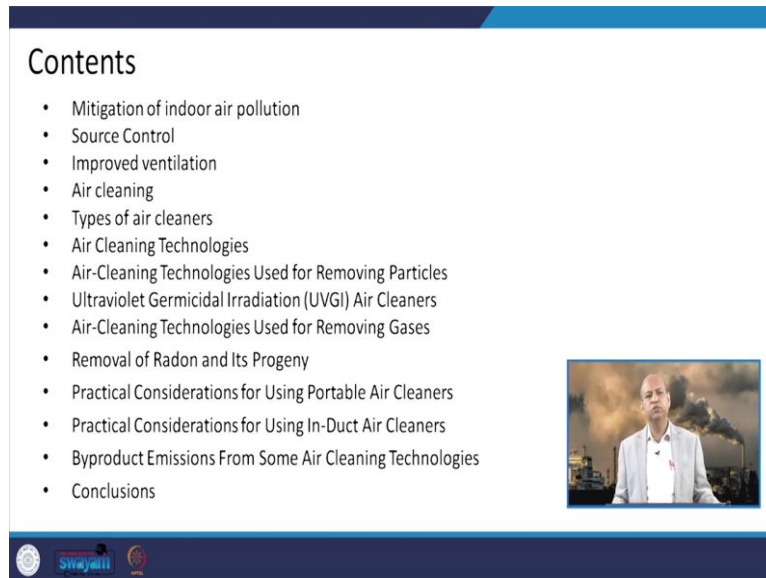


**Air Pollution and Control**  
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**Lecture 34**  
**Technologies to Mitigate Indoor Air Pollution**


Hello friends. So, in the series of indoor air pollution its effect and its sources, then assessment of indoor air pollution. Today we will discuss about the technologies which are used for mitigating or controlling indoor air pollution.


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- Practical Considerations for Using Portable Air Cleaners
- Practical Considerations for Using In-Duct Air Cleaners
- Byproduct Emissions From Some Air Cleaning Technologies
- Conclusions





So, in this lecture we will include like what is the requirement of mitigation of indoor air pollution, why do we need it? Then, what are the sources that can be controlled to reduce the contaminants in indoor environment, and then how to improve the ventilation which is one important aspect of improved indoor air quality.

Then air cleaning and types of air cleaners which are used for cleaning the air. Air cleaning technologies, different kinds of technologies, like, removing particles or using ultraviolet germicidal irradiation, UVGI air cleaners, and then air cleaning technologies which are used for removing gases, removal of radon and its progeny and other products, practical considerations for using these portable air cleaners or in-duct air cleaners because there are issues means it is not always true that air cleaners will be very nice in handling to remove air pollution.



Sometimes, if you are not maintaining them properly then they can be also sources of indoor air pollution basically. Then by-product's missions from some air cleaning technologies as I

said that if we have to maintain them properly, otherwise, there can be additional sources from these controlling devices. If you do not maintain, we do not repair them timely, and then we will go for conclusions.

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**Mitigation of indoor air pollution**

- The development of technologies to mitigate indoor air pollution is important to avoid adverse health effects.
- Adsorption and photocatalytic oxidation are the current approaches for the removal of indoor VOCs and PM<sub>2.5</sub> with high efficiency.
- Another approach is to lowering the concentrations of indoor air pollutants by increasing the amount of outdoor air coming indoors.
- Usually the most effective way to improve indoor air quality is to eliminate individual sources of pollution or to reduce their emissions.



Source: Yue et al. (2021) image: www.sciencenews.org

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So, when we talk about mitigation of indoor air pollution, why it is required? So, the development of technologies which are needed for mitigating indoor air pollution is very important, because it otherwise the indoor air pollution can result into several kind of health effects or adverse health effects. So, to avoid that kind of situation, its necessary to employ certain technologies to mitigate, or to control, or to remove to reduce the indoor air pollution levels. Then there are several techniques, but adsorption and photocatalytic oxidation these are the current approaches which are kind of popularly they are used for removing indoor VOCs volatile organic compounds and fine particles like PM<sub>2.5</sub> with high efficiency.

These adsorption and photocatalytic oxidation these two processes are very popular in that sense, but there are other approaches like lowering the concentration of indoor air pollutants by increasing the amount of outdoor air coming indoor through ventilations. But it is a tricky thing, because if outdoor air quality is not good, then polluted air may enter into the indoor environment. So, we have to first see that the outdoor air must be clean, only then we can go for this kind of situation where we increase the amount of inflow of the outdoor air to indoor environment, then it can improve the indoor air quality. Otherwise, if the outdoor air quality is not good, then this is not the right approach.

Usually, the most effective and successful way to improve indoor air quality is to eliminate individual sources of pollution, or to reduce their emissions inside the indoor environment

itself. There should not be any source means, at the source itself we should do something which can eliminate these emissions of air pollutants.

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### Source Control

- Source control eliminates individual sources of pollutants or reduces their emissions.
- It is usually the most effective strategy for reducing pollutants.
- Many sources of pollutants in the home can be avoided or removed. For example, solid wood or alternative materials can be used in place of pressed wood products that are likely to be significant sources of formaldehyde, combustion appliances can be adjusted to decrease their emissions.

Source: [www.epa.gov](http://www.epa.gov) image: [yellowbluetech.com](http://yellowbluetech.com)

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So, basically the source control mechanism eliminates individual sources of pollutants or reduces their emissions. And this is usually the most effective strategy for reducing pollutants inside the micro environment. Many sources of pollutants in the home can be avoided or removed for example, like if we use these solid wood or alternative materials in place of the pressed wood or those ply woods or boards etc, which are basically significant sources of formaldehyde.

And the combustion appliances can be adjusted to decrease the emissions in kitchen etc. So those kinds of things we can accomplish through interventions of technological interventions or some changes in the usage of different products.

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### Improved ventilation

- Ventilation with outdoor air is also a strategy for diluting indoor air pollutant concentrations, provided that the outdoor air is relatively clean and dry or that it can be made so through mechanical means such as filtering.
- Outdoor air enters buildings in three ways.
  - Small amounts of air are constantly entering by infiltration through the building enclosure.
  - Larger amounts enter when windows and doors are left open for extended periods, and
  - can also be brought in by continuous supply or exhaust fans.



Source: [www.epa.gov](http://www.epa.gov) image: [www.linquip.com/ventilation-and-covid-19](http://www.linquip.com/ventilation-and-covid-19)

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Well, when we talk about it improve ventilation. So, the ventilation with outdoor air is also a strategy for diluting indoor air pollutant concentration, but, in that case the outdoor air must be clean with respect to the indoor environment provided it is relatively clean and dry means it should not be humid also, because humid air if it enters into the micro environment indoor environment, then there are several issues like moles or many kind of microbes can grow in the humid environment. So, the outdoor air is clean and dry only then it is a good strategy to bring it inside the micro environment of indoor environment.

Well, then outdoor air enters buildings in three ways basically like small amount of air constantly enters through various infiltration, building enclosures etc, then large amount can enter through windows or doors whenever we open them. And then it can also be brought by like a continuous supply or exhaust fans means that kind of mechanism can be developed where certain fan are there only for bringing air inside the indoor environment only.

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## Air cleaning

- Air cleaning has proven useful when used along with source control and ventilation.
- Air cleaning alone cannot ensure adequate indoor air quality where significant sources are present or when exhaust and outdoor air ventilation are insufficient.
- Using a portable air cleaner and/or upgrading the air filter in your furnace or central heating, ventilation, and air-conditioning (HVAC) system can help to improve indoor air quality.



Source: [www.epa.gov](http://www.epa.gov) image: [www.nytimes.com](http://www.nytimes.com)

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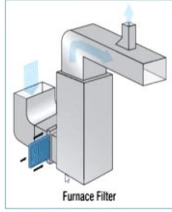
But the outdoor air must be clean and dry only then it is better to improve the air quality of indoors environment. Well, then there are air cleaning mechanism like air cleaners or these various devices are there portable as well as you can have mounted in the ducts etc. So, this air cleaning has proven useful basically and it is used along with the source control and ventilation. Air cleaning alone cannot ensure adequate indoor air quality where significant sources are present because then sources may be very dominating kind of these air pollution emissions.

So, when exhaust and outdoor air ventilation are insufficient, then alone this air cleaning may not be so effective. So, it is a kind of integrated approach you also have those ventilation mechanisms plus you also do air cleaning. So, using a portable air cleaner or upgrading the air filters which are used in the furnaces, because indoor environment does not mean only the domestic or residential houses. Indoor environments are there in factory spaces, industries, there are these occupational spaces where workers are working. So, those indoor environment are also needed to be clean. So, the Heating, Ventilation and Air Conditioning (HVAC), this system is there always for cleaning the air and to improve the indoor air quality.

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### Types of air cleaners

- There are two basic categories of air cleaners: portable air cleaners and HVAC/furnace filters.
- Portable air cleaners are generally designed to filter or clean the air in a single room or area.
- Furnace filters are installed in a home's central HVAC system and can provide filtered or cleaned air to many parts of a home.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)


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Well, so, there are two basic categories of air cleaners like portable air cleaners, and HVAC these heating, ventilation and air conditioning at the furnaces and other kind of locations. So portable air cleaners generally used where you can have these kind of filter mechanism where it sucks air and then passes through after capturing particulate matter etc. Furnace filters are there in these occupational spaces, in the factories etc. So, those kinds of HVAC systems can also be used.

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### Air Cleaning Technologies (1/2)

- Within each category of air cleaner, one or more air-cleaning technologies may be used to accomplish its goals, and some air-cleaning technologies have clear advantages over others.
- The available technologies vary in the type of pollutant that they can remove or reduce their mechanism of action (e.g., pollutant collection, conversion, inactivation, destruction), and the potential side effects of their use.



Source: ASHRAE, 2008

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And within each category of these yair cleaners one or more cleaning technologies may be used to accomplish the aims of better air quality. And, the available technologies can vary in the type of pollutant, when some gases has to be controlled and reduced then other kinds of

technology can be used, when particulate matter is the target then some other way of removal of these mechanisms can be employed.

So, like, pollutant collection, or conversion, or inactivation, destruction, all these kind of mechanism can be there in different technologies. And there may be some potential side effects also, we have to see like filters if we do not change filters of the portable air cleaners, those filters can be sources of the indoor air pollution. So, rather than cleaning the air, they can pollute it. So, that has to be kept in mind.

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Air cleaning technology	Targeted pollutant
• Fibrous filter media	Particles
• Electrostatic precipitation (ESP)	Particles
• Ionizers (i.e., ion generators)	Particles
• Ultraviolet germicidal irradiation (UVGI)	Microbes
• Adsorbent media	Gases
• Chemisorbent media	Gases
• Catalytic oxidation	Gases
• Plasma	Gases
• Intentional ozone generation	Gases

Source: [www.epa.gov/residential-air-cleaners-a-technical-summary-3rd-edition.pdf](http://www.epa.gov/residential-air-cleaners-a-technical-summary-3rd-edition.pdf)

Well, when we talk about different technologies of air cleaning, then you can see this is the list like fibrous filter media can be used, or electrostatic precipitation; ESP can be used, which you have studied, we have studied in the like industrial air pollution control mechanisms. So small size ESPs can be used in indoor environment also.

Then ionisers can also be there. I am repeating it again that please do not feel that only the residential rooms or those houses are the indoor environment. Indoor environment can be of various kinds like big factories, or libraries, or museums, or whatever built environment is there where people are working.

So those large size indoor environments can be there, and you may need these ESP etc, those kinds of instruments. Well, then Ultraviolet Germicidal Irradiation (UVGI) can also be used, adsorbent media can be used, or chemisorbent media can be used, catalytic oxidation like the three way catalytic things are used in exhaust pipes of vehicles.

So, similarly, in indoor environment also some catalytic oxidation mechanism can also be used, then plasma related technology is there. Then there is like ozone generation because ozone is your oxidizing agent. So, for oxidizing those gases which are pollutants ozone can be generated and that can be used.

So, for gases these adsorbent media, chemisorbent, catalytic oxidation, plasma, intentional ozone, these are the better technologies. For microbes these UVGI, and for particles filter media, or these ESPs and ionizers can be used most effectively.

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**Air-Cleaning Technologies Used for Removing Particles**

- Two types of air-cleaning technologies are commonly used in duct-mounted and portable air cleaners to remove particles from the air: **fibrous media air filters and electronic air cleaners.**
- Particle size and mass affects the performance of both types of particulate air-cleaning technologies.
- Because the larger particles settle out of the air and onto surfaces rather rapidly, air filters are not likely to remove them effectively from the home.

Source: [www.epa.gov/residential-air-cleaners-a-technical-summary-3rd-edition.pdf](http://www.epa.gov/residential-air-cleaners-a-technical-summary-3rd-edition.pdf)

The slide includes an image of various air filters and a video inset of a speaker. The slide footer contains logos for Swajati and the number 10.



Well the two types of air cleaning technologies are commonly used in duct-mounted, ducts are there and then portable air cleaners to remove particles like fibrous media filters and electronic air cleaners. So, these are the two types which are very popular. And the particle size or the mass of the particles they influence the performance of these kind of air cleaning technology basically, because the larger particles settle out of the air and onto the surfaces rather rapidly. So, the air filters are not likely to remove them effectively from the home. So, that is why other kinds of technologies are employed.



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## Fibrous Media Air Filters

- Fibrous media air filters remove particles by capturing them onto fibrous filter materials.
- Particle removal efficiency depends on a number of parameters including particle size, filter thickness, filter porosity, filter fiber dimensions, dust loading conditions etc.
- Filters that become excessively loaded will tend to decrease the effectiveness of a furnace filter or portable air cleaner because of reduced airflow through the filter and/or increased bypass airflow around a clogged filter.



Source: [www.epa.gov/residential-air-cleaners-a-technical-summary-3rd-edition.pdf](http://www.epa.gov/residential-air-cleaners-a-technical-summary-3rd-edition.pdf)

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Well, fibrous media air filters remove particles by capturing them onto fibrous filter material. So, this may remind you the bag filters also. So, those kind of fibrous filter materials are there and, depending upon the particle size or fiber thickness, then filter porosity and filter fiber dimensions dust loading conditions, all these things influence the efficiency of the removal of these particles.



And, these filters that become excessively loaded will tend to decrease the efficiency or effectiveness of the filters basically when porosity is less and because of reduced airflow through the filters and increased bypass airflow around a clogged filter can rather pollute the indoor environment instead of cleaning it. So, these kinds of things we have to keep in mind to do better maintenance or frequently we should do something to remove those clogging kind of situations.

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### Types of Fibrous Media Air Filters (1/3)

**Flat or panel air filters**

- These filters typically have a MERV (Minimum Efficiency Reporting Value) of 1 to 4 and thus have very low removal efficiency for most particle sizes.
- These filters are usually about 1-2 inches thick.
- They are commonly used in residential furnaces and air-conditioning systems, and they are also often used as pre-filters for higher efficiency filters.



Source: [www.epa.gov/residential-air-cleaners-a-technical-summary-3rd-edition.pdf](http://www.epa.gov/residential-air-cleaners-a-technical-summary-3rd-edition.pdf)

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Well, then flat panel air filters can also be there. So, this is again typically they have this MERV (Minimum Efficiency Reporting Value) 1 to 4. So, different values are there depending upon their efficiency, then thickness can also be a matter of concern. So, all those things we have to see.

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### Types of Fibrous Media Air Filters (2/3)

**Pleated, extended surface, and unpleated pad filters**

- These filters typically have a MERV of 5 to 13 or higher and generally have higher particle removal efficiency for most particle sizes compared to panel filters.
- Pleating the filter medium increases surface area, reduces air velocity through the filter media, and allows the use of smaller fibers without a large drop in airflow rate.
- Three main types of electrostatically charged media are used: resin wool, a plastic film, or a fiber called electret.



Extended surface filter



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)


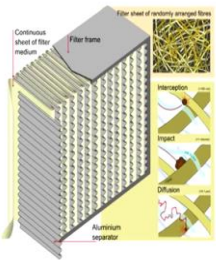
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Plus at the same time, this pleating of these pleats of these filter media can also give us better surface area and it can reduce the air velocity and better efficiency can be achieved.

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### Types of Fibrous Media Air Filters (3/3)

- **Higher efficiency filters** with a MERV of 14 to 16 will typically have a higher average resistance to airflow than medium-efficiency filters of the same thickness.
- **HEPA (High Efficiency Particulate Air) filters** are another type of pleated filter.
- They also have very deep pleats with a much larger surface area than conventional pleated filters.
- Consequently, they remove fine and ultrafine particles with higher efficiency than lower rated fibrous media air filters.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)

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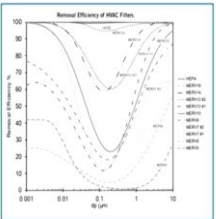
Well, when we talk about efficiency of these fibrous media, higher efficiency with the MERV of 14 to 16 will typically have a higher average resistant to air flow then medium efficiency filter, so, that again so it need more power you can say. Then HEPA (High Efficiency Particulate Air Filters), those kinds of filters are another type of pleated filters, they have more pleats and they also, they are very deep pleats and much larger surface area in comparison to the conventional pleated filters. So, that is why there performance is better and they can remove fine, ultrafine particles very efficiently in that way.

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### Practical Considerations for Using Fibrous Media Air Filters

The performance of fibrous media air filters depends not only on the removal efficiency of the media, but also on factors such as the:

- Indoor particle size and size-specific mass concentrations
- Amount of dust loaded on the air filter
- Airflow rate, velocity, and resistance to airflow through the filter media
- Bypass airflow that flows around the air filter because of poor installation



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07) image: Azimi et al. (2014)

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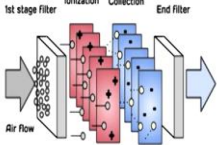
Well, when we talk about these practical considerations for using fibrous media air filters, because if you do not use them properly, then rather than creating the air quality making air

quality better they we, deteriorate it. So, the indoor particle size or size specific mass concentrations, amount of the dust loaded on the filter, and then airflow rate, velocity and bypass airflow that flows around the air filters, all these things have to be kept in mind and the optimization has to be done to have greater efficiency of those filters.

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### Electrostatic Precipitators (ESPs) and Ionizers (1/2)

- ESPs and ionizers are electronic air cleaners that use a **powered electrostatic process** to charge particles.
- These particles then become attracted to oppositely charged plates or other indoor surfaces to remove airborne particles.
- ESPs remove and collect small airborne particles and often have an initial single-pass removal efficiency of 60 percent or more for most particle sizes, increasing to as much as 95 percent depending on the airflow rate.



Source: Morawska et al. (2002) image: hawkenvironmental.com


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Well, when we talk about electrostatic precipitators or ionizers. So, as ESPs can be used for removing particles with high efficiency. But they can collect a small airborne particles and, they can have efficiency varying from 60 percent to even 95 percent depending upon what is the size of the particles and how much path is there, how many number of plates are there, all those issues are there.

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### Electrostatic Precipitators (ESPs) and Ionizers (2/2)

- ESPs can also have different removal efficiencies for particles with different compositions, as the electrical properties of some particles will affect their ability to hold a charge.
- **Ionizers, or ion generators**, use a high-voltage wire or carbon fiber brush to electrically charge air molecules, which produces negative ions that attach to airborne particles.
- Subsequently, the charged particles can attach to nearby surfaces such as walls or furniture (i.e., plate-out), or to one another, and settle faster.



Source: Waring et al. (2008)



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Then ionizers can be there, ion generators. So, they also create some situation where different of charged particles can be captured by other filters or those plates of different charges.

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### Ultraviolet Germicidal Irradiation (UVGI) Air Cleaners (1/2)



- UVGI, is designed to reduce the number of viable airborne microorganisms.
- UVGI air cleaners are designed to use UV lamps to kill or deactivate microorganisms such as viruses, bacteria, and fungal spores and fragments that are airborne or growing on surfaces.
- Both UV-A (long wave: 315–400 nm) and UV-C (short wave: 100–280 nm) are used in UVGI air cleaners.
- Given sufficient exposure time and lamp power, UV light can penetrate the outer structure of a microorganism's cell(s) and alter its DNA, preventing replication and causing cell death.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07) image: [www.ec21.com](http://www.ec21.com)

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### Ultraviolet Germicidal Irradiation Air Cleaners (2/2)



Source: [www.mgcs.net.in/uvgi-for-hvac](http://www.mgcs.net.in/uvgi-for-hvac)

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Well, when we talk about Ultraviolet Germicidal Irradiation (UVGI) air cleaners, you might have seen during COVID period these UV-based cleaning devices has come into the market. So, similar devices are there already for deactivating microorganisms such as viruses or bacteria. So, those are the devices which can be used for killing these kinds of microbes. And that given sufficient exposure in terms of time and the lamp power, these UV light can penetrate the outer structure of the micro-organism cells and they can alter its DNA so, they can prevent its replication or further multiplication and then they can cause the cell death. So, that way the bacteria or virus can be killed.

Well the ultraviolet, these UVGI kind of air cleaners, this is the diagram which shows how it is installed in the indoor environment, there can be different types of these UVGI cleaners, like air cleaners designed for air stream disinfection, where those rays UV rays are passed to the air and whatever microbes are floating into the air they will be killed, then surface cleaners like when we put something and then in the box there is this UVGI those rays are there, radiation are there then they kill. So, those kinds of devices which are cleaners for the surface, they are more efficient basically, in comparison to the air stream.

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Types of UVGI Cleaners and Their Effectiveness (1/2)

- Spores tend to be resistant to UV radiation, and killing them requires a very high dosage.
- A study reported a 99 percent reduction in microbial contaminants growing on exposed HVAC surfaces but a reduction in airborne bacteria of only 25 to 30 percent.
- One reason that the **surface disinfection** application provides only a slightly noticeable reduction in airborne microbial concentrations may be that microorganisms in the airstream are exposed to the UV light for a shorter time.



Source: Menzies et al. (2003)

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So, I know more time is needed for air stream cleaning. These spores tend to resistant to UV radiation and killing them requires a very high dosage. So, depending upon what kind of indoor environment is there, we have to settle down with the intensity of the UV rays as well as the time of the exposure for those cleaning purposes.

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## Air-Cleaning Technologies Used for Removing Gases

- A number of air-cleaning technologies are designed to either remove gases or convert them to (ideally) harmless byproducts using a combination of physical and chemical processes.
- Gas-phase air-cleaning technologies include sorbent media air filters, Photocatalytic Oxidation (PCO), plasma, and intentional ozone generators sold as air cleaners.
- None of these technologies are explicitly designed to remove particles.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)

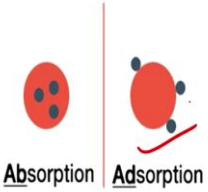
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Well, when we talk about like technologies for removing gases, then number of technologies are there like gas phase air cleaning technologies can be there for like Photocatalytic Oxidation, (PCO). Plasma-based technology can be there, or ozone generation. So, we will see one by one.


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## Sorbent Media (1/2)

- Sorption is the process by which a substance (sorbate) is sorbed (adsorbed or absorbed) on or in another substance (sorbent).
- Sorbent media air filters use a material with a very high specific surface area called a sorbent to capture gaseous pollutants.
- Two main sorption processes can be used to remove gaseous contaminants
- A physical process known as adsorption and a chemical reaction called chemisorption.



**Absorption**      **Adsorption**



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)      image: <https://qsstudy.com>

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Like sorbent media means sorption can be there absorption or adsorption. So, absorption means inside it can absorb some chemical reactions can be there. Adsorption maybe through attraction, physical attraction it can keep on the surfaces. So, the both the phenomena are used for removing those gaseous pollutants.

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## Sorbent Media (2/2)

A sorbent filter's behavior depends on many factors that can affect the removal of gaseous contaminants:

- Airflow rate and velocity through the sorbent
- Concentration of contaminants
- Presence of other gaseous contaminants
- Total available surface area of the sorbent
- Physical and chemical characteristics of the pollutants and the sorbent
- Pressure drop
- Removal efficiency and removal capacity
- Temperature and relative humidity of the gas stream



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)

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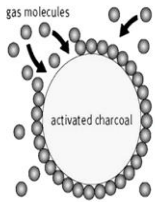
Wherever, you can see the sorbent media filter's behaviour depends on many factors like air flow rate or velocity through the sorbent media. Then what is the concentration of the contaminants or pollutants, presence of other gaseous contaminants rather than in addition to the gases which we want to remove, then total available surface area for adsorption purpose, physical chemical characteristics of the pollutants and the sorbent media.

Then pressure drop or removal efficiency, removal capacity, temperature and relative humidity of the gas stream. All these issues are there, or factors are there which influence the efficiency or performance of these absorption or adsorption related cleaning mechanism.

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## Adsorption (1/2)

- Adsorption results from the **physical attraction** of gas or vapor molecules to a surface.
- All adsorbents have limited capacities and thus require frequent maintenance.
- An adsorbent will generally adsorb molecules for which it has the greatest affinity and will allow other molecules to remain in the airstream.
- Solid sorbents such as activated carbon, silica gel, activated alumina, zeolites, synthetic polymers, and porous clay minerals are useful because of their large surface area, stability, and low cost.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)

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So, in adsorption you can see the physical attraction of the gases which can be captured on the molecules of the surfaces. And the solid sorbent and such as activated carbon, silica gel, activated alumina, zeolites, synthetic polymers, and porous clay minerals they are useful because of their large surface area and the stability and low cost. So, that is why in adsorption process they are the most popular media.

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**Adsorption (2/2)**

- Activated carbon is the most common adsorbent used in HVAC systems and portable air cleaners to remove gaseous contaminants.
- However, activated carbon is not especially effective against oxides of sulphur, hydrogen sulphide, low molecular weight aldehydes (e.g., formaldehyde), ammonia, and nitrogen oxide.
- Adsorbent media can also be impregnated in thin layers onto fibrous air filter media to remove both gases and particles.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)

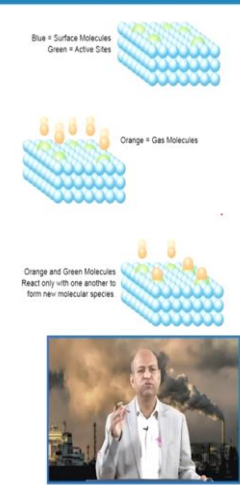
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Well, when we talk about like adsorbent media can also be impregnated in thin layers on to fibrous and filter media to remove both gases and particles. So, that way it is again versatile, but we have to be very cautious because the activated carbon is not especially effective against oxides of sulphur or hydrogen sulphide or low molecular weight aldehydes and even ammonia or nitrogen oxides. So, depending upon the nature of the gaseous pollutant, we have to use which kind of adsorption material we can use.

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### Chemisorption (1/2)

- Chemisorption occurs when gas or vapor molecules chemically react with sorbent material or with reactive agents impregnated into the sorbent.
- These impregnates react with gases and form stable chemical compounds that are bound to the media as organic or inorganic salts, or are broken down and released into the air as carbon dioxide, water vapor, or some material more readily adsorbed by other adsorbents.



Blue = Surface Molecules  
Green = Active Sites

Orange = Gas Molecules

Orange and Green Molecules React only with one another to form new molecular species

Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07) image: [www.particletechlabs.com](http://www.particletechlabs.com)

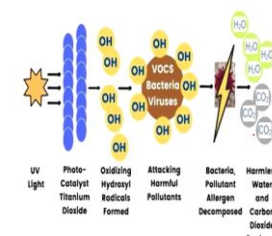
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Then chemisorption can be there where it can have gas or vapor molecules chemically it can react with the sorbent material or with the reactive agents, this impregnated into the sorbent. So, the chemical bond is there basically that is why we call it chemisorption.

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### Photocatalytic Oxidation (PCO) (1/2)

- PCO air cleaners use a high-surface-area medium coated with a catalyst such as titanium dioxide to adsorb gaseous pollutants.
- When the photocatalyst is irradiated with UV light, a photochemical reaction takes place and hydroxyl radicals form on the media surface.
- The hydroxyl radicals oxidize gaseous pollutants adsorbed on the catalyst surface.
- This reaction, called PCO, converts organic pollutants into (ideally) carbon dioxide and water.



UV Light

Photo-Catalyst Titanium Dioxide

Oxidizing Hydroxyl Radicals Formed

Attacking Harmful Pollutants

Bacteria, Viruses, VOCs

Harmless Water and Carbon Dioxide Produced

Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07) image: [thinkairpurifiers.com](http://thinkairpurifiers.com)

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Then there can be like photocatalytic oxidation, as I gave that example in vehicular exhaust. Three-way catalytic converters are used so, that we also in PCOs this photocatalytic oxidation in indoor environment. They can use a high surface area medium coated with a catalytic such as titanium dioxide to adsorb gaseous pollutants. So, when the photocatalyst is irradiated with ultraviolet light, a photochemical reaction takes place and these hydroxyl OH, hydroxyl


radicals, they are formed on the media surfaces. And, as you know these OH radicals, or hydroxyl radicals are very quickly they oxidize whatever they come into contact.

So, these hydroxyl radicals, they can oxidize gaseous pollutants and they can be adsorbed on the catalytic surfaces, so, that way very quickly action occurs and this reaction which is called PCO this converts the organic pollutants into carbon dioxide or water. So, they are harmless in the sense they are not pollutants, but of course, both are greenhouse gases. So, from that perspective, although things are there, issues are there, but from health point of view, at least they are not problematic.

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### Photocatalytic Oxidation (PCO) (2/2)

- The usefulness of PCO air cleaners depends on the amount of catalyst, the amount of contact time between gaseous pollutants and the catalyst, and the amount of UV light that is delivered to the catalyst surface.
- PCO of certain VOCs may create byproducts that are indoor pollutants if the system's design parameters and catalyst metal composition do not match the compound targeted for decomposition, particularly in the presence of multiple reactive compounds commonly found in residential settings.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07) image: purealizer.com

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Well, when we talk about further in this PCO technique. So, the usefulness of these PCO cleaners depends upon this amount of the catalyst and the amount of contact time between gaseous pollutants and the catalyst, and the amount of UV light that is delivered to the this catalyst surface. So, all these factors are there for influencing the efficiency or efficacy of the PCO devices and the PCO have certain VOCs like volatile organic compounds or hydrocarbons may create some by-products which are indoor air pollutants in itself.

So, the system design parameters are not good, rather than removing the pollutants it can generate some other pollutants by-products, so, we have to be very careful in that handling the PCO related techniques and so, it should clean rather than adding some pollutants, so, these side effects we should be careful about.

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### Plasma air cleaners (1/2)

- Plasma air cleaners apply a high-voltage discharge to ionize incoming gases, breaking their chemical bonds and chemically altering them.
- Thermal plasma air cleaners generate a high-temperature plasma flame using high voltage and high current.
- Non-thermal plasma air cleaners accelerate electrons to generate reactive ions and radicals, which convert compounds by oxidation reactions.
- However, a number of harmful byproducts are known to form, including particles, ozone, carbon monoxide, and formaldehyde.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)


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Plasma air cleaners can be there. So, these in thermal plasma air cleaners can be there or non-thermal plasma air cleaners can be there. So, depending upon their voltage and then the radicals we can use any of them. But a number of harmful by-products again in like in PCO in this plasma technology also there may be some particles or ozone, carbon monoxide, formaldehyde, they can be by-products if we do not handle properly this technology. So, these technologies are good if we are handling them properly otherwise, they may be problematic because they can also add some pollutants.

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### Plasma air cleaners (2/2)

- Moreover, plasma emitted directly to indoor air contains ozone and other reactive oxygen species such as hydroxyl radicals, superoxides, and hydrogen peroxide.
- Plasma air cleaners are sometimes combined with other air-cleaning technologies, such as PCO or adsorbent media.
- According to controlled laboratory tests, plasma air cleaners can have high removal efficiency for some gases as well as particles, and they can also kill or deactivate airborne microorganisms.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)

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Well, according to the control laboratory tests when we use properly these plasma air cleaners can have very high removal efficiency to some gases as well as particles as they can also kill


and deactivate airborne microorganisms. So, that way plasma air cleaners are very good, if it is, used in a controlled manner with those skilled people they can use otherwise, it can be dangerous also.

So, if we use it in a controlled way, this can be a very good technology because it can remove particles as well as gaseous pollutants, and it can also kill or deactivate airborne microorganism. So, skilled people or, personnel are needed for plasma air cleaners for using the plasma air cleaners, otherwise it can be problematic also, we should be careful.


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### Ozone Generators

- Ozone generators sold as air cleaners, which are typically designed to control odors, use UV lamps or electrical discharge to intentionally produce ozone.
- Ozone reacts with chemical pollutants to transform them into other compounds at high concentrations and can kill or deactivate biological pollutants.
- The chemical reactions produce irritating and corrosive byproducts that may cause adverse health effects and may damage building materials, furnishings, and wiring.



The diagram illustrates the process of ozone generation and its effect on biological pollutants. It shows an ozone generator releasing ozone into the air. The ozone then attaches to bacteria and viruses, forming atomic oxygen. This atomic oxygen punctures the cell wall of the bacteria, leading to their death and neutralization, leaving only oxygen behind.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)

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Then there can be ozone generators and, this also needs very careful handling otherwise, ozone itself is a problematic pollutant, but it can be used as a oxidizing agent also, as you know this ozone has nascent oxygen, so, it can oxidize and it can clean, it can oxidize the pollutants, and it can react with chemical pollutants to transform them into other kinds of compounds at high concentrations and it can also kill and deactivate biological pollutants.

So, that way similar to plasma technology, it is also good technology, but the chemical reactions produce irritating and corrosive by-products that may cause adverse health effects and may damage building materials also or furnishing or wiring etc. So, again, we have to be careful, and we need to handle it with the caution.

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### Removal of Radon and Its Progeny

- EPA recommends the use of source-control technologies to prevent radon from entering residential structures.
- The most effective radon control technique is active soil depressurization (ASD).
- An ASD system uses an electric fan to minimize radon entry by drawing air from under the slab/ floor and venting it to the outside above the building's roofline.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07) image: [radonremediesfargo.com](http://radonremediesfargo.com)


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Well then, when we talk about removal of radon and its progeny, so, the Environmental Protection Agency of USA recommends the use of source control technologies to prevent radon from entering residential structures. So, the most effective way of controlling the radon technique is Active Soil Depressurisation (ASD). So, the ASD system uses electric fan to minimize the radon entry by doing air from under the slab or floor and venting it outside the building. So, it does not enter into the air, you can see here, this kind of vents are there and it can take it out. So, from subways or those kind of locations.

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### Practical Considerations for Using Portable Air Cleaners

- Indoor particle concentrations are not constant over time.
- The placement of any portable air cleaner will affect its performance.
- Regular filter media replacement and/or cleaning are essential for ensuring performance.
- Caution should be exercised during replacement and cleaning of filter media and other air cleaner components.
- Noise may also be a consideration in selecting a portable air cleaner that contains a fan.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)

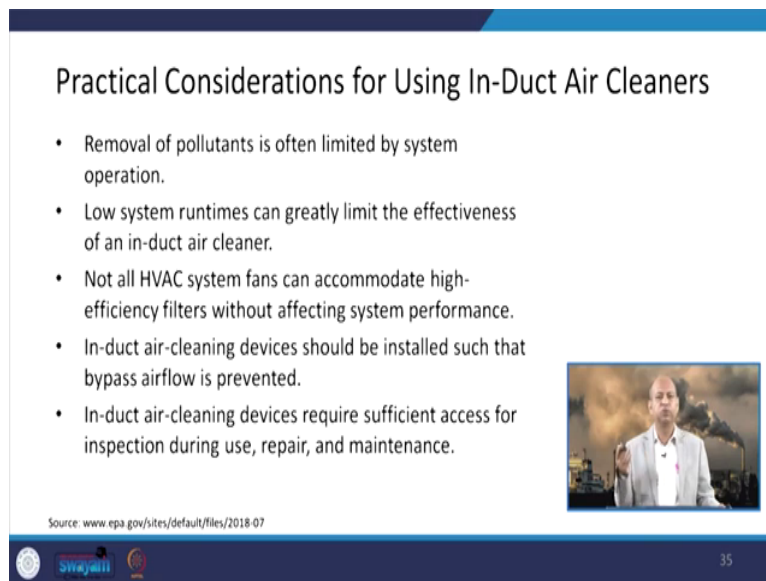
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Well then there are practical considerations for portable air cleaners, because indoor particle concentrations are not constant over time. Then the placement of any portable air cleaner will

affect its performance. So, we have to be careful where we need to put it. So, that efficiency is high.

Regular filter media replacement is needed otherwise it will be source of pollutant rather than cleaning. Replacement or cleaning of the filter media, again it needs to be handled carefully otherwise, this will add to the pollution. Noise may also be a concern when we are using some particular portable air cleaners. So, the noise pollution may be there. So, accordingly we need to do something so, that less noise related portable air cleaners are used.

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**Practical Considerations for Using In-Duct Air Cleaners**

- Removal of pollutants is often limited by system operation.
- Low system runtimes can greatly limit the effectiveness of an in-duct air cleaner.
- Not all HVAC system fans can accommodate high-efficiency filters without affecting system performance.
- In-duct air-cleaning devices should be installed such that bypass airflow is prevented.
- In-duct air-cleaning devices require sufficient access for inspection during use, repair, and maintenance.

Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)

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Well then removal of pollutants is often limited by system operation and the low system route these runtimes can greatly limit the effectiveness of in-duct air cleaner. So, means the system has to be designed properly so, that it has sufficient time. Then not all HVAC systems fans can accommodate high efficiency filters without affecting system performance. So, it is a kind of trade off you have to see where you can install it and run the HVAC system properly so, that it also do air conditioning as well as it removes the pollutants.

Well in-duct air cleaning devices they should be installed such that bypass airflow is prevented otherwise, efficiency will be greatly reduced, and the in-duct cleaning devices they require sufficient access for inspection during use, repair, and maintenance. Otherwise, if we do not have a proper access, then some kind of pollution accumulation can be there inside the ducts etc.

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## Byproduct Emissions From Some Air Cleaning Technologies

- Some air cleaning technologies may emit potentially harmful byproducts during operation.
- For example, PCO air cleaners have been shown to generate formaldehyde, acetaldehyde, nitrogen dioxide, and carbon monoxide.
- Plasma air cleaners have been shown to form particles, ozone, carbon monoxide, and formaldehyde as byproducts.
- Additionally, many electronic air cleaner devices—including portable and duct-mounted ESPs, ionizers, can generate high amounts of ozone which is a well-documented lung irritant.



Source: [www.epa.gov/sites/default/files/2018-07](http://www.epa.gov/sites/default/files/2018-07)


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Well, the byproduct emissions from some air cleaning technologies can be an issue. So, we have to see those technologies as we have seen that in PCO, or plasma, or ozone related devices. If careful handling is not there then rather than removing the pollutants, they can add into some other pollutants like formaldehyde, acetaldehyde, they can be generated in PCO technology. So, those things we have to be careful about.

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## Conclusions

- Common indoor air pollutants include a wide variety of particulate matter (PM) and gaseous contaminants.
- The most economical and effective way to address indoor air pollution is usually to reduce or eliminate avoidable sources of pollutants.
- Air-cleaning devices fall into two general categories: portable air cleaners and HVAC or furnace filters and other duct-mounted air cleaners installed in a home's central HVAC system.
- Two types of air-cleaning technologies are commonly used in duct-mounted and portable air cleaners to remove particles from the air.
- Gas-phase air-cleaning technologies include adsorbent media air filters such as activated carbon, chemisorbent media air filters, etc.



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Well, so, in conclusion, we can say that the common indoor air pollutants, they can be removed in terms of particulate matter or gaseous contaminants by certain technologies depending upon particulate matter is more or gaseous pollutant is more you can select the technology. And the



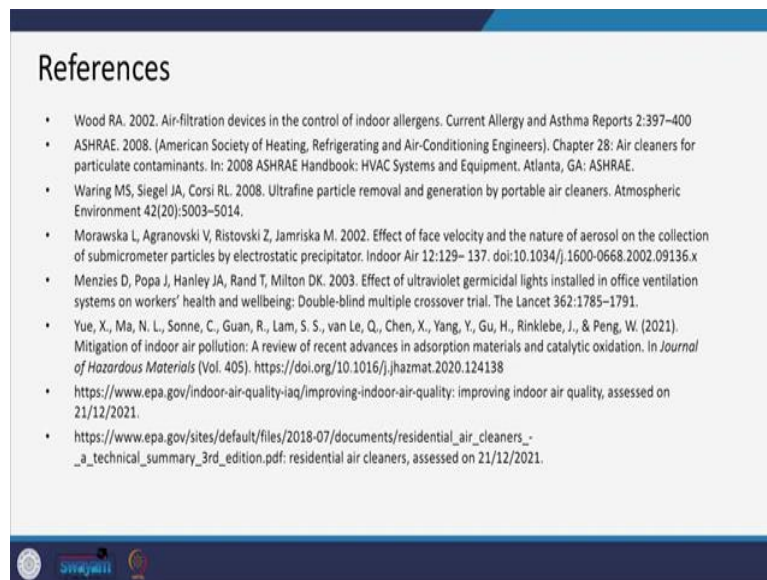
most economical and effective way to address the indoor air pollutant is usually to reduce or eliminate the sources itself at the source pollutants, we have to remove.

Then air cleaning devices they can be of two general categories portable air cleaning, and HVAC or furnace filters, which we have seen just now. And they can be mounted the duct mounted can be there or they can be at the central HVAC system. So, they can be independently installed or they can be part of HVAC system. And the two types of air cleaning technologies are commonly used in-duct mounted or portable.

Then gas-phase air cleaning technologies include adsorbent media, or absorption media, activated carbon, chemisorbent media filters. Then there are other technology like plasma or these kind of which we have seen like ozone related but they need very skilled people to handle it.

So, they are used only in industry related installations where indoor environment occupational hazards related issues are there, and well-trained people are there to handle those kinds of devices. Otherwise, we can go for simple filters and proper ventilation in residential areas. So, this is all for today for controlling or mitigating indoor air pollution.

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And these are the references for additional information. And you can go through that at the ledger. So, thank you for your kind attention and see you in the next lecture. Thanks again.