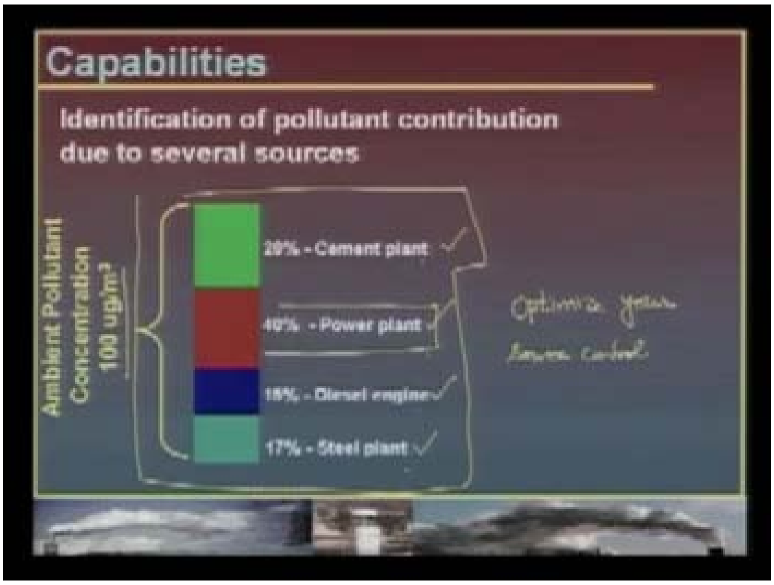

Capabilities

Identification of pollutant contribution due to several sources

This is what ideally you would like to know. For example, ambient air concentration was 100 microgram per meter cube at a particular location where you did the measurements. If you can clearly say out of this 100 how much came from the cement plant that was in your vicinity, how much came from the power plant, how much came from diesel engines and how much came from steel plant let us say. This is very good information if we can get such information. Obviously, one can quickly say that if I want to maintain a better quality than 100 micrograms, then if I control the sources from the power plant, that will significantly improve my air quality but you can also come to know, you can even optimize your source control – you can tag a cost function for the pollution control at the cement industry, for the power plant, for the diesel engine and steel plant and optimize that cost function so that you improve the air quality at the minimum cost. But the question remains as to…. This nice-looking picture with source contributions clearly specifies how to obtain such figures – we will objectively try to answer this question in this lecture. The idea here is once we know, then we can back calculate the impacts due to specific sources.

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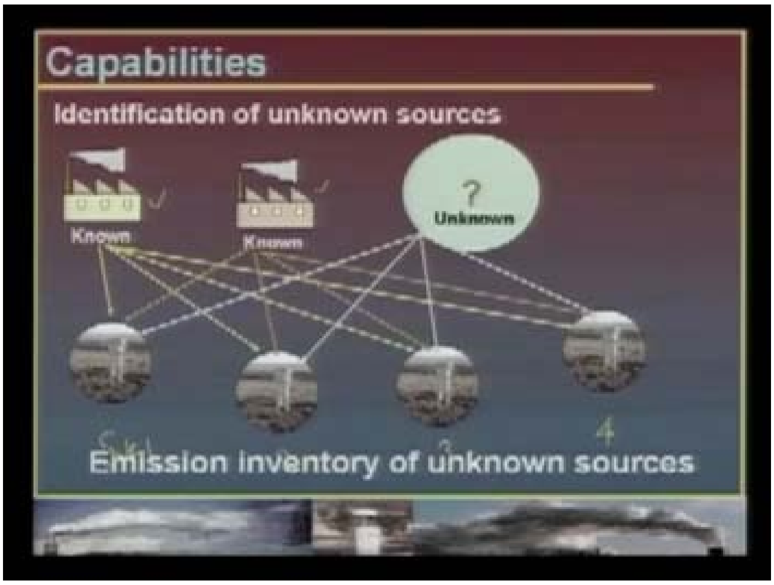

Capabilities

Identification of unknown sources

Emission inventory of unknown sources

Again, a similar thing happens if you are doing the measurement, let us say, at various locations. Let us say this is site 1, this is 2, this is 3 and this is 4. You may also be knowing your source in the area – one or two, but there may be sources not known to you. What happens when we are doing the measurements? All sources in some form contribute, so essentially we would like to know sometimes how much is the contribution of these sources at the locations where I am doing the measurements as well as any unknown source we have no information about. You can also, at least up to a certain degree of confidence, find out with the help of the receptor modeling that we are going to discuss even for the missing or unknown sources and we will see how this is done.

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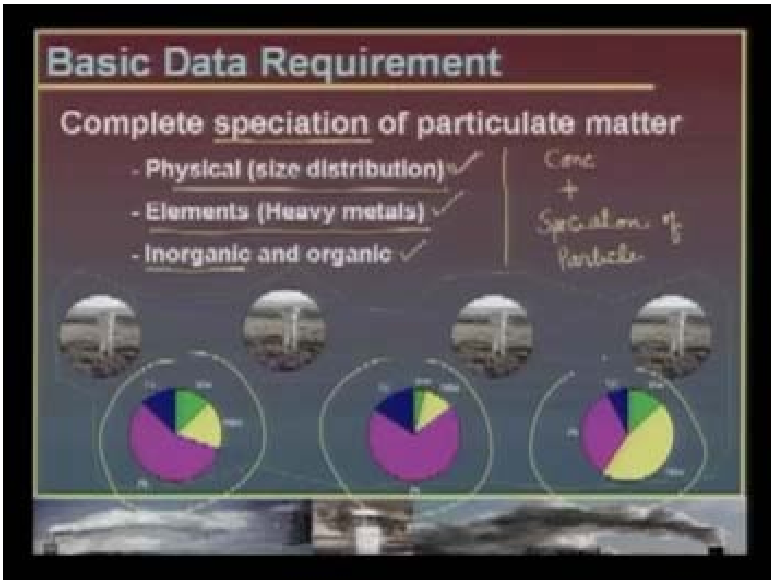

Basic Data Requirement

Complete speciation of particulate matter

- Physical (size distribution) ✓
- Elements (Heavy metals) ✓
- Inorganic and organic ✓

Conc
+
Speciation of
Particle

The basic data requirement is what we need to have in order for us to do such a modeling exercise. If you know these information as you can see here, all of them or some of them could be very useful and we call that as speciation – it means what are the different components of the particle, what is inside the particle in terms of its chemical composition or particle size distribution for the particles that we have sampled. This might be very good information because most of the particles you are getting may be very fine; you also know the soil that contributes particles that are larger in size – if most of the particles you are getting are smaller, it means you can be almost certain that this pollution is largely not from soil but it is from somewhere else; suppose you have lots of diesel vehicles in your area, then diesel vehicles will contribute very fine particles and then based simply on the particle size distribution, one can, if not fully, to a certain extent say what are those sources that are contributing.

Additional information in terms of the elemental composition of particulate matter is also a great advantage – we will see how this will become to our advantage as we proceed, but this information is required and also other inorganic information of this speciation – for example, what are the nitrate contents, what are the sulfate contents in addition to elements like heavy metals, so you also need to have information on the inorganics like sulfate, nitrate – that will be very helpful and even the organic components – whether aromatic hydrocarbons are there and within the aromatic hydrocarbons, what are the difference species of the hydrocarbon that are present in the atmosphere in the particle.

So in order for us to be able to do the receptor modeling, we just do not need the concentration but we also need speciation of the particles in what form? Possibly size distribution, elemental composition, additional inorganic and organic composition. If you have this additional information, then we might be able to say (of course, we have to learn has to as to how we can say that) what will be the contribution of various sources. Finally what we want to look at the end of the day is at some picture that looks something like this – this is the information we need to collect from the site and utilize this information for our source contribution or source apportionment. If more and more information is available, that is all the more better as you can see here.

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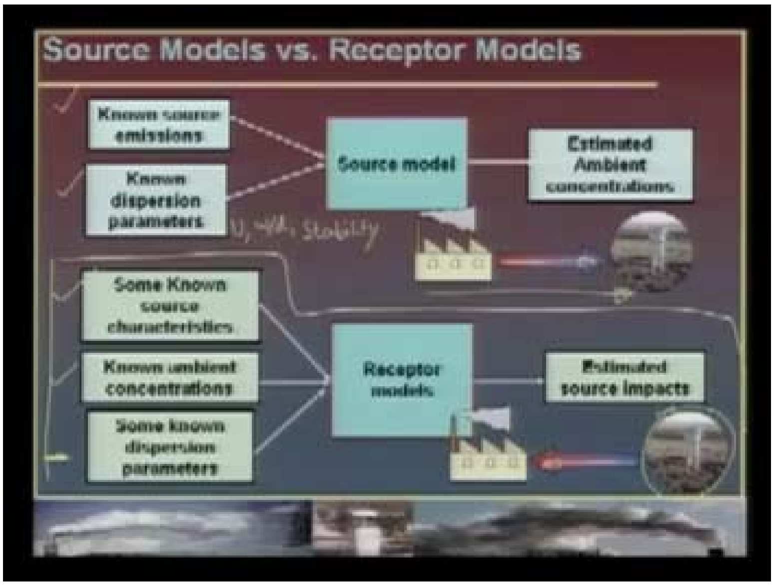

Source Models vs. Receptor Models

Now before we move to the receptor model, you also would recall that we had done some modeling exercise with the very same purpose – to find out the impact or contribution of the various sources in the ambient air or in other words, to develop the linkages between source and receptor and what we did was we studied something about dispersion modeling. You would also remember that we did something called the Gaussian blue model – we applied that model to large sources, we also applied that model to vehicular pollutants or area sources, so we will quickly take a recap of dispersion modeling and compare it with the new technique that we are going to learn, which is receptor modeling.

So there are two things: dispersion modeling and receptor modeling. Dispersion modeling is also known as source modeling. What you do that we have learnt in… we have the known sources and their emissions quantity, then you need to know the dispersion parameters and if you recall for example, what were the dispersion parameters? Wind speed, wind direction and if you recall, we had also discussed stability, atmospheric stability – these were some of the common things that we needed and we developed that model. Then, what that model eventually did? We started from the source and went all the way to the receptor, so our direction of the movement as you see the arrow here is from source to receptor.

In receptor modeling, it is just reversed – our whole idea is to go from the receptor to the source and to see which sources have contributed to air quality. Here, [13:58] such models are called… where we having some measurements already done and then trying to say what are the sources that contributed at the site, we call that as receptor model and the dispersion modeling was just reverse of that. So in order for us to be able to do the receptor modeling, what we need is some sources that are already existing in the area – sources means emission sources; but the interesting part is we do not need the quantity of the emissions from the sources, we do not need how much tons of sulfur dioxide is emitted from the source – what we need is the characteristics in terms of the fraction of emissions. [14:46] all right, the particulate matter is emitted from such a source, such and such a source, the calcium fraction is 20 percent – that is the information I need rather than having to know that calcium emission is let us say 1 ton per day, so that information I do not need, I need the information about what are the fraction of the various species that are present within the source.

Then, we also need to know the measurements we have done already on the field – known ambient concentrations, so this is essentially referring to the measurements here (Refer Slide Time: 15:25) and if you know, some dispersion parameters – it is not compulsory thing but then you can also kind of do the interpretation in a better way. So henceforth, the focus will be on receptor modeling, which will be something from here to here.

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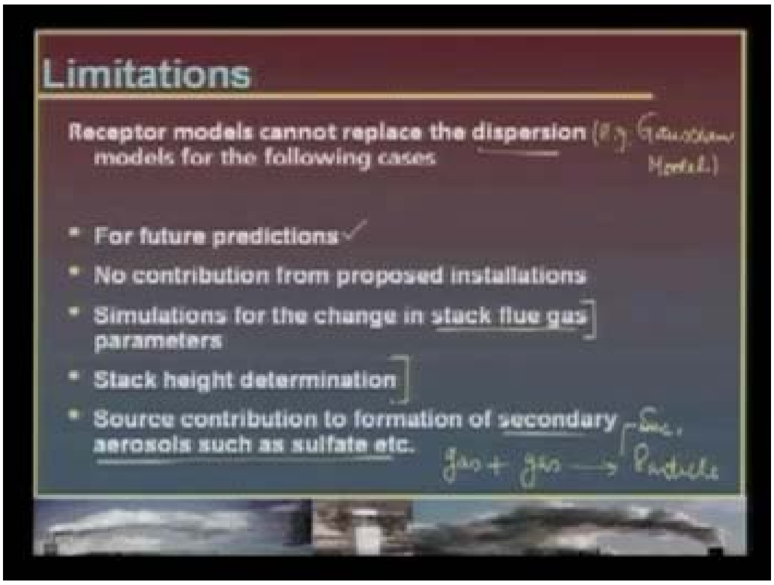

Limitations

Receptor models cannot replace the dispersion (E.g. Gaussian Model) models for the following cases

- For future predictions ✓
- No contribution from proposed installations
- Simulations for the change in stack flue gas parameters
- Stack height determination
- Source contribution to formation of secondary aerosols such as sulfate etc. Sec.

gas + gas → Particle

But before we talk about receptor modeling.… Receptor modeling sounds very good because it does not require many of the information that we needed in order for us to be able to use the Gaussian kind of model or dispersion kind of model, but then it also has its own limitations. What are the limitations of the receptor model?

It cannot replace the dispersion model or the… something like… you remember we had something called the Gaussian model, so it cannot replace those models under certain situations. When we want to do future predictions, suppose a new refinery is to about to come in your area, the receptor model cannot help you; no contribution from the proposed installation that is proposed or new installations – we cannot do nor can we say what the future thing will look like; simulation for the change in the stack and flue gas parameters cannot be done – suppose in the simulation I just want to say my chimney or stack height is increased, let us say, from 100 to 200, what impact it would have, what will be the benefits that will accrue out of such a change in the stack height – that the receptor model cannot say, one can only learn that from the dispersion model; and stack height determination cannot be done. Source contribution to formation of secondary particles: if you recall, secondary particles are particles such as sulfates and nitrates that are formed in the atmosphere; the interesting part is secondary particles there will be a gaseous pollutant that might react with another gaseous pollutant and what we may get are particles and with such a reaction or such a mechanism happening, the receptor model would not be able to tell you with great confidence as to who is contributing to the formation of the particles that are secondary in nature, let us write here secondary. So it is not that the receptor model can answer everything – there are certain things that the receptor model cannot answer; nonetheless, the receptor modeling is a very powerful tool and a very useful tool.

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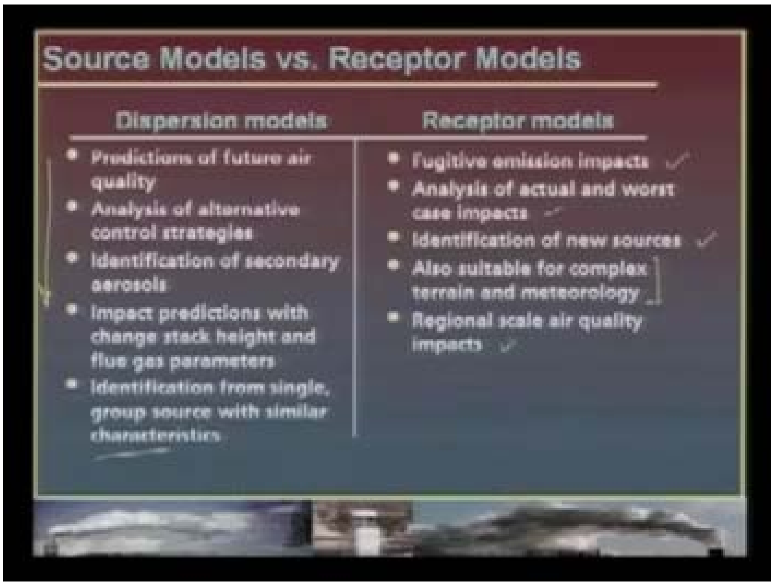

Source Models vs. Receptor Models

Dispersion models

- Predictions of future air quality
- Analysis of alternative control strategies
- Identification of secondary aerosols
- Impact predictions with change stack height and flue gas parameters
- Identification from single, group source with similar characteristics

Receptor models

- Fugitive emission impacts ✓
- Analysis of actual and worst case impacts ✓
- Identification of new sources ✓
- Also suitable for complex terrain and meteorology
- Regional scale air quality impacts ✓

This slide quickly shows you the difference between the dispersion model and receptor model. We will go rather quickly. In the dispersion model, the prediction of future air quality is possible, we will probably go this way and see, analysis of alternative control strategies is possible, identification of secondary aerosols is possible by employing atmospheric chemistry, impact of the prediction with change in stack height and flue gas parameters can be done, identification from a single group source with similar characteristics can be done.

In the receptor model, fugitive impacts can be very well be considered because we do not even know the physical location – we do not even need to know the physical location of the source, where it exists, we can still tell; analysis of the actual and worst-case impacts, identification of new sources is possible from the receptor modeling, it is also suitable for the complex terrain and meteorology – when we do not know the meteorology or our terrain is very complex terrain, complex terrain means we are having some analysis that we need to do in a valley or very hilly region, then the dispersion model will become very very complicated and cannot be used but the receptor model can still be used; one can also find out the regional scale air quality model by virtue of identifying certain sources – for example, suppose you want to know if the desert in Thar or desert in Sahara is causing or contributing to some air pollution in your area, there are ways in the receptor modeling that you can find out even if the transportation of the pollutants has been from long distances or from a long range transportation.

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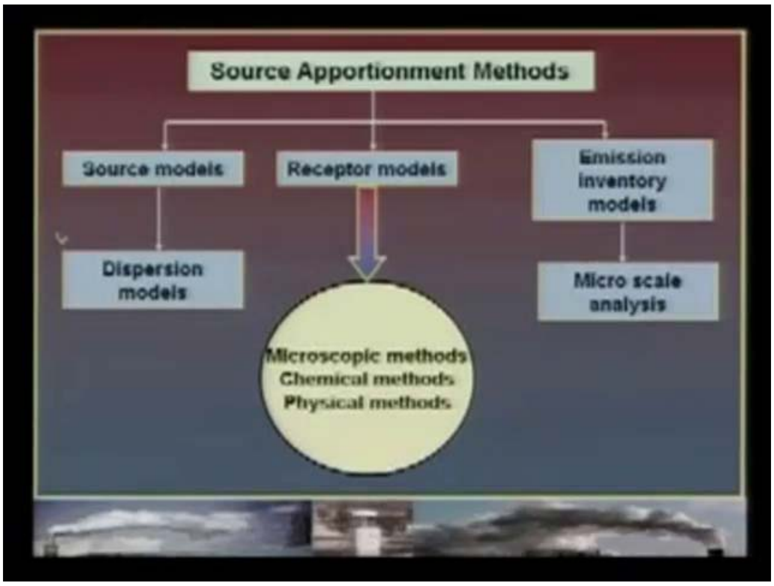

Source Apportionment Methods

Source models

Receptor models

Emission inventory models

Dispersion models

Microscopic methods
Chemical methods
Physical methods

Micro scale analysis

Again, a simple representation of the source model, the dispersion model the receptor model and the micro-scale analysis based on the emission inventory –that can also give you some idea.

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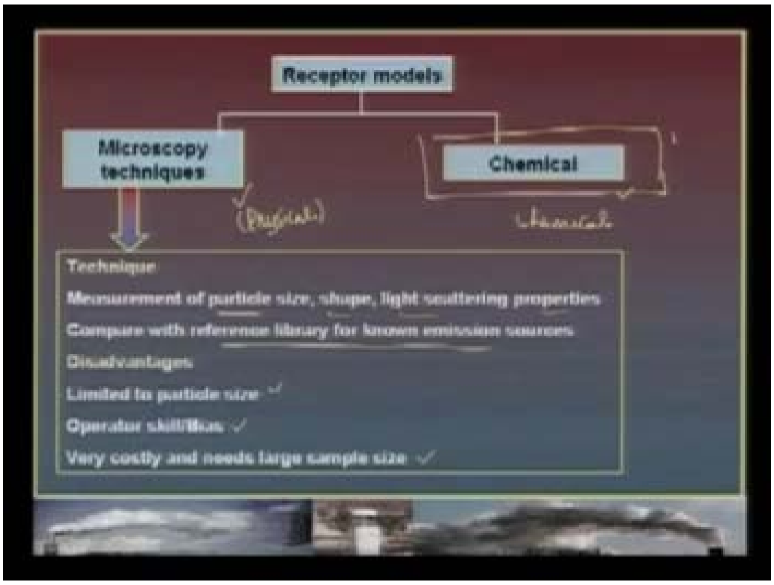

Receptor models

Microscopy techniques

(Physical)

Chemical

chemical

Technique

Measurement of particle size, shape, light scattering properties

Compare with reference library for known emission sources

Disadvantages

Limited to particle size ✓

Operator skill/Bias ✓

Very costly and needs large sample size ✓

There are two ways the receptor models are used: one is the microscopy technology and then another is the chemical technology. Here, what we are trying to do is for the particles that we have collected from the field, we are looking into the physical property or physical characteristics and in this case we need to look at the chemical property. What do you mean by physical properties? Measurement of particle size, shape, light-scattering properties, etc., and compare with the reference of the known sources. Suppose you know that certain property of the particles are emitted from certain source, which is scattering property of light. Suppose the [21:15] particles are available or are present in the atmosphere, then you can say well this source is contributing to this location. It is limited to the particle size, there can be some biases and it is also sometimes very costly to be able to measure these physical parameters, so most of the receptor models as we see and as we will find are mostly the chemical receptor models – we will spend some time on this one rather spending time on the microscopy techniques that was more to look at the physical properties of the particles.

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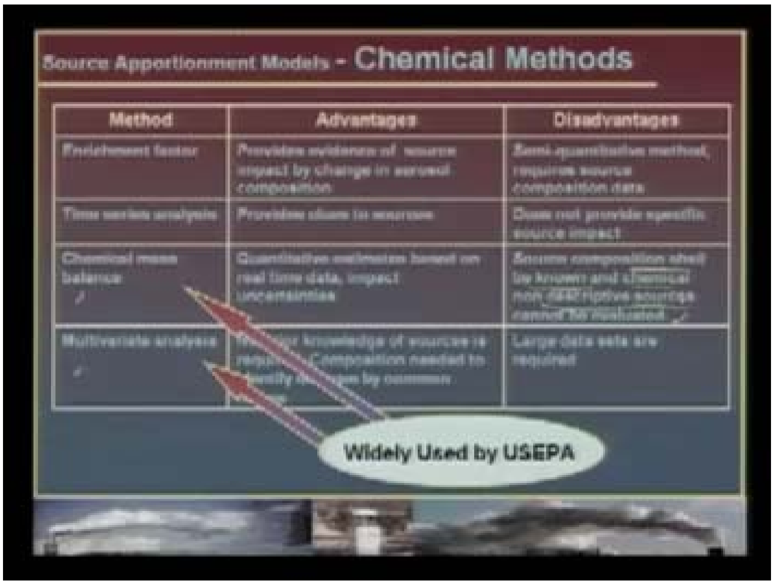

Source Apportionment Models - Chemical Methods

Method	Advantages	Disadvantages
Enrichment factor	Provides evidence of source impact by change in aerosol composition	Semi-quantitative method, requires source composition data
Time series analysis	Provides clues to sources	Does not provide specific source impact
Chemical mass balance	Quantitative estimates based on real time data, impact uncertainties	Source composition shall be known and chemical non descriptive sources cannot be evaluated
Multivariate analysis	No prior knowledge of sources is required. Composition needed to identify [illegible] by common [illegible]	Large data sets are required

Widely Used by USEPA

There are many methods and most of these techniques are being used all over the world, so we will just look at these two things. Chemical mass balance model: what is the advantage is the quantitative estimates based on the real-time data impact on certain things – that is the advantage because it can quantitatively estimate the sources, contribution of the sources. Source composition should be known, chemical and non-descriptive sources cannot be evaluated; source composition is… one should know the source contribution – that is essential, chemical non-descriptive sources cannot be evaluated – these are sources that cannot be defined in terms of chemical properties and they cannot be included in this model.

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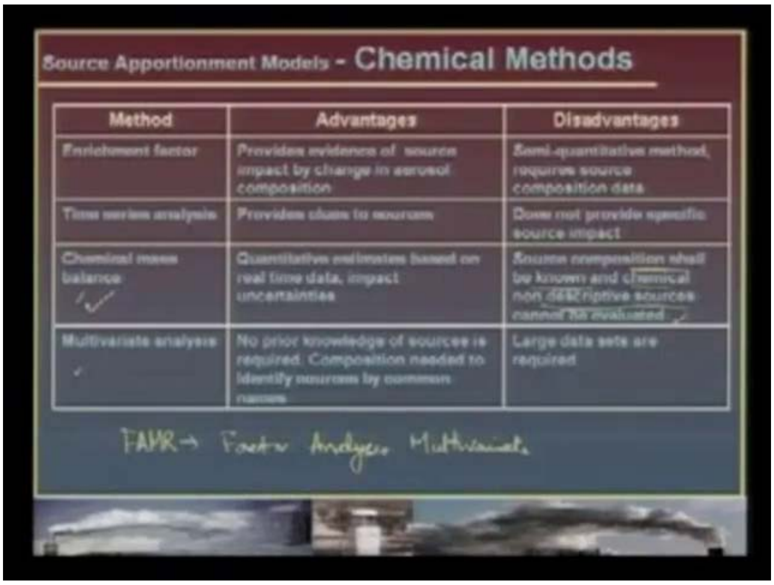

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Multivariate analysis ✓	No prior knowledge of sources is required. Composition needed to identify sources by common names	Large data sets are required

FAMR → Factor Analysis Multivariate

The second model, technique is more of a statistical technique but we will not talk about this in this lecture – it is the multivariate analysis or in fact, it is called as FAMR, factor analysis multivariate. What is the advantage here with FAMR is that no prior knowledge of the source is required – no chemical contribution, chemical compositions required and composition is needed to identify the sources by the common names; large data sets are required. Whenever we are dealing with statistics, we need to have more information but in this lecture we will be talking mostly about the chemical mass balance.

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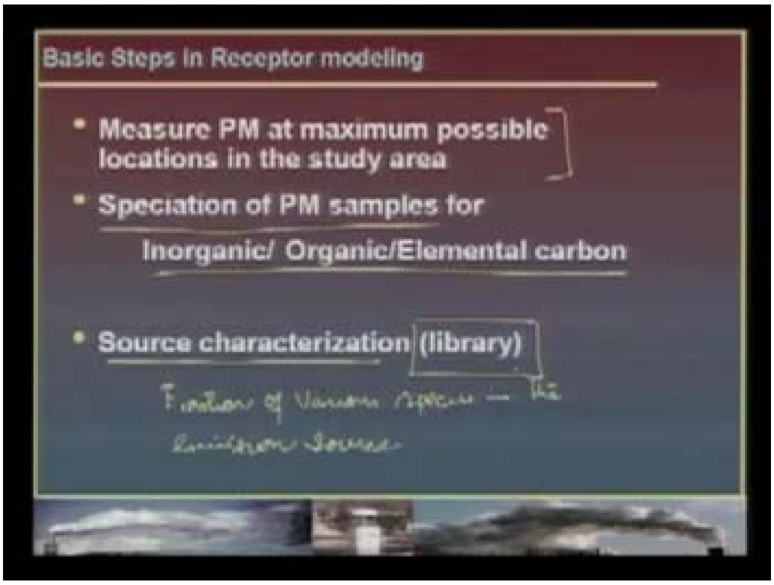

Basic Steps in Receptor modeling

- Measure PM at maximum possible locations in the study area
- Speciation of PM samples for
  Inorganic/ Organic/Elemental carbon
- Source characterization (library)
  Fraction of Various species in the Emission Source

Now the steps involved: measure the particulate in as many places as possible – important thing because we are talking now chemistry; speciation of the particulate samples for inorganic, organic or elemental carbon – we ideally need more and more information but sometimes information is limited, still we can proceed with the chemical mass balance or receptor modeling; source characterization is required and source characterization means fraction of various species in the emission source – that is what we require; sometimes, this information is available and that is what is meant by 'library' – it is not a bookshelf library or something, it is the library of information that is available on the different sources.

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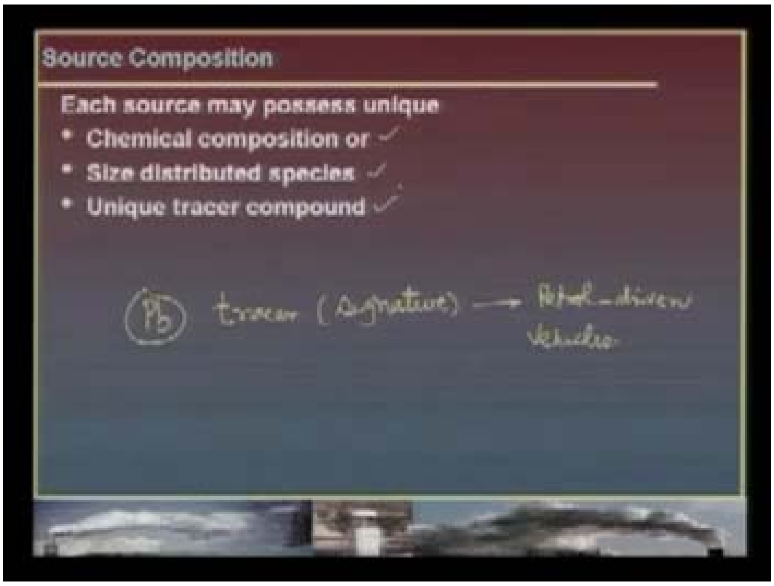

Source Composition

Each source may possess unique
- Chemical composition or ✓
- Size distributed species ✓
- Unique tracer compound ✓

Pb tracer (Signature) → Petrol-driven vehicles

Each source may possess a unique quality. What we understand by that is that each source may have a unique chemical composition, very distinct size distribution and unique tracer compound. For example earlier time when the gasoline was leaded, if we find the lead in the atmosphere, then it was the tracer or a signature and signature means you have a unique signature – everyone has a unique signature, so the air pollution source may also have a unique signature, lead was the unique signature for petrol-driven vehicles and we will see what are the different tracers that are available to you. You need to know the chemical composition, size distribution – if possible and then, one should also at least have some idea as to what tracer compound could be there in the emission.

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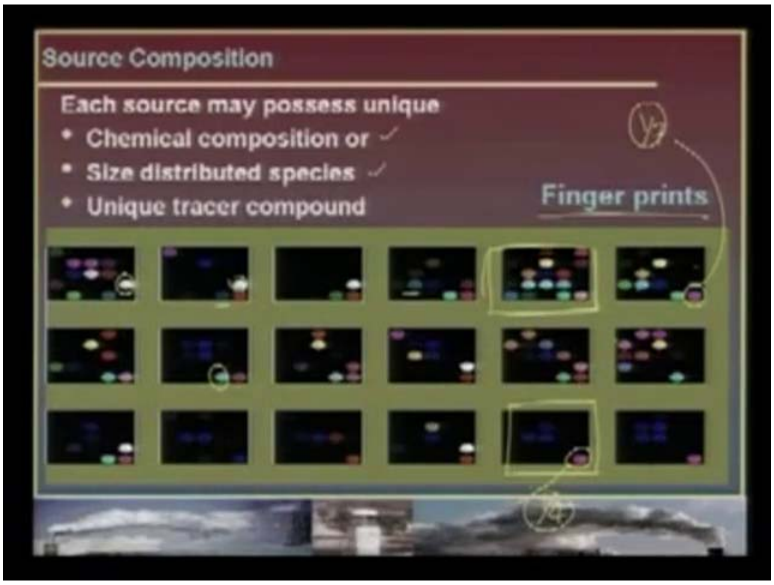

Source Composition

Each source may possess unique

- Chemical composition or ✓
- Size distributed species ✓
- Unique tracer compound

Finger prints

What it really means is… basically, there are different dots you are seeing here and they are the fingerprints of signatures of the sources, more from the concept point of view than the actual thing. So they are the various sources you see and they all look different in terms of the emission of the various species, for example let us say the white thing I am calling as calcium, so calcium is there and sometimes in the source and some sources you might find absence of calcium.

Suppose I am calling this as the source from the steel plant (Refer Slide Time: 27:18), so here you see there could be difference in their composition – there could be more there could be less, so we can identify depending on the composition what kind of source this is. This information is required in terms of the finger prints, in terms of the fraction as you can see here – the fraction will be smaller here in this source for example, it is [27:44] fraction of these things will be for example, fraction of this species is one-fourth, 0.25 whereas suppose I am looking for the same contribution of this species in terms of the fraction, let us count them: one, two, three, four, five, six, seven, the fraction of this element is only 1 by 7.

So this source signature is different here and the source signature is different here. What is the fraction? 1 by 4. Still, this was the concept – we can find and we can know what is the signature or specific source tracer species that would indicate very clearly that this is the source where it has come from. We have the basic signature that varies from person to person and so the source signature also varies from source to source. Sometimes, we are also interested in the particle size distribution; in the finer fraction of the particle, we try to see what is the composition and who is contributing to the smaller particles. In that case, what we need to do is we need to have a system.

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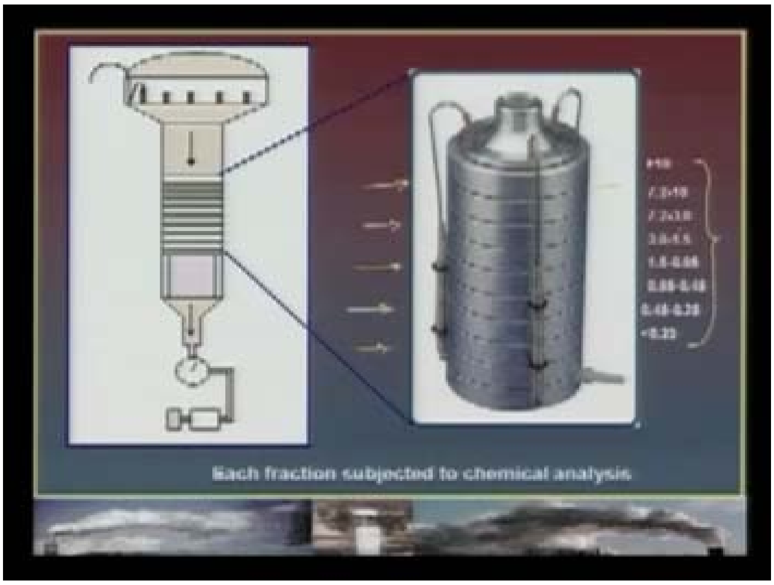

Each fraction subjected to chemical analysis

This is some kind of cascade impactor where you have different filter papers put in at various positions and you can estimate the concentration of the particles in various size ranges. Not only will you come to know about the concentration of the particle in various size ranges but you can also do the speciation of the filter paper and you can find out what is the chemical composition in the specific size range and for that specific size range, you can do the chemical mass balance analysis or receptor model and you can find out when the particle size particle size is less than that, which are the major sources, which is contributing to air pollution in this [29:54] range – so the modeling is not specific only to a certain size of the particles, you can very well do it for the particle of your interest. Let us go further.

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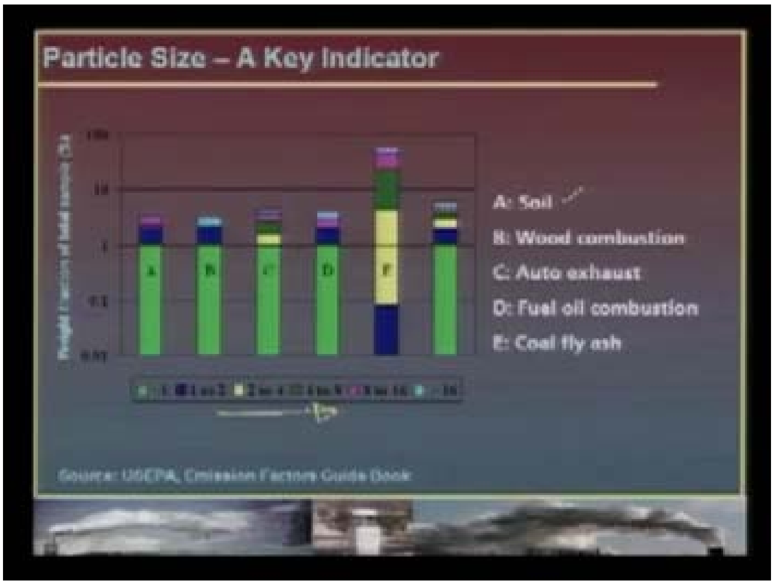

Particle Size – A Key Indicator

A: Soil

B: Wood combustion

C: Auto exhaust

D: Fuel oil combustion

E: Coal fly ash

Source: USEPA, Emission Factors Guide Book

Here again, an indicator of the various particle sizes and their fraction. You see here for example the soil, so again here what was it? This was the fraction in percentage. What was the contribution of the particles that were less than 1 micron, 1 to 2, 2 to 4, 4 to 8, and 8 to 16 – that could be the diameter in micron size. So you can come to know about different species, what are their particle size distribution and the source – that may be helpful in the interpretation of the results.

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Heavy Metals in Fuels

Source: Robert E. Lee, USEPA, JAPCA, 1975

We were talking about source signatures. For example, for fuel oil burning, the source signature as you can see from the picture is nickel and vanadium and for fuel combustion, it can be selenium and titanium and this can be a very specific source signature. So if you have in your area coal combustion or fuel combustion, then you would certainly like to analyze your filter paper, particle-laden filter paper for selenium, titanium, nickel and vanadium so that you know whether those specific tracers that are coming from coal or from fuel oil are present in your filter paper or not.

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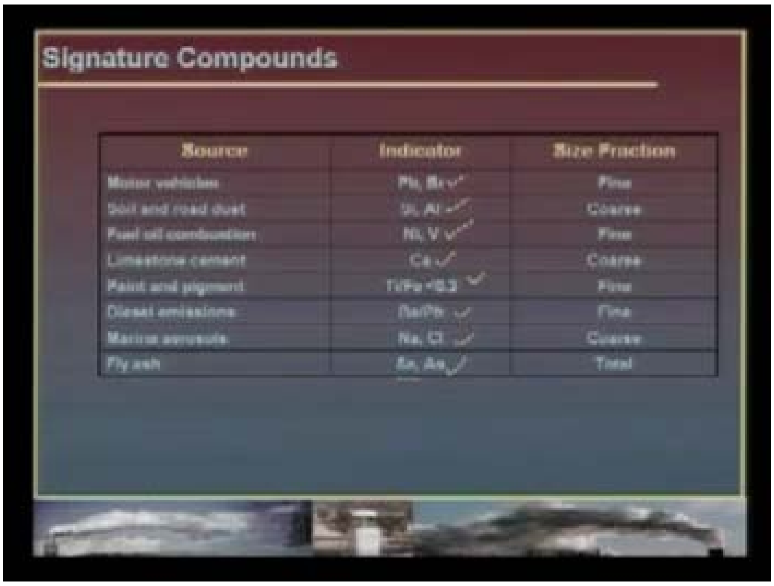

Signature Compounds

Source	Indicator	Size Fraction
Motor vehicles	Pb, Br ✓	Fine
Soil and road dust	Si, Al ✓	Coarse
Fuel oil combustion	Ni, V ✓	Fine
Limestone cement	Ca ✓	Coarse
Paint and pigment	Ti/Fe <0.3 ✓	Fine
Diesel emissions	Ba/Pb ✓	Fine
Marine aerosols	Na, Cl ✓	Coarse
Fly ash	Se, As ✓	Total

These are specific signatures that people have come up with – various researchers. For example, for motor vehicles, bromine and lead can be very good indicators; for soil and road dust, we all know aluminum is… the soil is so rich in aluminum – that can be of great advantage if you know the aluminum and you want to find out and particularly apportion the source that is of soil origin. For fuel combustion as we have seen in the last slide, it is nickel and vanadium; for lime stone (it could be cement), it is calcium – that calcium can also be used for the construction and building demolition activity to find out how much pollution they are causing; paint and pigment; diesel emissions – barium is a very important species from diesel emission; for marine aerosols, sodium and chloride and for fly ash, selenium and arsenic are the tracers or the specific elements that are possible to identify… with the help of those elements, it is possible to identify the sources and not only identify but we also can apportion the sources. Let us finally come down to the model and the model as you will see is a very simple model.

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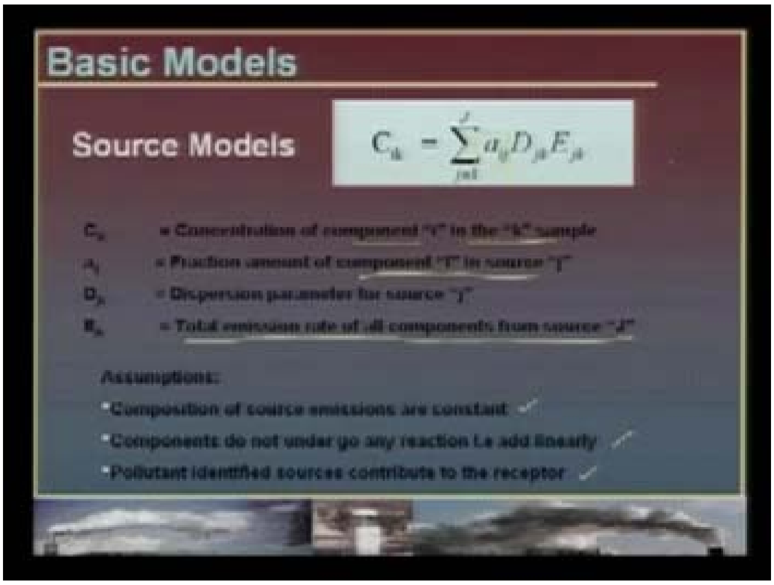

Basic Models

Source Models

$$C_{ik} = \sum_{j=1}^{J} a_{ij} D_{jk} E_{jk}$$

C_{ik} = Concentration of component "i" in the "k" sample
a_{ij} = Fraction amount of component "i" in source "j"
D_{jk} = Dispersion parameter for source "j"
E_{jk} = Total emission rate of all components from source "J"

Assumptions:

- Composition of source emissions are constant ✓
- Components do not under go any reaction i.e add linearly ✓
- Pollutant identified sources contribute to the receptor ✓

Simply what we have to see here… we want to find the concentration of a species i or component i at the in the k-th sample, so it will depend on the fraction amount of component of i in source j, so a_{ij} and then it will depend on the dispersion parameter and of course if total emission rate of the component from source J; the E_{jk} is the emission rate of all the components in the source J. The assumption is that the compositions of source emissions are constant, components do not undergo any reaction – that is, linearity in the system is maintained and pollutant identified sources contribute to the receptor. With that, we can say that this is basically the source model.

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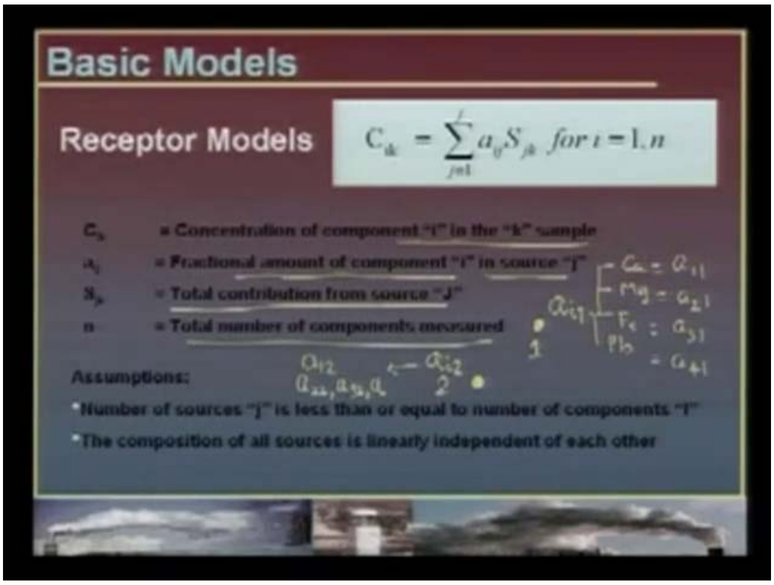

Basic Models

Receptor Models $C_{ik} = \sum_{j=1}^{J} a_{ij} S_{jk}$ for $i = 1, n$

C_{ik} = Concentration of component "i" in the "k" sample

a_{ij} = Fractional amount of component "i" in source "j"

S_{jk} = Total contribution from source "J"

n = Total number of components measured

Assumptions:

- Number of sources "j" is less than or equal to number of components "I"
- The composition of all sources is linearly independent of each other

Then, how the receptor model will look like is a little bit different. Here, what you see here, the interesting part is that the dispersion parameter is lost or the dispersion not lost, but dispersion parameters do not show. In that sense, when we are doing the receptor modeling, we do not need information on the dispersion parameter, so here the concentration is of the components i in the K-th sample, fractional amount of component i in source J, and S_{jk} is the total contribution from the source J and n is the total number of components measured.

Basically, what it really means is that you have a source, you have a fraction of various components sj, ij and i is the specific pollutant that you are talking about and j is the source, so I can even say suppose this is my source 1 and this is my source 2, for example, let us write 2 and here the composition is my a_{i1}, here my composition of the various species that are being emitted is a_{i2} and this can be calcium, for example or it could be magnesium, it could be iron, it could be lead. This is nothing but in a way I can say here a_{11}, a_{21}, a_{31}, and a_{41}. Similarly for this source, what I can write is a_{12}, which may be whatever – it may be calcium, magnesium, whatever – it does not matter, a_{22}, a_{32} and a_{32}, a_{42}. Once you understand what I am really referring to as a_{ij}, we will remove this because we are clear as to what our a_{ij}s are.

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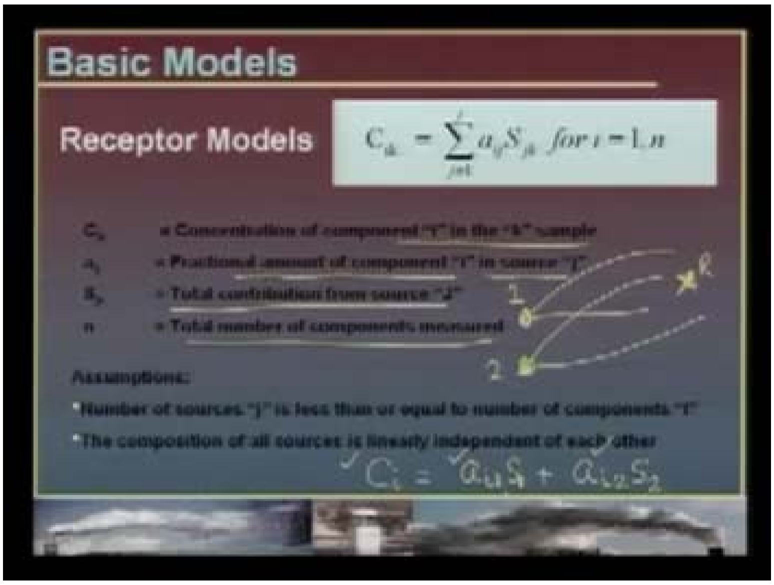

Basic Models

Receptor Models $C_{ik} = \sum_{j=1}^{J} a_{ij} S_{jk}$ for $i = 1..n$

C_{ik} = Concentration of component "i" in the "k" sample
a_{ij} = Fractional amount of component "i" in source "j"
S_{jk} = Total contribution from source "J"
n = Total number of components measured

Assumptions:

- Number of sources "j" is less than or equal to number of components "i"
- The composition of all sources is linearly independant of each other

$C_i = a_{i1} S_1 + a_{i2} S_2$

But now what we are doing is let this is the source 1 and it is contributing at some location, so what will be the concentration here at this location? Let us call this as R and source 1, this is my source 2 and this source will also contribute to this location R, so the total concentration at R because of these two sources for any species i that I am interested in will be… how many sources are there? Two. So for this species i, which is coming from source 1, i1 was the fraction, that was at the time of the exhaust or at the time of the source and times how much is the contribution from this source and that is source number 1, let us say and for the K-th location of the receptor; similarly plus… now the second source is also contributing, so a, same species because I am talking about I, fraction at source 2, then total contribution from source 2 and what I do not know in this one is this is what I have measured, this is what is known to me because I know exactly what kind of composition is there at the source, what is the signature of the source and this also I know from the source number 2, but what I do not know is the contribution of the source 1 because whatever is the contribution, the fraction of the species i at this source as it travels all through remains the same, so the a_{i1} will remain the same throughout and a_{i2} let us say in the opposite direction will remain the same deflection part. This way, I can write the equations one after another for various is, which can be calcium, magnesium, iron or lead.

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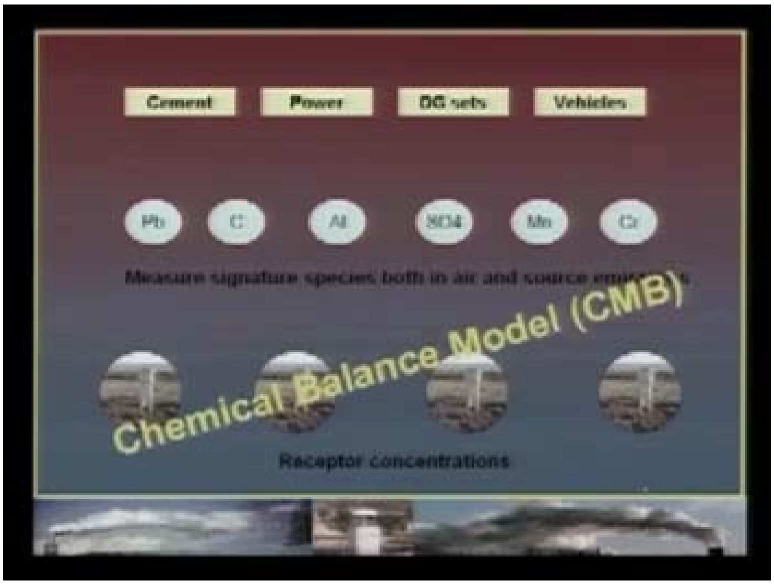

Cement

Power

DG sets

Vehicles

Pb

C

Al

SO4

Mn

Cr

Measure signature species both in air and source emissions

Chemical Balance Model (CMB)

Receptor concentrations

For example we have the sources, which can be cement, power plants, DG sets, vehicles and we are measuring the lead, carbon, aluminum, sulfate, magnesium and chromium and we can apply the mass balance model, the one I described in the previous slide.

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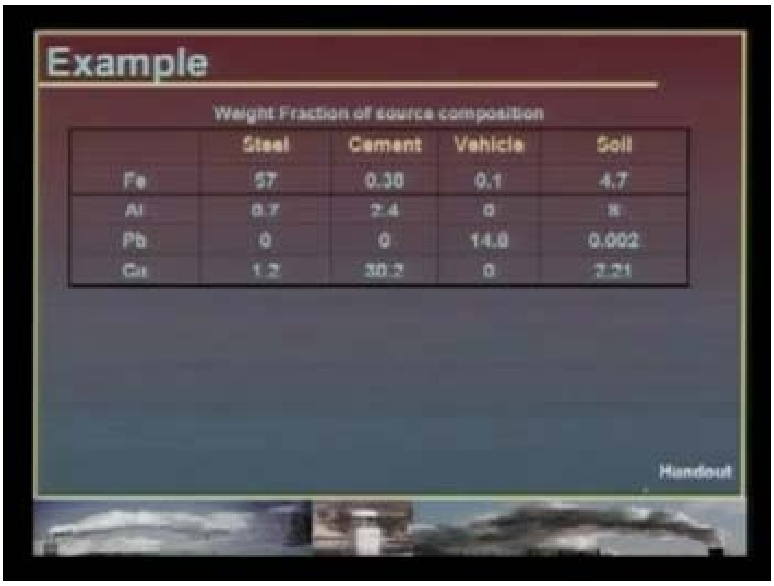

Example

Weight Fraction of source composition

	Steel	Cement	Vehicle	Soil
Fe	57	0.30	0.1	4.7
Al	0.7	2.4	0	8
Pb	0	0	14.0	0.002
Ca	1.2	30.2	0	2.21

Handout

For example, this is the weight fraction of source composition – this is in percentage.

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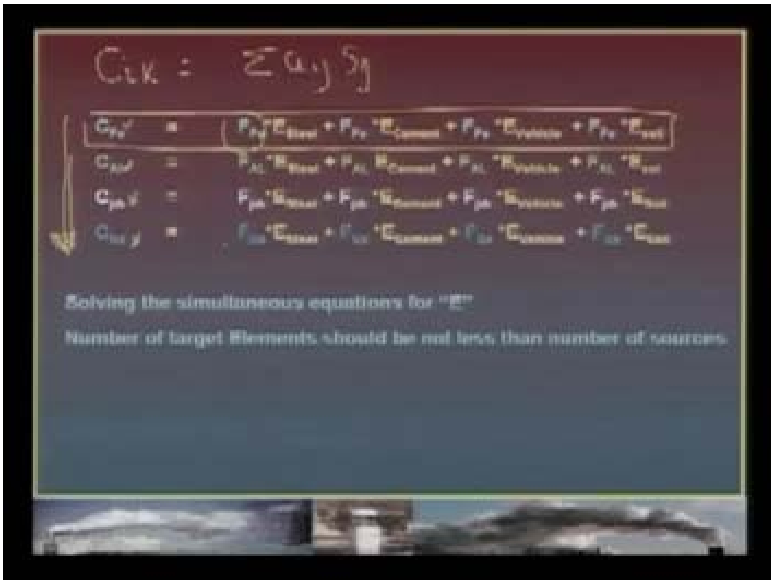

$C_{ik} : \Sigma a_{ij} S_j$

$C_{Fe} = F_{Fe} * E_{Steel} + F_{Fe} * E_{Cement} + F_{Fe} * E_{Vehicle} + F_{Fe} * E_{soil}$

$C_{Al} = F_{Al} * E_{Steel} + F_{Al} * E_{Cement} + F_{Al} * E_{Vehicle} + F_{Al} * E_{soil}$

$C_{pb} = F_{pb} * E_{Steel} + F_{pb} * E_{Cement} + F_{pb} * E_{Vehicle} + F_{pb} * E_{soil}$

$C_{\text{[illegible]}} = F_{\text{[illegible]}} * E_{Steel} + F_{\text{[illegible]}} * E_{Cement} + F_{\text{[illegible]}} * E_{Vehicle} + F_{\text{[illegible]}} * E_{Soil}$

Solving the simultaneous equations for "E"

Number of target Elements should be not less than number of sources

You can write the equations for various species. Here, the model was C_{ik} is equal to sigma a_{ij} S_j – exactly the same thing I have written here. This is the equation written for let us say concentration of iron. This is the fraction, this is nothing but a_{ij} component (Refer Slide Time: 40:39) – fraction of iron from steel plant and this is the contribution from the steel plant, fraction of iron from the cement plant that is what [40:55] cement plus fraction of the iron in the vehicles plus fraction of iron in soil and these are the total contribution from the soil.

Since I have done the measurement of the four species aluminum, lead, calcium, I can write such equations. Do not forget that this is what is collected on the site at my receptor locations and I have done the chemical analysis on the filter paper to find out the concentration of iron, find out the concentration of aluminum, find out the concentration of lead and calcium. The fractions, these Fs you see are known to me and what is not known to me is the contribution from the steel plant E_s or E_{cement} or $E_{vehicles}$ or the E_{soil}.

Here, you have four equations and four unknowns and you can very well solve this. Then, you can solve the simultaneous equations for Es – for the different kind of sources, it is very easy to find out what will be the contribution from each source, although there will be certain difficulties and problems when you really do things but then one has to learn more and more and use more sophisticated models and better information in terms of the species that you measure.

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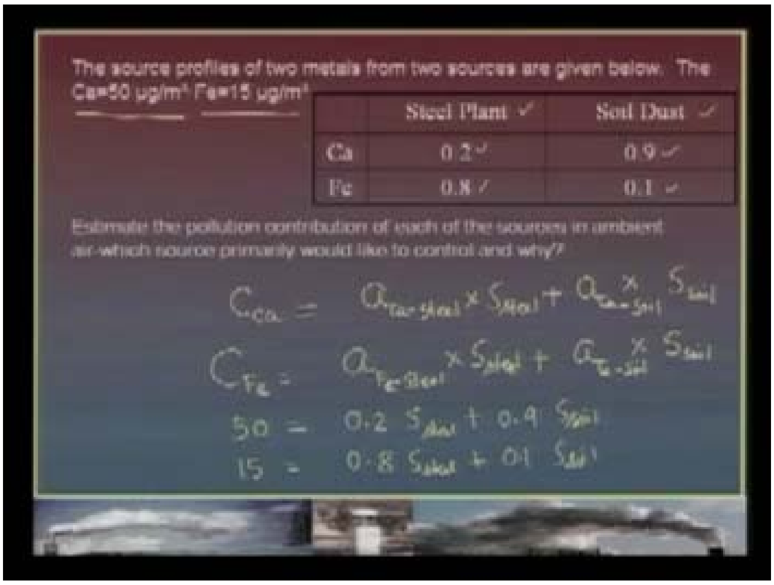

The source profiles of two metals from two sources are given below. The Ca=50 µg/m³ Fe=15 µg/m³

	Steel Plant ✓	Soil Dust ✓
Ca	0.2 ✓	0.9 ✓
Fe	0.8 ✓	0.1 ✓

Estimate the pollution contribution of each of the sources in ambient air-which source primarily would like to control and why?

$$C_{Ca} = a_{Ca-steel} \times S_{steel} + a_{Ca-soil} \times S_{soil}$$

$$C_{Fe} = a_{Fe-steel} \times S_{steel} + a_{Fe-soil} \times S_{soil}$$

$$50 = 0.2\, S_{steel} + 0.9\, S_{soil}$$

$$15 = 0.8\, S_{steel} + 0.1\, S_{soil}$$

Let us do a very simple-looking example here. We are saying the source profile of the two metals from two sources are given below and then it is measured that the calcium in the ambient air was 50 micron per meter cube and the iron was 15 micron per meter cube – 15 in this one for simplicity because we are just learning [42:44]. There are only two sources in the in my area: a steel plant and soil dust, which is dusty conditions and a very isolated steel plant that you may have. The fraction of calcium in the emissions that is taking place from steel plant is 0.2 and that of iron is 0.8 – obviously, iron will be way too high in the steel plant and for soil dust, it was largely calcium and the iron amount was very small.

So let us write the… then what we need to find out is estimate the pollution contribution of each of the sources in the ambient air and we also have to answer the question which source primarily we would like we like to control and why. If I have to write the chemical mass balance and then the equations here, what I can write here is the C, concentration of the calcium is equal to the fraction a_{ij} from steel plant, so I can say a_i or a calcium from steel plant times the source from the steel plant let us write steel here plus the fraction of calcium from soil dust, so let us write from the soil times source contribution from the soil – no problem in writing the equation.

Similarly, I can also write the equation for iron a of what? Iron from steel plant – the fraction times the contribution of the steel plant plus a of iron fraction in soil times the overall contribution to the particulate pollution by soil, so let us put up these values here. The calcium measured is 50, a_{Ca} is how much for the steel plant? It is 0.2, so let us write 0.2 here and contribution from the steel plant – if you want, we can make a subscript here plus what is the calcium fraction in the soil dust? 0.9 multiplied by S_{soil} – contribution of soil. Similarly for iron. How much is the iron? 15. How much is the iron fraction in the steel plant? 0.8 S_{steel} plus fraction of iron in soil dust is 0.1 times S_{soil}.

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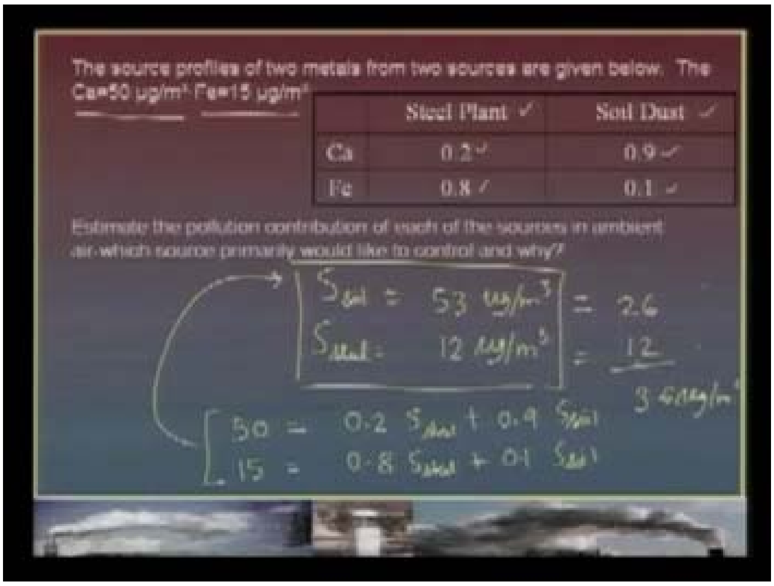

The source profiles of two metals from two sources are given below. The Ca=50 μg/m³ Fe=15 μg/m³

	Steel Plant ✓	Soil Dust ✓
Ca	0.2 ✓	0.9 ✓
Fe	0.8 ✓	0.1 ✓

Estimate the pollution contribution of each of the sources in ambient air which source primarily would like to control and why?

$$\boxed{\begin{aligned} S_{soil} &= 53\ \mu g/m^3 \\ S_{steel} &= 12\ \mu g/m^3 \end{aligned}} \begin{aligned} &= 26 \\ &= \underline{12} \end{aligned}$$

3 [illegible] μg/m³

$$\left[\begin{aligned} 50 &= 0.2\ S_{steel} + 0.9\ S_{soil} \\ 15 &= 0.8\ S_{steel} + 0.1\ S_{soil} \end{aligned}\right.$$

If we solve them, I will remove this. I found S_{soil} as 53 and $S_{steel\ plant}$ as 15 or 12; you could apportion the sources that were there and we can see this. So in order for me to improve the air quality, I must rather control the soil dust emissions that are taking place and that would certainly improve my air quality much more. Suppose I control 50 percent of my soil emission, the likelihood is there that 50 percent is gone, so [46:56] is 26 and suppose I am not doing any control at the steel plant and then so 2 plus 1, 36 microgram is the air concentration that I will get. I have got good information from the receptor model and then to a reasonable degree of confidence, we can say what is the contribution of the individual sources to the ambient air and what it would take to control the sources that will give us the maximum benefit in terms of the improvement of the air quality at the ambient level, which really people are exposed to.

This is where we will end this presentation. This is a new technique that involves receptor modeling to estimate the contribution or the apportionment of the sources to the ambient air but we went about doing this one in a very different way by starting the measurements at the site or at the receptor location, speciating them, finding out the contribution of the various… finding out the species of the various metals, elements and organic compounds and then trying to ascertain what are the sources and what their contributions are. Eventually, this information can be used for pollution control planning and strategies. We learned a new technique of receptor modeling and let us see what were the advantages of this technique, why we have to … why we really learn this in the first place.

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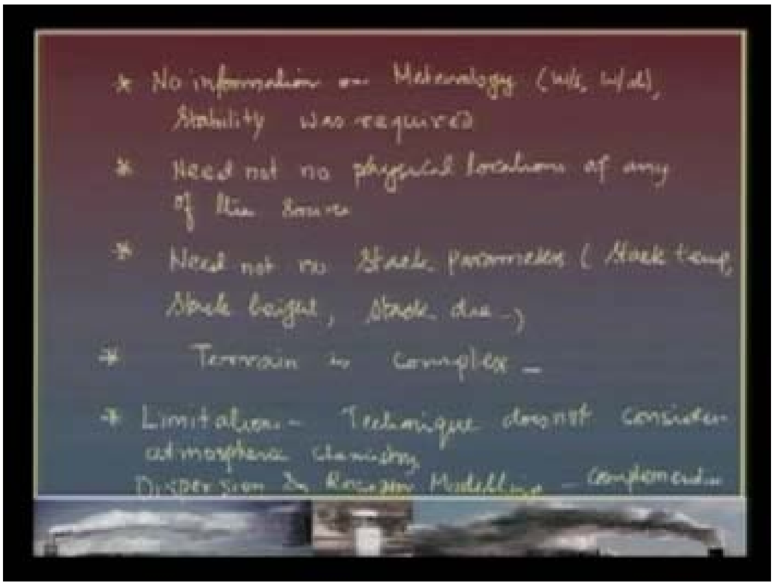

- No information on Meteorology (w/s, w/d), Stability was required
- Need not no physical locations of any of the Source
- Need not no Stack parameters (Stack temp, Stack height, Stack dia ..)
- Terrain is complex –
- Limitation – Technique does not consider atmospheric chemistry

Dispersion & Receptor Modelling – complementary

The first thing you will see here is no information on meteorology in terms of wind speed, wind direction but stability was required. Sometimes, it becomes a little difficult to get this information, which is specific to a location; still, we need to do this analysis, so we better use the receptor model.

The second thing is we need not know the physical locations of any of the sources because in the dispersion modeling, it becomes very important to know where the sources are. The third thing is we need not know the stack parameters like stack temperature, we need not know the stack height and we need not know the stack dia, for example – this is to the great advantage. Then, we need not care if the terrain is complex – the model will still work whether the terrain is complex or flat. However, the problem or the limitation is… or let me say limitation is the technique does not consider atmospheric chemistry.

In conclusion, we want to say ideally one can do both dispersion and receptor modeling, which are contemporary, which are complementary to each other and then we can draw useful results and we can make useful decisions. These are two different techniques, two different approaches and both have advantages and disadvantages. One should be able to judge which technique will be better under a situation and which one to use and if one can use both, use both of them and make the best decision because the techniques complement each other and they are not against each other, so we can certainly make very useful meaning and interpretation and take proper decisions.