Sustainable Architecture
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Lecture - 41
Indoor Environmental Quality – I

Good morning, welcome to this new lecture this week on Indoor Environment Quality, which is the part of an online ongoing course on Sustainable Architecture and I am your instructor doctor Avlokita Agrawal from Department of Architecture and Planning IIT Roorkee.

So, in the past few weeks we have seen how different aspects related to sustainable buildings sustainable architecture would be addressed would be dealt with. And today in this series we are at the last component of sustainable buildings which is indoor environment quality.

So, through this week through the set of these 5 lectures over this week, we would be looking at different aspects of Indoor Environment Quality and we would be talking about them in detail through these lectures.

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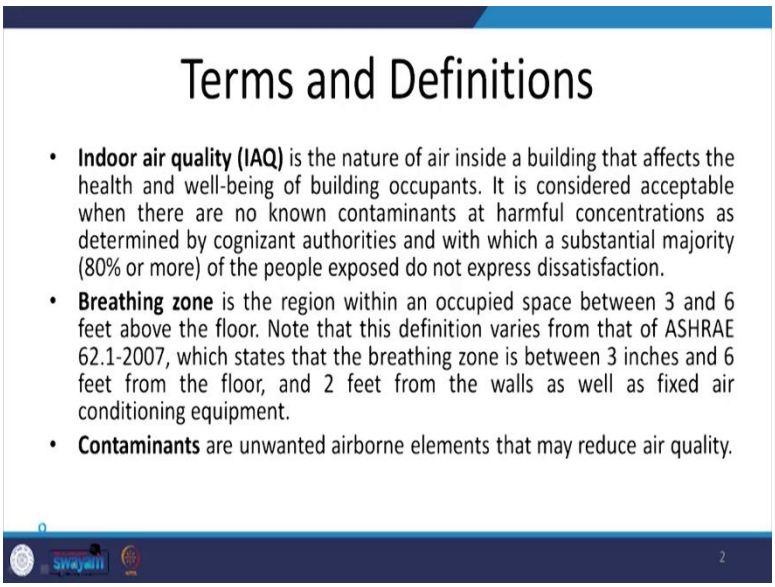

So, here we start our discussion on indoor environment quality. So, before we go ahead and talk about what is indoor environment quality and what are the different requirements for it, how do we design and all those things. Let us quickly brush up a couple of terminologies to understand the subject better.

So, the first one is indoor air quality. So, when we talking about indoor air quality, we are talking about the quality of air inside the building which affects the health and well - being of occupants. Now, when we are talking about the quality of air we are talking about what is the composition of air, what are the contaminants different types of contaminants and what are their concentrations and what is the acceptable standard of this indoor air quality which is standardized as per the norms standards and which is also the quality of air at which substantial majority of the occupants express their satisfaction.

The next we have breathing zone. So, it is the zone which is defined inside the building of the occupied space. So, different codes define it differently as per ASHRAE 62.1- 2007 it is defined as the space between 3 inches and 6 feet from the floor and it is at a distance of 2 feet from the wall. Other quotes define it differently, but it is the air, it is the air space, where the occupants largely breathe the air from. So, this is what the breathing zone is.

The next is contaminants. So, when we were talking about indoor air quality, we talked about the concentration of different contaminant, now contaminant is any unwanted element or substance which has a negative impact on air quality. So, there are different types of contaminants we will see as we go ahead.

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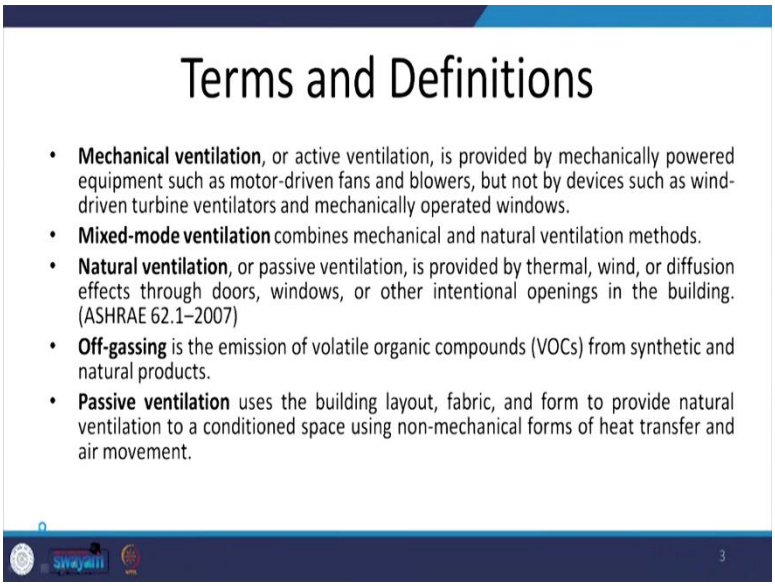

Next we have mechanical ventilation or active ventilation. So, it is the amount of air movement exchange which is provided by using mechanically powered equipment. For example, fans, blowers or you know more of such mechanically driven equipment, but it does not include ventilation provided by using devices such as wind ribbon turbine ventilators or mechanically operated windows, because these are only operating the openings, but not really supplying the air inside. So, that is not part of mechanical ventilation, all other equipments fans blowers etcetera and where they are used to provide for ventilation are part of mechanical ventilation.

We also have natural ventilation or passive ventilation which is provided by the movement of wind, because of the thermal differences, because of the pressure differences, diffusion, etcetera, infiltration all of that naturally through the openings which are provided in the building, again for this ASHRAE 62.1 - 2007 will be used. And there is a third type of ventilation which is the mixed mode ventilation, where both these modes mechanical as well as natural they come together. So, sometimes in the year or in some spaces there might be natural ventilation, other spaces and other times of the year it may be mechanical ventilation.

The next terminology is of gassing, which is the emission of Volatile Organic Compounds which is what we commonly known as VOCs from synthetic and natural products. Next is passive ventilation, it is the ventilation which is provided based upon the building layout

fabric and the form to provide natural ventilation to a conditioned space. So, it is directly related to natural ventilation.

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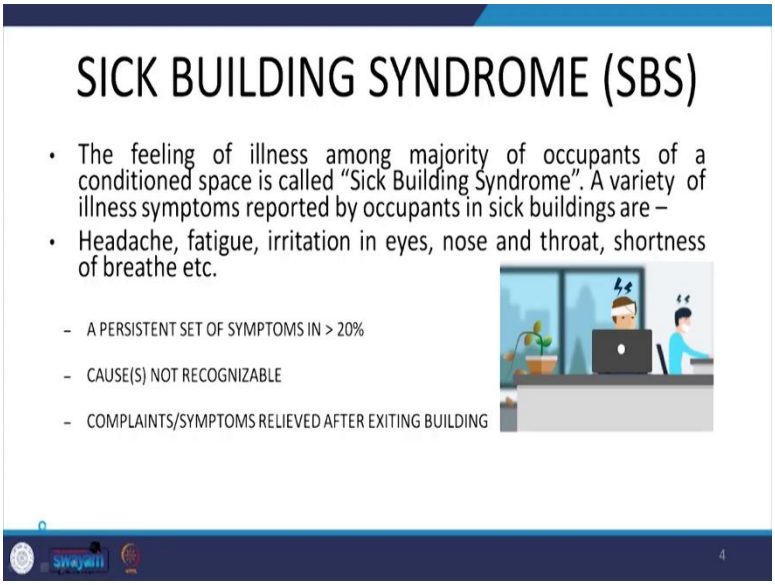

Now, why at all are we talking about the indoor environment quality? We have talked about the consumption of resources. So, in all the previous discussions for the past 4 weeks we have been discussing about how the resource consumption should be optimized in buildings. So, we talked about how the energy should be consumed. So, it should be reduced, the consumption should be reduced, how the water should be conserved, how it will be treated and reuse on the side. So, there is energy, there is water, we have site, there we also have materials and resources, in all these 4 different sections, we discussed about how the resources should be consumed and their consumption should be optimized. But at the end of it the building is being delivered for human beings, they are going to be the users of it.

So, even though we might have reduced the consumption of a particular resource we cannot do any of that at the cost of human comfort and well being. Unfortunately, many a times our buildings are designed in such a manner that your occupant is not actually comfortable and which is what results in a syndrome which we know as sick building syndrome. Now what is a sick building syndrome? You might have heard about this terminology on and off, but it is the feeling of illness among majority of occupants of a conditioned space and which is what we call as sick building syndrome. It includes a

variety of illness symptoms which are reported by occupants including headache, fatigue, irritation in eyes, nose and throat, shortness of breath etcetera. So, these are the physical health related problems, which people experience and they report which is what is commonly known as sick building syndrome.

Now, how do we define that a building has sick building syndrome, where there is a persistent set of symptoms in more than 20 percent of the occupants and the causes for those symptoms are not recognizable. So, somebody might be having a nose and a throat infection for a particular reason, maybe there was a flu or something like that. But if 20 percent more than 20 percent of the occupants report such symptoms and there are no recognizable causes that is when we conclude that the building has sick building syndrome. And most often these complaints of symptoms they will be relieved after the occupant exits the building.

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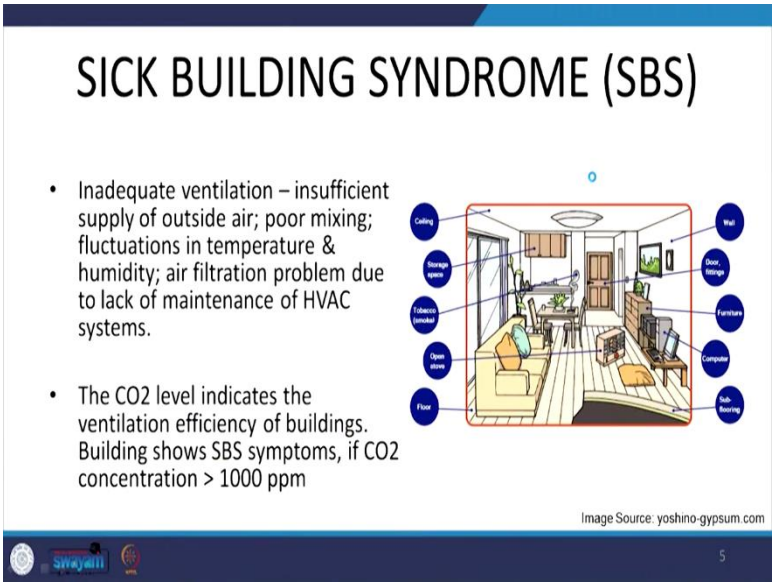

So, sick building syndrome has multiple reasons, but largely it is because of inadequate ventilation which is now inadequate ventilation may not always mean insufficient amount of air supply, but it may mean a lot of other things. For example, largely it is insufficient supply of outdoor air, but it may also be that there is a poor mixing of air, there are fluctuations in temperature and humidity, there is a plug problem of air filtration because of which the contaminants are quite high, all of that would lead to or is a part of inadequate ventilation and would lead sick building syndrome.

Another very important reason of sick building syndrome is very high amount of carbon dioxide level. So, if there is an inadequate ventilation, the carbon dioxide content would rise inside the buildings, the concentration would increase much beyond the standard. So, it would be larger than thousand parts per million; ppm of carbon dioxide. The more is the amount of carbon dioxide greater is the chances of illnesses which will be experienced by occupants.

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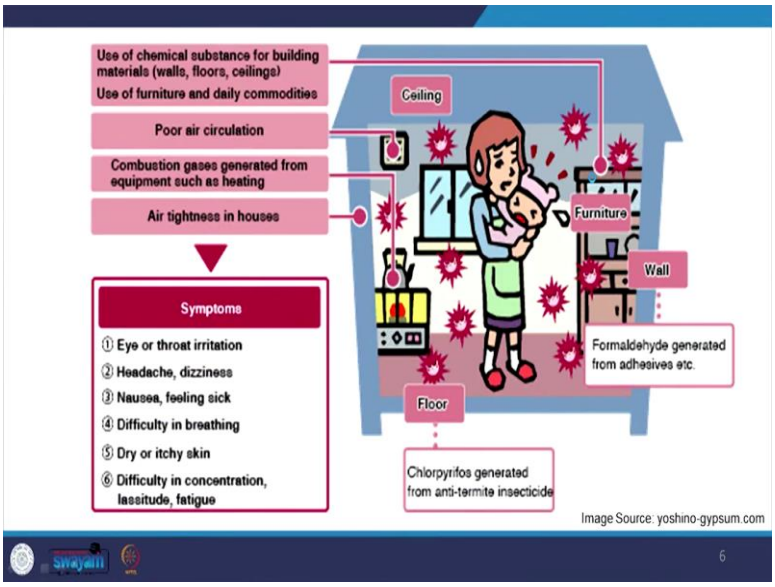

So, commonly the sick building syndrome the contaminated environment inside the building is caused because of the use of chemical substances which are there in almost everything these days. So, the furniture has adhesives which are used to bind the furniture together, the paints have chemical substances, the flooring has chemical substances, even the walling has a chemical substances, the wall covers have all these chemical substances, this is a major cause of the contaminant in indoor environment.

Another very important reason is this poor air circulation which is how the concentration of contaminants in a particular space would increase. There are combustion gases which are generated from equipment such as heating equipment or even cooking inside the kitchen. So, if the exhaust is not being done properly all these contaminants all these suspended particles which are coming out, they would remain trapped inside and they would act as contaminants.

And air tightness so, if there is insufficient ventilation and the house has been made as very tight airtight, all that would lead to the contamination and hence the sick building syndrome. And sick building syndrome as I have already discussed would include eye throat irritation, headache, dizziness, nausea, breathing problems, itchy skin or even fatigue and concentration and less focus on work.

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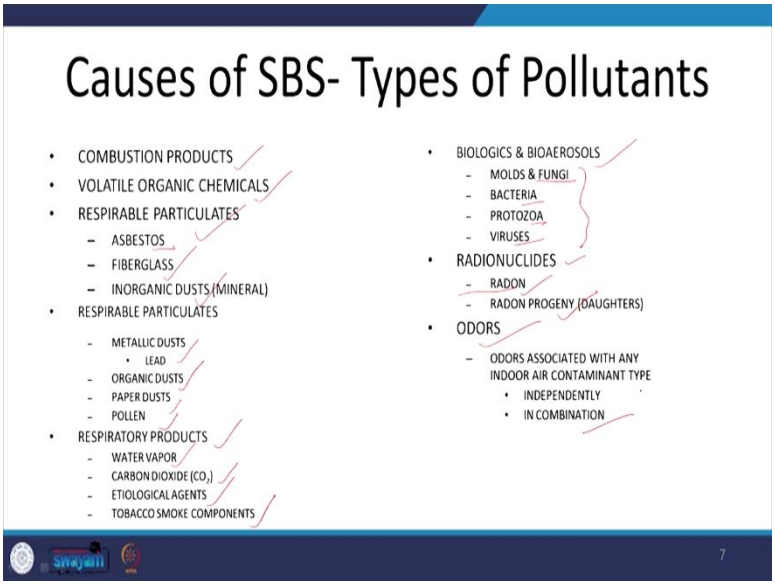

So, quickly looking at the causes of sick building syndrome and the different types of pollutants, which cause this. So, we have combustion products, which is what we just discussed because of the consumption of fuel inside. Then VOCs volatile organic compounds, we have respirable particulates for example, asbestos so, if it is being used as a building material. So, it will give rise to these suspended particulate, fine particulate which is respirable which can be taken in and it is a health hazard; because of fiberglass and also inorganic dusts the mineral dusts. So, all these are respirable particulates.

We also have metallic dusts from even heavy metals dangerous metals like lead, we have organic dust, paper dust, pollens, all these are respirable particulates which are present in the indoors from different sources. We also have respiratory products for example, carbon dioxide, we have water vapor, we have etiological agents and tobacco smoke components all these are respiratory products. So, these are also contaminants and there are standards to how much of each can be present, some are absolutely prohibited they should not be there at all well, some can be present within given limits.

Then you also have biologics and bio aerosols, for example molds and fungi, we have bacteria, protozoa, viruses all these are also there. And majority of the airtight buildings and also the buildings which do not receive adequate amount of direct sunlight indoors report and overgrowth of such biologics and bio aerosols. Then we also have radionuclides, which includes radon's and radon progenies which are the alternative substances for radon's.

And then we have odors so, they might not really be getting inhaled and affecting some of the body system, but it is an inconvenience a discomfort. So, odors which may be associated with some contaminant or they may be independently there or in combination. So, these are the different types of pollutants which cause the sick building syndrome. So, we have already seen the different types of pollutants, the sources of these pollutants may vary.

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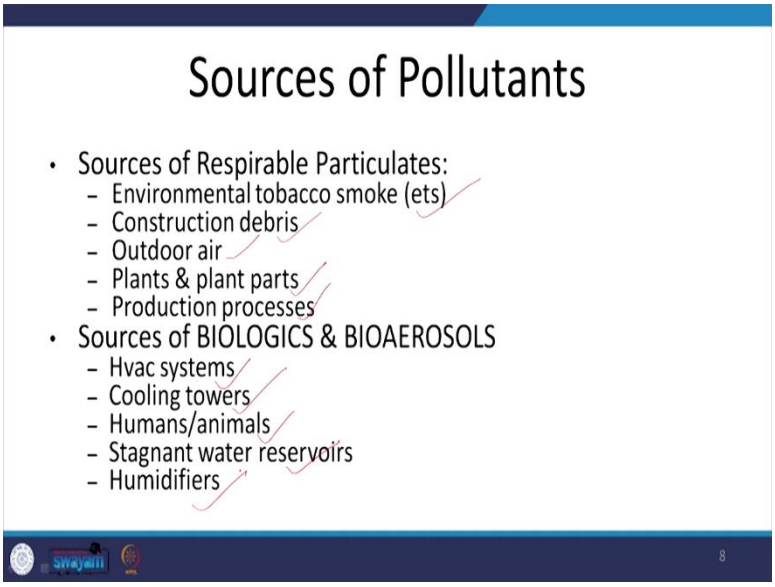

We have two types of sources, one for respirable particulates and the other one for biological and biologics and bio aerosols.

So, we have environmental tobacco smoke, we have construction debris, the outdoor air, outdoor air itself might be quiet contaminated as we are seeing these days, the majority of our large cities actually have a contaminated outdoor air. If the same air is taken inside through mechanical ventilation or natural ventilation it is going to give us contaminated indoors. So, that air will probably properly need to be filtered. So, outdoor air itself can be

a source of the pollutant indoors. Then even plants and plant parts can sometimes cause pollution and production processes, if there are some processes, which are part of the indoor environment then that will also be a source of respirable particulate.

We also have source of biologics and bioaerosols, the hvac systems in themselves if the air is not getting filtered, if sufficient amount of filtered outdoor air is not being mixed may become a source of biologics and bio aerosols. Then we have cooling towers, humans and animals are one major cause of this biologics and bio aerosols, because of our skin, perspiration, breathing all of that, then stagnant water reservoirs and humidifiers. So, all these together are sources of biologics.

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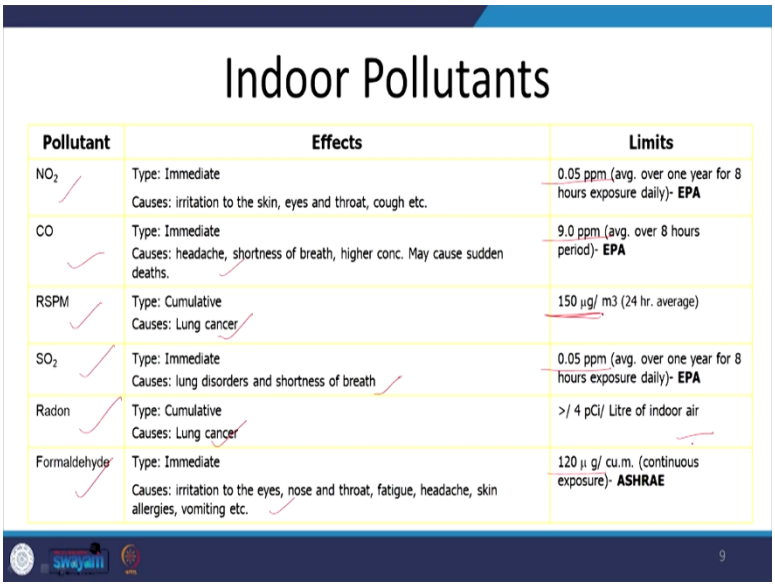

Now, looking at now all these contaminants and the sources of pollutants they generate different types of pollutants. And let us look at the different types of indoor pollutants which are there and also the limits. So, we have nitrogen dioxide NO 2 and it causes irritation to skin, eyes and throat, coughing etcetera and it has a limit of 0.05 parts per million.

We have carbon monoxide, it causes headache, shortage of breath, higher concentration may also cause sudden deaths; in case of carbon monoxide and maximum limit is 9 parts per million as per the EPA. Then we have RSPM which is a cause for lung cancer the maximum limit is 150 micrograms per meter cube that is a 24 hour average so, maximum limit is this.

Sulphur oxides can cause lung disorders and shortage of breath and maximum 0.05 parts per million, which is an average for over 1 year for 8 hours of exposure. Radon is also a cause of lung cancer and not more than 4 pCi per liter of indoor air is recommended. Formaldehyde causes irritation to eyes, nose and throat infections, fatigues, headaches, skin irritations, troubles, vomiting etcetera and 120 micrograms per cubic meter of air that is for continuous exposure. So, if someone is continuously exposed to this concentration, this limit is as per the ASHRAE standards.

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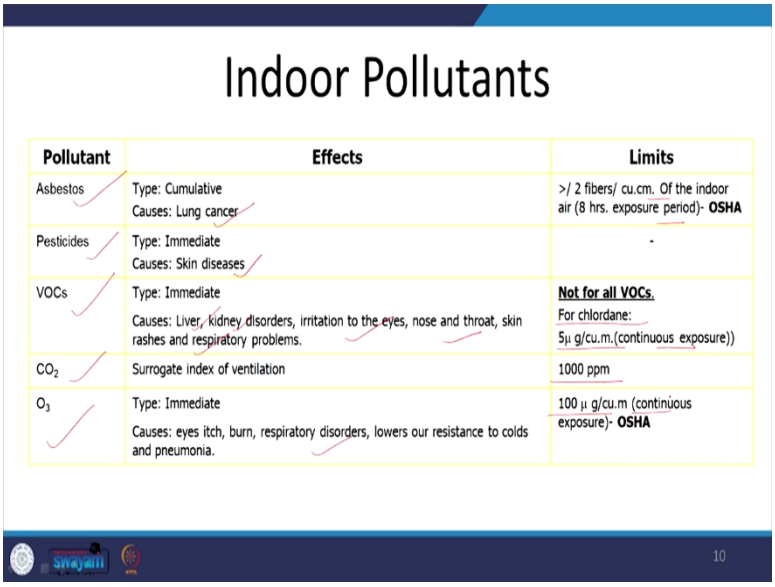

Then we have asbestos which is again a cause for lung cancer not more than two fibers per cubic centimeter of the indoor air for an 8 hour exposure period. We have pesticides which may cause skin diseases, there are different types of pesticides which ideally should not be present, then we have VOCs which have multiple effects, it affects liver, kidney, it causes irritation to eyes, there is nose and throat problems, skin rashes and respiratory problems. And for each type of VOC different types of VOCs different limits are prescribed, but for chlorine which is one of the most impacting ones the limit is 5 microgram per cubic meter for a continuous exposure.

Then carbon dioxide, it is a cause for multiple health effects and it has similar types of health effects as carbon monoxide, but in reduced intensity and maximum is 1000 parts per million we have also seen that earlier. And ozone so, ozone we normally understand that it is good, but beyond a certain concentration, beyond a certain limit even ozone causes

troubles problems. So, it causes itchy eyes, burning sensation, respiratory disorders and it reduces the resistance to colds and pneumonia. So, maximum 100 micrograms per cubic meter of air for continuous exposure is prescribed.

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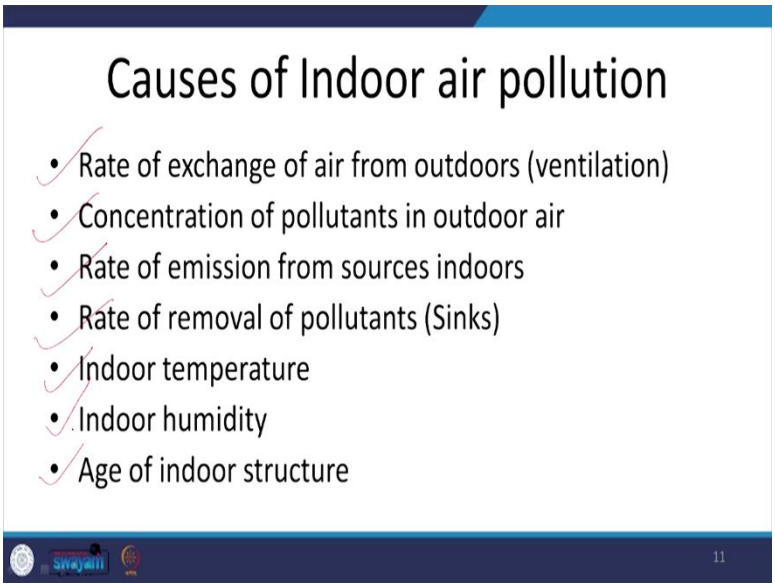

Now, there are limits for all these indoor pollutants and each one of it has to be monitored and checked. And if the outdoor air is already contaminated then filter power filtration process has to be put in place in order to clean the air for these contaminants and bring them within the acceptable limits and zones.

Now, how does this contamination happen? So, there are different sources of this contamination and pollution, but how will it actually happen in indoors. So, it may happen because of the rate of exchange of air from outdoors. So, it may be inadequate. So, if there is not sufficient air, fresh air being brought from outside and the carbon dioxide, carbon monoxide and even the VOC level increases, the concentrations increase then it may cause a problem.

Then we have concentration of pollutants in the outdoor air itself. So, I was just talking about it and if there is an outdoor air which is already contaminated, we keep seeing, we keep hearing the air quality index for different cities. So, the same air cannot be directly brought inside it has to be properly filtered before it is supplied indoors.

Then, the rate of emission from indoor sources so, for example, we have photo copiers, photocopying machine photocopying machine is a source of a lot of contaminants, which are produced because of the process. So, it is a source, now what is that rate and whether the extraction or removal of concentrate contaminants and their concentration is being taken care of has to be properly planned. So, rate of emission from indoor sources of pollutants and along with it the rate of removal of pollutants. So, both will be taken together.

And then we have indoor temperature. So, comfort indoor environment is affected by the indoor temperature and also the indoor humidity which affects the comfort of occupants. And then the age of indoor structure because different structures different materials they disintegrate differently. So, the structure itself releases some of the suspended particles. So, what is the age of indoor structure, at what rate does it disintegrate, if it is fresh there may be higher concentration of volatile organic compounds VOCs, because of the adhesives and all other kind of compounds which are released from fresh structure, while the older structures may have other types of disintegration and pollutants.

So, how do we manage these air contaminants?, We will go in detail and the compliance options subsequently, but when we are talking about managing the air contaminants there are some major points to be kept in mind.

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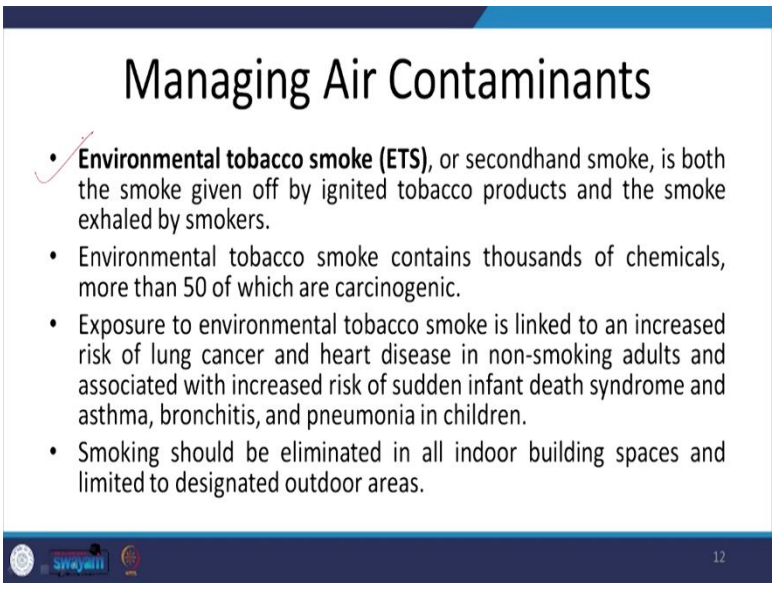

First of all it is environmental tobacco smoke or the secondhand smoke which we say, it is the smoke given off by ignited tobacco products and the smoke exhaled by smokers both of this comes into environmental tobacco smoke. The intent is to not allow environmental tobacco smoke to mix in the supply air and exhaust it separately.

So, as to keep the environmental tobacco smoke totally out of the breathing zone. So, there will be there are different strategies, where the smoke will be contained within an area. So, there are designated areas for smoking and the exhaust for this environmental tobacco smoke will be done separately, it will be directly exhausted, it should not be near to the supply duct and all of that comes as part of managing this environmental tobacco smoke, but the intent remains it should not get inside the building and in the breathing zone the habitable areas.

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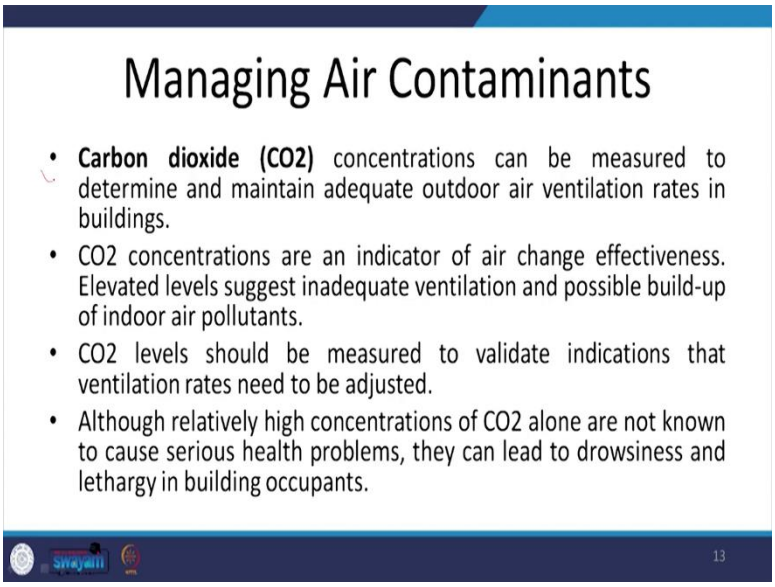

The next is an important parameter is carbon dioxide managing it is level. So, we have also see already seen that there is a threshold limit of 1000 parts per million of CO 2 in the indoor environment. It can be managed by bringing in more fresh air, which has more of oxygen, exhausting the air from indoor to outdoor, which has already been contaminated or has higher concentration levels or there might also be strategies such as planting of more trees plants indoors. So, that the plants absorb the carbon dioxide and exhale oxygen so, as to manage the limits of carbon dioxide.

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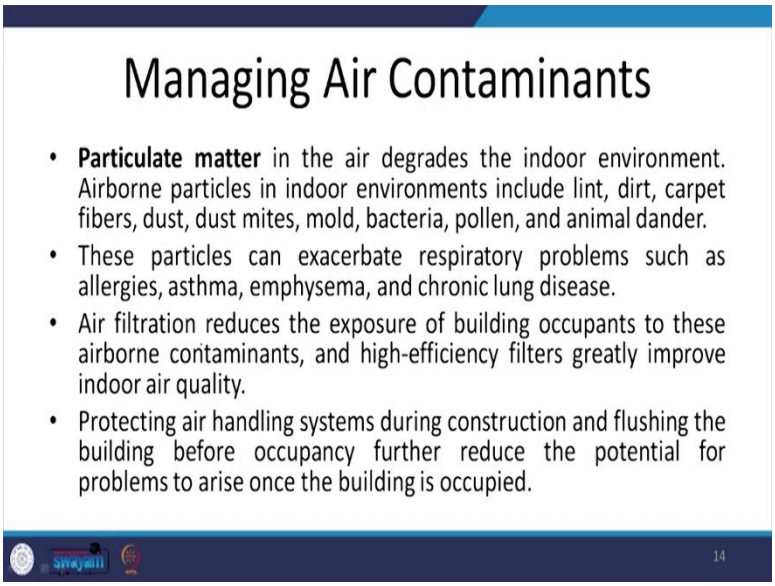

Next is particulate matter. So, it is the matter which is suspended in the indoor environment in the air and these are the airborne particles which include lint, dirt, carpet fibers, dust, dust mite, even mold and bacteria, pollens, animal dander. So, all these things are part of particulate matter. Now, these particles can cause respiratory problems they may lead to allergies, asthma, lot of these problems, chronic problems also and the intent is to remove this particulate matter and this will happen with adequate ventilation.

It may be natural ventilation or mechanical ventilation, but adequate ventilation. So, that clean air is brought inside and the used air is exhausted or even if it has to be taken back into the system it goes back through the filtration process. Now, how can we do that? So, besides the design of mechanical systems and ventilation systems largely, we may also specify less harmful materials, materials which have less VOC, 0 VOC ideally, but at least lesser VOC generation.

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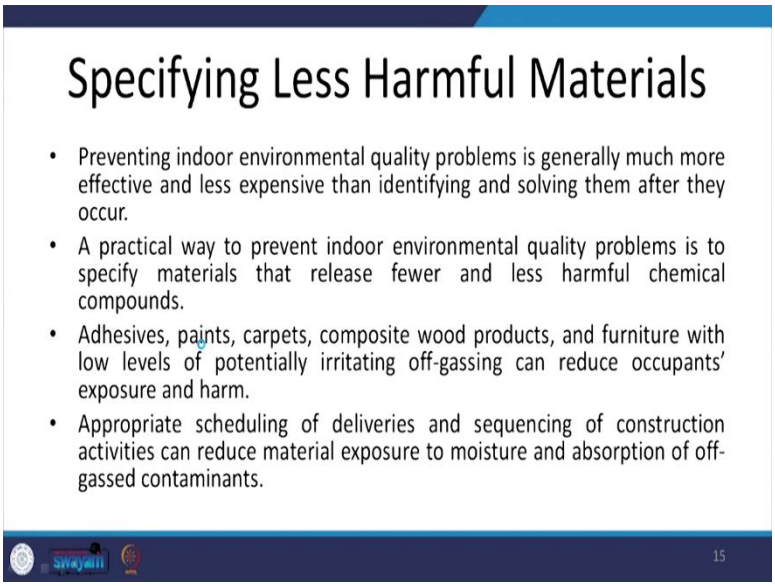

So, proper materials should be specified in building construction.

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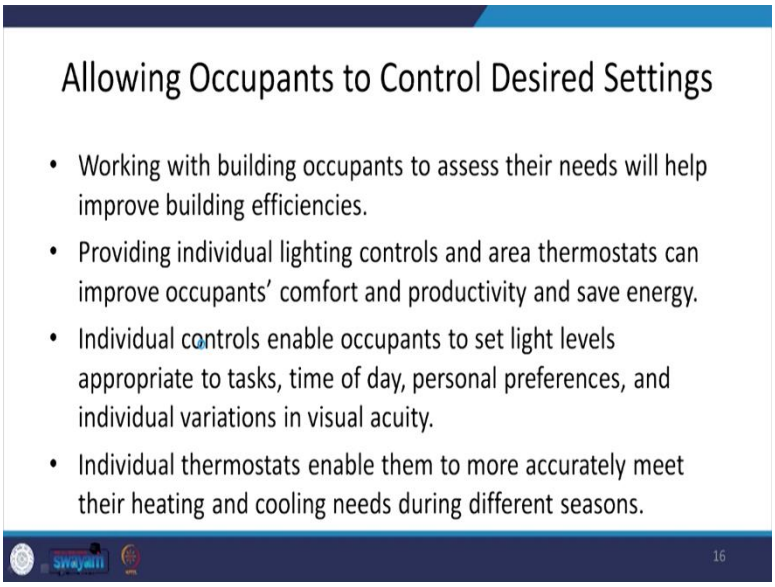

And another strategy which is not a design strategy, but a maintenance operation strategy is to allow occupants to control their immediate environment to the desired settings. For example, allowing them to choose the temperature at which they want to be allowing them to choose the ventilation rate the amount of air, which is being flown into their immediate space, allowing them to control the amount of daylight that they want, amount of artificial light the type of light it may be a focus light.

So, giving more control to the occupants and allowing them to change the environment according to their preferences. Another very important strategy is to plant indoor plants, which take up a lot of carbon dioxide and give out oxygen and they reduce the sick building syndrome substantially besides absorbing the pollutants and releasing oxygen. Another interesting thing is the psychological impact of plants, which improved the ambience in an indoor environment and it reduces a lot of associated problems such as headache and fatigue and lack of concentration so, they act as relief to the eyes.

So, these are the different strategies that we can use for improving the indoor environment quality. We would subsequently look at what are the different compliance options and how can we work for the better indoor environment quality in subsequent lectures. So, thank you for being with us, see you in the next lecture tomorrow.

Thank you, bye-bye.