Air Pollution and Control
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Lecture – 32
Assessment of Exposure to Indoor Air Pollutants

Hello friends, these days we are talking about sources, characterization, health impacts of the air pollutants which are in the indoor environment. So, today in this series we will discuss about assessment of exposure to indoor air pollutants.

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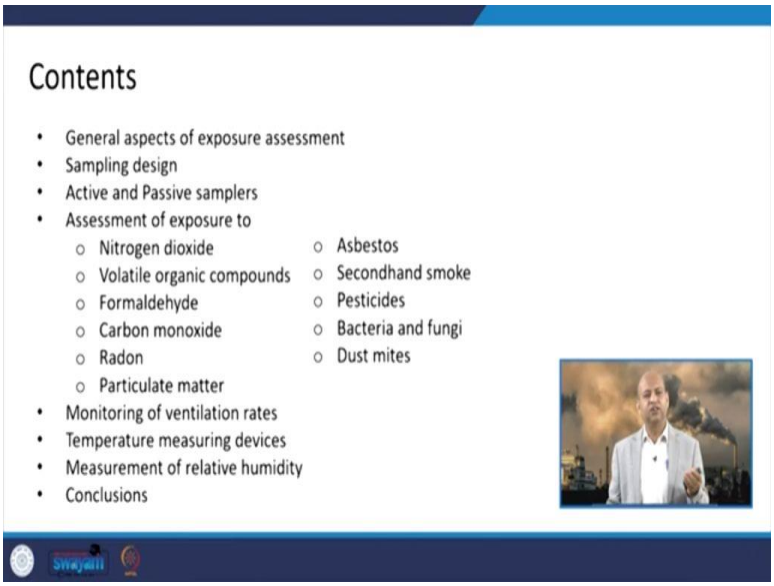

The contents of today's lecture is like general aspects we will discuss in the beginning about the exposure assessment. Then, how does sampling is done in the indoor environment, what are the principles of the sampling, how to design the sampling that we will see. Then, active and passive samplers; the difference between active and passive samplers, we will go through.

Then, assessment of exposure to different indoor air pollutants like nitrogen dioxide or VOCs that is Volatile Organic Compounds, or formaldehyde, carbon monoxide, radon, particulate matter, asbestos, secondhand smoke, pesticides, bacteria and fungi, dust mites; all these indoor air pollutants which are very important with respect to the human health exposure and deterioration of indoor air quality we will discuss about how to assess the concentrations of these particular pollutants in the indoor environment.

And the monitoring of ventilation rates is important, because whatever sources are there within the indoor environment or something is coming from outdoor also; because of door opening windows etc. So, the ventilation plays very critical role to decide how much air quality is deteriorated or improved. So, the monitoring of ventilation rates we will discuss about, then temperature, measuring devices, and measurement of relative humidity; because temperature and relative humidity also plays role in deciding about or determining of the indoor air quality. So, that we will discuss and later on, we will conclude.

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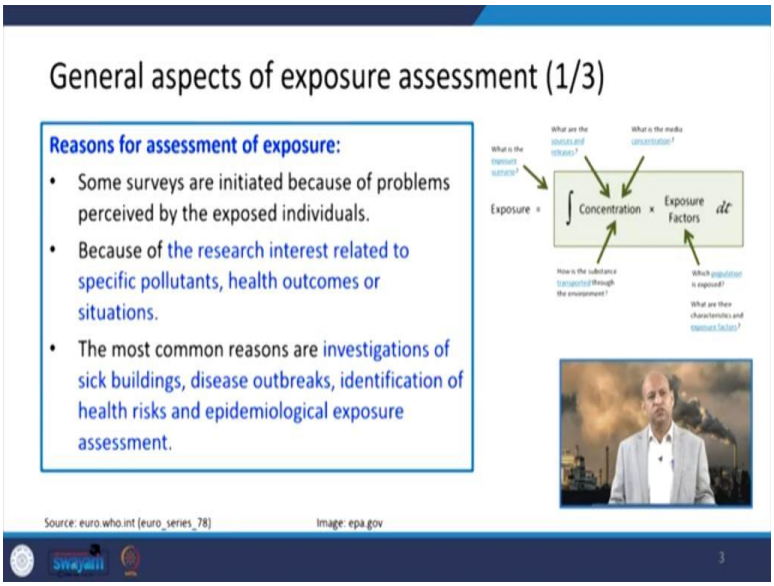

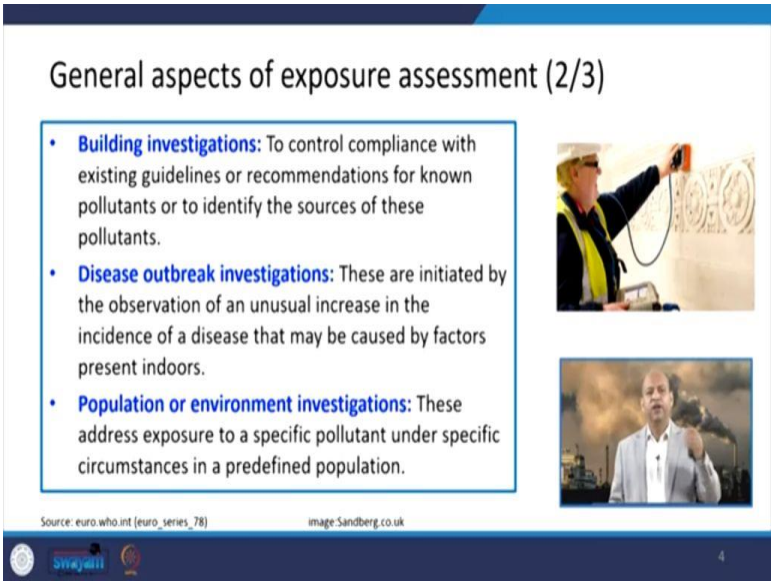

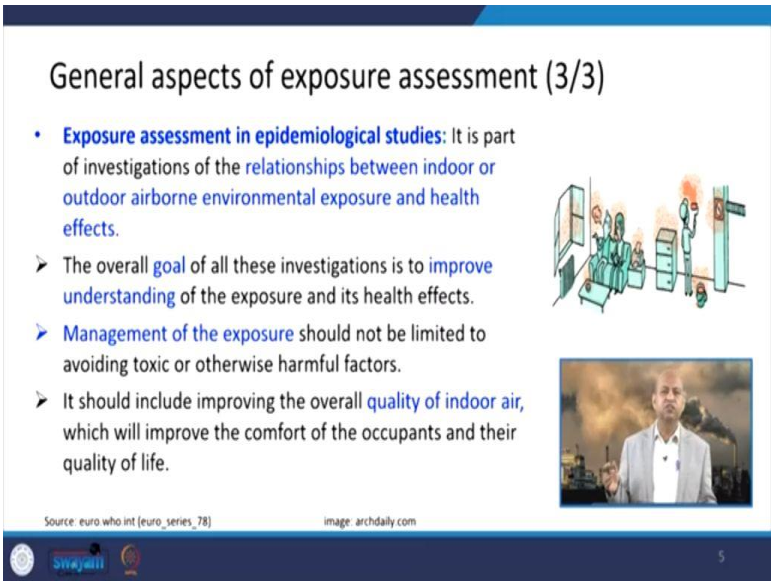

So, if we talk about the general aspects of exposure assessment, then we focus on regions for assessment of exposure. Why do we go for that basically? So, some sources based on some sources we can say that, these surveys are initiated because of problems perceived by the exposed individual. So, if somebody is complaining, then we conduct some survey in the particular indoor environment offices or in buildings etc. Because of research interest also related to specific pollutants or health outcomes of that particular situation or pollutant; researchers also go for these exposure assessments related studies.

The most common reasons are investigations of sick buildings. You might have heard sick building syndrome, which sometimes we talk about because of their indoor environment; and people frequently fall sick in those buildings because of certain reasons. So, those sick building related issues or disease outbreaks in particular indoor environments, identification of health risks, and epidemiological exposure assessment. So, for these kind of investigations or studies, we need to go for exposure assessment. Then, these building investigations related aspects are because the control compliance with the existing guidelines, because there are guidelines; or, recommendations for known pollutants or to identify the sources of these pollutants.

Although there are no well-defined guidelines, as we have for ambient air quality. But, still there are some recommendations based on some research, and from WHO and other organizations, they give some recommendations. So, for those kinds of comparisons, we want to study those. Diseases outbreaks, as we have discussed there are these are kind initiated by the observation of an unusual

increase in the incidences of a particular disease in that particular environment. And the causal factors, if it is not known, then we need to study it in the within the indoor environment.

And population or environment investigations are also important factors. These address exposure to a specific pollutant under specific circumstances in a predefined population; because sometimes, complaints come that a particular segment of population is affected by certain disease, which are related to indoor environment. So, we have to see whether that particular segment of population is living in a particular indoor environment, which is highly polluted.

Then, when we talk about exposure assessment in epidemiological studies, it is part of investigations of the relationship between indoor or outdoor airborne environmental exposure and health effects.

So, series of studies are conducted for several years, then we derive some conclusions. And the overall goal of all these investigations is to improve understanding of the exposure; and its health effects in the indoor environment terminology. Management of the exposure should not be limited to avoiding toxic or otherwise harmful factors. We have to go for overall management of the indoor air quality basically. So, it should include improving the overall quality of the indoor air, which will improve the comfort of the occupants and their quality of life, their health; so that will be improved and people will live the healthy life.

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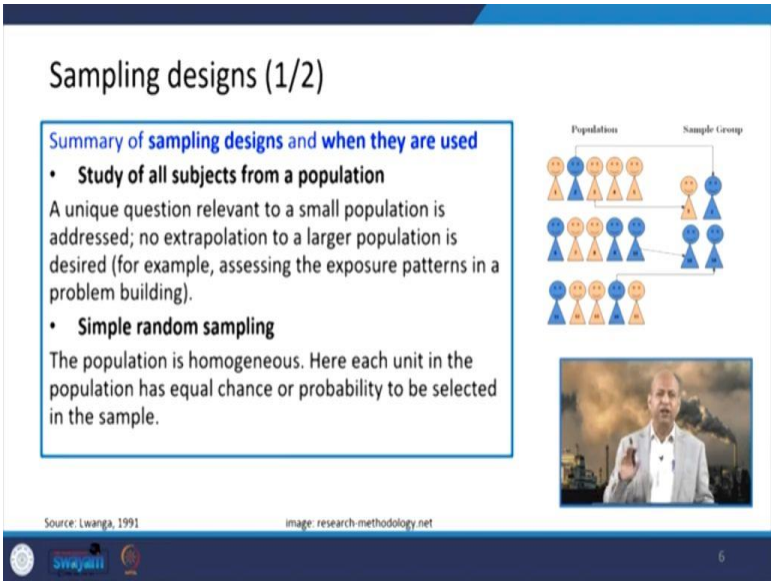

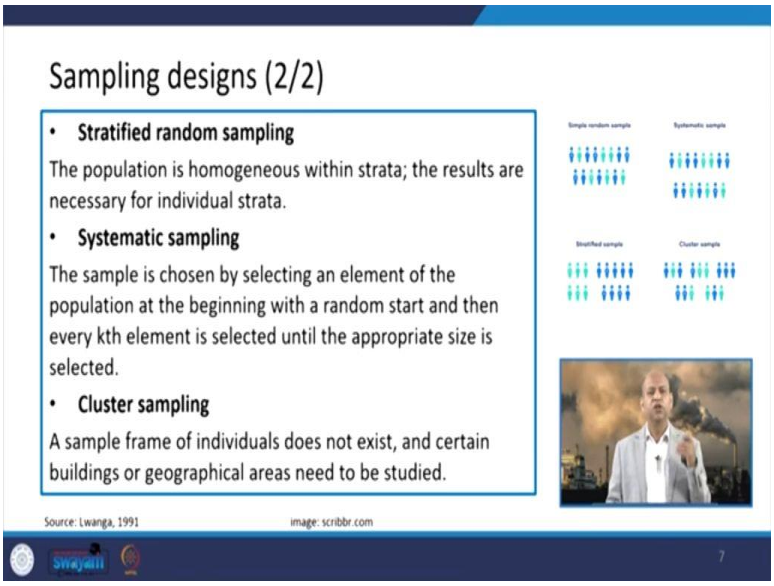

Then we talk about sampling designs, how to design the sampling? So, it depends upon the population, size; so sample size is also dependent on population size. There are certain statistical ways also to go for how much, how many sample population should go for observations, for assessment, or for evaluation? Simple random sampling is done or with the help of certain, systematic methodologies are also done; like a stratified random sampling can be there, or systematic sampling can be there, or cluster sampling can be there. So, depending upon the situation, we can go for either of these kind of sampling strategies.

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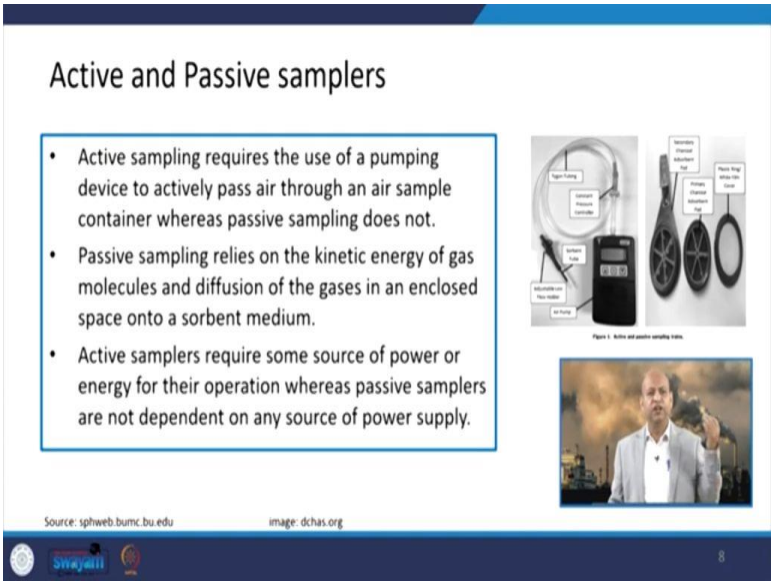

When we talk about samplers, so, there are two major kinds of samplers, like active samplers or passive samplers. Active sampling requires the use of a pumping device to actively pass air through an air sample container; whereas, passive sampling does not. Passive sampling is like something you have pasted at the particular wall or at a hanging kind of situation, it is there; and something it is getting exposed to air, so some gas will be absorbed; some particles will be there. So, the passive sampling relies on the kinetic energy of the gas molecules; and diffusion of the gases in an enclosed space on to a these absorbent medium, absorption, adsorption, those kinds of things.

Whereas, active samplers need some type of pump when we suck the air; and then it will pass through certain solutions or on the filter paper; so, those kind of are the active samplers. So, active samplers requires some source of power, like electric or battery related, or energy for their operation, whereas passive samplers are not dependent on any source of power supply. So, depending upon situations, we can also go for active and passive sampling.

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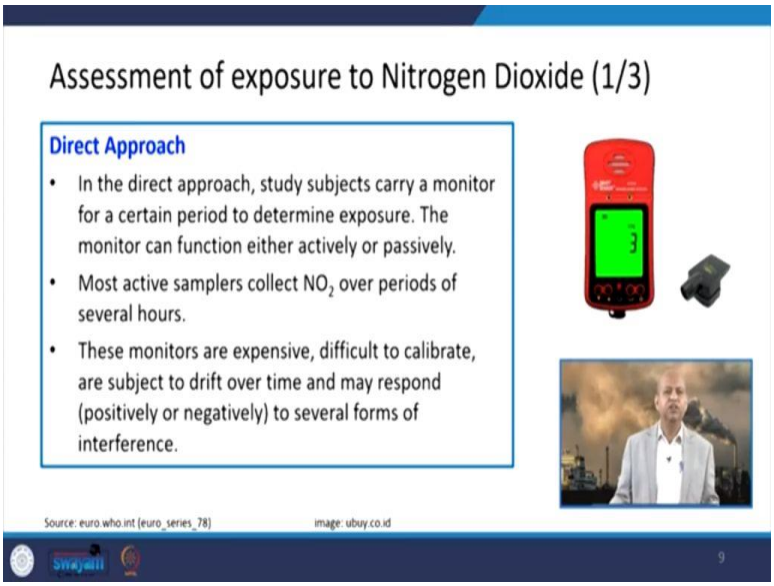

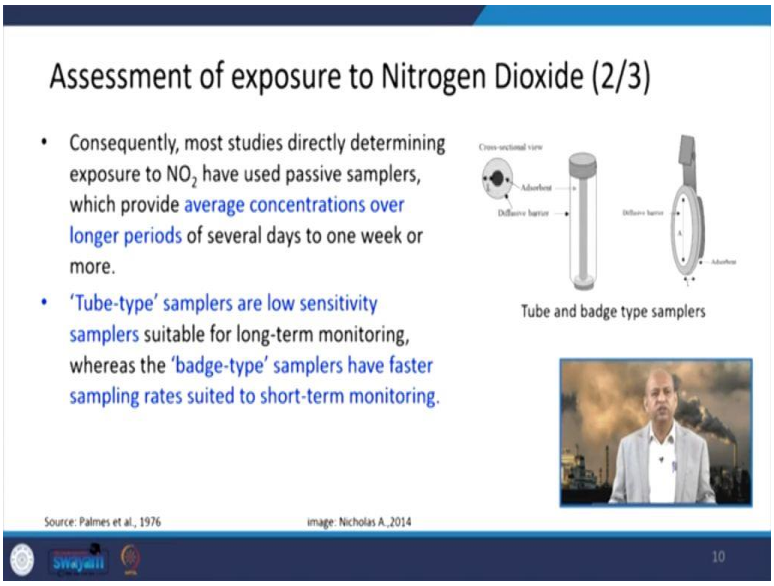

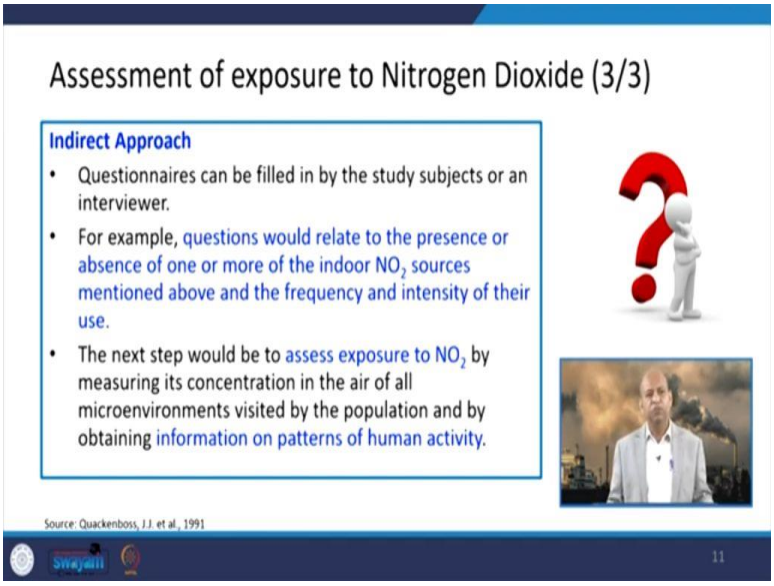

Plus, active samplers for short exposure, active samples are important; whereas, passive samplers are good for long term kind of exposure assessment. Then there is assessment of exposure to nitrogen dioxide if you want to do, then there are direct approaches and indirect approaches. In direct approaches, the study subjects carry a monitor for a certain period to determine exposure; it maybe personal sampler kind of thing.

So, the monitor can function either actively or passively but it should be with the person who is who is exposed. Most active samplers collect these oxides of nitrogen over periods of several hours; and these monitors are expensive, difficult to calibrate, are subjected to drift over time; and

may respond positively or negatively to several forms of interferences. So, these are kind of limitations or challenges in case of these direct approaches.

Then consequently, most studies directly determining exposure to NO_2 that is nitrogen dioxide have used passive samplers, which provide average concentrations over a longer period of several days to one week, or more even months. Then, the tube-type samplers are low sensitivity samplers suitable for long term monitoring; whereas, the badge-type samplers are kind of they have faster sampling rates, and they are suited to short term kind of monitoring. When we talk about the indirect approach, then basically we can go through like questionnaire based surveys; so that it can be filled by study subjects or an interviewer.

For example, we have questions; those questions would relate to the presence or absence of one or more of the indoor NO_2 sources mentioned above and the frequency, and this intensity of their use. The next step would be to assess exposure to NO_2 by measuring its concentration in the air of all micro environments visited by the population; that is under study or of the interest of the researchers or policymakers. And by obtaining these information on patterns of human activity, so that we can correlate with them.

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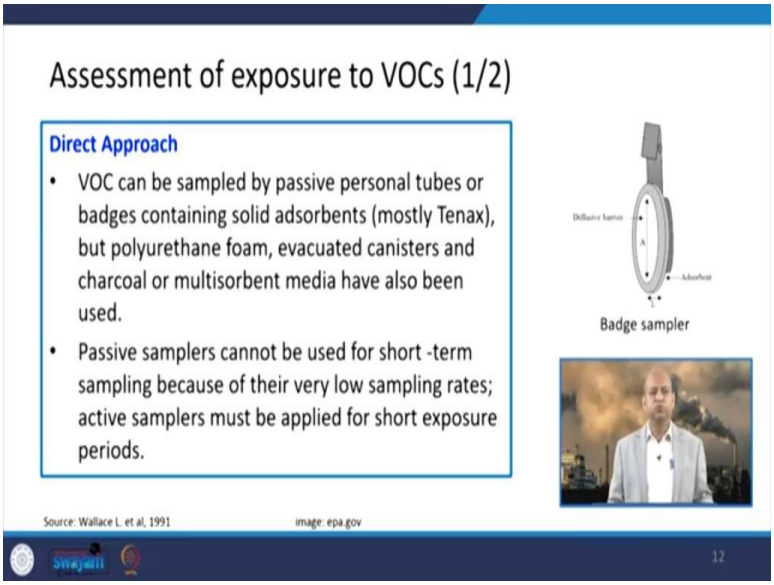

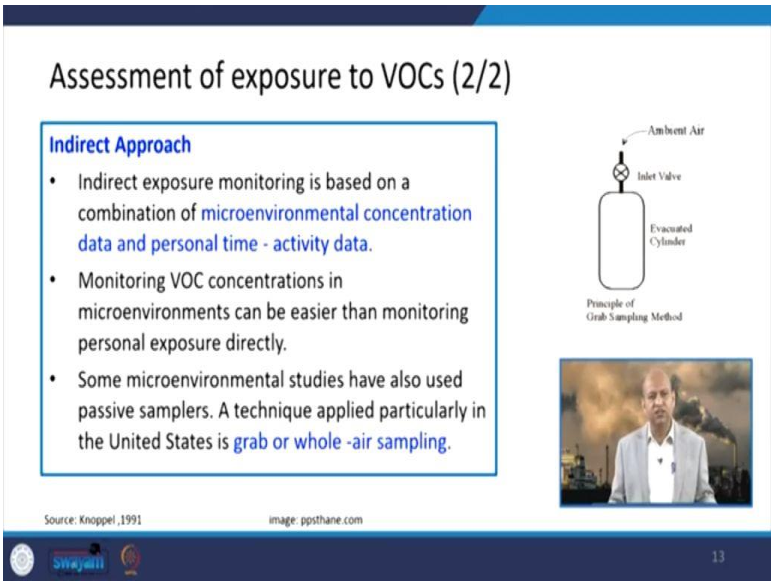

Then, when we talk about tax assessment of exposure to volatile organic compounds; so, again we go for direct approach like VOCs can be sampled by passive personal tubes, or badges containing solid adsorbents, mostly Tenax. But, these there are certain other chemicals, which are evacuated the canisters can be used, and charcoal or multisorbent media have also been used for this purpose. Passive samplers cannot be used for short-term sampling as you know we have discussed, because of their very low sampling rates. So, they do not represent the surrounding concentrations of VOCs. And the active samplers must be applied for short exposure period.

When we go for indirect approach to assess the exposure of VOCs, then basically, this indirect exposure monitoring is based on a combination of micro environmental concentration data; and personal time like activity data, time and activity kind of variation. Then, monitoring of VOC concentrations in microenvironments can be easier than monitoring personal exposure directly; so, this is very important point. Some micro environmental studies have also used passive samplers, a technique applied particularly in the United States is grab or whole air sampling, those kinds of techniques have also been used.

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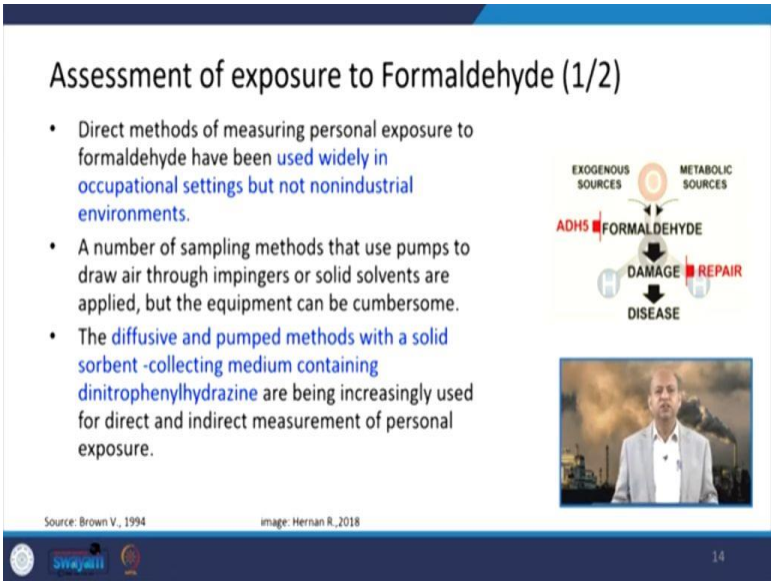

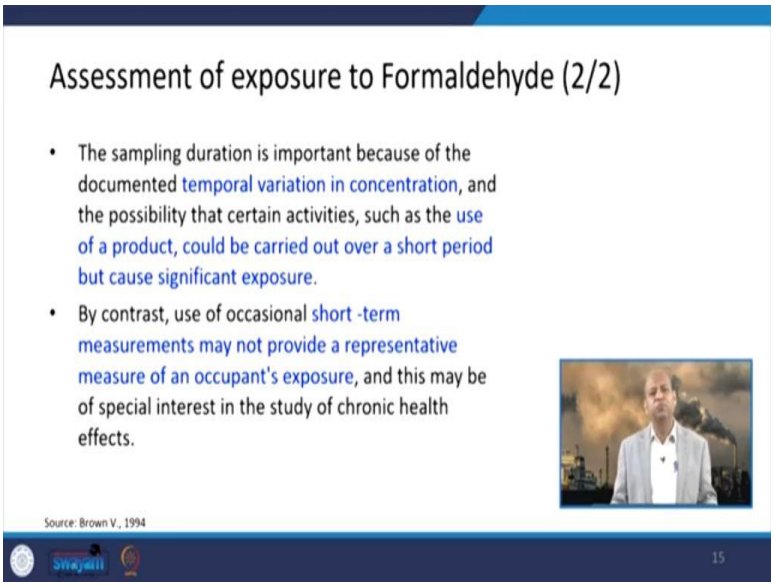

When we talk about formaldehyde related assessment of the exposure of the formaldehyde assessment, then direct methods of measuring personal exposure to formaldehyde have been used widely to occupational settings; but not non-industrial environments. A number of sampling methods that use pumps to draw air through these impingers or solid solvents are applied. But, the equipment can be cumbersome, very complex kinds of things; so, sometimes we avoid these kinds of methodologies. The diffusive and pumped methods with a solid sorbent collection medium or collecting medium containing those required chemicals, are being increasingly used for direct and indirect measurement of personal exposure in this particular exposure.

The sampling duration is important because of the documented temporal variation in concentration of the formaldehyde. And the possibility that certain activities such as the use of a product could be carried out over a short period; but cause significant exposure because of that relationship of the user, and the emissions of formaldehyde from that particular product.

By contrast, use of occasional short-term measurements may not provide a representative measure of an occupant's exposure, and this maybe of a special interest in the study of chronic health effects. So, short-term impacts of acute concentration or long term impact of very low concentration; both things are to be seen and differentiation has to be made properly.

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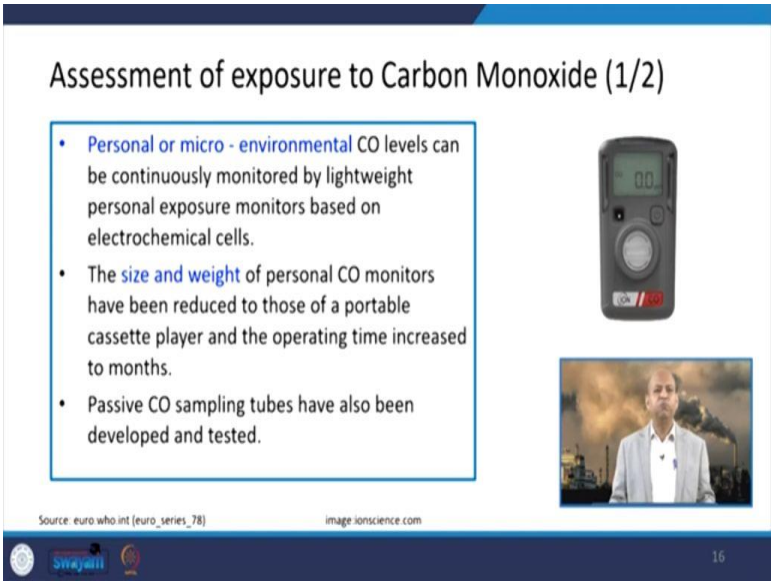

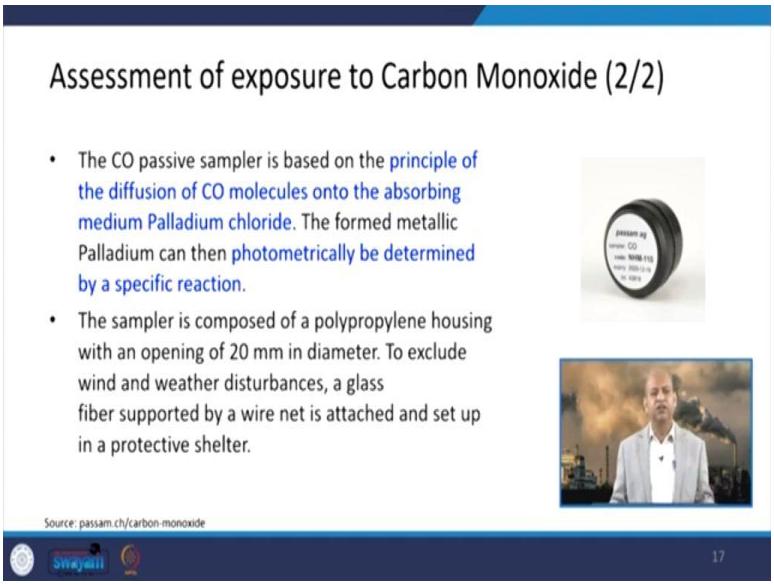

When we talk about assessment of exposure to carbon monoxide; we have several times discussed its health impacts as you know. Then, the personal or micro environmental CO levels can be continuously monitored by lightweight personal exposure monitoring methods, based on electrochemical cells. The size and weight of personal CO monitors have been reduced to those of a portable cassette player and the operating time increased to months; so, that it is easy to use for a longer period. And the passive CO sampling tubes have also been developed and tested. So, active and passive both kind of sampling strategies are available for CO exposure assessment also.

The CO passive sampler is based on the principle of the diffusion of CO molecules onto the absorbing medium. And the formed metallic Palladium can then this photo metrically be determined by a specific reaction in the laboratory. The sampler is composed of a particular housing related that the case is there, with an opening of 20 mm in diameter. To exclude wind and weather related disturbances, a glass fiber supported by wire net is also attached and set up in a protective shelter; so, that those weather and air related disturbances are not there.

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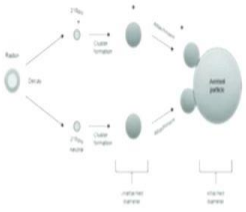
Assessment of exposure to Radon (1/3)

- The most frequent methods of exposure assessment are indirect: the radon concentration is monitored in various indoor spaces and information on activity patterns is collected using questionnaires.
- Several biomarkers of exposure to radon can be measured, including the presence of radon progeny in bones, teeth, blood and hair.



Source: AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY, Toxicological profiles image: krystian,2019

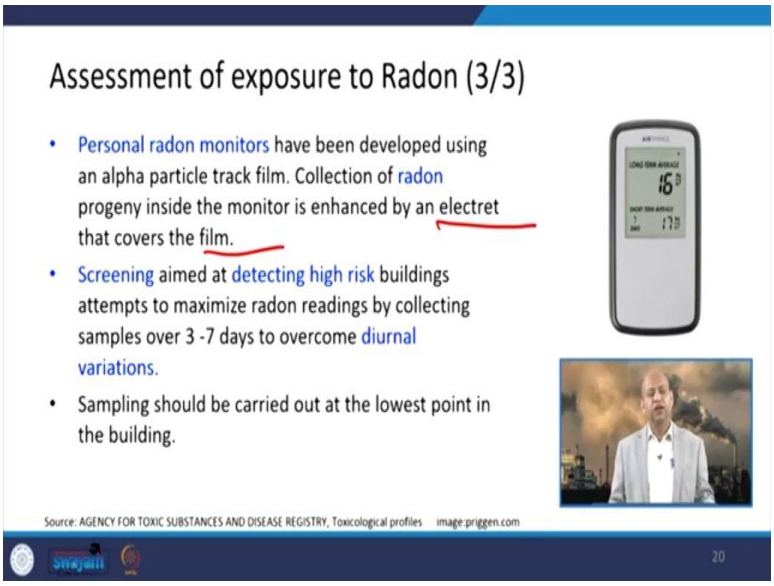
Assessment of exposure to Radon (2/3)

Sample collection and analytical methods for detecting radon in environmental air samples

Sample preparation	Analytical method	Exposure time	Sample detection limit (Bq/m³)
Radon			
Activated charcoal canisters	Gamma spectroscopy	A few days	48
Activated charcoal extracted with toluene	Liquid scintillation	A few days	7.7–13.7
Alpha particle track detectors	Microscopic analysis	A few months	518
Progeny			
Alpha particle track detectors	Alpha particle spectroscopy	A few months	40.7

Radon concentration is expressed in **Becquerels per cubic meter** (Bq/m3)

Source: AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY, Toxicological profiles



When we talk about the exposure to radon, then the most frequent methods of exposure assessment of this particular chemical is indirect basically. And the radon concentration is monitored in various indoor space and information on activity patterns is collected using the questionnaire based surveys.

Several biomarkers are also there of exposure to radon. It can be measured including the presence of radon progeny in bones, or teeth, blood and hair. So, those kinds of ways are also there to measure the radon exposure. Here you can see the sample collection and the analytical methods for determining or detecting radon in environment air sampler.

So, this table gives a sampling preparations, analytical methods, and exposure time, and the sample detection limit for these particular different kinds of methodologies. Personal radon monitors have been developed using an alpha particle track film. This collection of radon progeny inside the monitor is enhanced by an electret that covers the film.

And a screening aimed at detecting high risk buildings attempts to maximize radon readings by collecting samplers over three to seven days to overcome any diurnal variation. Diurnal variation means in daytime, it varies from morning to evening because of several reasons; some these situational reasons are also there temperature, humidity also play a role.

And the sampling should be carried out for radon exposure assessment at the lowest point in the building; because that is the place where a lot of concentration occurs, because it emits in those

places which are at the like, you can see kind of basement areas where a lot of emissions can be there.

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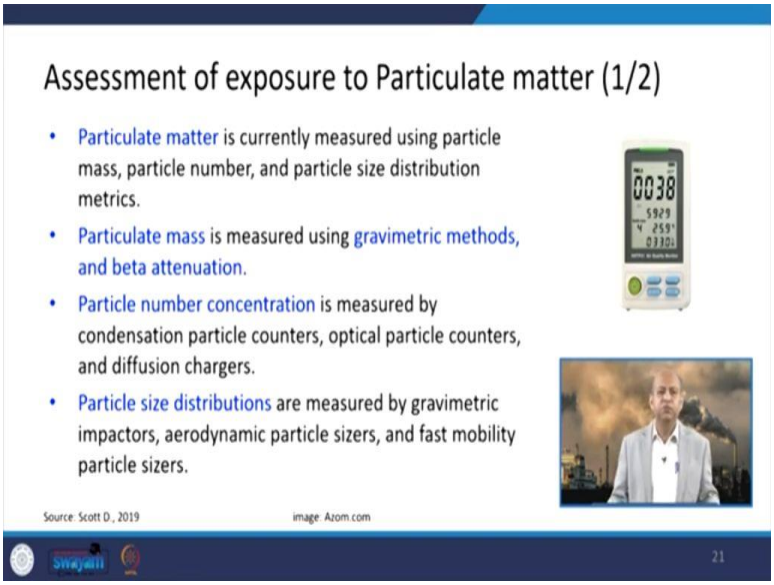

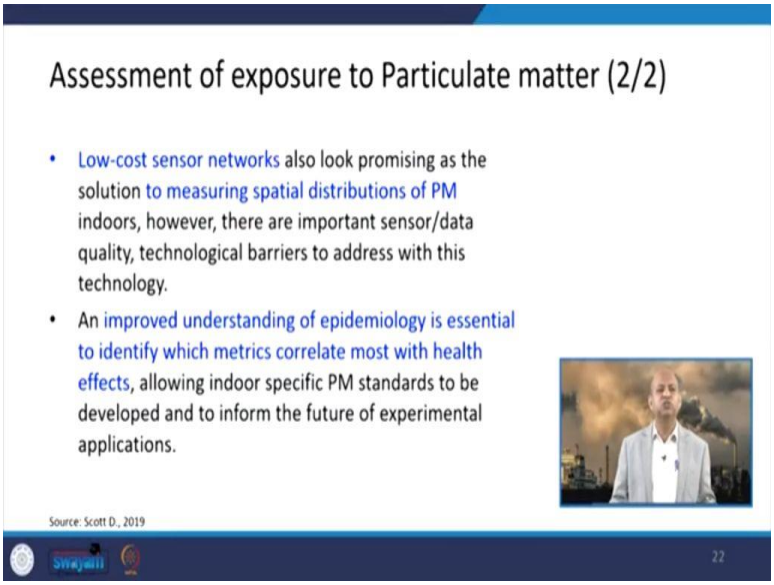

Then, when we talk about particulate matter related exposure assessment, then currently measured using particle mass, particle mass, and particle number, and particle size distribution, all three matrices are measured. Nowadays, several instruments are available and these particulate mass is measured using gravimetric methods and beta attenuation methods also. Then, particle number concentration is measured by condensation particle counters; optical particle counters are also there and diffusion charges, charger based instruments are also there. When we talk about particle

size distribution, they are measured by gravimetric impactors, aerodynamic particle sizers, and fast mobility particle sizers.

So, these are different methodologies for these three important mass, size, and number of the particles. Then, low cost sensor networks are also available to monitor for these kinds of particulate matter related observations. And they look promising as the solution to measuring the spatial distribution of particulate matter indoors. However, there are important sensor or data quality technological barriers which are challenges to address with this technology; so, we have to keep that mind, keep in the mind.

An improved understanding of epidemiology is essential to identify which matrices correlate most with health effects; and allowing indoor specific particulate metric standards to be developed and to inform the future experimental applications. So, that is also very important aspects for particulate matter exposure assessment.

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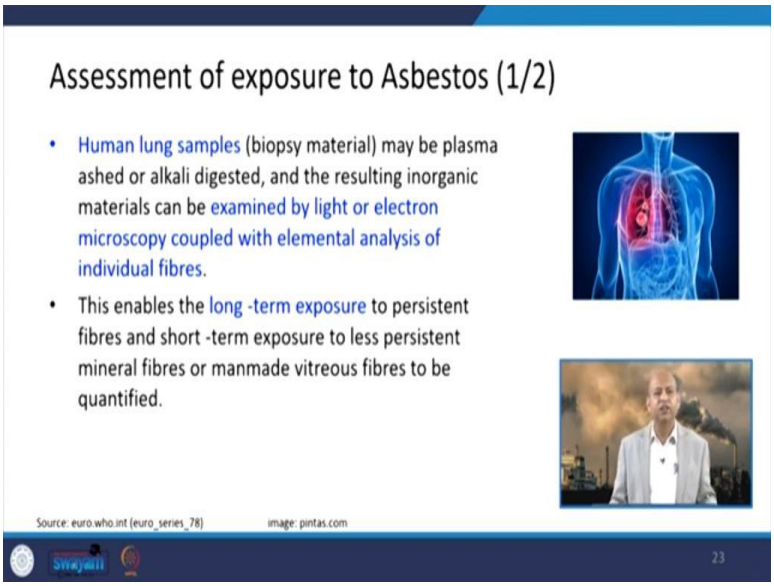

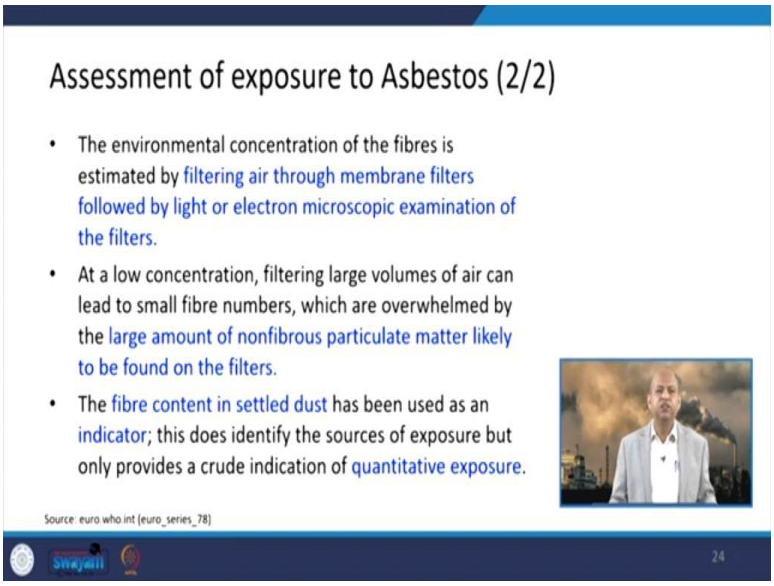

When we talk about asbestos related exposure assessment, so basically, these human lung samples biopsy material maybe plasma ashed or alkali digested; and the resulting inorganic materials can be examined by light or electron microscopy coupled with elemental analysis of individual fiber. So, that is the important technique for that particular exposure. This enables long-term exposure to persist fibers and that persisting fibers, and short-term exposure to less persistent mineral fibers or man made these fibers to be quantified. So, differentiation can be estimated.

The environmental concentration of the fibers is estimated by filtering air through membrane filters followed by light or electron microscopic examination of those filters. At a low concentration filtering large volumes of air can lead to a small fiber numbers; that is we be careful about, which are overwhelmed by the large amount of these non-fibrous particulate matter likely to be found on the fibers; so, the results can be affected accordingly.

The fiber content is settled dust has been used as an indicator; this does identify the sources of exposure, but only provide a crude indication of quantitative exposure. So, those are the things which are important in that particular exposure assessment. When we talk about exposure assessment of secondhand smoke, then personal monitoring can be there, biomarkers can also be used for assessment purpose.

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Assessment of exposure to Secondhand Smoke (1/3)

Personal monitoring

Portable monitors can be used for sampling particulate matter (PM2. 5 or PM_{10}) as a nonspecific indicator of exposure to environmental tobacco smoke.

Biomarkers

Nicotine and cotinine in the saliva, blood and urine are widely used biomarkers of recent (within 24 hours) exposure, and hair nicotine is a promising new biomarker for assessing exposure lasting several months.

Source: euro.who.int (euro_series_78) image: mdpi.com

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Assessment of exposure to Secondhand Smoke (2/3)

Stationary monitoring

- Both active and passive methods are available.
- Air sampling pumps have been developed to collect air for the assessment of concentrations of nicotine and respirable suspended particulate matter.
- Nicotine can be collected on a glass fibre backup filter treated with sodium bisulfate and analysed by gas chromatography with a flame ionization detector.
- Samples of respirable suspended particulate matter can be collected on Fluropore® or Teflon® filters.

Source: euro.who.int (euro_series_78)

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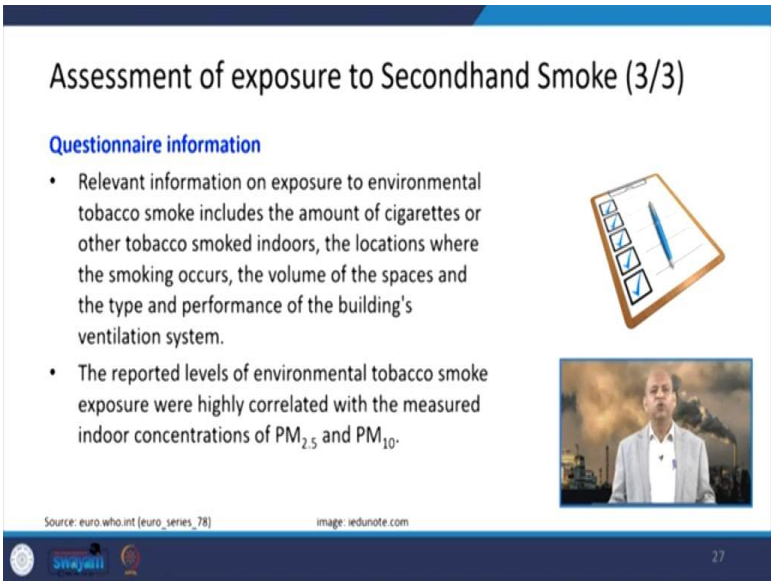

When we talk about personal monitoring, these portable monitors can be used for sampling particulate matter which could be of size $PM_{2.5}$ or PM_{10}. And, as a nonspecific indicator of exposure to environmental tobacco smoke for that size span you can see. Biomarkers like nicotine and these cotinine in this saliva, blood and urine are widely used biomarkers of recent that is within 24 hours exposure. And here nicotine is a promising new biomarker for assessing exposure lasting several months. So, these are also developing biomarkers for assessment of exposure assessment to the secondhand smoke.

Even if people are not smoking, they can get secondhand smoking kind of exposure. The stationary monitoring can also be done like both active and passive methods are available. So, air sampling pumps have been developed to collect air for the assessment of concentrations of nicotine, and these respirable suspended particulate matter SPM that is PM_{10} basically. Then, nicotine can be collected on a glass fiber backup filter treated with sodium this bisulfate; and analyzed by gas chromatography with a flame ionization detector. Samples of respirable suspended particulate matter RSPM can be collected on these Teflon kind of filters.

Then, there are questionnaire based information which is also important in this particular assessment of exposure to the secondhand smoke; because relevant information on exposure to environmental tobacco smoke includes the amount of cigarettes or other tobacco smoked indoors, and the location where the smoking occurs. The volume of the space and the type and performance of the buildings ventilation systems; all these variables can also affect or influence the exposure of the secondhand smoke. The reported levels of environmental tobacco smoke exposure were

highly correlated with the measured indoor concentrations of $PM_{2.5}$ and PM_{10}. So, these need to be properly recorded.

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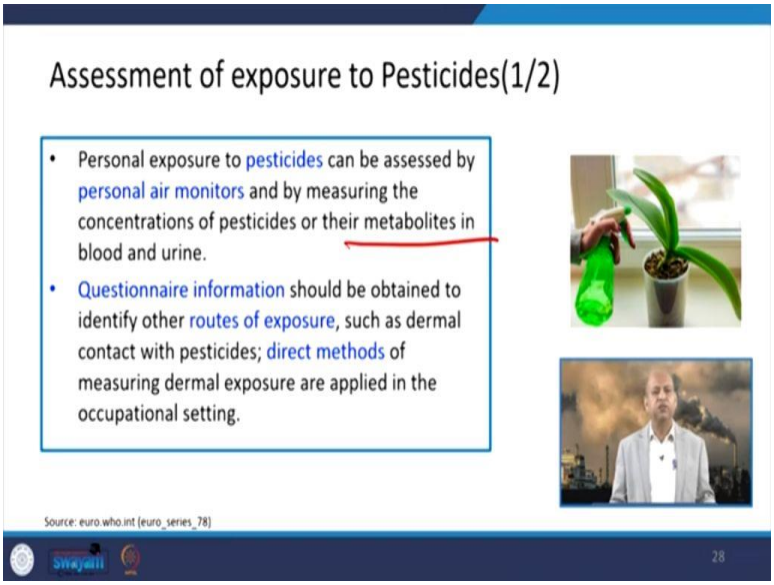

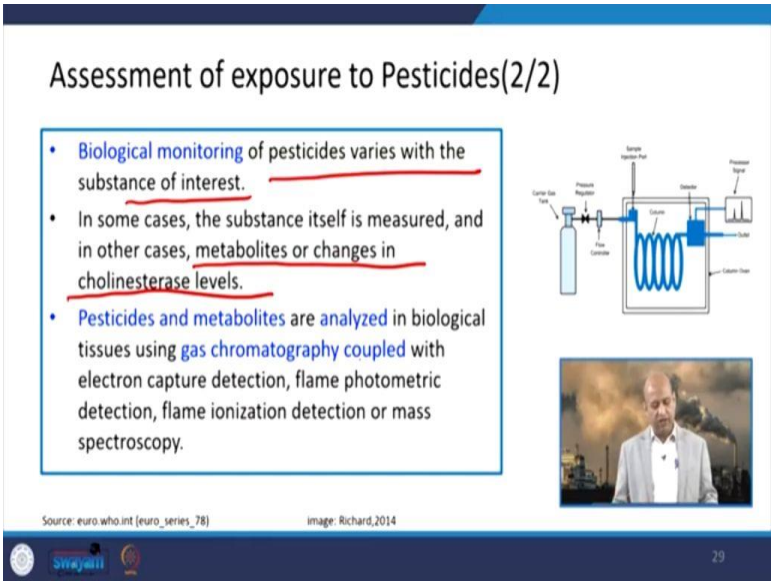

When we talk about assessment of exposure to pesticides, so the personal exposure to pesticides can be assessed by personal air monitors, and by measuring the concentration of pesticides on their metabolites in the blood and urine. Then, questionnaire information should also be there for obtaining to identify other routes of the exposure, such as dermal that is through skin, dermal contacts with pesticides, or direct methods of measuring dermal exposure are these applied in the occupational settings.

When we talk about biological monitoring of the pesticides assessment, then biological monitoring of pesticides varies with the substance of the interest. In some cases, these substances itself is measured. And the other cases, these metabolites or changes in the different kind of these chemical levels related to the pesticides, they are also measured and then it is related.

Pesticides and metabolites are analyzed in biological tissues using gas chromatography coupled with electron capture detection, and the flame photometric detection or flame ionization detection, or mass spectroscopy. So, these kind of technologies, methodologies has to be available; otherwise, it is difficult to assess the exposure of pesticides.

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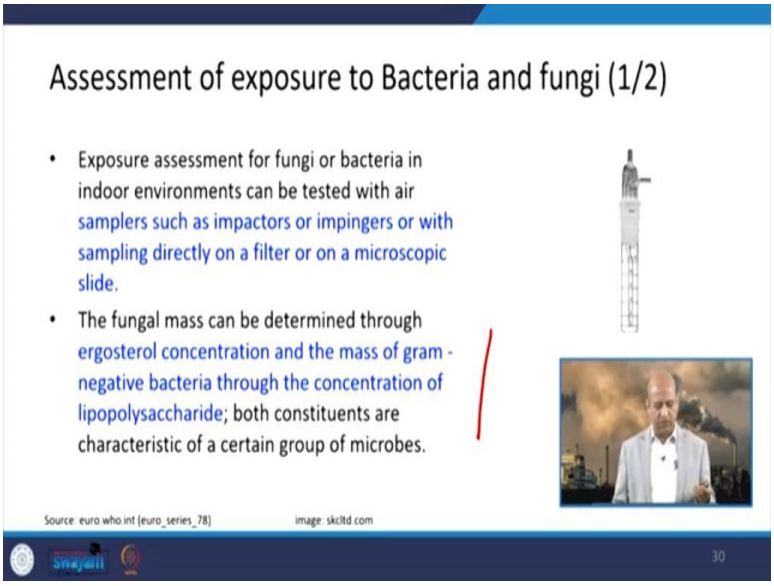

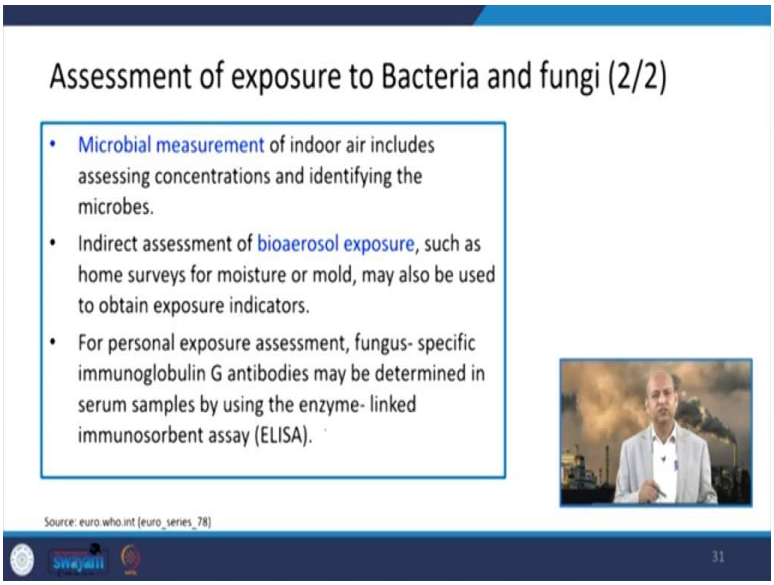

When we talk about exposure assessment of bacteria and fungi, then for this particular assessment in the indoor environment, we can test air samplers we can use such as impactors, or these impingers or with sampling directly or a filter, or on microscopic slide. Because, they are they also behave like particulate matter you can see; they can be collected on filters.

Then, the fungal mass can be determined through this ergosterol concentration and the mass of gram negative bacteria; different characteristics related to these kinds of pollutants has to be related to different kind of groups of the microbes, and that correlation has to be established. When we talk about microbial measurement of indoor air includes assessing concentration and identifying the microbes; the particular types of the microbes.

Then indirect assessment of bioaerosol exposure can also be done, such as home surveys for these moisture or mold, it may also be used to obtain exposure indicators. If this is there, then certainly there are chances of the exposure. For personal exposure assessment fungus specific these kind of antibodies may be determined in these serum samples, by using enzyme-linked these immunosorbent assay (ELISA). These kind of techniques are there which can be used for assessment of exposure to bacteria and fungi.

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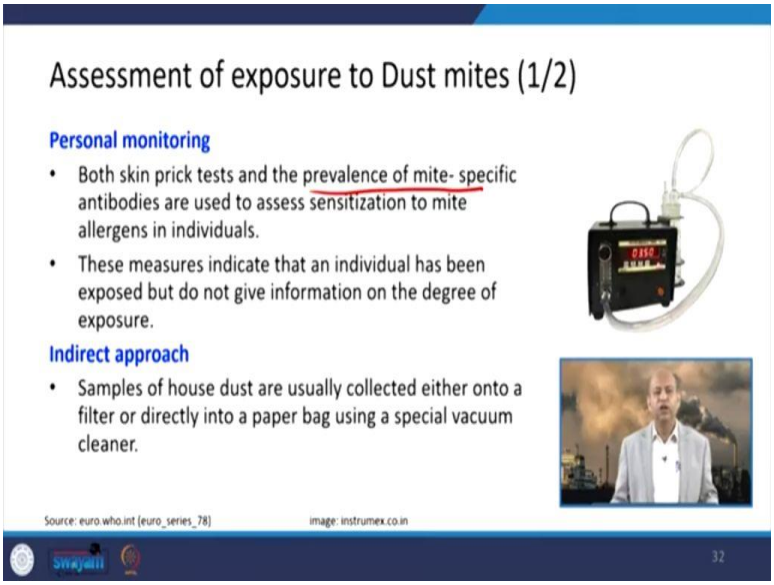

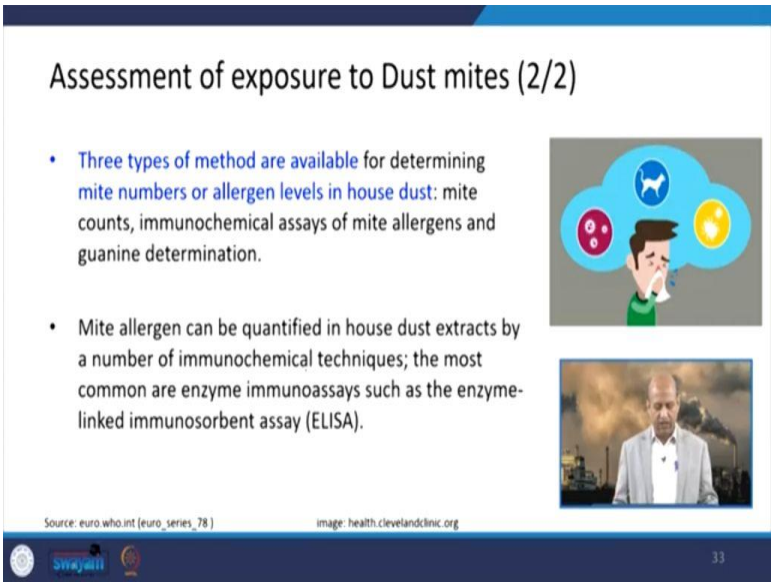

When we talk about exposure to the dust mites, then again personal monitoring and indirect approaches are also available. Like both the skin prick test and the prevalence of mighty specific antibodies are used to assess sensitization to mite allergens in the individual; so, that allergy related test can be carried out.

These measures indicate that an individual has been exposed but do not give information on the degree of the exposure; so, that is a reliable approach in that sense. Indirect approach is there like samples of house dust are usually collected either onto a fiber or directly into a paper bag using a special vacuum cleaner. So, those kind of indirect approaches are also available.

Three types of methods are available for determining mite numbers or allergens, allergens means those kinds of those causes allergic reactions. So, allergen levels in house dust and mite counts, or these immunochemical assays of mite allergens; and related determination of the quantities can be done. Then, mite allergens can be quantified in house dust extracts by a number of techniques. And those techniques are already we have discussed like ELISA, ELISA.

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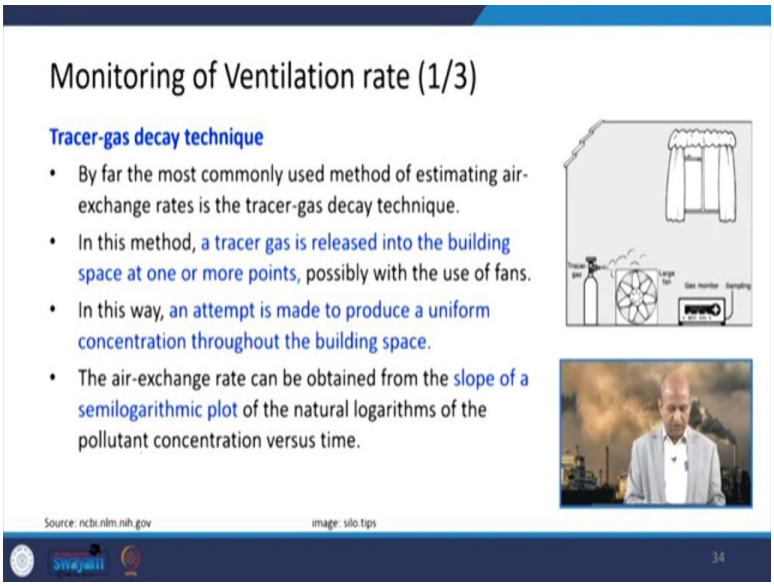

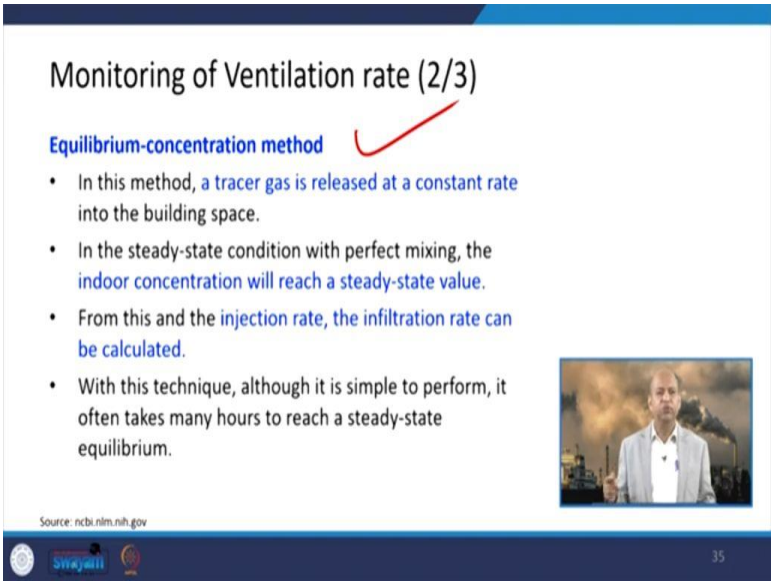

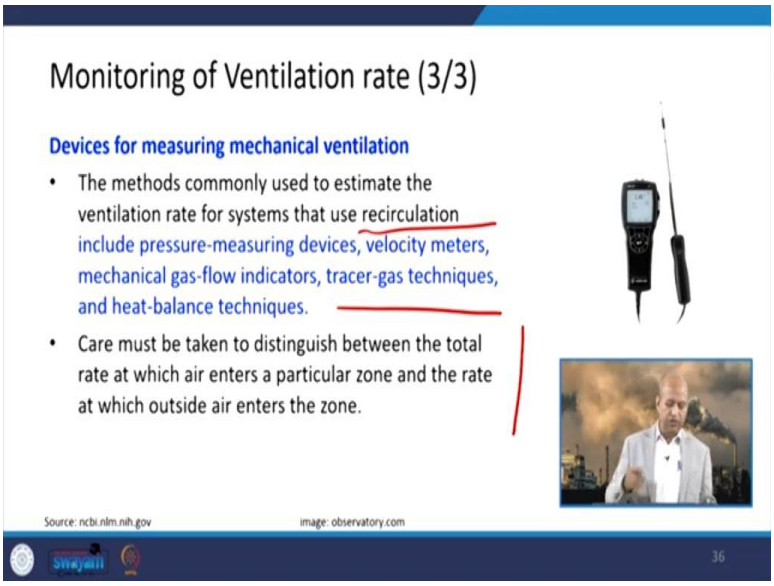

When we talk about ventilation rate related monitoring because they influence the exposure of those living in the indoor environment. So, that tracer-gas related decay technique can be used. So, by far the most commonly used method of estimating air exchange rates in the trace- gas decay technique is the most popular. In this method, a tracer-gas is released into the building space; or at one or more points, possibly with the use of fans. And in this way an attempt is made to produce a uniform concentration throughout the building space; so that we can see the decay rate later on.

And the air exchange rate can be obtained from the slope of this semi logarithmic plot of the natural logarithm of the pollutant concentration versus time kind of plots; so, the correlation can be established.

And then equilibrium concentration method is also used. In this method, a tracer gas is released at a constant rate into the building spaces. In the steady-state condition with the perfect mixing, the indoor concentration will reach a steady state value. Then from this and the injection rate, the infiltration rate can be calculated. With this technique, although it is simple to perform, it often takes many hours to reach a steady-state equilibrium; so, it is time consuming basically.

Then, we also have devices for measuring mechanical ventilations; and the methods commonly used for this is to estimate the ventilation rate for systems that use these recirculation. And this include pressure-measuring devices, velocity meters, mechanical gas-flow indicators, tracer-gas techniques and heat balance techniques; all these kinds of instruments are used for these parameters. Then, care must be taken to distinguish between the total rate at which air enters at a

particular zone, and the rate at which outside air enters the zone. So, those differentiation must be made otherwise, there are chances of erroneous estimations.

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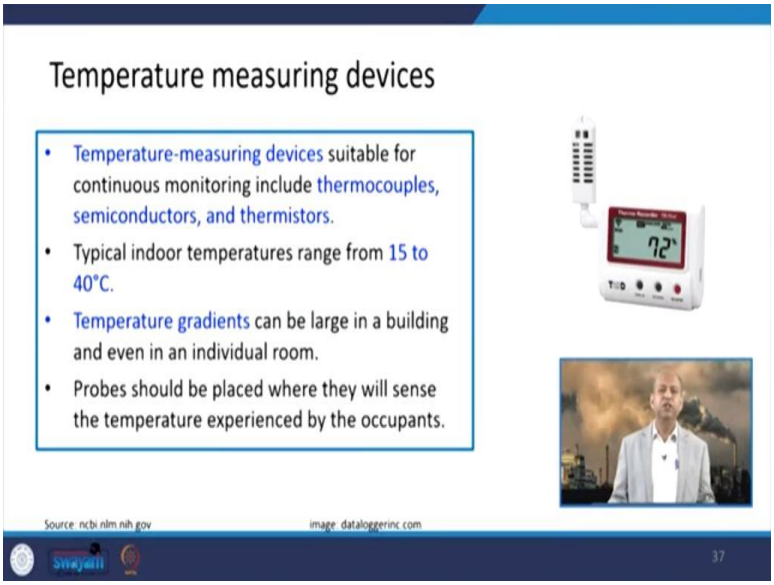

Then, temperature-measuring devices are also important; because we need to measure temperature which also play a role in indoor air quality, temperature, and humidity; humidity we will discuss. First we will discuss about the temperature measuring devices which are suitable for continuous monitoring include thermocouples or semiconductors and these thermistors. And typical indoor temperature ranges from 15 °C to 40 °C; so, that kind of range this instrument should be applicable for. Temperature gradients can be large in a building and even in the individual room. So, that gradient must be captured by the instruments, so that kind of sensitivity must be there. And the probe should be placed where they will sense the temperature experienced by the occupants; so, that realistic kind of measurements can be taken.

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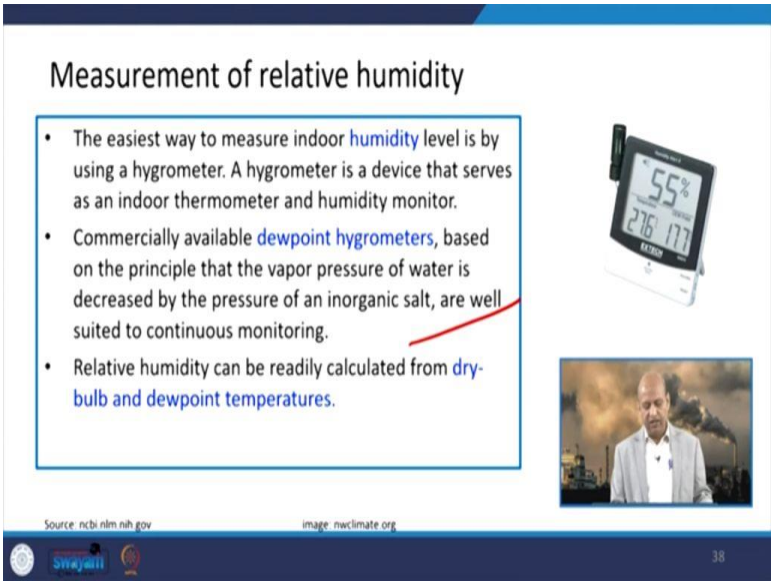

When we talk about measurement of relative humidity, the easiest way to measure indoor humidity level is by using a hygrometer. And this hygrometer is a device that serves as an indoor thermometer and humidity monitor basically; both things can be measured. Commercially available dew point hygrometers based on the principle that the, this vapor pressure of water is decreased by the pressure of inorganic salt are well suited to continuous monitoring purposes. Relative humidity can be readily calculated from dry-bulb and dew point temperature; so, these are well established methodologies for measurement of relative humidity.

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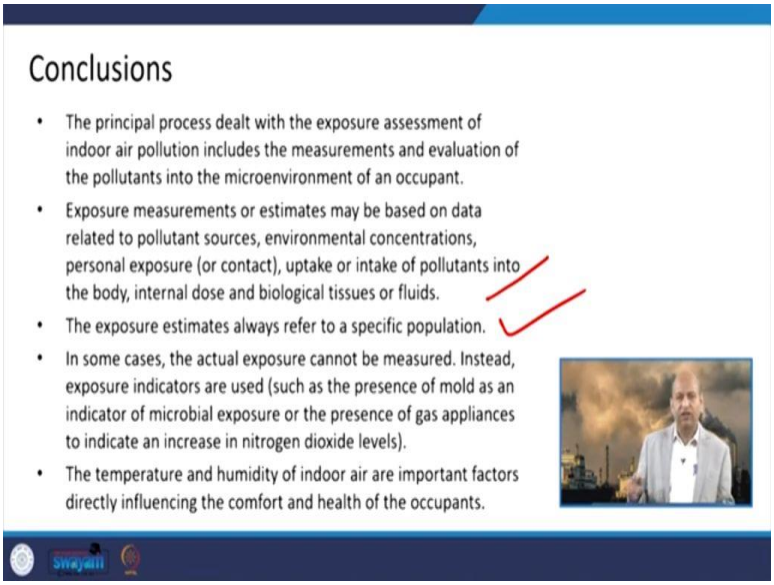

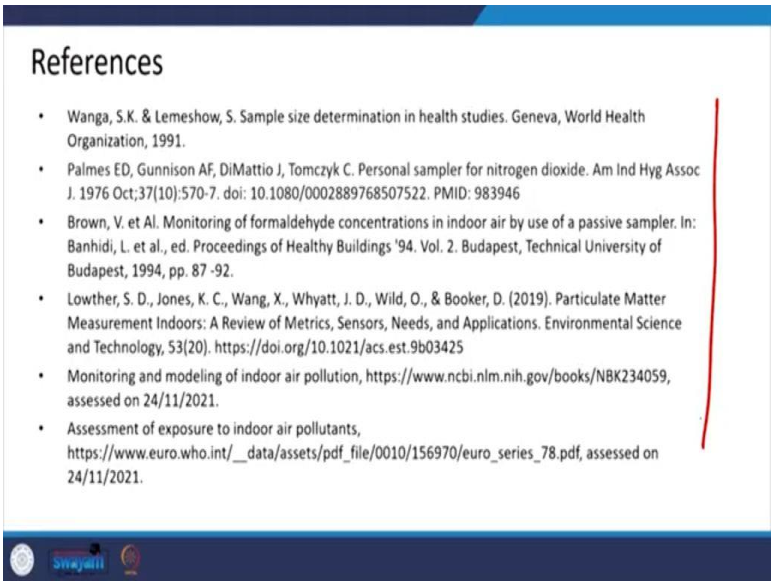

So, in nutshell we can say that the principle process dealt with the exposure assessment of indoor air pollution, includes the measurements and evaluation of the pollutants into the microenvironments of an occupant. Exposure measurements or estimates may be based on data related to pollutant sources, environmental concentrations, personal exposure or contact, uptake or intake of pollutants into the body, internal dose and biological tissues or fluids.

The exposure estimates always refer to a specific population; so, that relationship we should keep in mind. In some cases, the actual exposure cannot be measured. Instead, these exposure indicators are used such as presence of mold as an indicator of microbial exposure or the presence of gas appliances to indicate an increase in the nitrogen dioxide.

So, emission related of those pollutants, we have to see the situation. And the temperature and humidity of indoor air are important factors directly influencing the comfort and health of the occupants; they also influence the concentration of pollutants. So, this is all for today related to exposure assessment within the indoor microenvironments. So, these are the references for your additional information. Thank you for kind attention; see you again in the next lecture. Thanks again.