Air Pollution and Control
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Lecture 27
Methods of Source Apportionment

Hello friends, you may recall we have already completed how to develop emission inventory. Today we will start about source apportionment studies, means how to apportion the sources means different sources of the pollutants and what are different methods for carrying out the source apportionment.

So, first of all, we will discuss about the introduction of source apportionment, then we will look into the significance of this particular study which is known as the source apportionment and then major methodologies like bottom up or source based methods which are which kind of models we are using for bottom up approach of the source apportionment studies, and what are their advantages and disadvantages.

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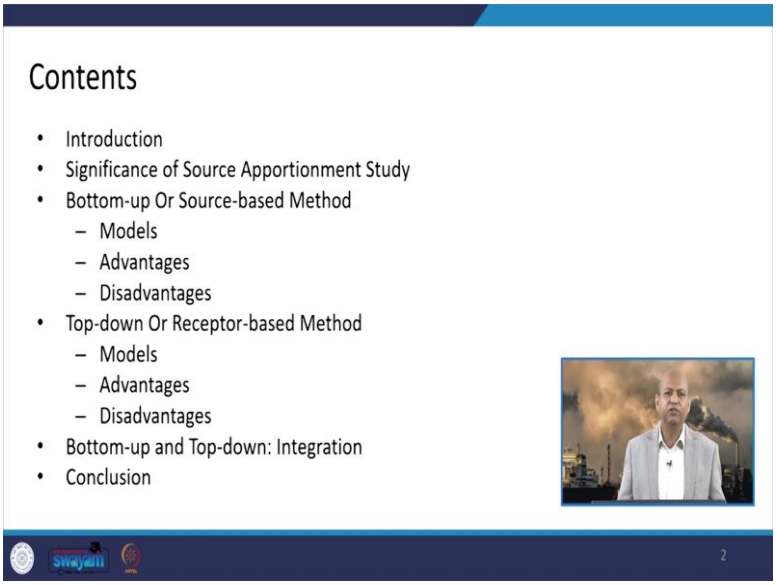

Then, we will look into top down approach or receptor-based method models and advantages and disadvantages. And then we will look into the possibilities of integration of both the approaches so, that we can have the win-win situation or best features of the both the approaches and then we will conclude.

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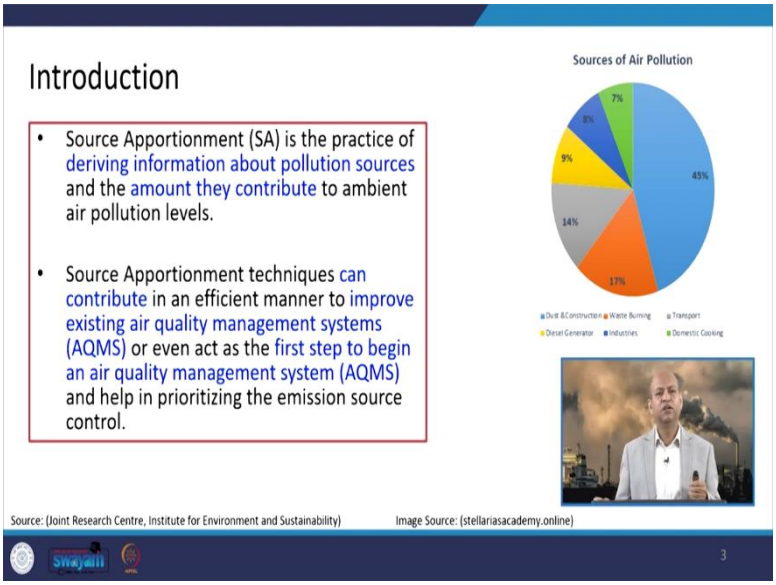

So, when we talk about source apportionment basically, this is the process or practice for deriving information about different pollution sources and the amount they contribute to ambient air environment, in terms of different pollution levels. So, you can say that this source this source apportionment techniques, they can contribute in efficient manner of air quality management and they are used in looking into variety of sources which contribute in significant manner. So, that we can target those sources which are dominating sources to control the emissions from those sources and then we can reduce the air concentrations or particular source-based emissions.

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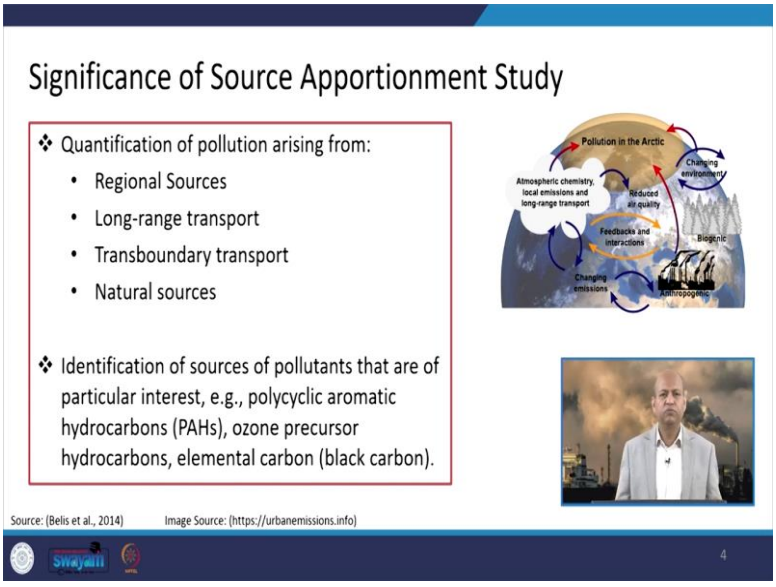

Well, when we talk about significance of source apportionment study, then the quantification of pollutants or the pollutions which are coming from different regions. So, the regional sources or whether it is coming from long range transportation from different areas and trans boundary transportation of pollutants also happen, then there may be natural or these anthropogenic sources.

So, we can really categorise we can see which pollutant is coming from which particular source in dominating manner. So, the identification of different sources of the pollutants that are of our interest or particular interest like these polycyclic aromatic hydrocarbons or pH or ozone precursors like NOx emissions or CO emissions, then hydrocarbons or elemental carbons, black carbons, particulate matters, PM_{10} $PM_{2.5}$ all those, which are very important from a health risk point of view also. So, we look into those pollutants and their specific sources.

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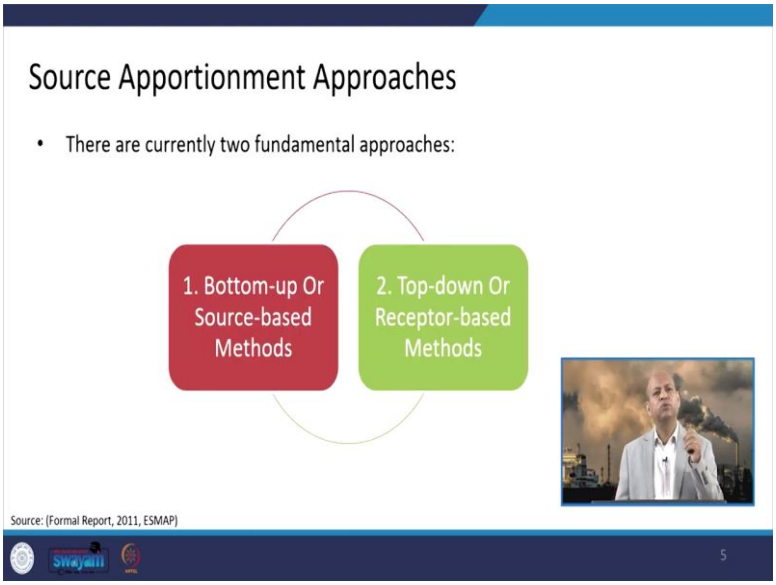

So, the key thing is that a particular pollutant because you name ambient air there are so many pollutants. So, if you want to know, whether this CO emission or particulate matter emission, which has contributed to the air quality degradation, so that PM_{10} has come from how many sources and what is the amount of that PM_{10} from different sources, so that we can know that we can list this is the major source this is the moderate, this is the minor, so that we can look into the major sources basically.

Now, there are different approaches for doing this source apportionment like bottom up or source-based approach or method, then top down or receptor based method or approach. So, when we look into bottom up or source-based method, so basically, we focus on the sources. So, how many sources are there which are the major sources like we can have in your town or

city, several kinds of sources like industrial sources, maybe their power plants or maybe there are from transportation sector or domestic sources like and we have to develop emission inventory with specific to the sources basically.

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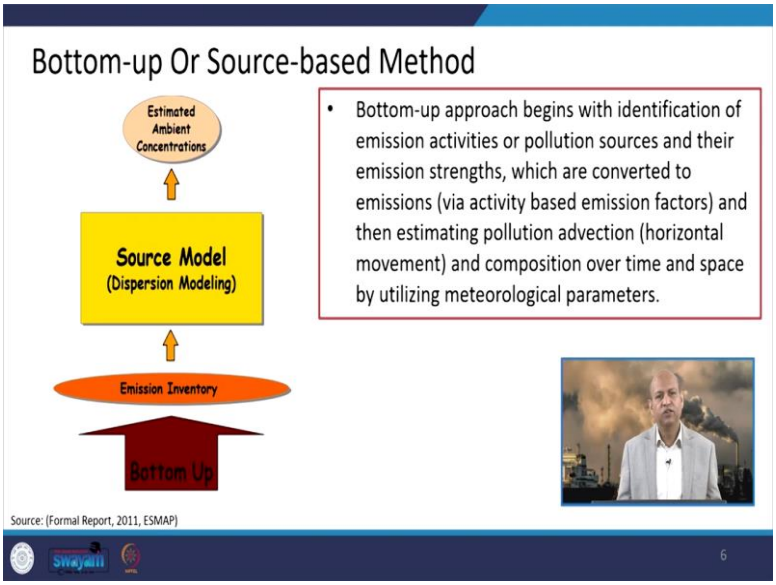

So, when we talk about the source-based methodology of the source apportionment study or bottom up approach, then we are basically talking about emission inventory development and then using the emission inventory into the dispersion modelling. So, the dispersion modelling gives us the air quality concentration at certain locations which are of our interest.

So, that is the, bottom up means at the ground level we need to know how much pollution sources are there how much pollution is coming from those sources and those pollution, those emissions, how do they contribute into deteriorating the air quality. So, for that we use different dispersion models.

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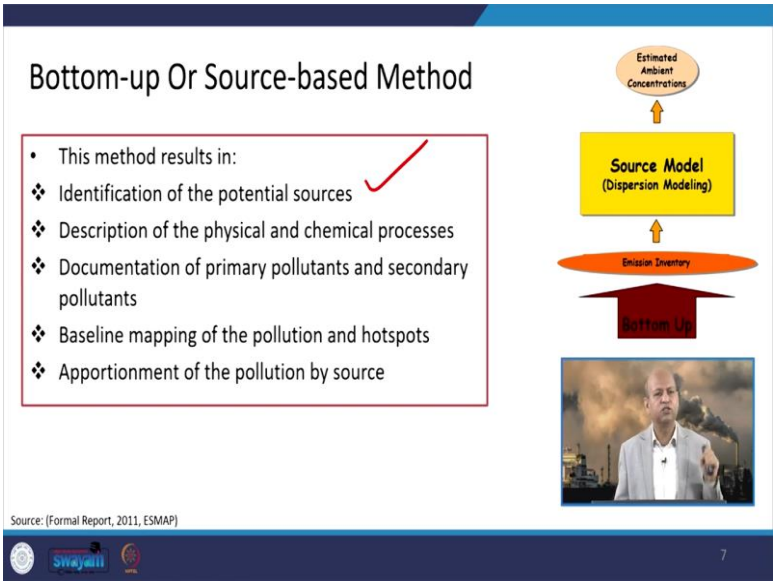

So, basically when we talk about bottom up source-based approach, we go into different kinds of steps like identification of the potential sources is an important sources, description of the physical and chemical processes, which will contribute into, formation of secondary aerosols or pollutants. So, we have to document those primary pollutants, secondary pollutants, which are going to be there because of the emissions of different types of pollutants.

Then we need to baseline mapping and pollution, hotspot pollution levels, because like, there may be some intersections of the transportation or highways. So, there may be very high emissions of NOx or CO. So, we have to categorise or we have to point out that these are the hottest spots or there may be some particular industries in nearby areas, the new power plants, so, maybe SO_2 or particulate matter may be more in those particular places. So, we have to identify the hotspots or we have to do the baseline mapping. Then we need to do the apportionment of the pollution by the source using the dispersion modelling.

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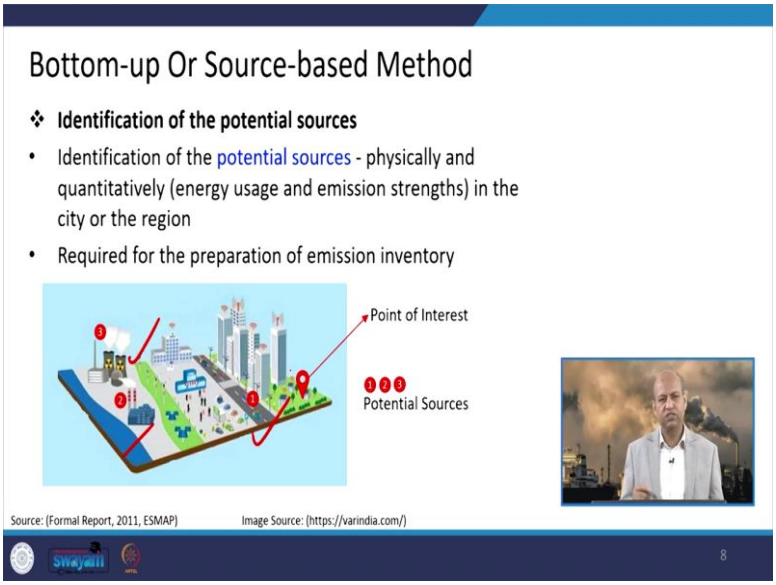

So, when we go step by step, when we go for identification of the potential sources, basically we have to look into physically quantification of those different kinds of energy usages in industries or domestic sources or sectors and then their emission strengths, source wise as well as pollutant wise in the city or particular region of our interests.

Then we need to go for requirement of the preparation of the emission inventory because without emission inventory, we will not be able to use the dispersion models, those dispersion models which will give us the concentrations of different pollutants. So, we have to identify different sources like maybe, some power plants or industries, then there may be some particular, like roadways or transportation sector. So, we have to identify first these are the dominating or potential sources of the pollutants.

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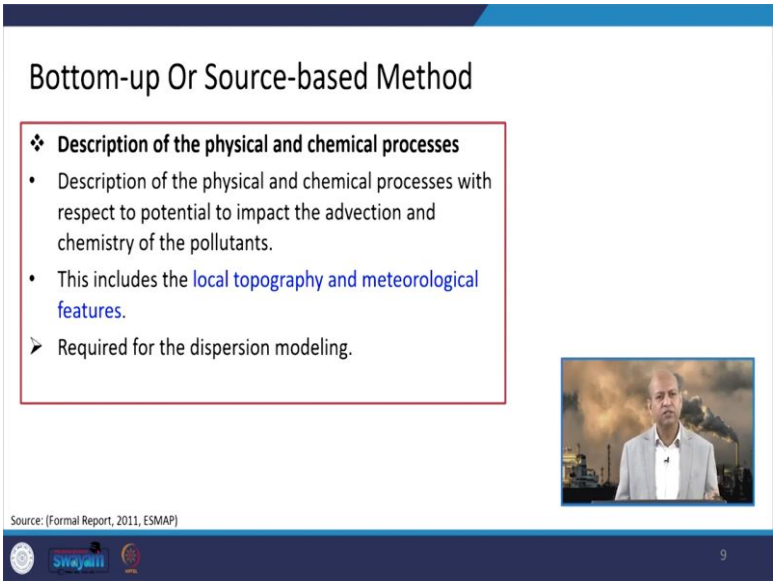

Then we need to describe their physical and chemical processes, which will contribute into like primary or secondary kind of pollutants plus we have to look into local and these regional meteorological parameters, whether wind speed or temperature because they will be used for dispersion modelling.

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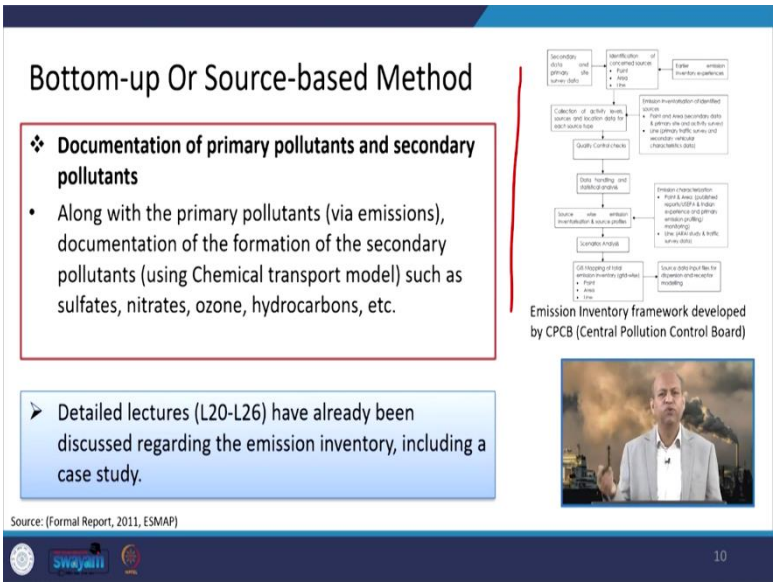

So, in the same process, we have to document the primary pollutants, secondary pollutants and like some chemical transport model can be used for looking into these secondary pollutants like WRF-CHEM model or some other models can be used and we have already discussed in lecture from 20 to 26 basically, about these emission inventory which we develop and different case studies, how to develop the emission inventories.

Plus, at the same time, this framework of the central pollution control board in terms of emission inventory framework or development of the emission inventory is very important. So, step by step in terms of the flowchart it has been given. So, it is very easy to follow basically.

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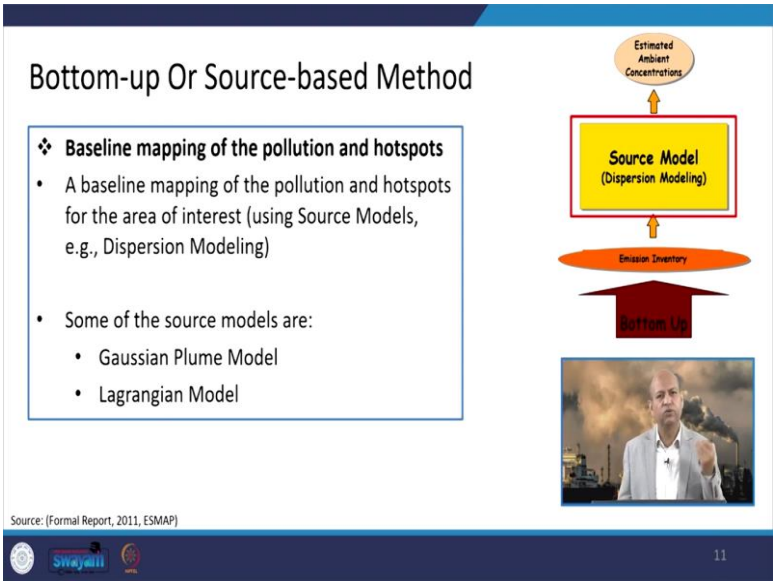

Then we go for this baseline mapping of the pollution or the hotspots as I said, there may be certain hotspots where a lot of pollution is coming from activities. So, the baseline mapping of the pollution and the hotspots has to be done, for dispersion modelling and this source models when we use so, hotspots in terms of emissions, hotspots in terms of high air quality concentrations. And for that, we have to use some models like Gaussian dispersion model Gaussian Plume model or Lagrangian model depending upon the situation.

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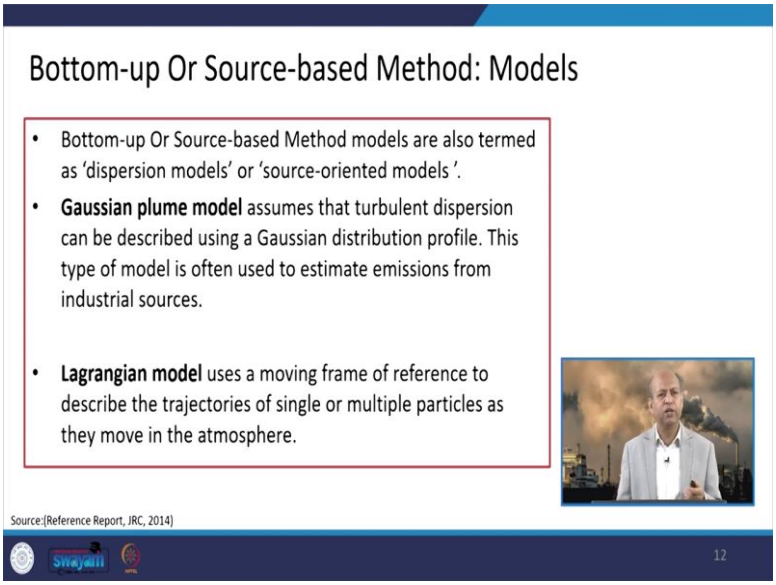

And there are differences like Gaussian dispersion model, which assumes like turbulent dispersion is there and it can be described in normal distribution kind of at the centre line highest concentration, when we go to the lateral direction or vertical direction, then concentration decreases as we go away from the centre line, then Lagrangian model may be there which uses basically the moving framework with a reference like trajectories, so multiple particles they follow up.

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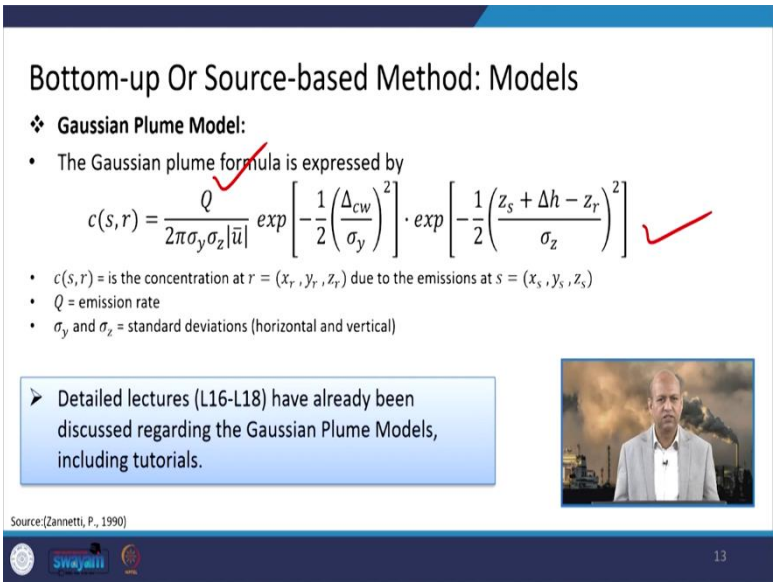

So, this is this is a kind of complex model and mostly we use Gaussian dispersion model and this equation you might be remembering this concentration which is based on the emission and then σ_y σ_z that is the lateral and vertical dispersion coefficients and like this stack height plus

plume rise all those kinds of things and then x, y, z can be the coordinate where we are interested to calculate the concentration.

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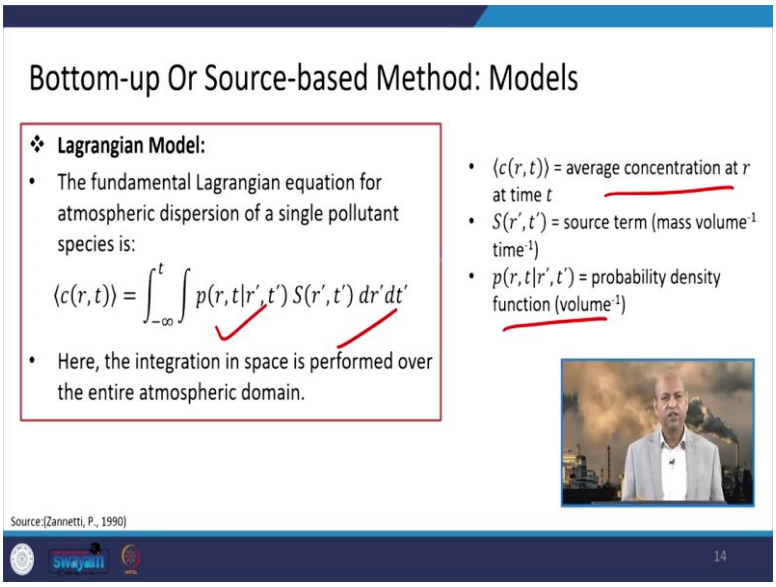

When we talk about the Lagrangian model basically, this fundamental equation is used where the average concentration and the source term concentration in terms of mass per volume per time and the probability density related function is also used per volume. So, you can see this integration of these kind of variables.

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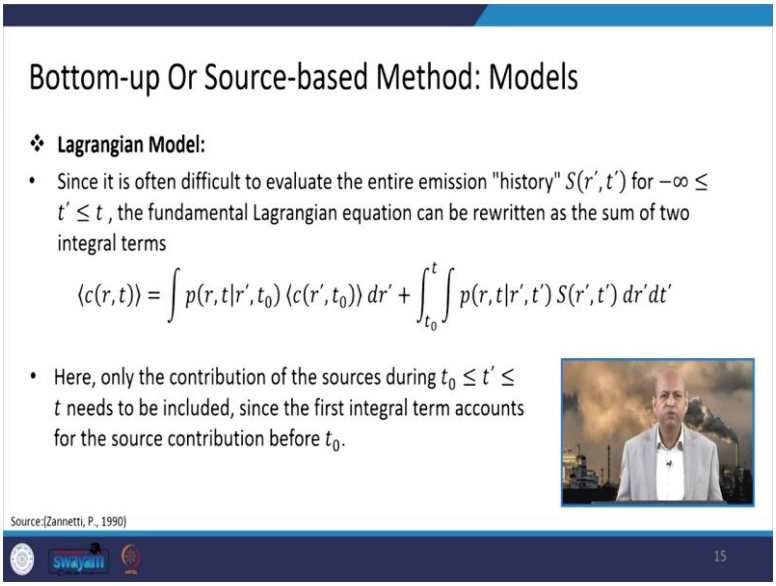

But for simplification, we can distribute into two very simple terms basically, when we use these Lagrangian model and there are computational models now, nowadays available which you can use, whether based on the Gaussian dispersion technique or Lagrangian technique.

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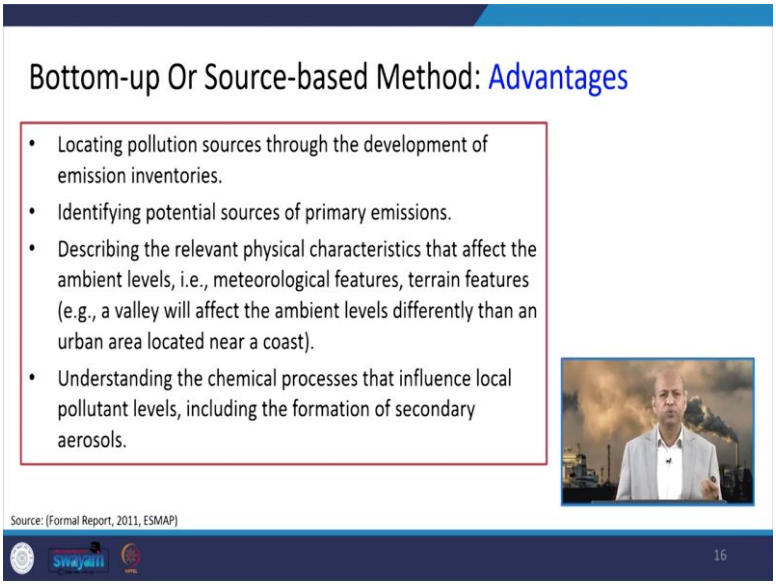

So, when we talk about the advantages, what are the advantages of this using bottom up approach? So, there are several advantages basically like it can help us locating pollution sources through the development of emission inventory. So, we know which kind of source is more dominating because we have these emission calculations then we can identify the potential sources of primary pollutions or primary emissions.

Then we can describe those relevant physical characteristics or chemical characteristics in the sense of their, physical parameters or chemical parameters. We can also understand those chemical processes which can contribute into the secondary aerosols or secondary pollutants. Like secondary pollutants like ozone or secondary aerosols, maybe sulphate or nitrate etc.

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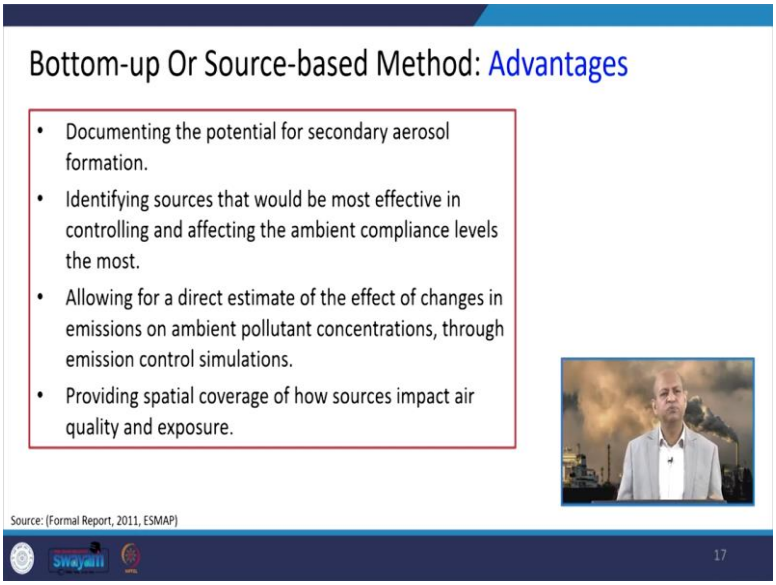

Then, we can also document these potential, sources of secondary aerosols formation processes, and we can identify the sources which will be most effective, because we know different kinds of sources in terms of quantity as well as in terms of their effect on the air quality concentration by using the dispersion model.

So, we can now know which source is dominating or which is culprit which is deteriorating the air quality in a significant way. So, we can identify those particular sources and we can, directly estimate the effects of those changes in terms of emissions and in terms of ambient air quality concentration. Plus, spatial variation, temporal variation, those kinds of things in terms of the quality and exposure we can do in this particular activity of the bottom up approach.

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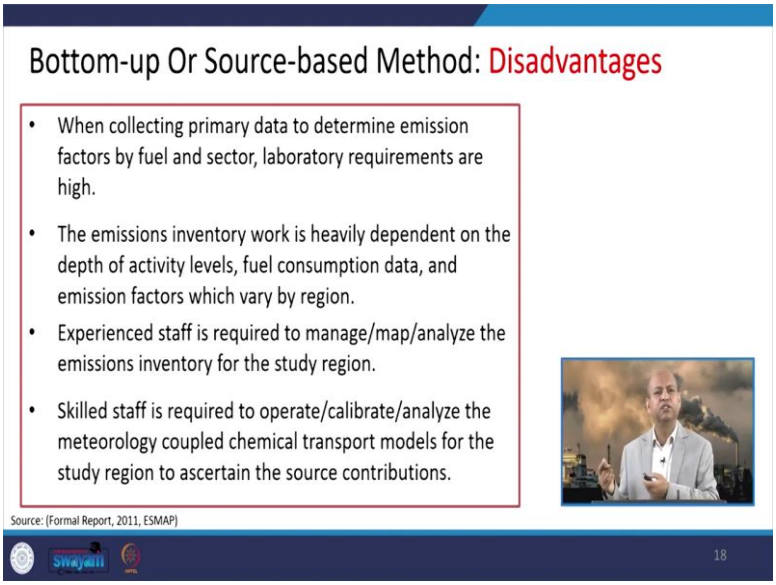

But, there are certain disadvantages also, like when we go for collection of primary data, and we go for emission inventory development, based on emission factors and laboratory requirements for those generating those emission factors, it is very expensive process basically, highly complicated laboratory equipment's, we need for like, different kind of vehicle emission factors.

So, for each activity, if we need to have the emission factor, it is a huge task basically needs a lot of resources, a lot of infrastructure and a skilled manpower. Similarly, for development of emission inventory, we are heavily dependent upon those activity level data, fuel consumption data, so uncertainty may be there and it can vary from, region to region. And then experienced or skilled staff is needed for developing emission inventory for calibrating the emission, estimating tools or models plus dispersion models.

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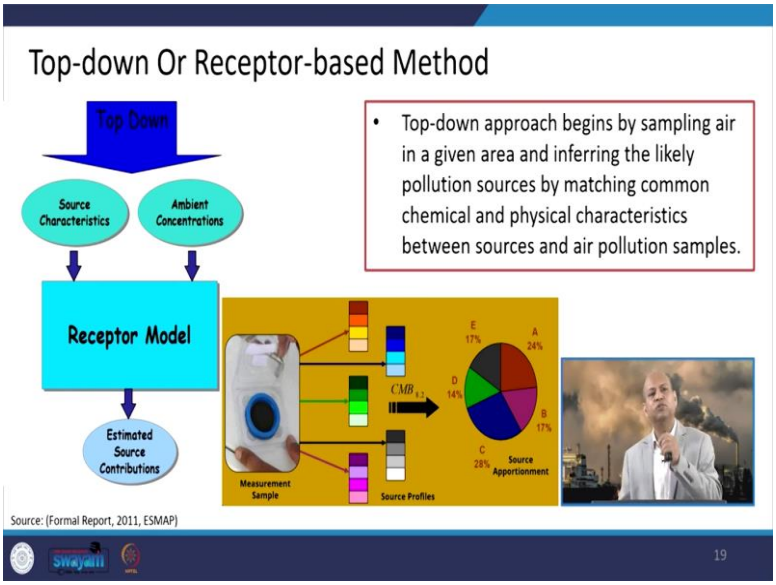

Now, if you go for top down, or receptor-based approach method, which is another very popular method which we will see. So, in this basically we go like for sampling, we go for the air quality concentration sampling, and then we match those air pollutants concentrations to the pollution sources, because we also identify the pollution sources.

So, different markers are there, there are different signatory pollutants from different sources like as I said in one lecture that if you are given a table and in that table, you see the NO_x emissions, NO_x concentration is very high your CO concentration is very high. So, you will intuitively think that this site may be near to the transportation sector or some highway or something like that, if you get high concentration of the SO_2 etc, then you may assume that maybe coal based thermal power plant is nearby. So, that way you can link you can match basically, and there are statistical tools also.

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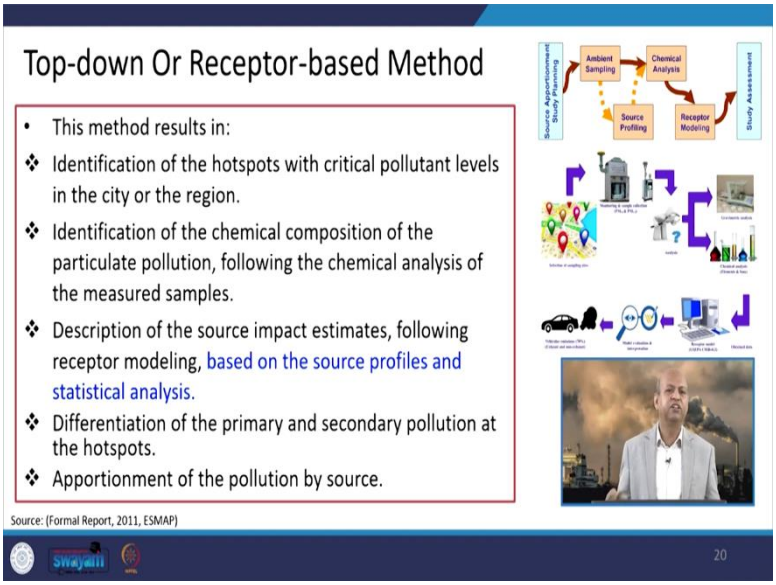

So, we will see in this particular top down approach basically, we need to identify first of all the hotspots of the pollution sources and the levels as we do mapping through air quality monitoring and the identification of the sources. Then we go for, identification of chemical compositions of different particulate pollution, chemical analysis is to be done after when you collect like particulate matter, then you go for chemical analysis in the laboratory.

So, how much heavy metal is present in that particulate matter or which kind of different pollutants are present there. Well, then we describe based on the source profile and the statistical analysis we have to do. So, we can basically match the sources and the pollutants and we can differentiate between primary and secondary pollution also, and then we do the detailed apportionment of the pollution with respect to the source.

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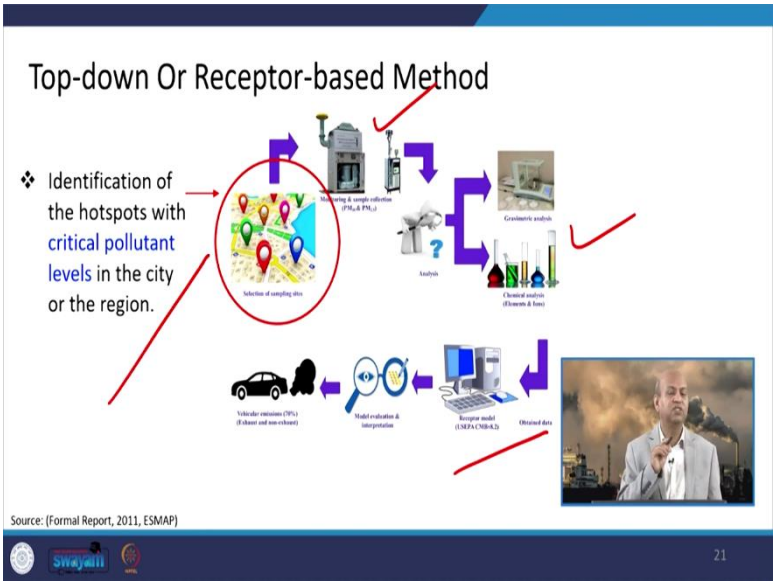

Basically, when we go for, this identification of sources, the monitoring of the pollutants, and then we go for this chemical analysis, and then we go for this matching of the statistical tool utilisation for apportionment. So, all these are given in this particular picture, so the first of all the critical pollutant levels have to be identified those locations where a lot of pollution is there.

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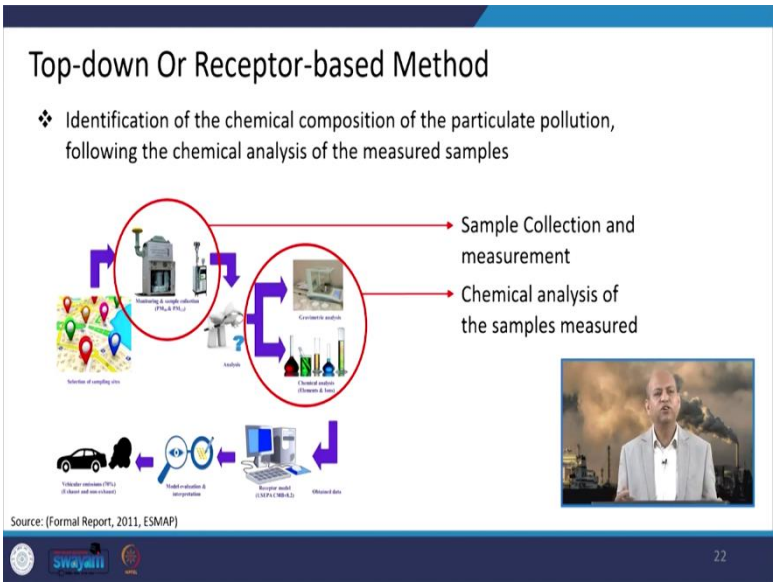

The second is identifying the chemical composition of the particulate pollution. So, for that we have to do chemical analysis in the laboratory basically, so sample collection and then the measurement of those samples and take to the laboratory for chemical analysis, so that we can know several kind of pollutants which are toxic chemicals available in those particulate pollutants.

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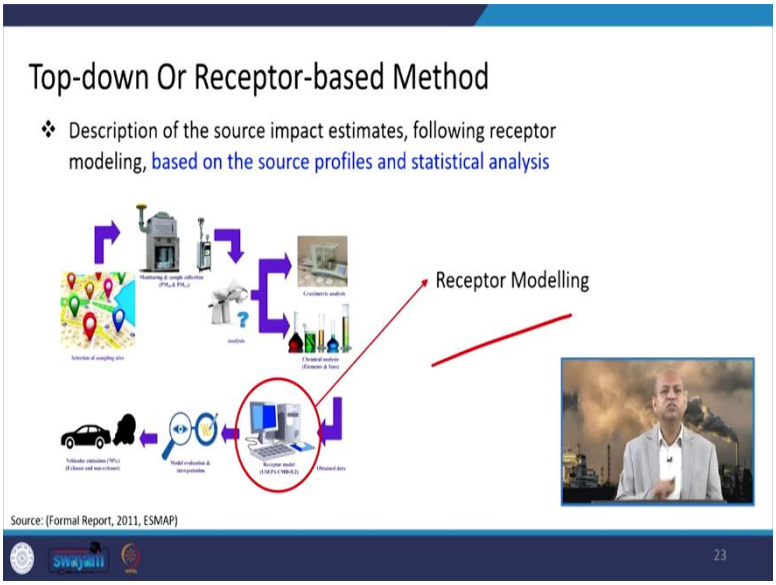

Then we go for this receptor modelling, so like chemical a mass balance or PMF, etc we will see later on, so those kinds of tools we will basically use.

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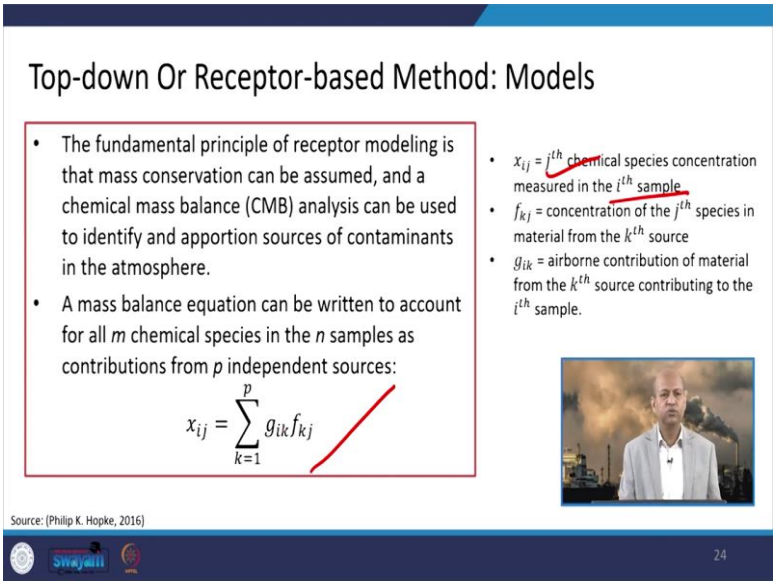

So, like as I said that the fundamental principle of the receptor modelling is basically the mass conservation. So, the chemical mass balance analysis can be used to identify and apportion the sources of the contaminants in the atmosphere using the CMB technique basically. So, mass balance equation which is used for this particular purpose is this one you can see the chemical species of different nature i^{th} z^{th}, in i^{th} sample z^{th} chemical especially can be mean different samples may be there different species may be there.

$$x_{ij} = \sum_{k=1}^{p} g_{ik} f_{kj}$$

So, we represent like that, then the concentration of that particular species in the material form from the k^{th} at source right and then airborne contribution of those particular material from the k^{th} source contributing to the sample. So, their relationship is expressed with this particular equation.

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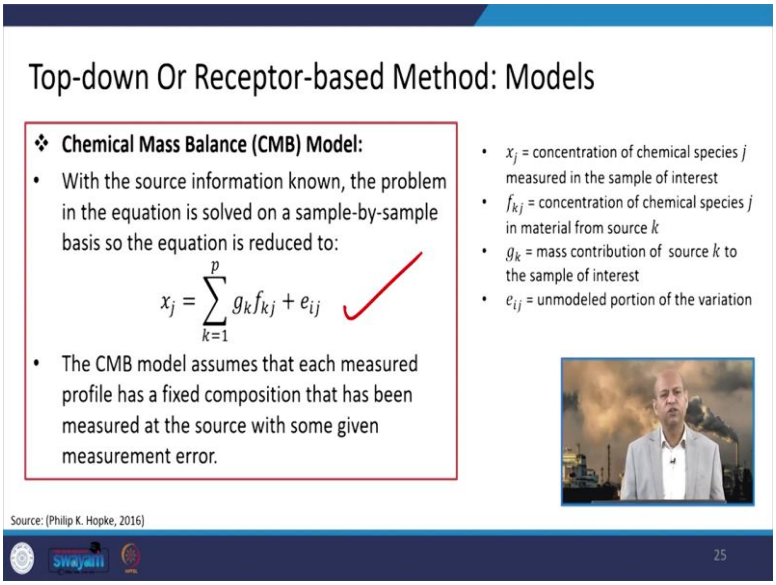

And this equation further simplified as a CMB model in this particular form, so that you can easily calculate, which kind of species coming from the, which kind of a specific source.

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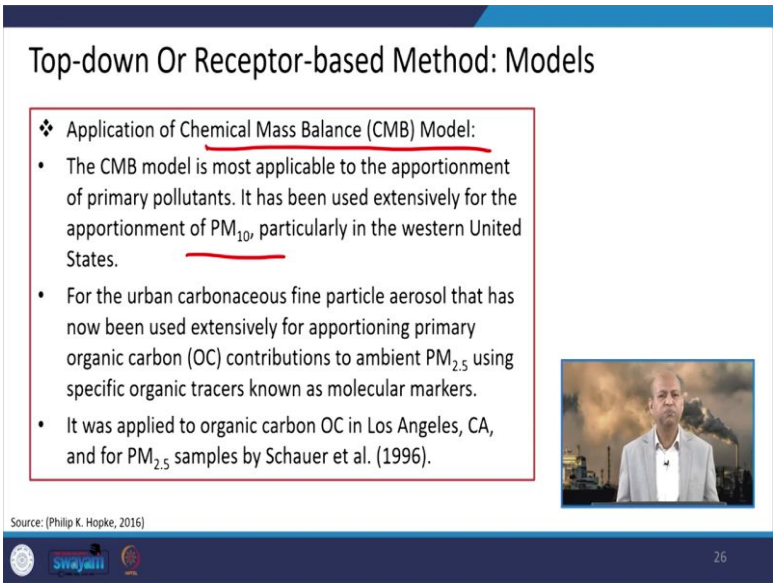

Well so, when we go for this top down or receptor-based modelling, that is the CMB modelling or Chemical Mass Balance modelling basically. So, for example, we go for PM_{10} apportionment, so, in PM_{10}, whether elemental carbon, organic carbon or some heavy metals are present or carbonaceous fine particles are there for that it is quite usable for using the CMB technique.

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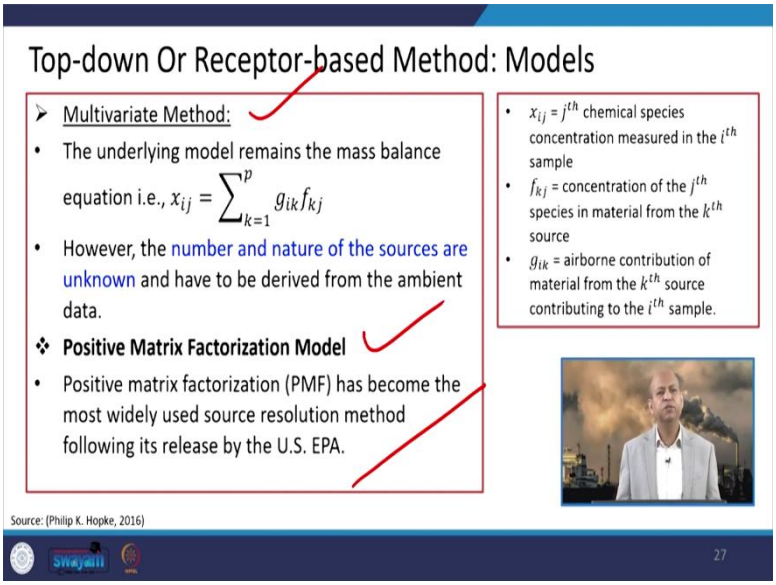

Then, there is another method that is the multivariate method. And that that multivariate method basically, you can use this Positive Matrix Factorization model or PMF that is very easy tool and that kind of late the pollutant with a specific source and this is computer based technique and statistical analysis is to be done, and the US EPA has used it and after that, it has been very popular among atmospheric researchers or air quality scientists.

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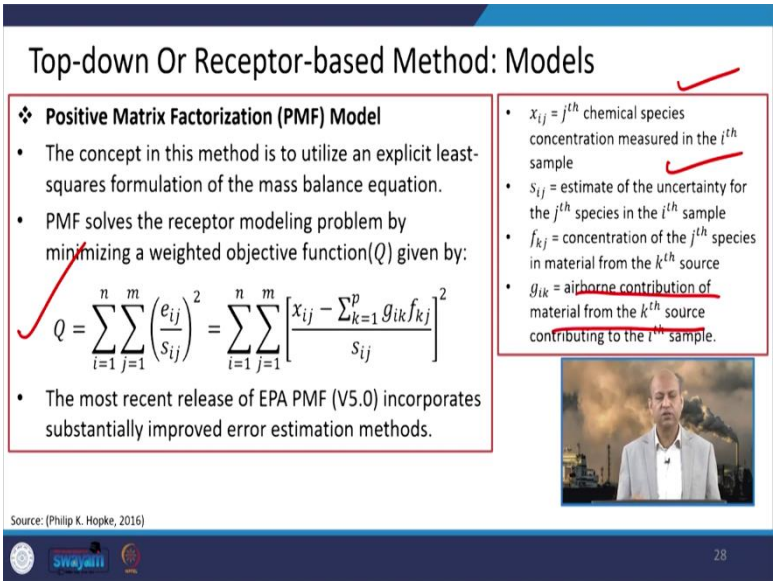

So, this is particular relationship which represent this PMF model which can be used like chemical species then uncertainties maybe their concentration of that particular j^{th} species again the same concept airborne contribution from particular source. So, all those i, j, k whether it is species or that sample or the source that has to be related with each other.

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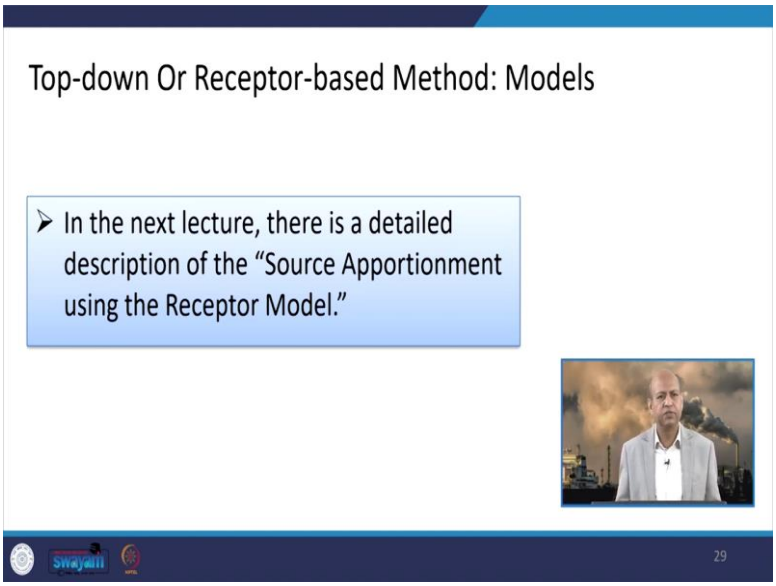

So, this particular top down or receptor-based model or method in the next lecture, we will discuss in detail. So, we can just skip at present the source apportionment using the receptor model.

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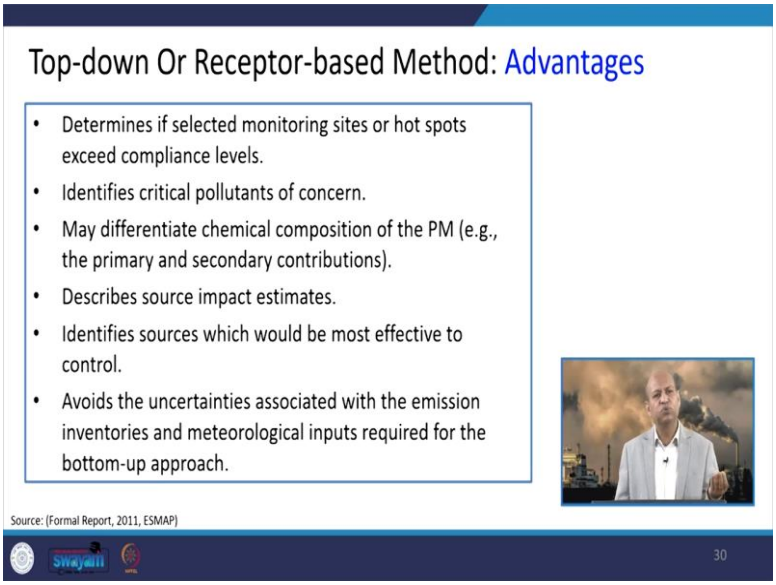

So, we can directly come to what are the advantages and disadvantages of the receptor-based method basically, it can determine those monitoring at the selected monitoring sites hotspots some particular compliance levels whether it is exceeding or meeting the those air quality standards or not, it can also help us in identification of those critical pollutants of the concern which can have severe health effects etc.

It can also be used for differentiating chemical composition of particulate matter in terms of primary or secondary contributions, how much is there, then description of source impact estimates can be done by this technique receptor-based model, identification of sources with respect to the most effective controlling technique because when we know the dominating source we can just what kind of technology we can use to control that particular source.

And it can also avoid some uncertainties which are quite part of that emission inventory-based modelling or the bottom up approach. So, that kind of uncertainty can be reduced and it is much simpler and must cost it for much cost-effective in terms of resources and skilled manpower.

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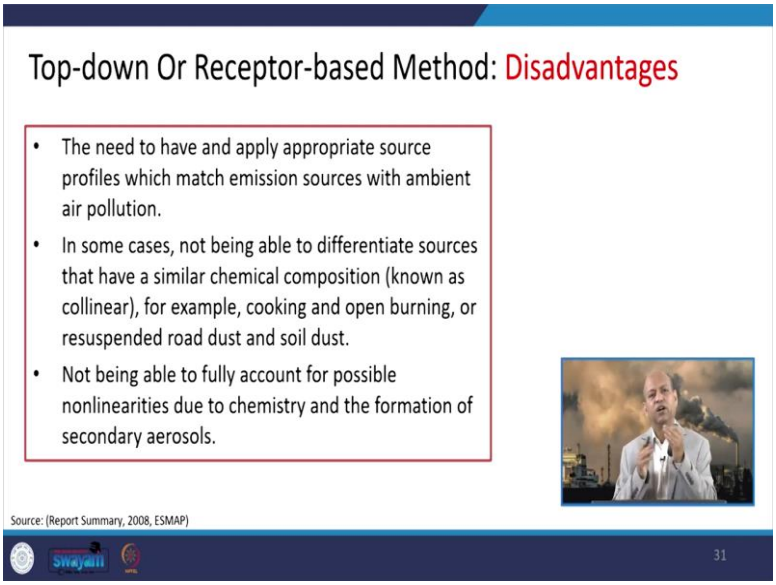

Then there are certain disadvantages also, like it needs to have an apply appropriate source profile, which can match emission sources with the ambient air pollution which is again it is not so, easy, it needs some intuitive gas as well as some laboratory-based analysis, those kinds of things we need to know and the computer modelling skilled manpower is needed.

In some cases, not being able to differentiate between the sources that can have similar chemical compositions for example like, cooking and open burning will have similar kind of air quality pollutants. So, it is difficult whether it is coming from the, open burning or from the cooking. Otherwise in emission inventory, we can have, different permissions so, that is the advantage in that bottom up approach, but in top down, this is the limitation, because we cannot differentiate in terms of those particular pollutants, which are common in both the sources.

Like road dust and soil dust can be simple. So, it is coming from the resuspension of the road dust or from the soil dust, we do not know, so that is the limitation in this particular approach. Also, it is not possible to be able to fully account the possible, non-linearities due to the chemistry and the formation of secondary aerosols, because that is one more limitation in this particular approach.

But, now we talk about the integration of the bottom up and top down approach, because both have certain advantages, both have certain limitations. So, if we get those advantages, integrated then we can have better kind of analysis and better kind of rituals.

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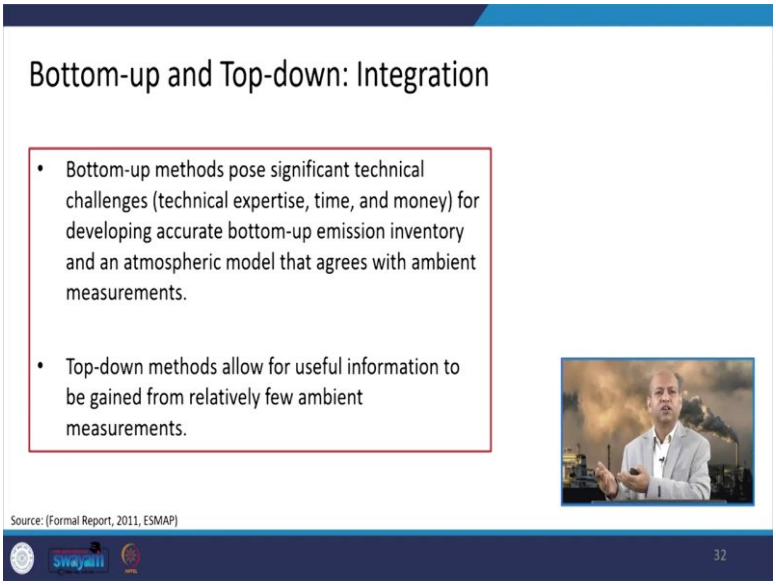

So, the like bottom up approach, which give the technical challenges or like in terms of time in terms of resources, etc whereas this top down approach is quite simple in terms of very few resources are needed. So, that way we can integrate those approaches.

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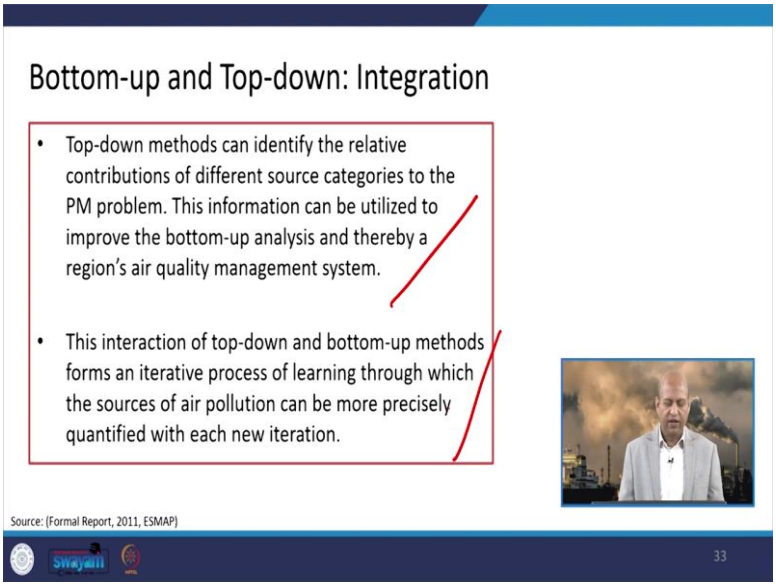

Well, so we can look into this information which are available through bottom up or to the top down and we can have the best aspects of the both the techniques and we can, that way minimise the limitations of both approaches.

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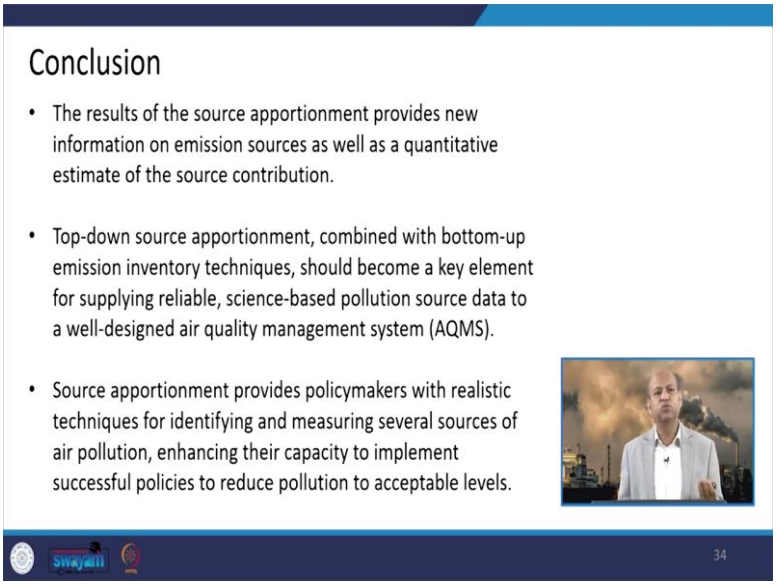

Well, in conclusion, we can say that the results of the source apportionment provides new information in terms of emission sources as well as it gives us the quantities of different estimations of source specific pollutants. Then top down source apportionment combined with bottom up when we integrate that approach, like I mentioned inventory techniques as well as, PMF technique etc it gives us much better results for air quality management systems.

Plus, source apportionment provides, policymakers with realistic techniques and information, so that we can go for targeting only those sources, which are more dominating and which are like low hanging fruit so that air quality improvements are quite quick. If we do not know the specific sources which are contributing to a particular pollutant, then it is very difficult to make a policy or to make a programme to reduce those pollutions. So, that way source apportionment is very important, because it gives us an idea which particular pollutant is coming in large quantity from which a specific source so that we can target that source.

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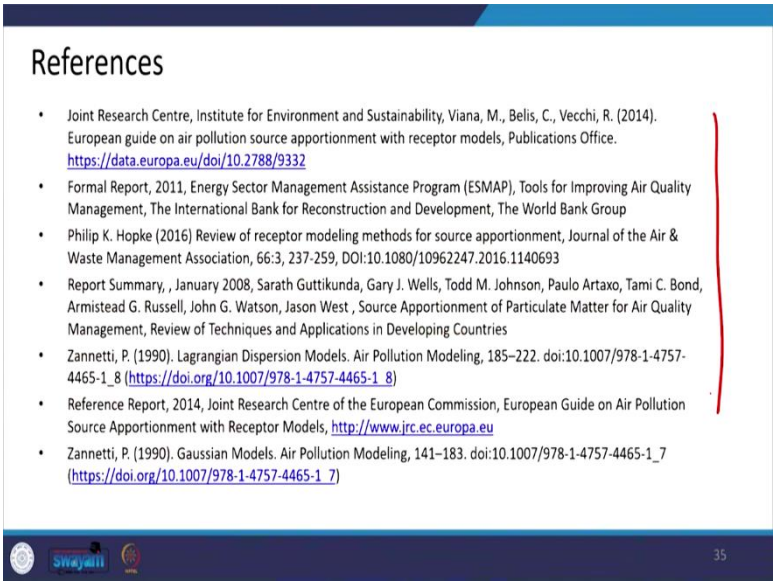

So, this is all for today, this is the reference for your additional information. And in next lecture, we will look into the source apportionment study based on the receptor modelling. Thank you very much for your kind attention. Thanks a lot.