Environmental Quality:
Monitoring and Analysis
Prof. Ravi Krishna

Department of Chemical Engineering
Indian Institute of Technology-Madras

Lecture No. 28
Monitoring methods for Air PM - Part 1

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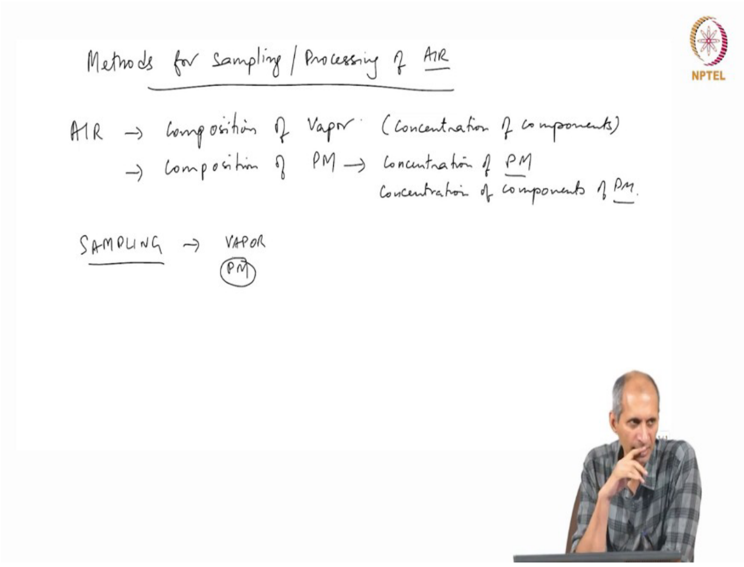

So, will continue from where we left off. So we are looking at we just finished looking at the analysis methods. So, today we will quickly go over the method for sampling and processing of air. We already covered sampling of water and processing of soil. We will do sampling of soil today we'll finish that also. But for sampling and processing of air, you may have two sampling objectives, one you are interested in looking at the composition and concentration of the vapor phase. In other words, we are looking at concentration of different components then we are looking at composition of the PM, the particulate matter associated with air. So, in this we can look at either the concentration of PM and components of PM. It means you are taking the entire particulate matter as a whole without any specific distinction, all particulate matter. And then you also make a distinction that this particulate matter is now composed of what is the elemental composition or organic composition of the particulate matter itself. So, these 3 things are the objectives for air sampling typically, these are used for various purposes, for exposure measurements or for transport estimations and so on.

So, the sampling and analysis method as with all our cases that we have done, you need to have objective first, based on the objective your final analysis, which instrument you are using and you backtrack, the entire trajectory of the sampling protocol is developed based on that. So, before sampling you have to decide whether you are sampling for vapor or PM.

So in PM there are two things and in vapor there is only one, the vapor phase component what we mean by vapor phase component is in this atmosphere here I am looking at the composition of benzene vapor only that is in the vapor phase, pure vapor phase as against benzene that is adsorbed on particulate matters sitting on this and flying around in the air. So, these 2 distinctions that we make.

So let us start with the PM because by in general when you are sampling air PM is part of the air. So if you are really looking for vapor you need to separate the PM out so that is one. So we look at the PM part first and then we will go to the vapor part next.

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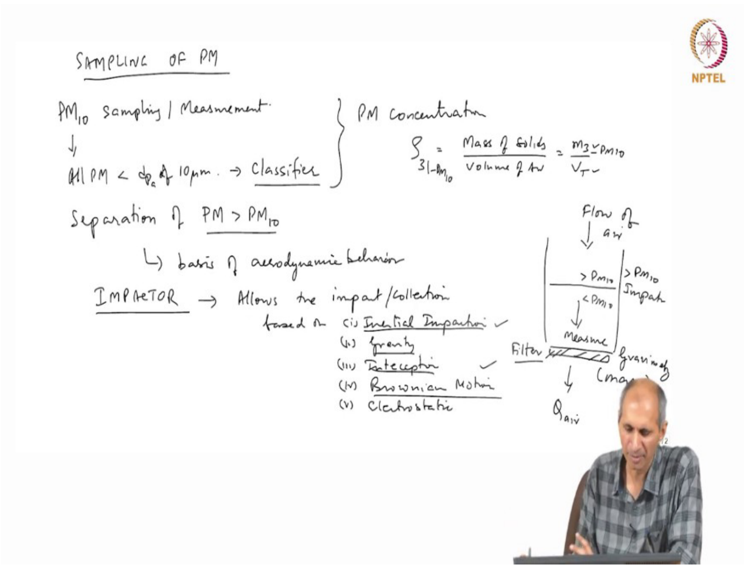

So sampling of PM there is a large set of methods that are available now. So again, when you say sampling of PM, we know that PM is classified again as PM 10, PM 2.5 and, a whole bunch of things, and ultra-fine particles and so on, so you need to know what is it that you are looking for. So, let us say that you are interested in sampling PM 10. So, PM 10 sampling and measurement this is an example for what would you need to do.

The general design of PM 10 sampling, which means that PM 10 as the definition is everything all PM with less than the aerodynamic diameter of 10 micron which means you are classifying you need a classifier you need to separate, remove all particles above aerodynamic diameter of 10 microns and then you want to measure the rest of it. So, when you say PM concentrations, we are talking about ρ_{31}, 3 is a solid, 1 is air flow so ρ_{31} is

$$\rho_{31}=\frac{Mass\ of\ solids}{Volume\ of\ air}=\frac{m_3}{V_T}$$

V_T is the air, typically we say V_T equals V_1, when we are doing this kind of sampling, so, we need to estimate these two (m_3, V_T) for calculating and it's true for everything, for vapor also, it is the same kind of definition that we are looking at but here, if we say PM 10, then this m_3 must be PM 10. If ρ_3 is PM 10 then m_3 must be PM 10. So, we must find a way to separate the all particles above the PM 10 and below PM 10.

So, what is a good way of doing it, a classifier. You are interested in collecting anything below PM 10, above PM 10 you don't care so, you have to separate it. On what basis will you do it? So, we are talking about aerodynamic diameter. So, they separation on the basis of aerodynamic diameter. Aerodynamic behavior of the particles which means that the way the PM is defined, you use the same principles to get rid of it so, we use what is called as an impactor. An impactor allows the impact or collection based on (I) Inertial impaction, (II) Gravity, (III) interception, (IV)Brownian motion (V) electrostatic attraction or electrostatic forces. These two, Initial impaction and Interception are the most important.

And gravity, a lot of times does not apply to these kind of situations, but it is important all of these things can happen in an open environment. But we can engineer the impact in such a way that we can use one of these things. So a PM impactor, let us say you have an impactor. So, what will happen in impactor is let us say that this is the flow of air and I have an impactor or something and what goes through the impactor or what is retained on impactor is anything greater than PM 10, less than PM 10 goes through and then you have to measure it. So you have various options of measuring it. One of the simplest option of measuring it is by gravimetry. Gravimetry is mass measuring so, if you are going to measure the mass then you have to collect it.

The easiest way of collecting solid in a fluid is by using a filter. Just as what we do for total suspended solids, we are sending water, we collect all the particles we measured the filter paper before and after. So, whatever is collected on the filter paper is the mass of the particulate matter in a given volume of air. So, you have the volumetric flow rate of air and you have the mass that is collected on this.

So, now we have separated the components by the impactor. The impactor will separate whatever you want to separate and the filter collects the particles and you want to do gravimetry but you don't have to do gravimetry you can do anything else, you have another way of measuring particles you can do that also. So, this is evolving.

So, whatever I say now, may not be applicable 2 years later, so, it is always evolving depending on what you want. But the PM 10, PM 2.5 methods are fairly well established and we will just go over that once.

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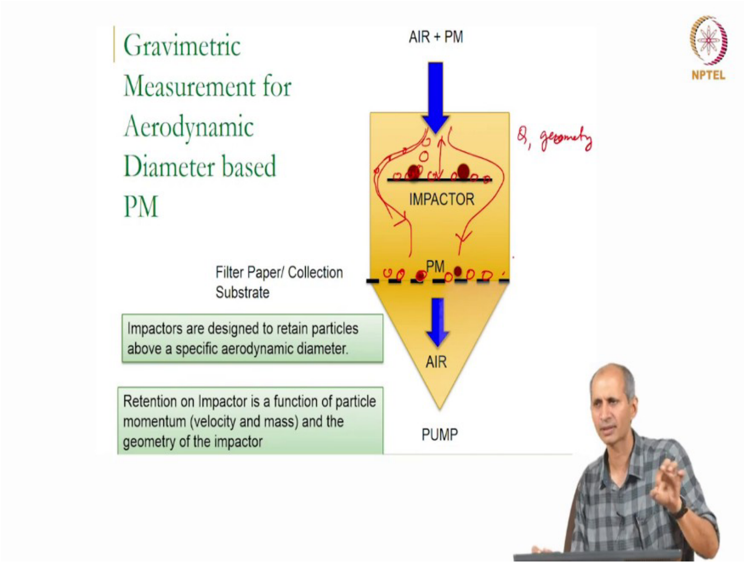

So, the impactor is typically a device that will impact particles in a flow. So one example of an impactor is something that looks like this. So there is an impactor as there is no size segregation. So you are just doing, you have a filter paper and it will trap all particles, you have a flow here, all particles are coming through it, and there is a filter paper air goes across there is a pump.

This is in general without an impactor, if I just want to take everything and put a filter paper which will trap all particles. Now, if I have an impactor here, what will happen is particles will go, some large particles will get trapped on the impactor. what essentially means is the smaller particles as you can see, tend to go around this thing. So, what we are seeing here is there is a diversion, the flow goes around this impactor along with it.

This is the same principle what we talked during the impaction, larger particles which have larger momentum will go and will not be able to change the trajectory their momentum is very high and smaller particles momentum is smaller, can move around with the air. So, depending on the momentum, which means it is a velocity and very specifically what we call as the stopping distance, there is a stopping distance.

This is how speed limits are designed for roads. It is based on stopping distance if some vehicles come right in front of it, how long does it take for you to stop? So, if you don't stop you are going to collide, this is impaction. If your speed is low enough, so, you can see something, you can veer off or you can you can adjust your speed. So, the stopping distance is very small. So, the distance can be made such that the impact is very close to the entrance or very far away from the entrance, you can adjust the behavior of the particle, trajectory of the particles.

So the aerodynamic trajectory of the particle is impacted and is designed in such a way that certain size of particle we will go around. So, the factors that we are looking at is the flow rate and the geometry of the design, these two things are important for the design of an impactor. So, you can have a PM 10 impactor, you can have a PM 1 impactor, you can have PM 2.5 impactor whatever. So, this is based on some fluid mechanical, solid mechanics calculation or by trial and error.

You can observe, you need a strong basis for doing that whereas, this is not easy to first of all figure out which particle has which Aerodynamic diameter. Design of this is done using spherical particles of known density. So, you can know exactly on the basis of definition of aerodynamic diameter and then this is used to define PM.

So, if you know that, based on differential aerodynamic diameters, this impactor works for that particular x, particular size then it should work for anything that comes through it, then it has an aerodynamic diameter of that size. If you designed it for PM 10 and you have tested it a spherical particles of PM 10, if it collects particles of any random shape and density it means that they are all PM 10 that is all it means, this is the way we calibrate it.

So, the impactors will accumulate particles here and the rest of it will accumulate on the filter paper and then you take the filter paper and measure. This is a general design of an impactor. The impactor can be anything. In one of the final designs depending on the flow rate, one of the impactors is a small plate.

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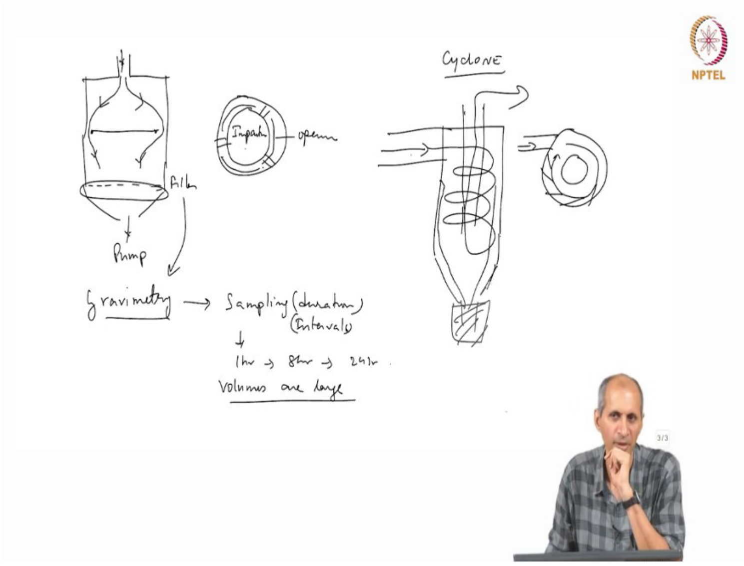

And there is a plate here and there is an opening in the side you can see there is a cylinder and there is a nozzle, the nozzle allows flow to come in and air moves around like this and there is a filter paper here. So, this is held in place so, if you look at the top view, it will look like this the impactor will look like this there is impactor, this is an opening and this is an impaction surface to look it from the top.

So the air can go all around it and in the middle, so, the size of this things will change. You can adjust the dimensions of this you can adjust distance between it. Sometimes what happens is because the air is going out from the side, the next impactor stage maybe something in the middle of the opening maybe in the middle, right in the middle. So, that air has to curve and go through in the center particles which cannot do that will deposit in the top outer surface, so on.

So, all kinds of possibilities exist this is one type of impactor, the other type of impactor is a cyclone. Cyclone is a device where the air and the particle are allowed to impact, the impaction is not a single surface it is continuously happening. So, this is based on the turning of the fluid right so, in the cyclone, the air comes in and it has to go around and then it escapes to the center. So, if you look at it from the top, this is what is happening.

Air comes in and this is the central cylinder and outer cylinder. The air goes in and it takes it has to turn at every point it is turning particles can the tangential velocity the particles can go and hit.

So, we have a larger residence time and therefore you have a larger possibility of particle deposition. So, you can have a larger classification of particles here you can have a lot of particles that can be removed based on this.

It is a simpler device to design and make so, cyclone is used. So, in the case of air sampling, you have industrial cyclones big huge cyclones, the size of this room are bigger, which will remove particulate matter from very large power plants and all that. But these ones you are not sampling. For sampling, you are doing very small amount you are not pulling in million liters of air and all that you are, doing small amount we will come to that.

So the cyclones are very small here, as small as this fist, sometimes very smallest size of few inches' diameter, 1 inch in diameter, 2 inches in diameter, they are attached to a sampling system, an impactor. So, cyclone design is fairly advanced. So, you can so, the particles will get collected on the side of this thing and they will settle down here because the air that is coming has a certain you know, if you close this bottom part there is only one way the air can go.

If it is upright, you don't even have to keep it close you can keep it open, the air will naturally tend to go up and escape unless it is dense gas that is denser than air then you have to worry about that. So all these are operational details. We won't get into that. So one of the constraints for doing PM measurement is the measurement itself. The filter measurement is gravimetry.

So if you have gravimetry as the measurement so what we are doing in cyclone impactor, we are separating it. But this filter is now undergoing gravimetric measurement, which means that a filter has to be weighed, and the amount of particles matter that is collected on it must be measured. So what is the concern for gravimetry here? The same thing what we did in the TSS example? What is the constraint for gravimetry?

The minimum mass that you can measure, and you are talking about particles that are in a micron range. And we already mentioned that in that discussion, that micron range particles, the lower you keep going, they don't contribute much to mass so if you are going to do gravimetry what is the other way out? If you are doing gravimetry, you have to sample large volumes, volumes big enough so that your mass accumulation is big enough.

So, sampling times which is also called as sampling intervals can be anywhere from, you know, 1 hour or 8 hours, 24 hours or longer. And volumes are large you have a very large volumes of air that you are collecting. So if you have PM is mass by volume so you have very large volumes. So if you are collecting it for shorter duration of time, you can still get a reasonably high amount of mass that you can collect that is the idea.

So when we report PM we report PM as concentration. If you are doing 8 hour sampling, it gives you an 8 hour average you are not able to say that the concentration is higher at this point is within 8 hours say I am doing from 8 o'clock in the morning to 4 in the evening, or 6 in the morning to 2 in the afternoon.

It will say that between 6 and 2 the total accumulative mass concentration is this much. It cannot give any finer detail than that and if you are unable to do 8 hour sampling, you will do 24 hour sampling which is the entire daily average, from this morning, 6 o'clock to next day morning, 6 o'clock, this is what I am measuring. How will we use this information if you are able to do only 24 hour average sampling, it is only as good as that.

So, when you look at standards, this is the basis for when standards are seen in CPCB's website if you go and see you have a 24 hour average standard what it means is if I am exposed to a 24 hour standard concentration and this is the possible health effect. So if you are above the standard if the concentration of the 24 hour PM 10 value is above this, it is likely to be harmful to your health.

The reason they are doing it is that if you cannot get if you cannot get less than 24 hour averages, you cannot define a standard which is less than that. Because this is your measuring measurement tool. So if I have a tool that can measure round the clock, they'll say somebody is outside I say between 2 and 3 in the afternoon don't go outside, its concentrations are very high.

So just don't go outside during that time. Rest of the time if you are outside does not matter, your average exposure is going to be very small.

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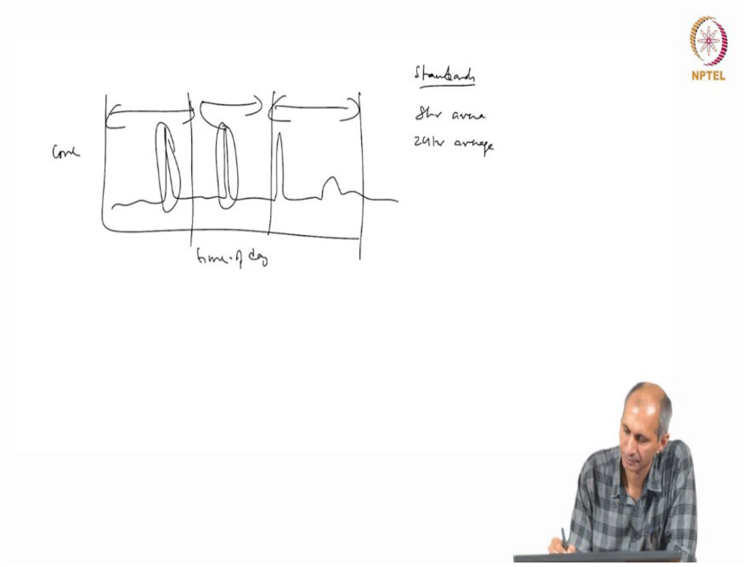

So if you look at these kind of things, you have time of the day and the concentration. So you have a spike, you have several spikes, and some baseline concentration. You are going to miss all of this if your sampling measurement window is the entire thing. The measurement window is this full thing you are going to miss this spikes you don't know when the spikes but the reason why these standards are reported like that are because that is that is what they have.

You cannot measure the final resolution for a very large network of samplings. So, as I said all of this will change because every year as we go there will be new developments in the protocols of measurement you are able to measure it for cheaper, therefore, a lot more deployment of PM sampling is done and therefore, you can go lower and lower. What we would like to have is actual full real time concentration maps.

So, that you exactly have what information that you need, when are the spot times, which area is highly polluted and all that so, we would like to full information so that we can use the information in whichever way you want. So these are time average samples and these standards are based on the protocols for measurement. I think that is why we see in the standards 8 hour or 24 hour average, there is a number of different.

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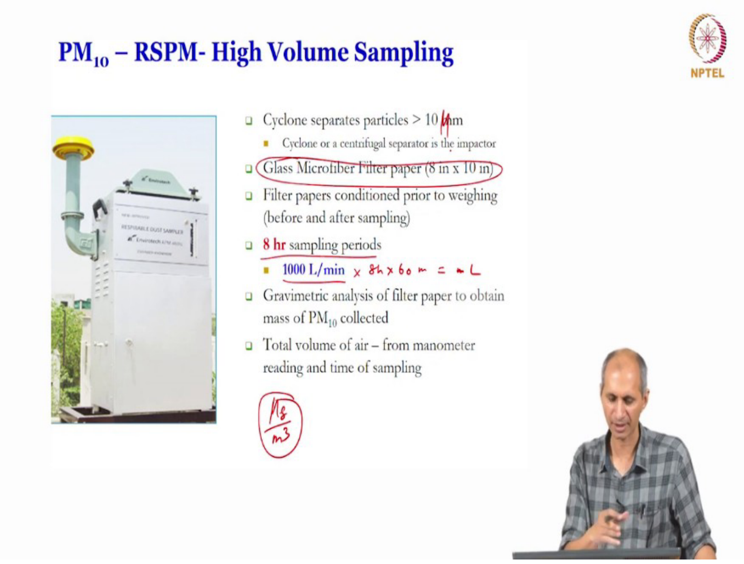

So one of the devices that is used for large volume sampling, we are looking at gravimetry. A gravimetry remains its 4-digit balance.

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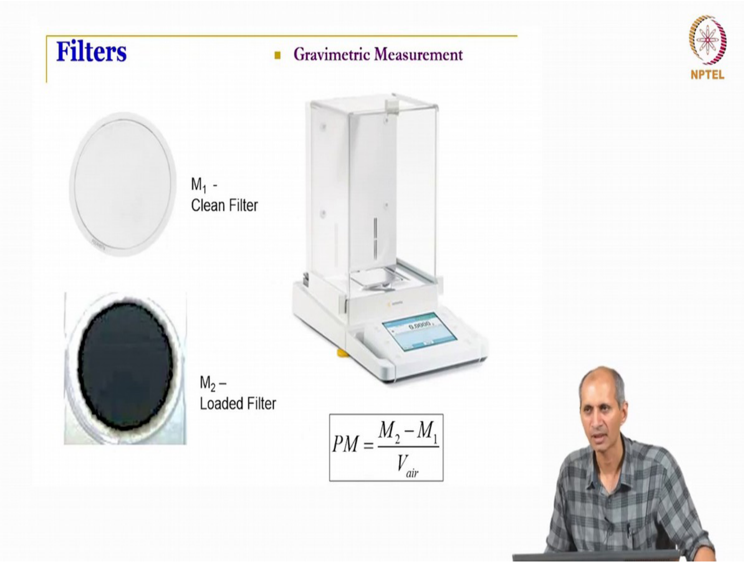

It is very commonly available it is not very expensive, it costs anywhere between 40,000 to a lakh maybe depending on the range of what you are using for that, then it is easier for 1 measurement to be made. So one of the goals of this kind of ambient measurement is you must have as many measurements as possible it is easily accessible, people must be able to afford it. You cannot have a 60 lakh equipment to do nobody will do it.