Environmental Air Pollution

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Lecture No. 15

Emission Inventory

We will talk about something very important. People very often ask how much is the pollution. People also ask if Delhi is more polluted or Calcutta is more polluted and whether India has a serious problem at the world level or whether it is the United States or China. Very often, we encounter this problem. At the broad sense, we always want to know. One thing that helps you to answer such broad questions is the emission inventory or air pollution loads. I will give you an example. These are figures from Delhi.

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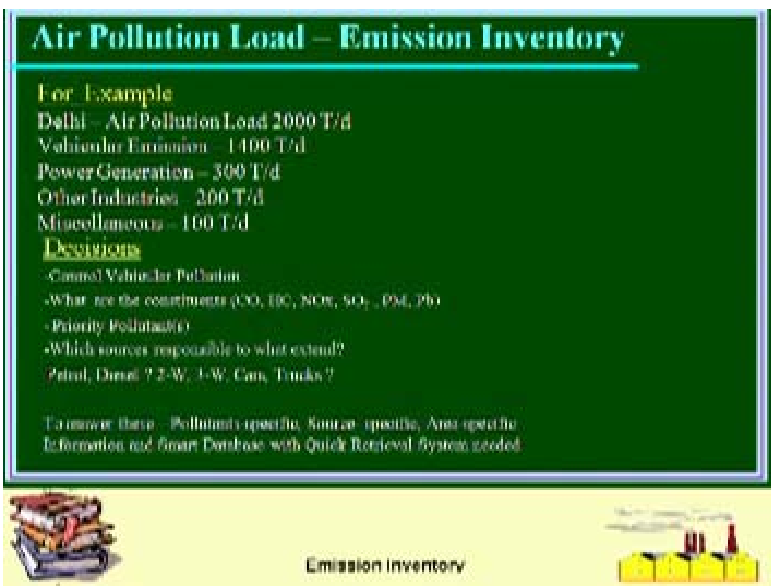

The air pollution load, total pollution load in Delhi is 2,000 tons per day. For example, the vehicular emission is contributing 1,400 tons per day of the total pollution, power-generating units in Delhi are producing about 300 tons per day of the emissions, other industries are about 200 tons per day and other miscellaneous sources, which may include domestic source as well cooking, could contribute up to this. Useful information. Why? If you look at that, you say we should do something about the vehicular pollution because you all need to take decisions and we need to do something about this. Suppose within these, I further had the breakups in terms of CO, hydrocarbon, NO_x, SO_2, particulate matter and lead, then I can prioritize that CO is the serious problem for example in Delhi. So I must attack or rather I must control the sources that are largely responsible for carbon monoxide – I am just giving an example.

Then we can say that CO is largely an issue or we may say that particulate matter is an issue. Then we should control the diesel vehicles or two–wheelers or three–wheelers and then we can take decisions. To answer these, we need pollutant-specific, source-specific, area-specific information and a smart database that can quickly retrieve the answers to the questions that you may pose to the database system. These questions can be very general, could be required by the experts, could also be required by very ordinary people to know what is happening in the area and they could also be required by politicians and bureaucrats to make a decision.

It may also be required at the ministry level or the inter-ministerial meetings. It can also be required at international meetings and forums. For example, if I was talking about the greenhouse gases, then at the international forum, we always need to pose [03:12] condition that in India, we are producing so much of CO_2, so much of methane. That assessment is sometimes very very important and we will see some of the uses of this and how to really do this.

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What is this really? What is emission inventory? Systematic collection, complication and collation of data concerning air pollution emission in a given industry or an area is referred to as the emission inventory. Immediately, something is specified and you are always specific to some area. We cannot say that the area can be the entire world but we need to define some area. Broadly speaking, what it can do is it can give you the broad options for pollution control – not very specific but broad [04:08].

Assist in air quality surveillance program. Surveillance means…. Suppose you did the emission inventory for Kanpur and you find that, let us say, you have a lot of pollution and emissions are high in the Panki industrial area or Dada Nagar industrial area. Then, you would like to put regulatory enforcement, send out people and surveillance to that area more often to see what is happening there. Seasonal and geographical distribution of pollutants change. So your inventory may also have the information that things are like this in winter. For example, some industries are very season-specific like sugarcane industry. Then you have this.

For example, leaf burning is very common during fall time. That may be season-specific. Even geographically, sometimes, pollution changes and so sometimes, we need to consider that also. Aiding in regional planning and zoning. You can say that these are the protected areas, these are the clean areas, you can do community education and you can tell the people that their area is more polluted and ask what they are doing about it. You can tell the industry, you can prioritize the industries, you can give the listing of the industries – these are more polluting, less polluting because you have some information. Then, you can provide the competitive environment to the industry and say "You are the most polluting", the industry feels bad about it and they improve (we all want to improve). If given bad publicity, people do change.

You can also use the emission information for air quality modeling. What I mean by modeling is that once you have the emission inventory, you couple this with the wind speed and wind direction and you can say how the pollutants are being emitted, because inventory is the quantity only. Then, you can do the dispersion with the information on the quantity and you can see what will be the impact. Finally, you can take very good decisions primarily based on the emission inventory as well as air quality modeling.

Why was vehicular pollution controlled in Delhi? We have opted for CNG largely. Sometimes, you do not need very sophisticated instrumentation. You could very clearly see from the emission inventory that vehicular pollutants are a serious problem. Out of 2,000 tons, they were contributing about 1,400 tons. You do not need models, you do not need experts, you do not need scientists but you can very quickly take decisions. They decided to go for CNG instead of diesel and things improved. Then at most sophisticated levels, you can do more fine–tuning but the emission inventory is of great information.

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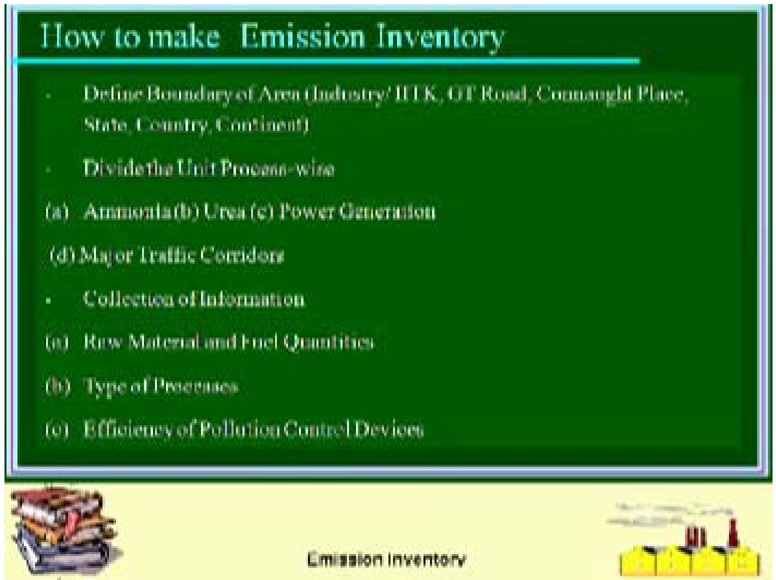

How to make emission inventory? Define the boundaries [07:04]. For example, it could be simply GT Road, it could be simply IIT Kanpur institution (we will do an example of IIT Kanpur), it could be just the area of Connaught Place, it could be a state, it could be a country or it could be a continent. Divide the unit process-wise. I am just giving an example for industry and this thing. You also want to divide certain pollutants and then you want to divide the major traffic corridors. Then, you need to do the collection of the information – we will see later how much and what information.

You also need the information of raw materials and the fuel quantities. You also need to know the type of process. If you are burning [07:49] coal, the emissions will be different; if you are burning coal with the hand fire shovel, the emissions will be different; if you are producing let us say urea, the technologies are different and the emissions will be different.

You also want to know exactly what kind of process is there and on top of everything, you also need to know the pollution control devices because sometimes, these are uncontrolled. Suppose an industry has a control device, you must modify your emissions based on the efficiency of the pollution control devices that are installed. We will see how these things are really done.

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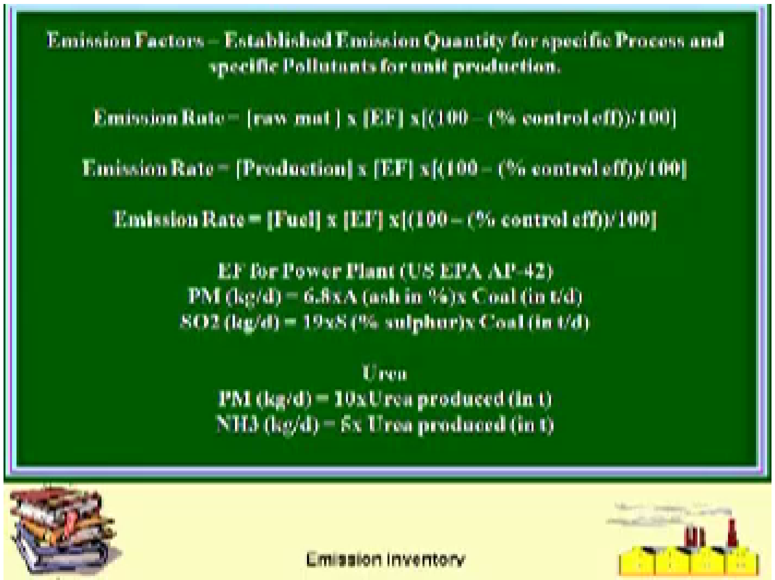

What people have done and this has been going on for the last 30, 40, 50 years is that have developed certain factors. If you are producing, you are using so much of coal multiplied by a factor you will come to know so much of the particulate matter that will be emitted. Some kind of factors have been established – not a very easy job to do but still these are available. Established emission quantity for a specific process. For a specific process, there is a specific factor and a specific pollutant for unit production.

For example, if you want to find out the emission rate, an example may be based on the raw material. If you are using let us say…. For example, I can say in the cement factory you are using x ton of let us say limestone and then there may be a factor for let us say particulate emission. That factor [09:29] quantity of the raw material…. The factor will look something like emission of whatever the pollutant per ton of raw material processed. You get the emission and then you can put the efficiency of the pollution control device that has been used by the industry because this can vary from industry to industry and you can find out.

The emission rates could also be based on the production. The factor would be based on the megawatts of power generated and so much of carbon dioxide will be produced because you are using a particular kind of fuel. The emission rate could be based on the fuel into emission factors. These things people have really generated. I will just give you an example. The emission factor for power plant is the reference and we will come back to this reference again and again.

Most of the times, Americans do a very fantastic job. In fact, they are the leaders and the world tends to follow them – it happens. The AP-42 started somewhere in the '60s. Then, they kept on modifying and improving and everyone tends to see this. Of course, people change as per the local condition but this becomes a mother document for most of the people in the world if you are generating an emission inventory.

For example, if I want to find out particulate matter emissions from the power plant, the factor is 6.8 times the ash content in percentage times coal in tons per day and the unit here will be kg per day. It is not very difficult to understand how this factor has been arrived at, but we have to be careful with the units. The coal consumption is in tons per day; ash is in percentage (which is A) – 40 percent, 50 percent, 30 percent; 6.8 is the factor. 19 into for example sulfur dioxide, S is the percentage of sulfur, coal consumption in tons per day. This will be tons per day. You see the difference in unit – tons per day and kg per day.

If you really try, you can figure out as to why this factor 19 has come. This is basically unit conversion and you get this kind of information. For example, a urea plant is there, the particulate matter emission could be based not on the fuel but based on how much urea is produced. You produce in tons; it should be tons per day – so much kg per day. So is the ammonia emissions from the urea plant – that could be in terms of kg per day and 5 times the urea produced in tons per day will be this thing.

If you have the information…. Inventory is always an estimation – it is not something where you say 29.0612 kg per day. These are estimates – reasonable estimates. Emission inventory and objective methods, present practices in developed countries – we will see that and we will also do a case study.

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Again, a repetition: systematic estimation and collection of data on emissions of desired pollutants. You have to always do little scoping of your work – you cannot be doing indefinite and infinite things. Otherwise, you will never be able to finish. You should have the inventory that you develop. Scope it properly. You can decide for example that you want to know only for SO_2 and nothing else. That will be governed by specific objectives you have. That is what I am trying to say.

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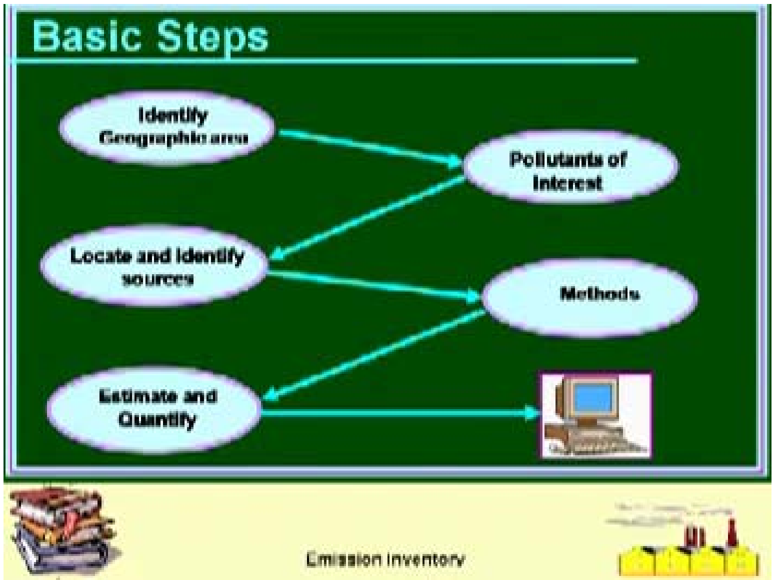

How to do the basic steps? Earmark the area, decide the pollutant of interest – you might decide only CO_2, for example, or more and then you locate and identify the sources – where are these sources because the sources must be known to you (where they are). You have to come out with certain methods. For example, my objective may be simply to find out how much is the diesel and petrol related emission in the city. My designated area is fixed, pollutant of interest could be related to diesel and petrol and my method could be simple – I go to all the oil depots, for example, BPCL, HPCL, Indian Oil Corporation, Reliance and ask how much is their sales.

They will give me the sales figures and then I get the quantity that is being used – diesel and petrol in the city of Kanpur. For the methods, you have to again decide as to what you want, how accurate you want because somebody will immediately question by saying that is fine, but what about some of the trucks that are coming into the Kanpur city? They will also consume some petrol and diesel and they may not draw petrol and diesel from Kanpur city. There will be questions. You need to identify the methods and also say to some extent how confident you are about things and estimate the quantity. Then of course, database – for everything, a database is required.

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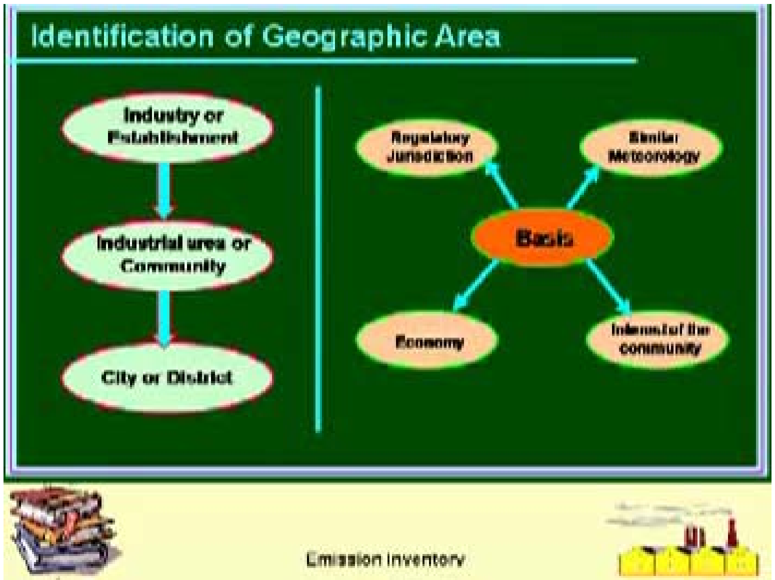

Then, what could be the basis? You want to compare the cities with similar meteorology, regulatory jurisdiction because let us say you want to do for all the districts in UP for example because UP State Pollution Control Board says [15:15]. You may have economy based – this city's economy is high, let us say you want to do it for Bombay because economic activities are high. So you need to know the basis – whatever that may be – and then you can decide the pollutant as you see here. We will not spend time here.

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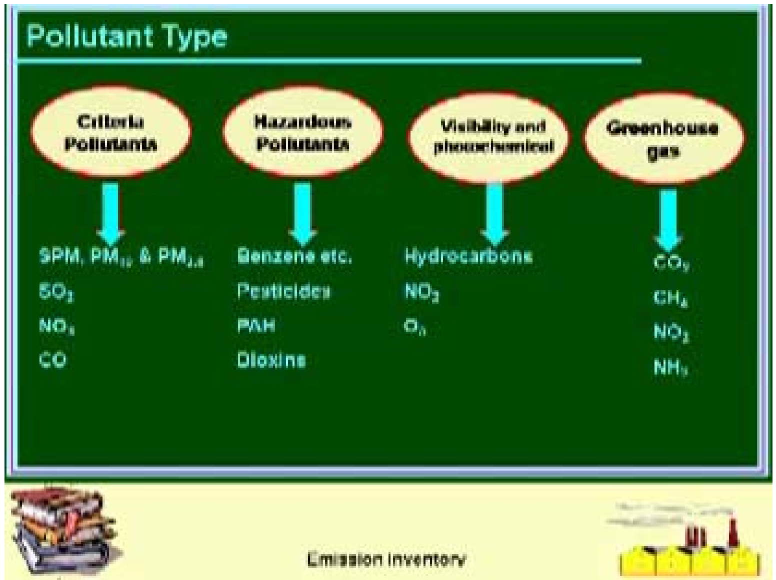

But you can decide which pollutants you want to do. There could be some other specific pollutant that are specific to the city and then the hydrocarbons. Sometimes, this may be of great interest to people working on global warming. Then, you have to identify what are the sources that you want to deal with.

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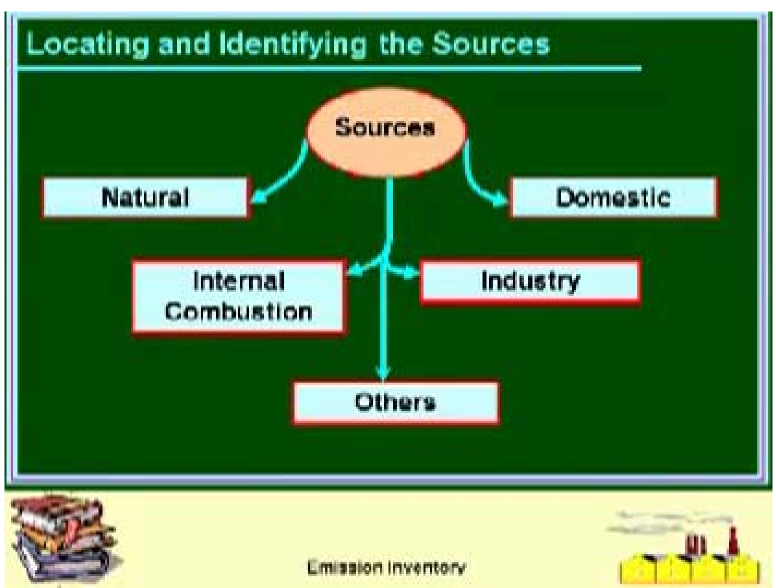

Sometimes, you may only want to deal with anthropogenic sources or sometimes, you want to deal with only natural sources – you want to find out the contribution of the natural sources in your area. Sometimes, you want to quickly know and it really happens. You can control man–made sources but for natural sources, the control is extraordinarily difficult. So maybe you want to see this. Since we are talking about sources…. Let us go to the next slide.

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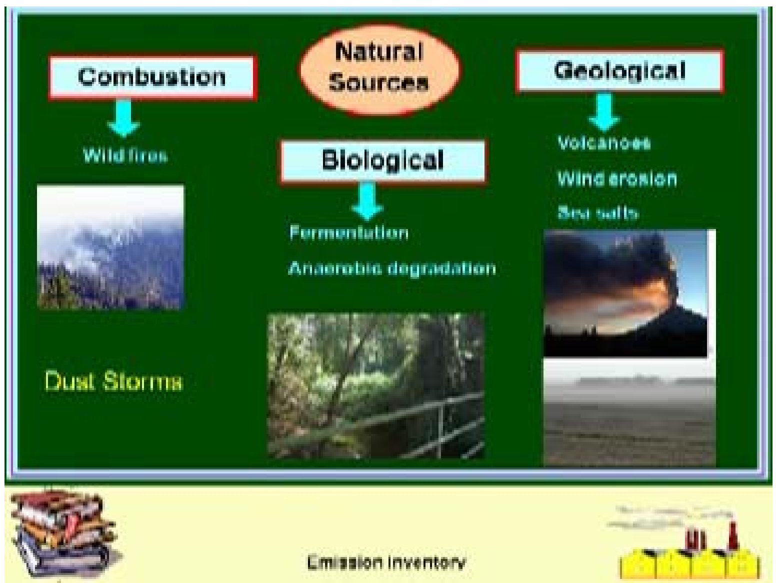

Natural sources can come from different…. You can list many more actually. You can have wildfires. This is considered a natural source – the fire occurs naturally. You see the problem – it is so difficult to control the natural source. I do not know how to control. Of course, we all try for this. Again, Malaysia has regular forest fires as well as US and Australia. You can also have volcanic eruption – it causes huge emissions of various gases and particles and dust.

Then, wind erosion, which includes the dust storms. You can see here the volcanic eruption, the dust storm and sometimes, all the particles like the leaves fall, will undergo fermentation and produce methane. Sometimes, if you have been attending that lecture (I just remembered [17:33]), even plants can give VOC emissions as we had shown in this lecture – they continue to emit… some of the plants depending on that. You need to identify the sources and you have to also identify the industry.

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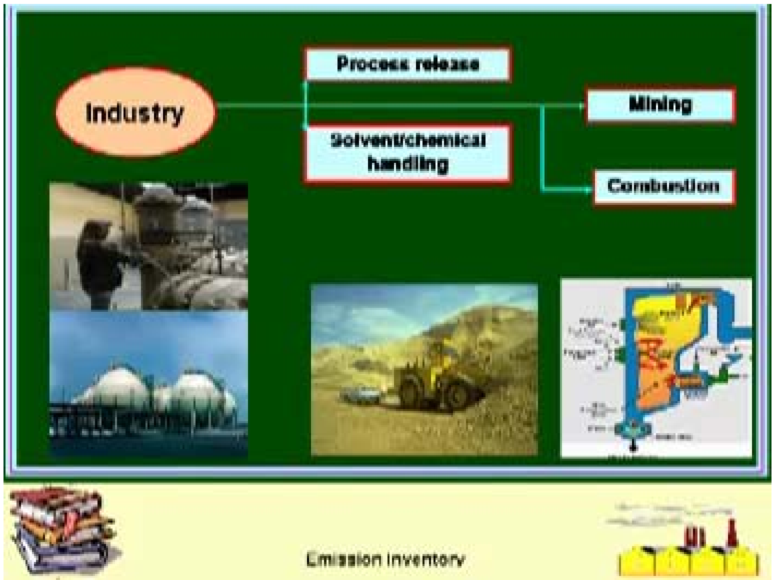

In an industry, you want to see both. Process releases because you want to keep the mining because mining causes serious problem and you also need to look at combustion as you see here. You also need to look at the solvents and chemical handling and then you also need to see the processes. I have not mentioned here….

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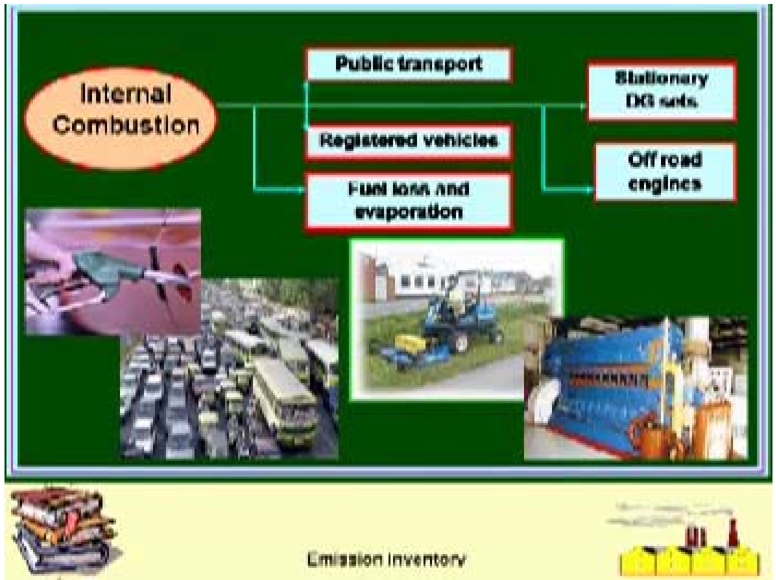

From internal combustion engines, you want to find out these sources. You want to find out the big engines that are stationary. Not only sometimes but you need to find out even the automobiles that are not on the road. I can tell you a good story about this. You are trying to control air quality in a certain area. They had all the sources known to them and they did a very good job. It was in California – Santa Barbara area. They said the air quality was not improving. Everything was controlled here and the models were run and they said that everything looked fine. Why is it that….?

It was only a little later on that it was found out that…. Americans have huge houses and huge lawns and they were all are using this thing and this thing was so inefficient. The emissions from the lawn mowers was so much that they decided…. They came to know that this was a significant problem (not that it was the only problem). Then people started working on the efficiency of this. You see how information can help you to do something that you do not even think can be an issue.

That is how you have to be a little open-minded and be a keen observer as to what is happening, because many of the ideas come mostly from observation rather than solving huge differential equations – that can come later on. As you become…. This was the [20:00] area. This was just an example. In fact, what the Americans did was they made a separate inventory for the vehicles on the road and the vehicles' internal combustion engine off the road, which also includes tractors for agriculture and [20:18].

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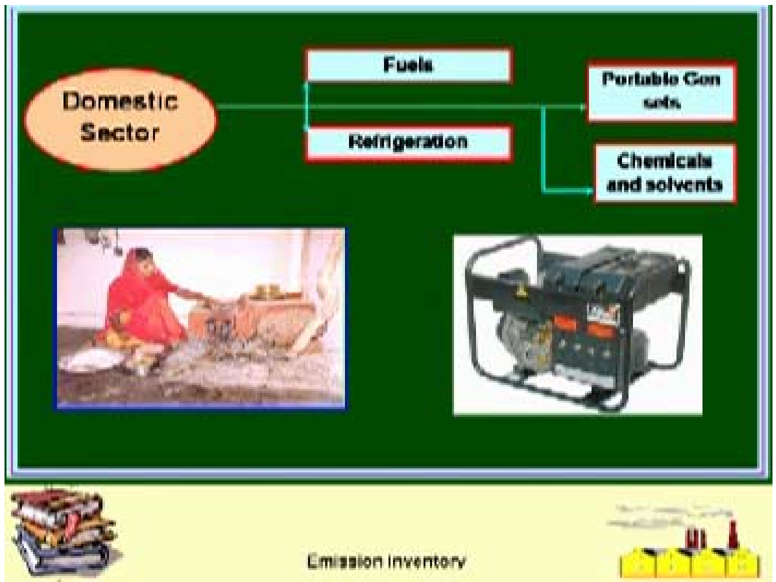

Just to give an idea [20:22] importance. Domestic sources: we all know that in India this could be a very significant source of emission. I can replace this thing with LPG but then we also have to consider the various fuels, how refrigeration may require CFCs, portable generator sets also become an issue in India, chemicals and solvents that might be used in the house because sometimes, you want to find out every source. You may find that you have varnishes, the wood and it can also cause a lot of emission of VOCs – everything needs to be looked into.

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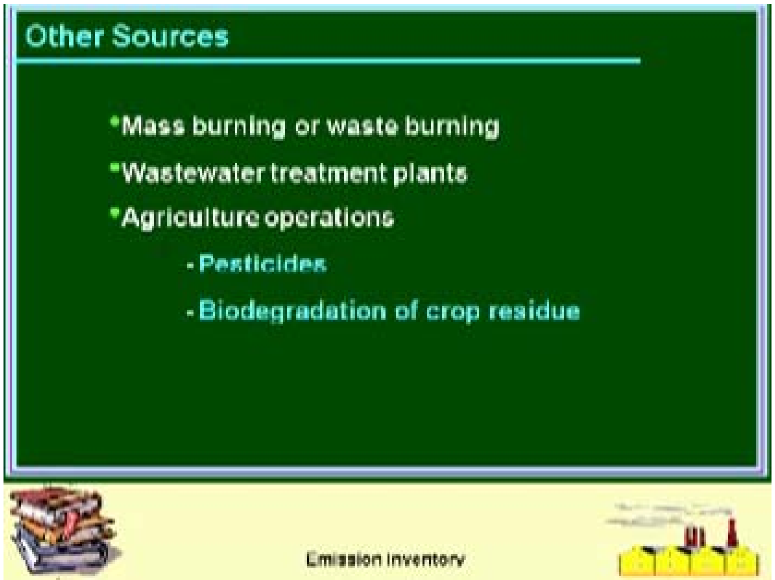

Then other sources [21:13] mass burning or waste burning – we all see that even in IIT. At the end of every March, they will burn this thing. Wastewater treatment plants are a source of emissions. Agriculture operations – spraying of pesticide is a source of emission and biodegradation of crop residue is a source. What is the main pollutant that comes out? Methane. Do not forget that there is a huge amount of ammonia. People are not even realizing that. The ammonia levels are largely responsible for the crop residue and for the animal production facilities. So all need to be looked into.

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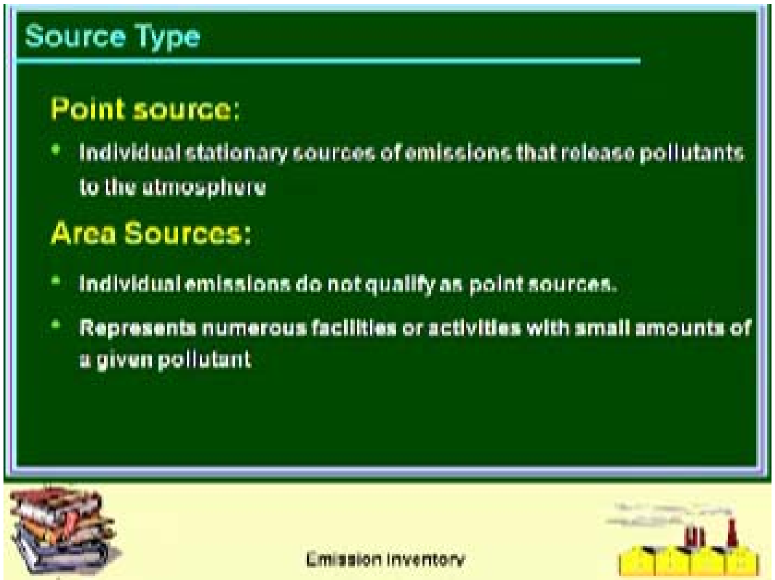

All the time, emissions are…. This is not so important but we want to define the emission inventory also based on the foreign sources, industrial sources and area sources.

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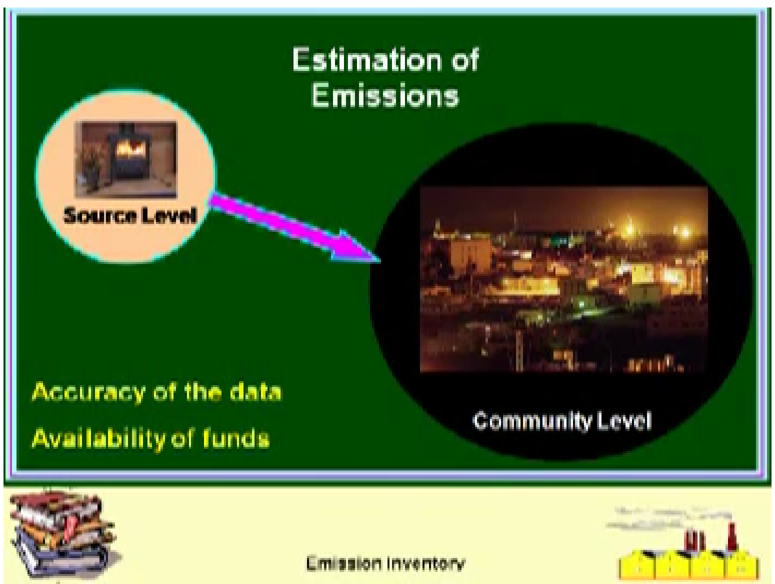

How do we do? We will just touch some specific method. Sometimes, you can do very specific high-level measurements and then what you really need to do is…. This is a little city, which you cannot see very clearly. You really need to know how many stores or how many fireplaces people have and then simply multiply them and you can get the data at the community level. Sometimes, you want to do some basic things very well and then rest of the things become more of interpolation.

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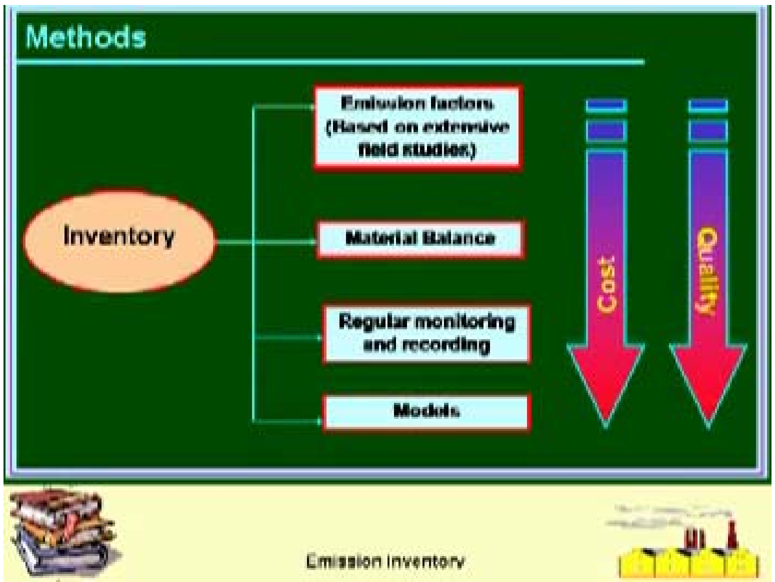

Apart from the factors I have talked about, you can do the material balance and sometimes you can actually measure it – you can go to the power plant. You can do it based on the coal consumption multiplied by the emission factors. You have to really go with your equipment and put those equipment in the stack if you want to have very accurate information. The cost will go up and so will the quality in this direction as you can see.

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The steps involved are planning, data collection, calculation, consolidation, documentation and quality assurance and that is something which…. Let us skip that.

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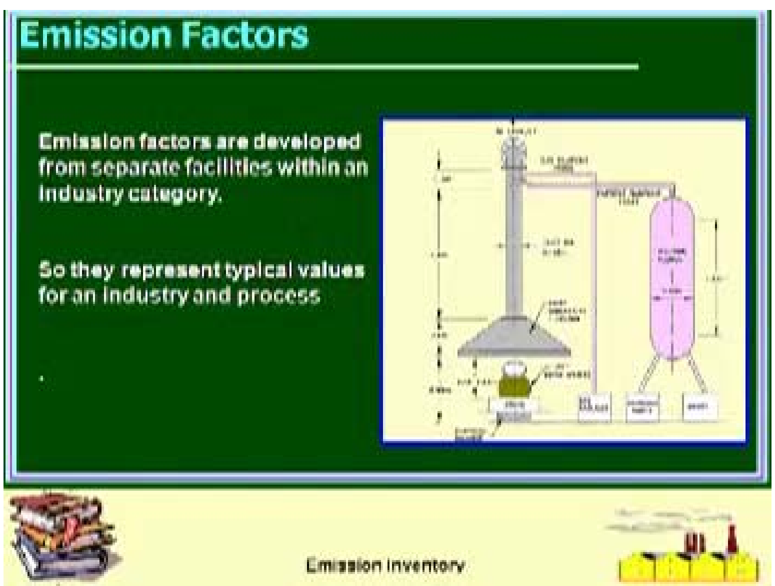

Sometimes for our own sources, we have to develop the emission factors. This exercise is very important. For example, this is a stove. You want to see how much will be the emissions and then you want to develop the factor. You make all these arrangements for the exhaust and then your particulate sampling [23.42] and then you have the device where you can collect the particles. We do not collect the particles immediately. This is an interesting thing to note – we do not collect the particles very close to this point.

It is because some of the volatile organic vapors that are emitted take a little while. You want the VOCs that are there. As soon as they come out, they are going to condense to the particulate form within certain region. If you take a sample too close to this, you will never capture where are the particles. We know that eventually in 2 seconds, they will become particles. So whenever you are doing the monitoring at high temperature, you should have some residence time so that you are capturing it after 2 seconds.

If you want to measure the particulate matter at the auto exhaust, you put the probe, put some time residence time and then put your filter holder on the back of this. You cannot put the filter holder on this. The sampling probe becomes fairly long. That is what is shown here. [25:02] factors are developed. It is not one sampling; you do n number of sampling in different kind of stores, different practices and then you come up with the factors. These factors are available here.

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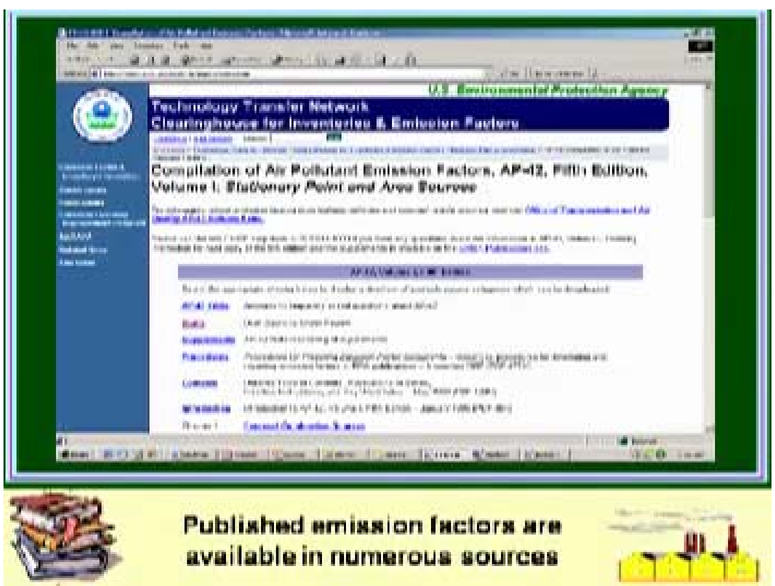

That is the AP-42 that I was talking about. You will probably end up doing this job for an environmental concern. It becomes an issue on how to quantify them because assessment is very important. Sometimes, we need to do the assessment even if things are not in existence. How do you estimate? I am going to put a power plant let us say in this region. What will be the emissions? You can only base that quantification based on certain factors. Americans disseminate the information so that everyone can use it.

This is the site. I will pass on the slides to you. AP-42 should be somewhere. I cannot see it but maybe you can see it on the back. AP-42 is a classic document. Anyone working even a little bit on air pollution would know about AP-42 – it is that important. You see how nicely they have listed the various sources. You go click and you will get all the details of the emissions that might occur from the various sources.

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These include fugitive emissions from the wall, the flanges, different pressures, miscellaneous data, greenhouse gases, metallurgical industry – anything. The list really goes on. Evaporative losses, solid waste disposal. Who would think that it would cause serious air pollution? But then all are listed there and we all very frequently use all the information that is there. I made this slide for you.

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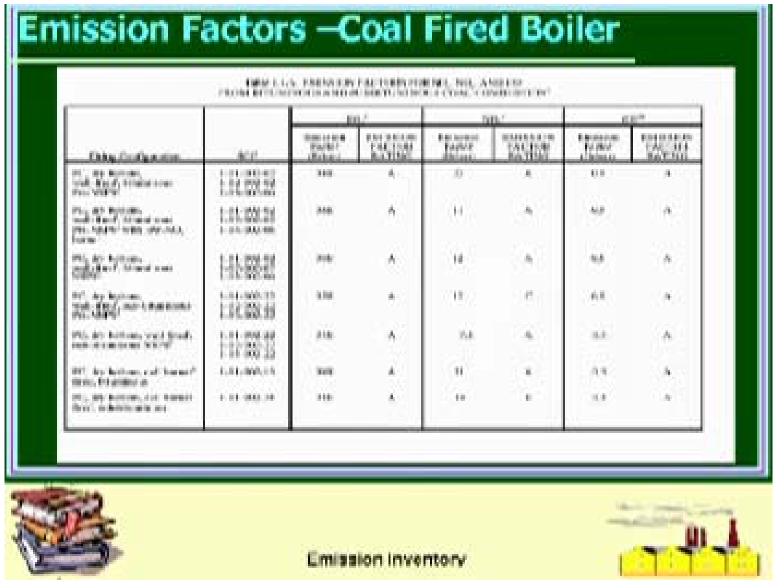

I click on to this and then, I get more detail about the external combustion sources. Then again, you can need to define what kind of coal you are using – is it anthracite coal or are you are using the bituminous coal or sub-bituminous coal, because all the emission quantities will be very different. Of course, doing the things is simple but you should still be exposed as to how this is done and where the information is available.

Finally if we further go inside AP-42, it may look like this. I have not seen this but let us see what it says. PC stands for pulverized coal, dry bottom. The boilers may have different bottom. Sometimes, the boiler has wet bottoms. Why do they have wet bottoms?

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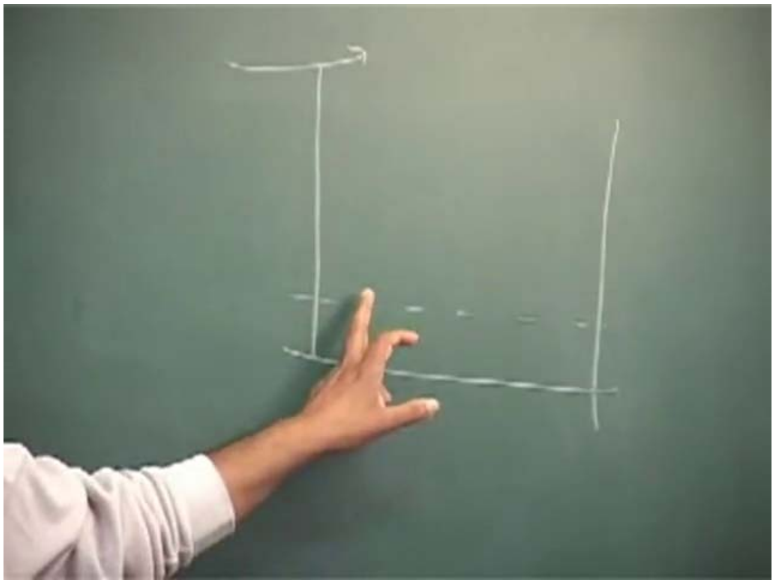

This is a boiler and then you are supplying the air from here and then put some water underneath this. This water provides a seal really so that nothing like…. More air is coming from here. Here, you are firing the fuel and here, you are firing the air but you do not want things to come from here. You have provided some layer of water. Water is always very good as a seal for the gases and for air. To give you a little feel, the emissions will be different depending on what kind of firing, what kind of combustion you have. It may be different for pulverized coal, dry bottom, wall fired (his could be wall fired or it can tangentially fired) and for the bituminous.

There is some code they have. For sulfur dioxide 38S in pounds per ton; in the kg per ton, it will be 19S if you recall that later. The emission factor for NO_2 is 22 or it will become 10 in terms of kg per ton. Then, they are giving the rating – what is the confidence level the USEPA has on these emission factors. At the end, you can also say how reliable you are about the emission quantities. Here you see AC and things like that and similarly for carbon monoxide.

Good information. I think A was very good. Depending on what kind of combustion you have…. Let me tell you again and again: you go to AP 42 and most of the time, you can see your process and you will have some information on that. If you do not have, then you generate your own information but this is very very important. Then in addition to the emission factor, they also describe the process, which is very good – you get an idea about the process. This was just an example because we do not want to go into many more things. Now, what I will do is I will show you an example of how this is really done. Recently, what we are trying to do here at IIT is an emission inventory for the Kanpur city.

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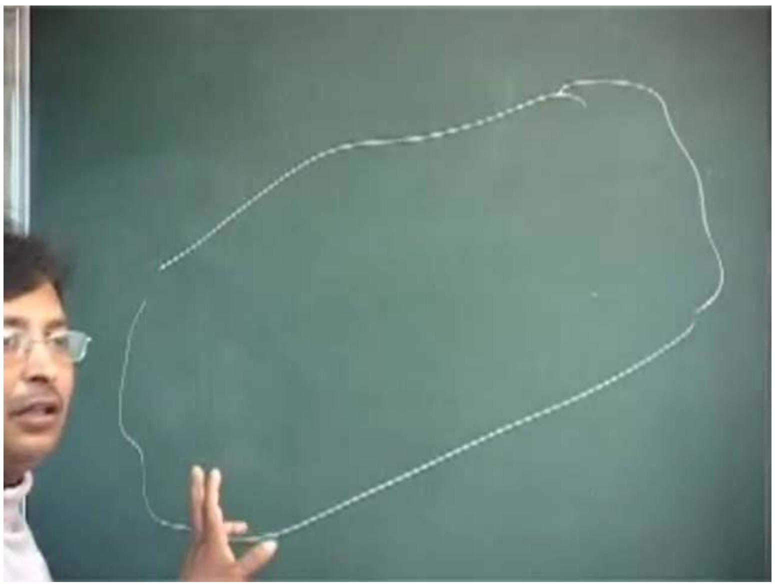

Kanpur looks something like this. In this emission inventory that I talked about, we are trying to create and make this GIS-based so that a person who has a map and he can click in this area and then he can find out…. He can write the question and then he will get the answer. We are working on that. A student Neha Prasad is working on this. Information has been sent. A lot of information, raw information has been collected by….

You will be surprised that to cover the entire area, we got 20 people to do the emission inventory. For the vehicle emission inventory, what we are doing is we are fixing the video cameras in the Kanpur city. It is so difficult to send out people. People start from morning 8 o'clock until night 10 o'clock and count the number of vehicles. What we are doing is we are setting the video cameras all over the place and then we make the film, bring those films to the office and then the boys can sit down in the night or in the evening and then they can count the number of vehicles that are going by. We need that information to get the vehicular pollution. I am going a little fast because I do not want to encroach on to the time for the next class. This is for the IIT campus that was done.

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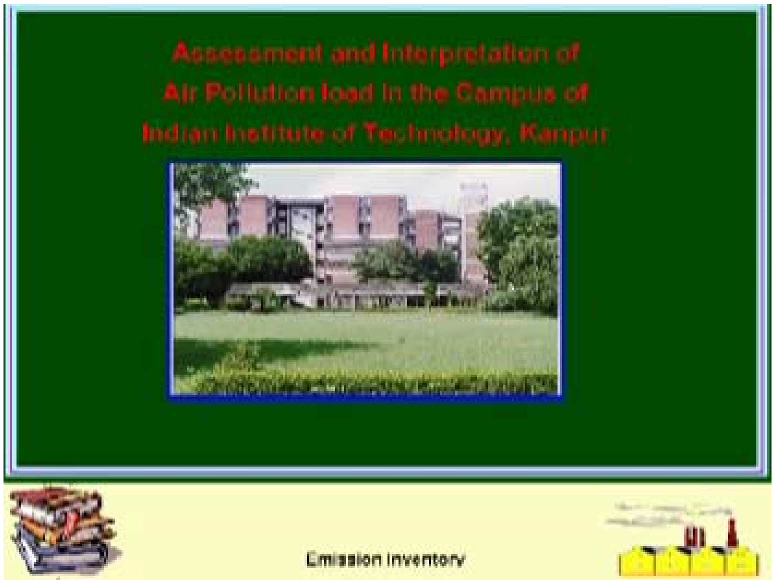

You will have little [31:31]. Unfortunately, this does not look very good because of too much of light. This was done for the campus.

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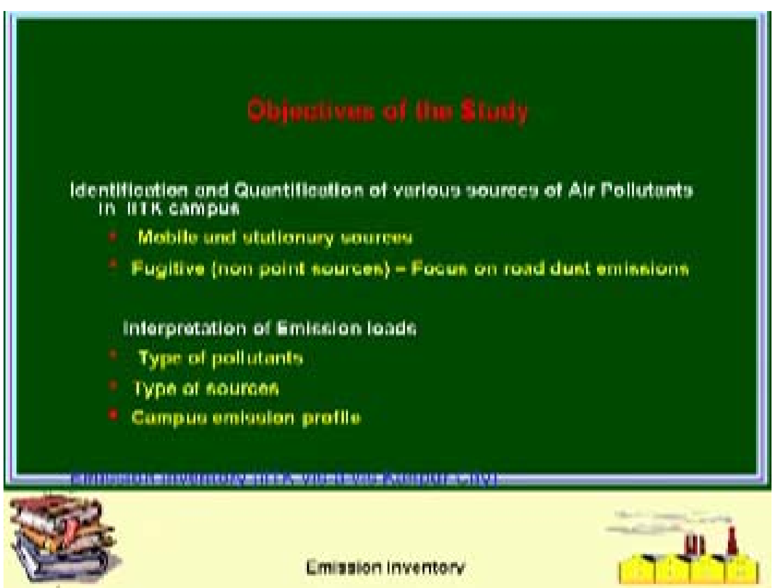

The objective was identification and quantification of various sources of air pollutants in the IIT campus – mobile and stationary, quiet please, fugitive (which is important) – focus on road dust emissions; interpretation of emission loads – type of pollutants, type of sources and campus emulsion profile. Then, we should interpret the data. We wanted to compare how the data from IIT Kanpur will compare with the Kanpur city. It may be possible that 15,000 people here are causing a greater problem than the 100,000 in Kanpur – it may happen. That comparison is a good idea.

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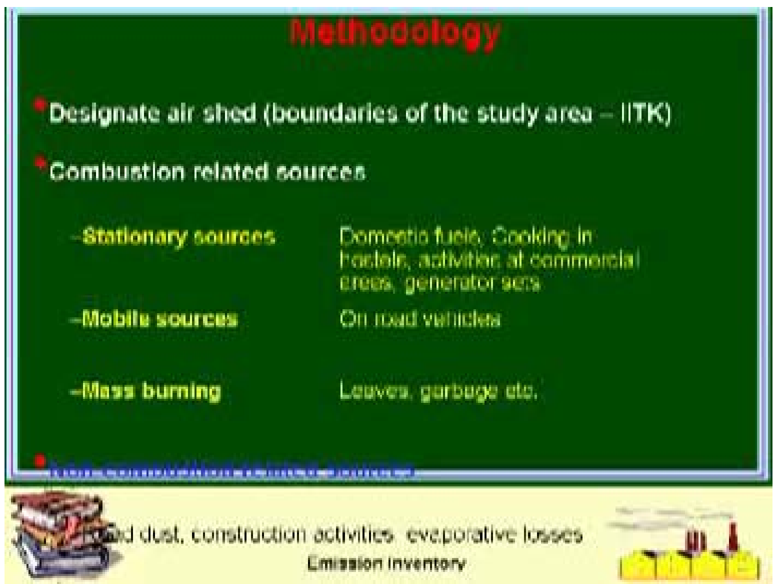

Methodology. Again, we will quickly go through the same thing. Designate the air shed (boundary of IIT campus), combustion-related sources: stationary sources – domestic fuels, cooking in the hostels (you need to cover everything and you have to be serious about this), activities at commercial areas, we have the DG sets, then mobile sources on the road, mass burning of leaves, garbage, etc., and non-combustion related sources – you have to consider that also and it will include road dust, construction activities on the campus and evaporative losses from the… even went on to see the evaporative losses at the petrol pumps that we have. We do a serious job.

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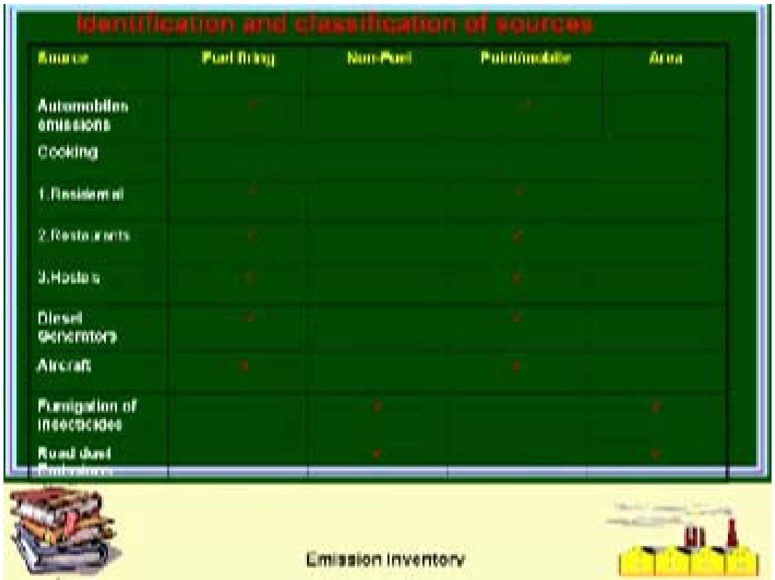

You try to identify and such kind of tables are made. Identification and classification of the sources. Automobile emissions: it will be fuel firing, it will be point source or the mobile source and you can go for cooking. It will come from the residential area, it will come from the… it will be mobile, it will be a point source, restaurants (cover every restaurant here), hostels, diesel generators and we also include aircraft. Why leave the aircraft out there? We have aircraft that are used and then you have to become very local. Yesterday, there was so much of fumigation if you recall. We need to consider everything, so fumigation.

This is non-fuel sources, road dust and then in road dust, we consider the…. We can also say [33:57] point source or the area source or the mobile source – we do that classification. This is what [34:03] you need to do. Then you look at the other information, the geographical information – so much acres, total residential houses are so many, total population estimated was like the earlier data (this is a little old), population of staff and total population approximately on the campus was 15,000. It is a little less, I guess but we assume this to be 15,000.

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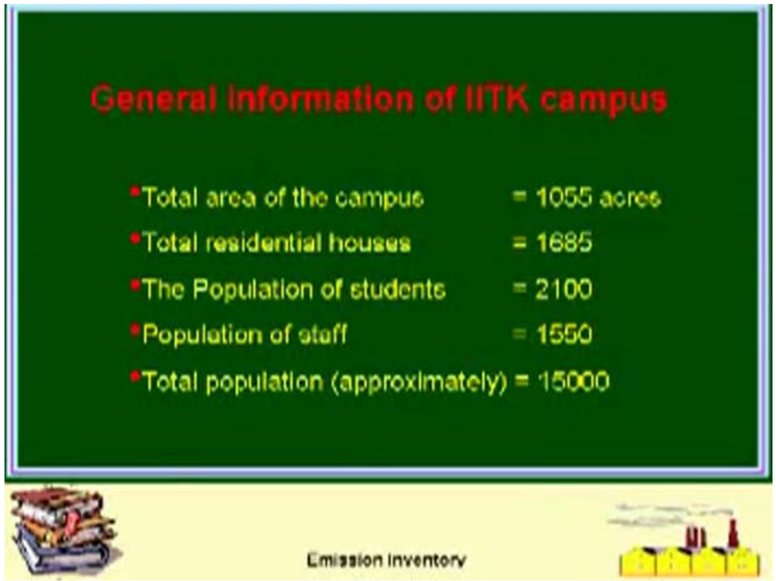

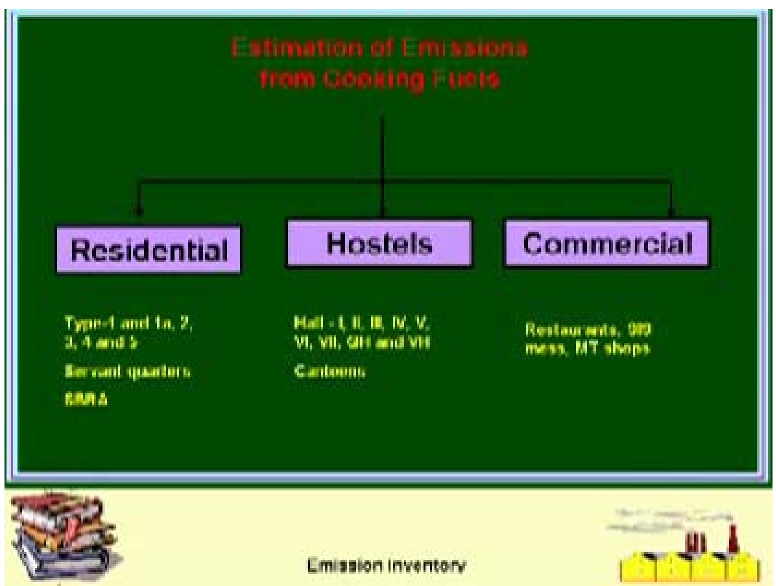

Then, estimation of the emission that we want to do for cooking fuels. We went to the residential areas type 1, type 2, type 3, 4, 5 include servant quarters and do not forget the SPRS because we are taking residential hostels etc., including VH because they also emit this and all the canteens in the hostels and the commercial restaurants and MT shops in that area. In fact, you will be surprised that when we looking for this, we went and found out that the SIS security people also have a mess of their own – that also was considered. This is the information that was collected in terms of the LPGs per day.

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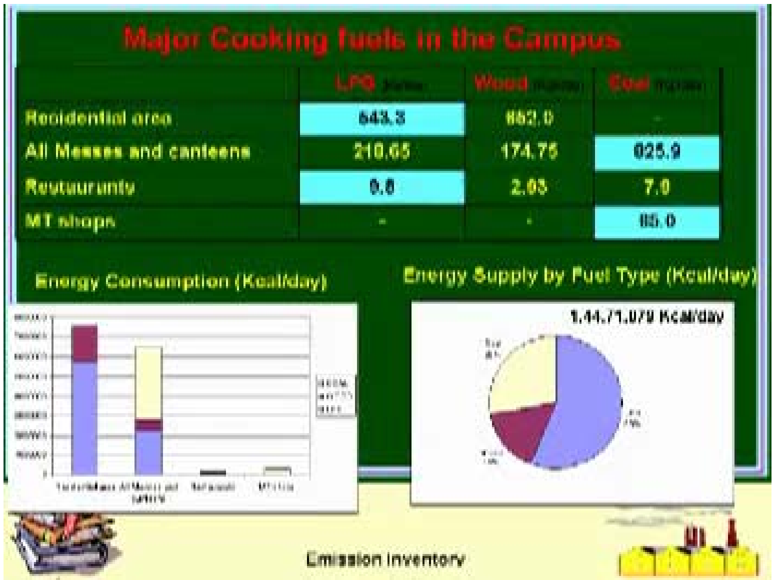

The residential areas were so much, the wood was largely from the hostels as well as… The mess was here and these are the servant quarters [35.25]. Students went there and they weighed things to find out how much wood they are firing. Coal is not used in the residential area. Then again, from the messes and the canteens. Now, things are changed. This was done three or four years ago. The mess was also using wood and was also using coal.

The restaurants and MT shops were using coal – I do not know for what. Based on this information, not only do you do the pollution estimation but we can also find how the energy is being used. If you can manage you energy, you can manage the [36:00]. In the residential areas, most of the energy was coming from LPG. From the messes and canteen, again LPG, wood and coal. In restaurants, it was largely LPG. The MT shops (the shops that you see here) use a lot of coal, so you can see the coal. The energy supply by fuel type – this is information. LPG was the major source of energy in the campus and so was wood; coal was not small either. Then, you the compare the per capita domestic energy consumption.

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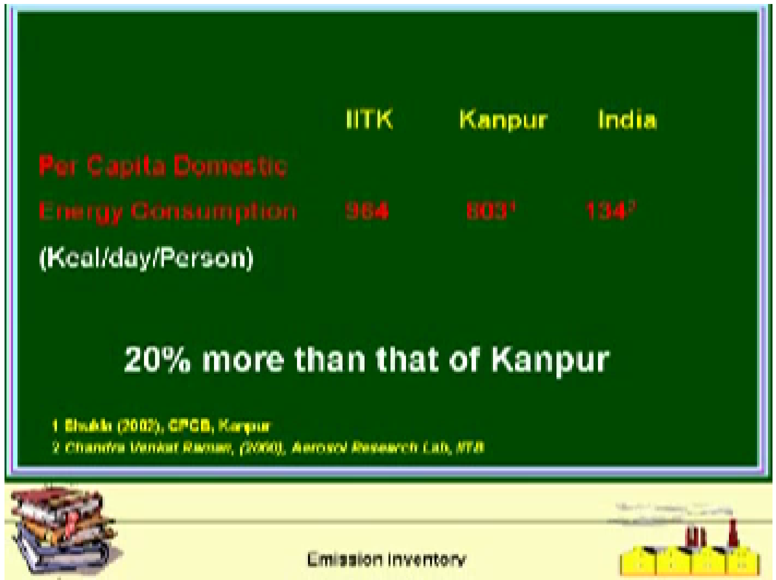

IIT Kanpur was a little higher – we use more energy than Kanpur and India. This data is for the entire country. Poor people including the rural areas…. In urban areas, we may sound very good but clearly, we are not using more energy – we are also creating more problems. This gives you a lot of understanding as to what is happening.

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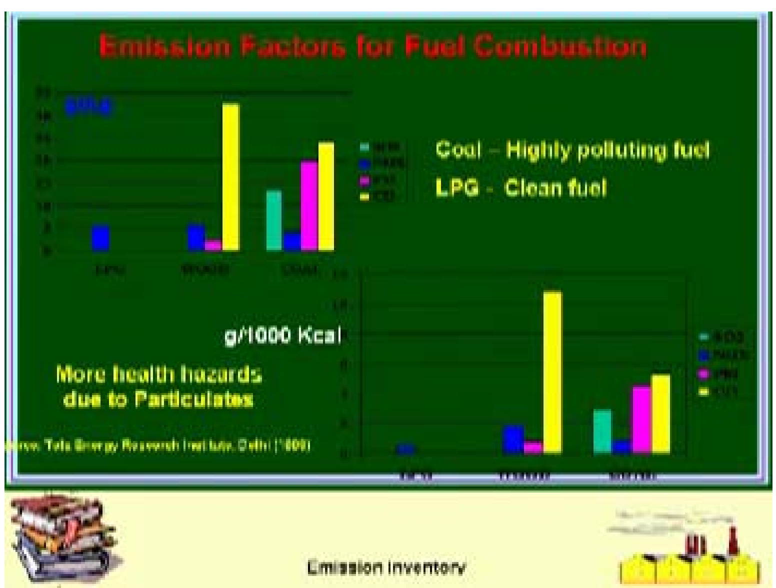

Emission factors were again taken from AP-42. What you see here is…. You see various pollutants – they will be emitted in terms of the grams per kg of LPG burnt. It will be 5 grams of particulate matter per kg of the…. For example, you come for the CO; for wood, the CO will be very high. These are all the factors taken from literature – it is nothing that that we have done. Here for example, if you look at the coal, the particulate matter emission is high and so is the SO_2 because the sulfur is there. LPG is only related with NO_x – this is the difference here. LPG will produce some NO_x and not particles. You collect all the information, the other information has been collected from your quantities and then you can find out the emissions.

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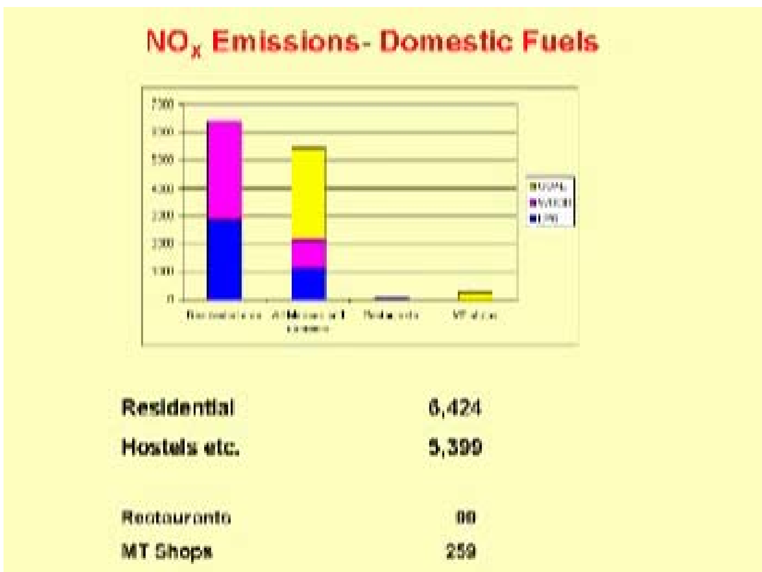

For example, the NO_x emissions. You say that the residential areas were largely responsible for the emission of NO_x and so were all the messes and canteens. The restaurants were small, so neck and neck. But then you can see here that mostly it was from LPG and wood. Wood came from the servant quarters and here, most of the NO_x emission from the hostels are coming from LPG and coal that was being burnt that time. You can get this information and take some decisions. SO_2 emissions were again largely from coal.

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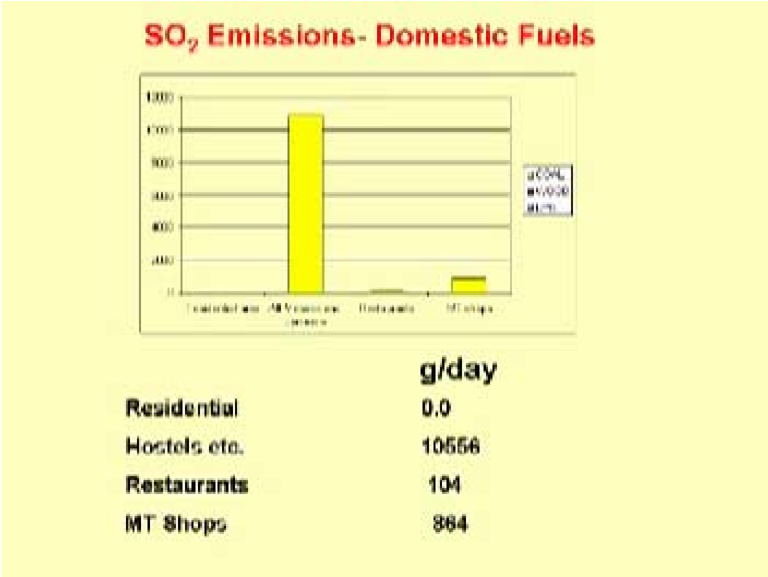

No other source of SO_2 emissions.

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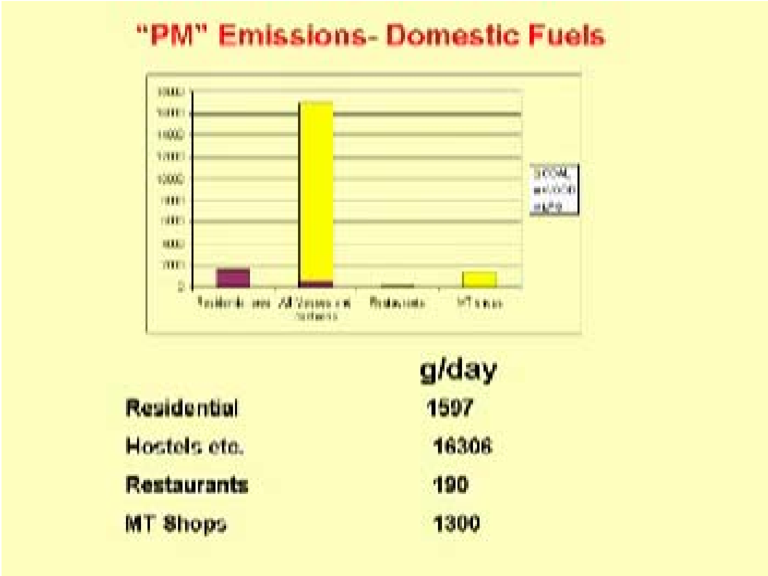

Particulate matter emission. Again, coal caused a lot of problem. Particles were mostly commercial oriented – mostly from the hostels.

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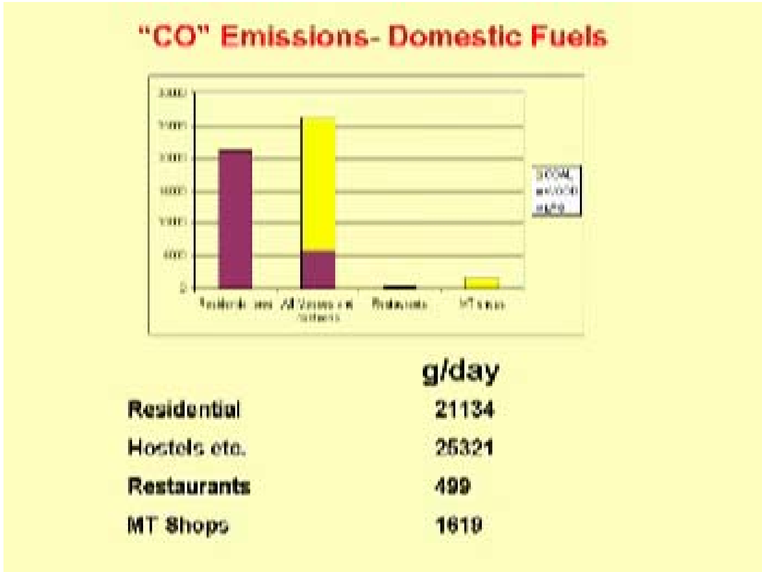

Same for the CO emissions. Residential area you see here, this is from the wood that is being burnt, coal and LPG were not significant, there will be no CO from LPG and MT shops.

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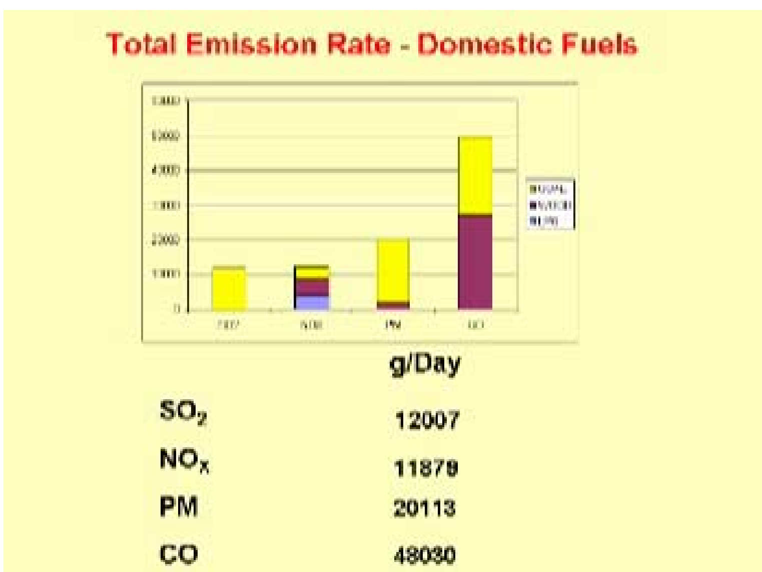

This is the total emission from the domestic use. This picture will look like this. Then you can say who is responsible for what, how much is CO, how much the particulate matter is and so on and so forth.

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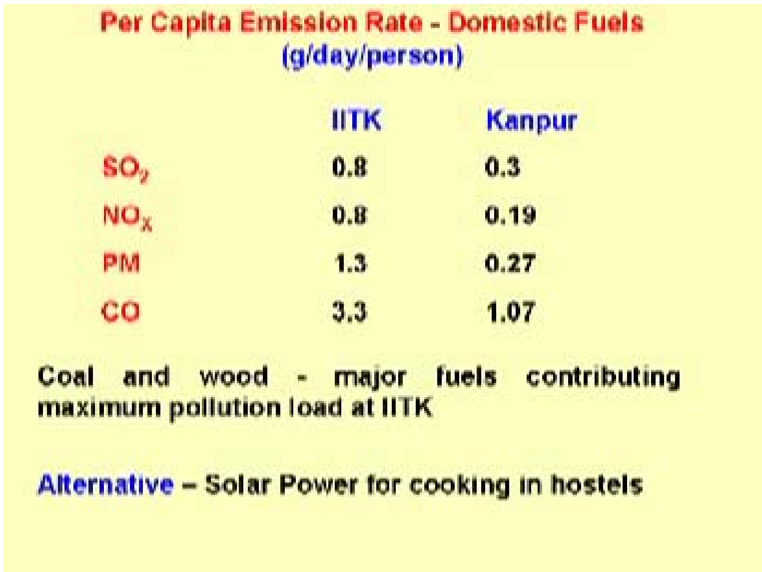

This is the per capita emissions rates for domestic fuels. SO_2 was high because we need a lot of energy, NO_x was high, particulate matter was high and CO was high as compared to Kanpur. You can see here that we caused more pollution in terms of per person. The richer you get, more pollution you cause.

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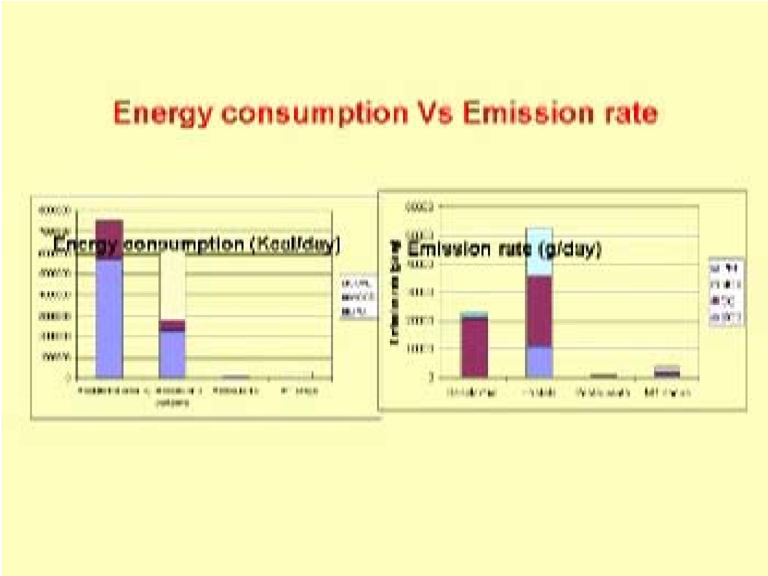

This is energy consumption versus rate. What are we trying to compare here? The energy was used mostly in the residential area and this. Most of the source was LPG and the source was again LPG and coal.

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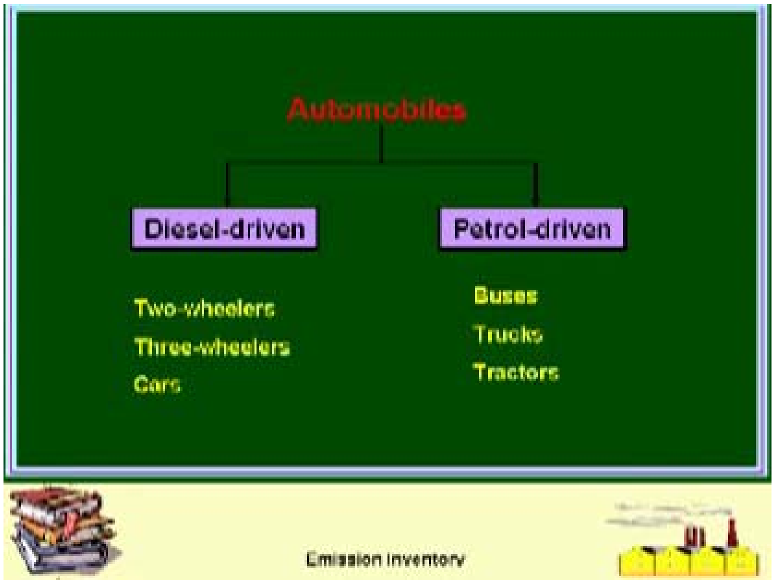

This is interesting. You want to do for automobiles also.

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You see the map of IIT Kanpur roads and then you divide the road as A, B, C, D, E, F. The students went and did the traffic counts at all the locations. [40:46] different roads that are there.

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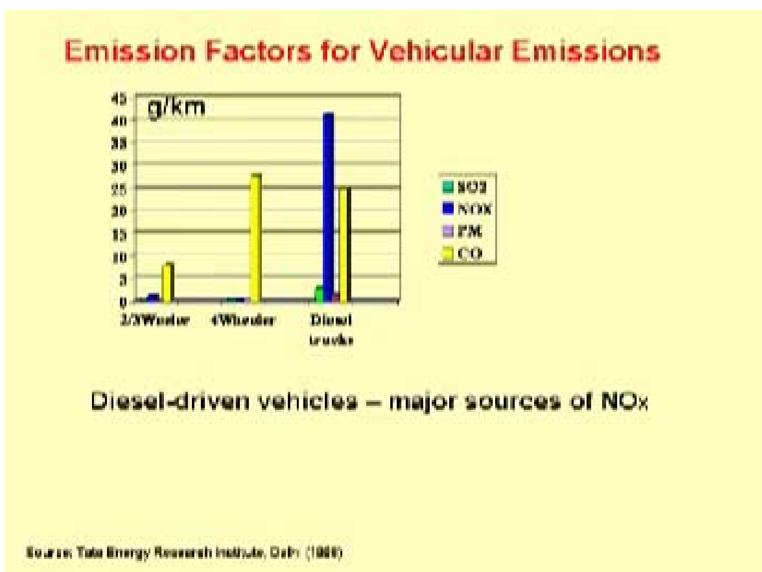

Emission factors. What you need is the kilometer run. Once you have the traffic count, you can find out the kilometer run, apply the emission factors and you see here the diesel vehicles – the trucks that were coming [41:10] the construction activity. They are largely responsible especially the particulate matter was coming from the this thing.

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Air pollution load due to automobiles

Locations	Pollution (g/day)				
	SO_2	PM	NO_x	CO	Total
Road BC	49.95	610.15	179.42	10394	11233.4
Road AD	512.30	10279	871.33	43978.6	55641.3
Road DE	60.13	1942.9	206.57	10881.4	13121
Road DF	85.5	1773.5	189.17	9831.6	11879.8
Road DG	356.7	7620.7	660.78	34372.5	43210.6
Total (g/day)	**1094.5**	**22426**	**2529.7**	**109206.3**	**135086.1**

This is the air pollution load due to automobiles. You can see from which road there were larger problems.

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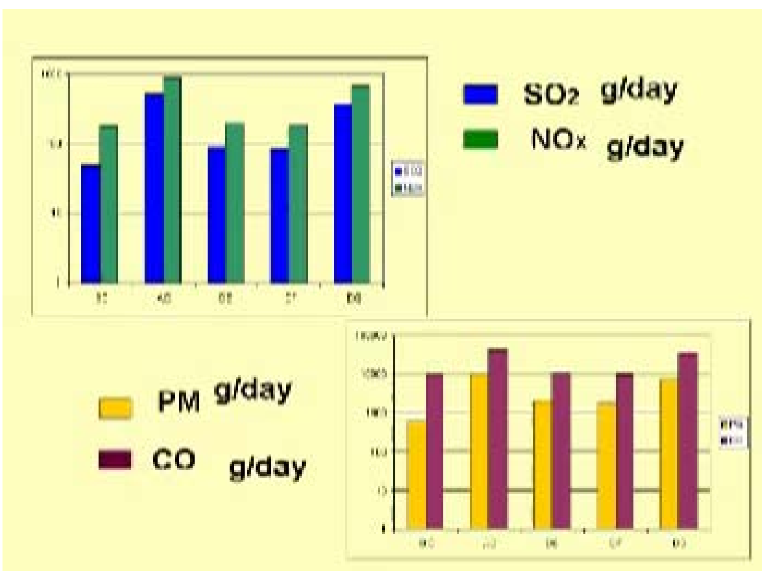

There were different roads as you can see here and what were the issues at the different roads. Why I am giving you all this information is that you can get a feel. Then finally, you combine all the information and say NOx [41:43] by the different type of vehicles.

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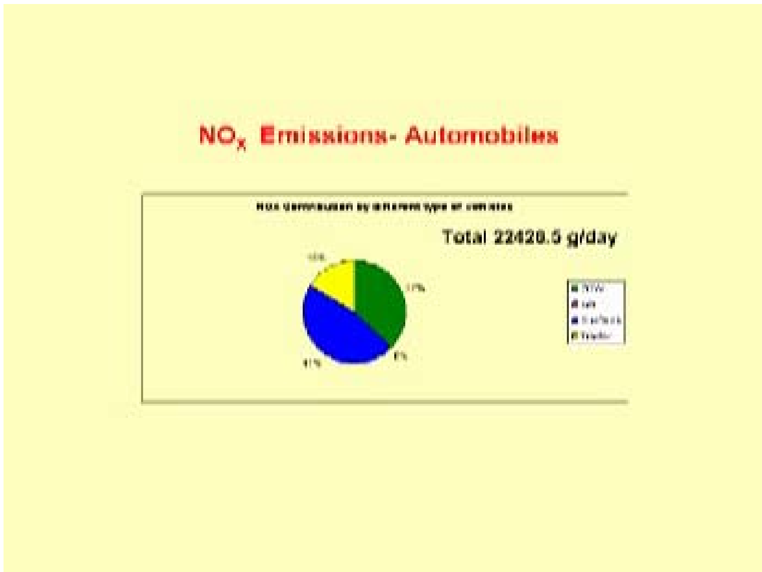

Buses and trucks – 47 percent and tractors were also not so small either. If you want to take a decision for the campus, it is just an example but then you already have this information for the entire city if you want and then you can take the decision.

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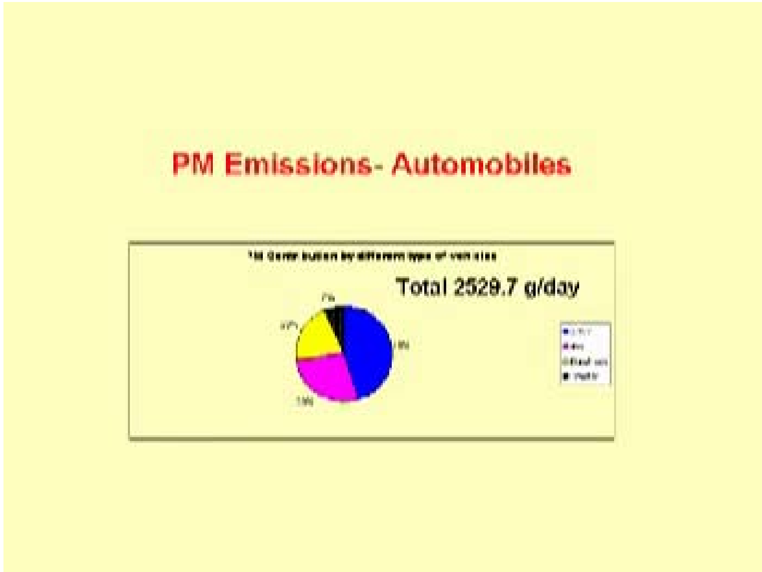

This is particulate but you see contribution for different type of vehicles. You can see here the CO emissions from different vehicles. Contribution of the composition of the various pollutants by different vehicles that is the total. CO, NO_x and particulate matter put together. 54 percent of the emission is coming from buses and trucks. Two–wheelers and four–wheelers were also not so much. The number of vehicles has gone up on the campus. This is the composition of the total pollution load due to vehicles.

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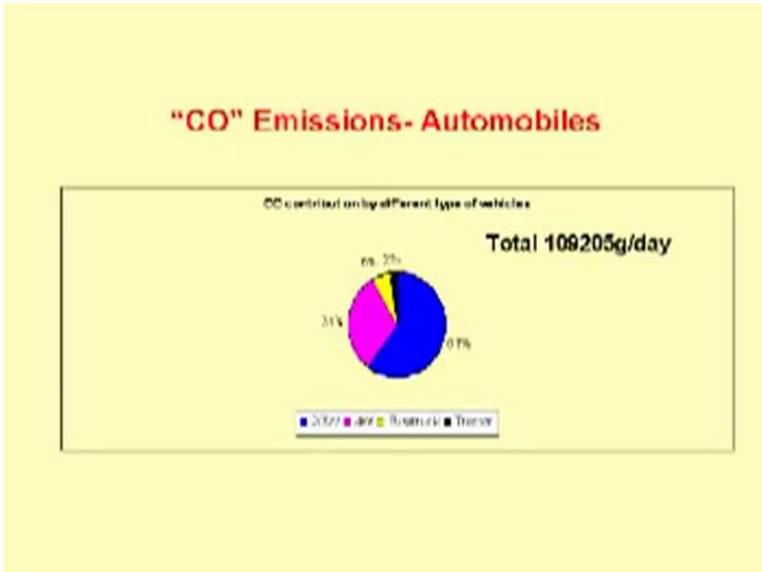

This is the same slide. The students also did how much road emissions will happen. I will send you these slides so that you can understand these.

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We also need to know how much is the fugitive emission from the road. What the students did was to take a certain area, take how much square meter is there and then they vacuum cleaned and then they wanted to find out how much was the loading of the particles on the road.

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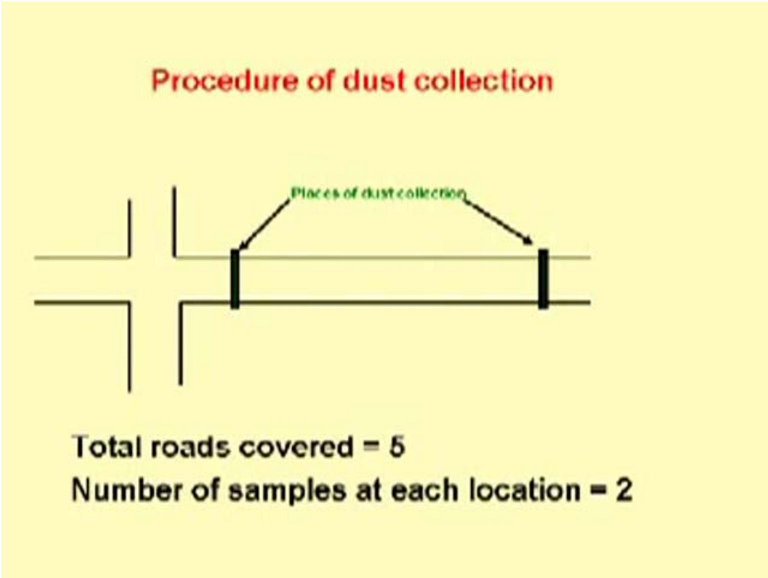

The total roads covered were five and the number of samples taken from each site was 2.

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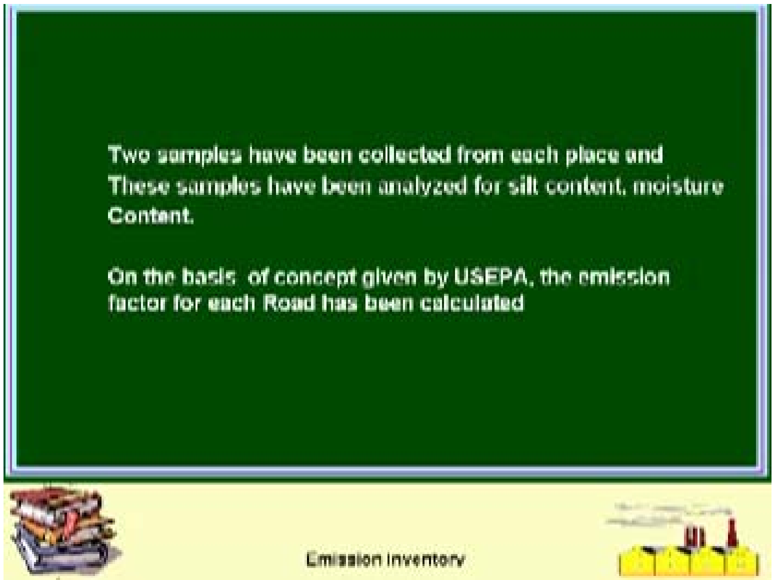

Two samples have been collected from each place and these samples have been analyzed for silt content, moisture content and on the basis of the concepts given by USEPA, the emission factor for each road has been calculated and I will show you how it is.

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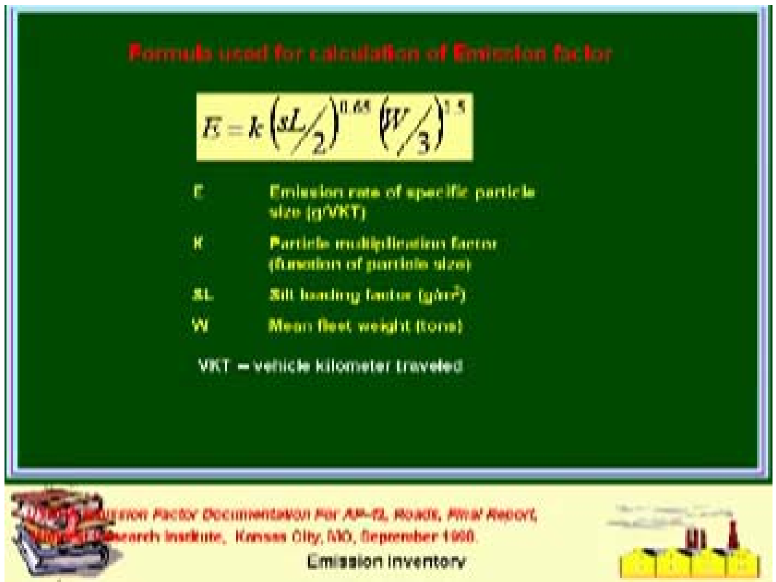

This is the equation to estimate the emission. You estimate the emission in terms of on grams per vehicle kilometer travelled. We are doing for the particulate matter – do not forget that. k is the particle multiplier and you need to find the silt load per meter square. You took the sample from the ground and then you see how much of the silt content and then you see what is the mean fleet weight of the vehicles. You have x number of trucks, y number of cars and z number of two–wheelers. You can find out the weighted average weight of the vehicles and tons. Then, you can find out how much vehicle kilometer travel will be there. You can again find out what will be the emissions.

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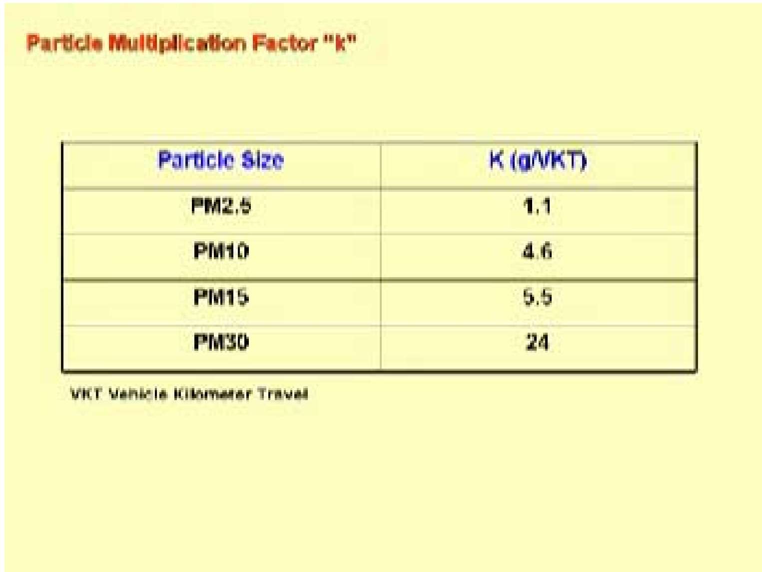

Particle Size	K (g/VKT)
PM2.5	1.1
PM10	4.6
PM15	5.5
PM30	24

This is the k factor. Not only can you find out PM10 and PM2.5…. All of you understand PM10, PM2.5, PM15, PM30. Then you see the k value is becoming smaller because PM2.5 will be smaller than PM10 in terms of emissions. You see that this is also changing. How the students did was…. This was the procedure that they followed.

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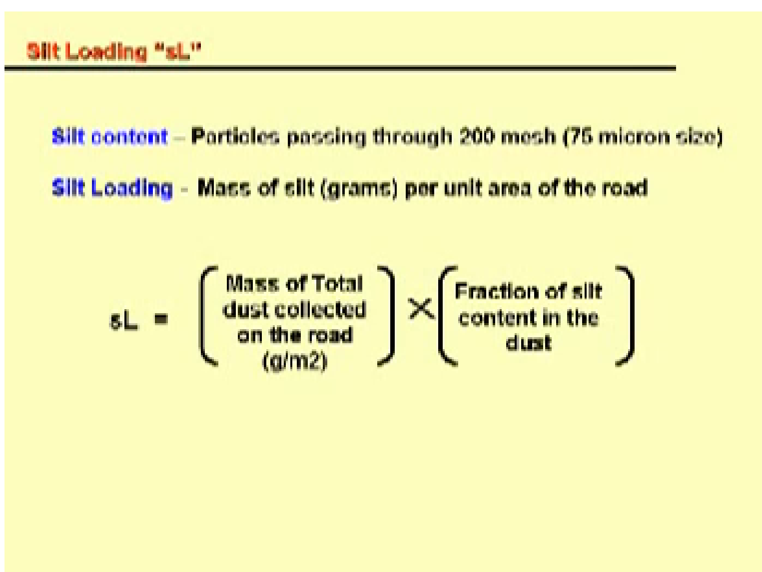

Dust collection across the road, estimation of the silt content, estimation of silt load in grams per meter square, hourly vehicle population they had and so they knew hourly how much vehicle kilometer travel was there. They could find out the mean vehicle kilometer travel hourly because they knew that hourly, 4 trucks were passing, 16 cars were passing and 200 scooters were passing. They could find out the hourly vehicular population. Based on that, they find out the mean weight and then finally they apply the factors.

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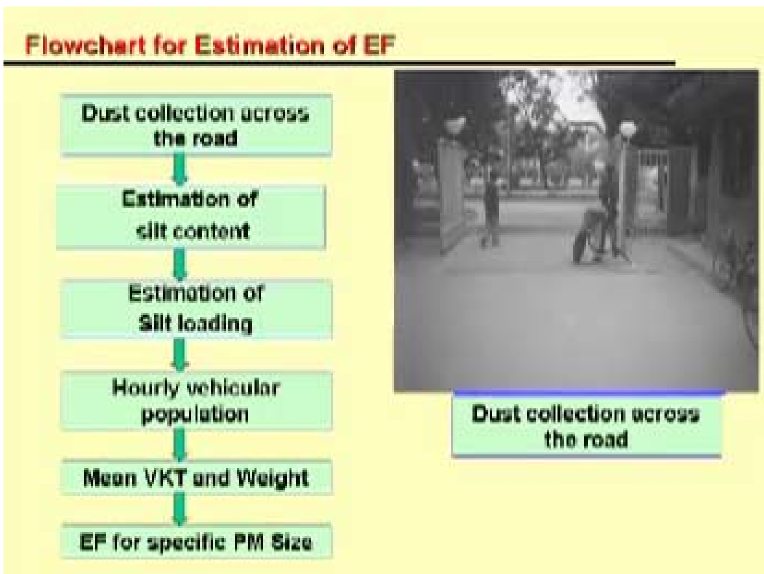

This is just a picture of students taking the sample at the IIT gate. You have the bag on the back here. They suck whatever is there on the ground, the air will pass through the bag and the particles will all be trapped inside. Bring the bag, take a newspaper, put everything there. Weigh the newspaper and then you know how many grams of the area you had sampled. Grams per meter square is equal to the dust that was there. Find out the silt, take a little sample from there, do a little sieving. What size was silt? 75 micron. The sieve will be 200 mesh (Refer Slide Time: 46:02) – size of the silt. They really did this physically and they could estimate things.

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Emission factors and total PM loading

Location	LENGTH (km)	MEAN FLEET WEIGHT (t)	SILT LOAD (g/m2)	E F FOR PM 10 (g/vkt)	E F FOR PM 2.5 (g/vkt)	LOAD PM10 (g/day)	LOAD PM2.5 (g/day)
ROAD BC	1.05	0.33	60.3	1.57	0.375	1131.88	270.66
ROAD AD	1.65	1.02	47.5	7.21	1.72	26160.67	6263.1
ROAD DE	0.5	0.83	96.8	9.98	2.38	8523.00	2038.13
ROAD DF	0.65	1.73	35	12.96	3.1	9706.3	2340.2
ROAD DG	1.1	0.805	61.3	7.05	1.88	20487.37	4801.6
TOTAL						66009.3	15803.96

Then they came up with the emission factor and total pollution load for the various roads. They had the length, they had the mean fleet weight, they had silt load – that varied. But our roads are similar to each other and so, the variations were not so much. They could find out the emission factor for PM10 in terms of gram per vehicle kilometer travel and then finally this information depending on how much kilometer travel or the distance. They could indicate that the road AD (that is the main road) has the highest dust emissions. This is an example. You need to do this for the entire city before you can take any decision.

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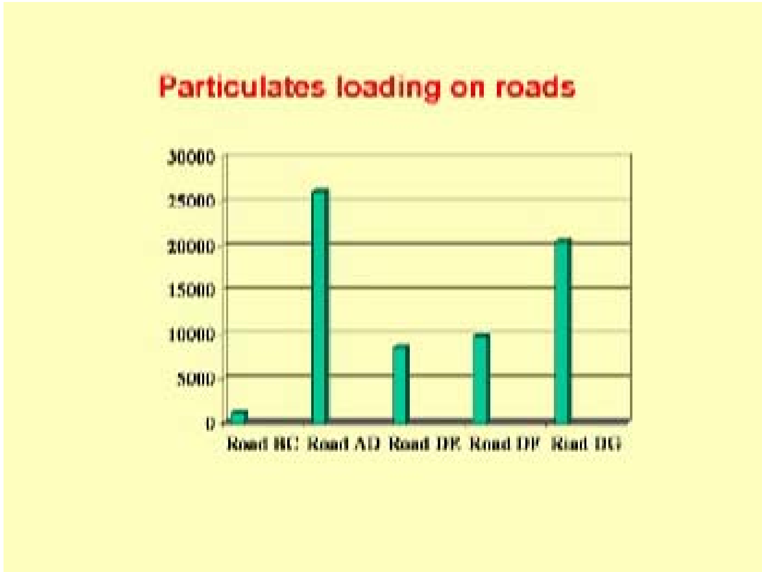

After all, we are here to study– not only to pass. You have to do the work on the field, you have to take decisions, you have to make a difference. Unless your knowledge, unless your approach, unless your observation is good, what decisions will you take? That is the general training that you go through in the process. This shows the various loads that you can get. This also was done for the fumigation.

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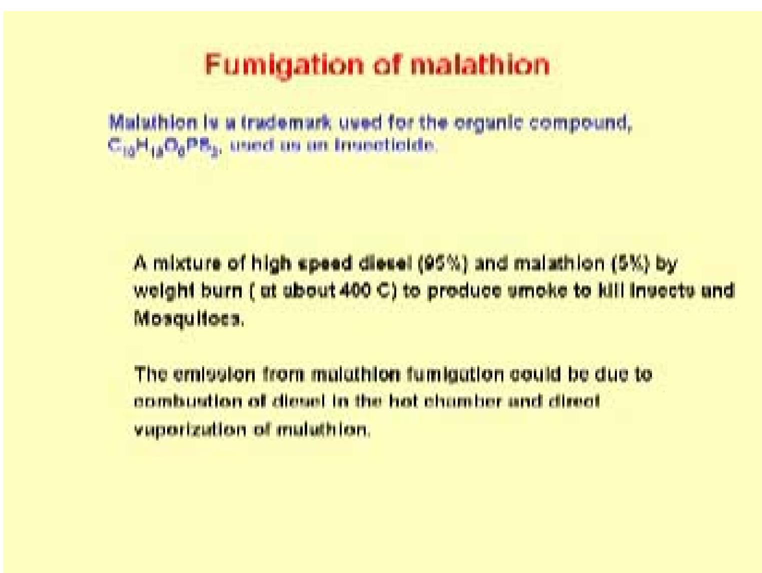

This was serious and a very interesting thing. The students went and figured out what they are using for fumigation was malathion, which you use for killing of mosquitoes. They used the insecticide. They mixed high speed diesel, which was 95 percent, and 5 percent malathion by weight and burned it at about 400 degree Centigrade to produce smoke and then to kill the insects and mosquitoes. The emission from the malathion fumigation could be due to the combustion of diesel in the hot chamber and direct vaporization of the malathion.

Unfortunately, there was no factor that was available but you apply the science that you know. That kind of temperatures were there and so you see what is the possibility of vaporization of the malathion and diesel smoke. Some estimate was made – it was just an estimate. You can even call it more of a guesstimate if you like – it was more like a guess than an estimate. It was more like a guesstimation that we did and this quantity was estimated.

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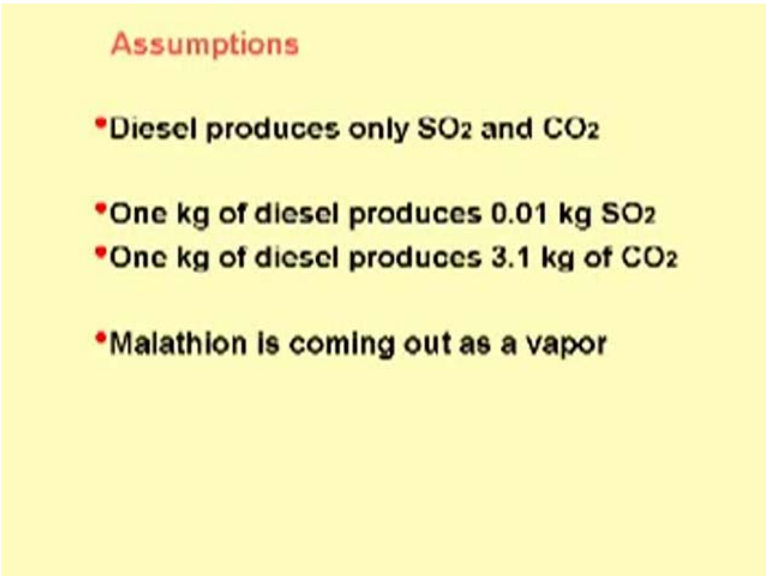

It was found that some of the sulfur could also burn, there could be CO_2 and malathion is coming out as a vapor, which eventually condensed. We assumed that the entire malathion will condense as particles. We could quantify as to how much will be the particulate contribution of malathion.

[Conversation between student and professor - Not Audible (48:46 min)]

Yes, it is injurious to us – more injurious to the mosquitoes but then of course, malathion is an insecticide, so it will affect you also, there is no doubt about that.

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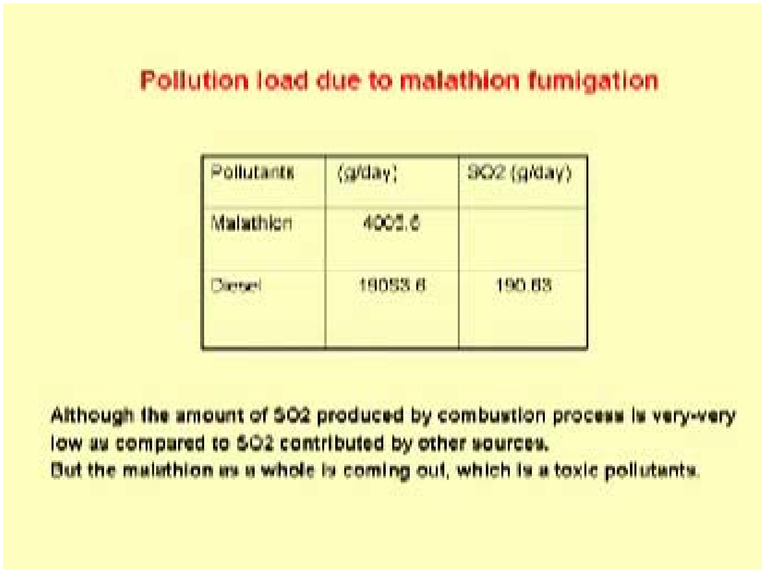

You can see malathion and diesel. These were more taken as the SO_2 emissions and particulate was also done. We got emission from the diesel generators sets. We went to the DG set people.

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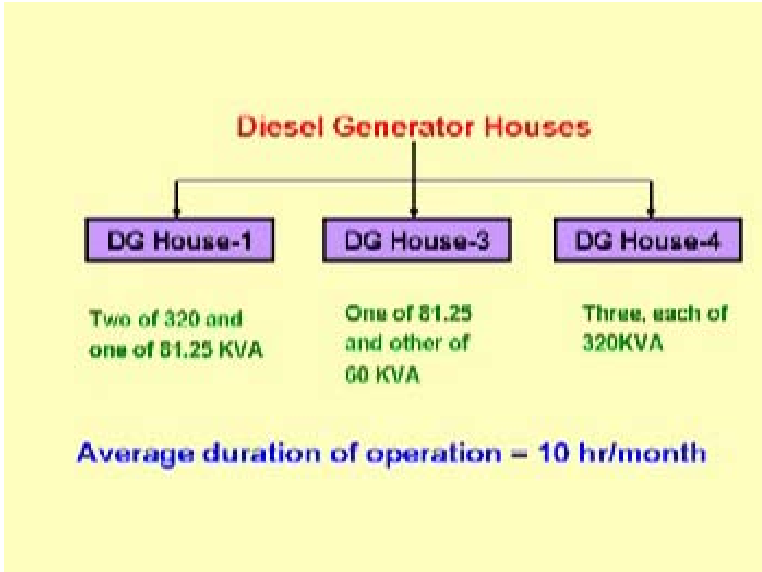

They have three or four DG sets and they gave the number about 10 hours per month – that is the frequency they were using the DG sets in IIT Kanpur during that time (I do not know if it is more or less now) but then, you can find out the…. The factors were in gram of emission per kilowatt hour.

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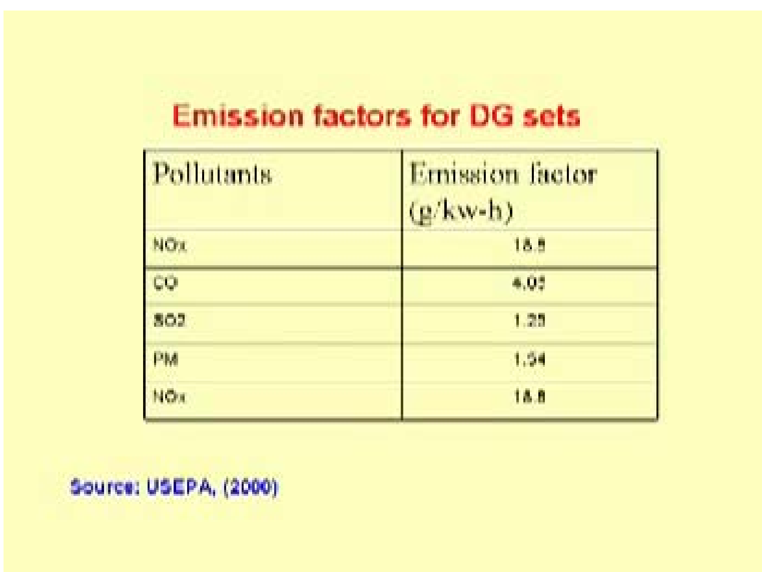

Pollutants	Emission factor (g/kw-h)
NOx	18.8
CO	4.05
SO2	1.25
PM	1.54
NOx	18.8

Those factors are available and you could estimate practically everything from there. Then, pollution load from the various DG sets.

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Pollution load due to DG Houses

Pollutants	Emission Factor	DG House-1	DG House-2	DG House-1	Total (g/day)
NOx	19.8	2011.9	705.7333	4812.8	7532.533
CO	4.08	434.42	152.9267	1030.38	1620.707
SO2	1.26	133.76	47.08333	320	500.8333
PM	1.54	164.76	58.00667	394.24	617.0267
Total(g/day)		2744.15	990.15	6560.90	10277.19

The pollution load scenario. Overall, the picture looked like this. The total emission for the campus was found out to be like this.

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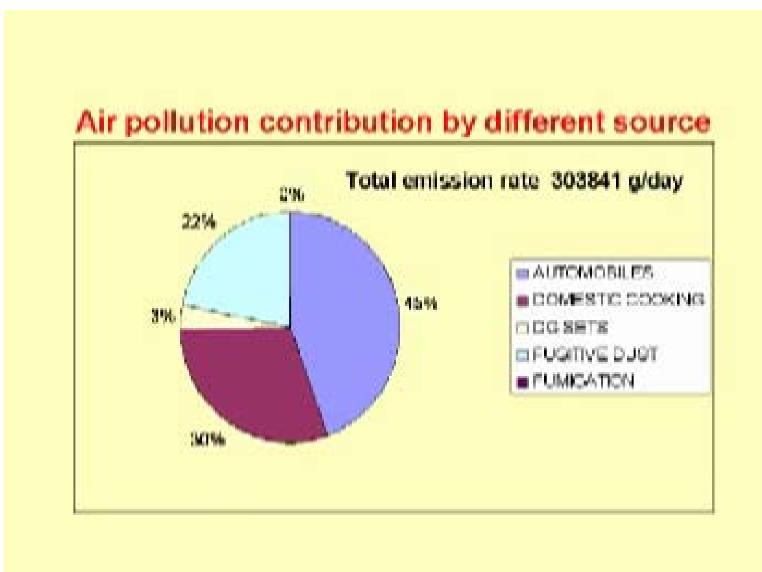

You see here, automobiles were high – 45 percent contribution, domestic sources were not small and to my surprise, fumigation was 3 percent and DG sets… Am I am reading wrong? The DG sets was this amount and fumigation was insignificant in the total. Then, you can exactly say that the major problem comes from vehicles and from domestic cooking as you can see.

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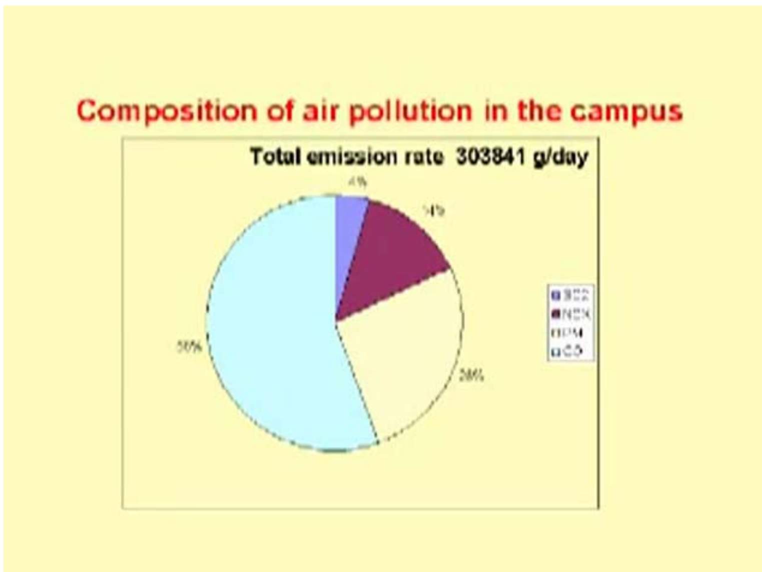

This is the composition of air pollution in the campus. 50 percent was carbon monoxide, SO_2 and particles….

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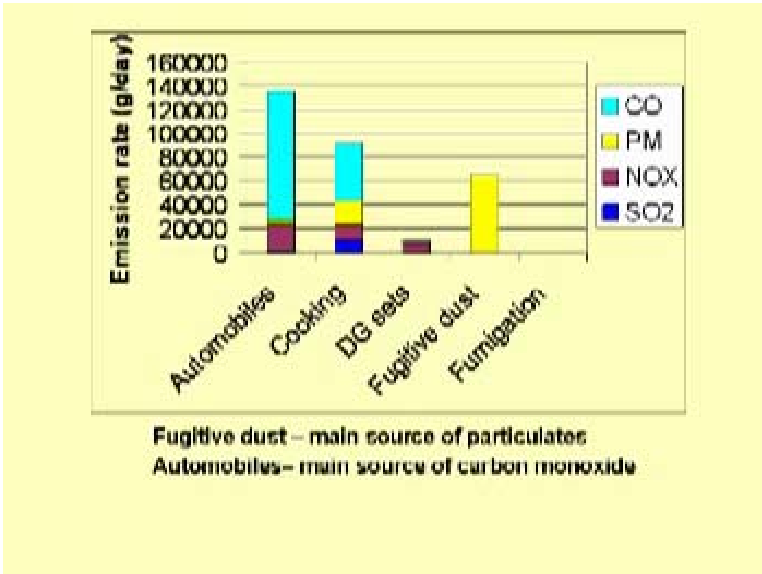

You could also see the emission rates in grams per day – how much was there from automobiles, from cooking, from DG sets, from fugitive dust and fumigation. There was some conclusion that we can escape for a while. I am not showing this one. Very quickly before I end, one of the messes was already privatized and we compared the emission and energy uses of the private mess vis-à-vis the sarkari mess. The emissions were low, energy efficiency was high and we could not explain as to why so much of energy was required in the sarkari mess compared to the private mess. It is all up to you to figure it out as to why it happens.

Private people were very efficient. Not that our recommendation was followed but we also said that if you move on to LPG, your energy efficiency of cooking will go up and so emission will come down. It makes sense to go for LPG and do away with coal and wood in the mess. I do not think they [51:54] our this thing but eventually, LPG has to replace everything and that will improve both… your cost will go down eventually and so will the emission. We will stop here.