



# Health risks of air pollution: comparison between indoor and outdoor pollution

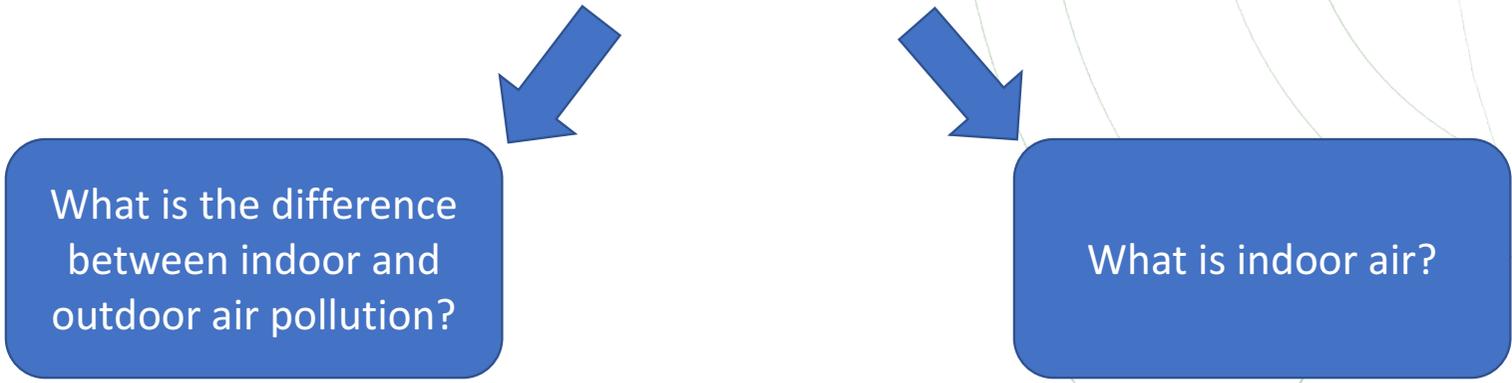
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**IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System**  
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-  
Mission 4 “Education and Research” - Component 2: “From research to business” - Investment  
3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”



At this point, the majority of Society understands the issue of air pollution and its repercussions not only on the climate but human health as well. But still, not many people seem to realize that indoor air quality is important as well.



What is the difference between indoor and outdoor air pollution?

What is indoor air?

As the name suggests, it refers to air that is present in confined spaces, whether they're public or private. That includes homes, apartments, offices, car interiors, schools, hospitals, museums, public transport, and other areas. Unfortunately, indoor air is also susceptible to pollution, and as studies show, its presence can be up to 8 times higher than in outdoor air.

**This information is especially alarming when we learn that people spend around 80 to 90% of their time indoors.**

*Obmiński A. Sci Rep. 2024 Sep 11;14(1):21185. doi: 10.1038/s41598-024-70631-z; Thompson R, et al. Environ Int. 2024 Aug 18;191:108963. doi: 10.1016/j.envint.2024.108963.*

## Indoor air vs Outdoor air pollution – know the difference

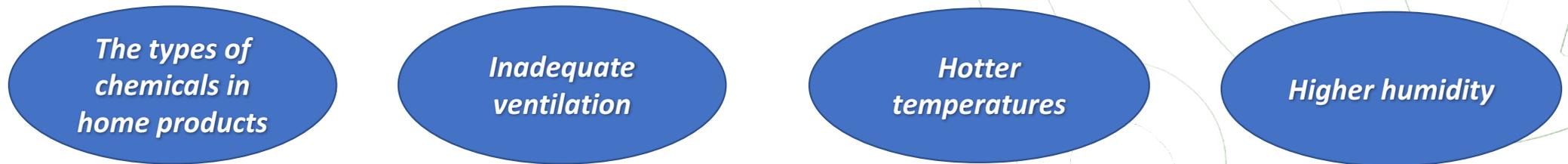
Inside close areas we are breathing exactly the same pollution as the one present outside?



- Some outdoor pollutants can seep inside as well, but most of the time, there's a significant difference between indoor and outdoor air pollution. Outside, we have to deal with such compounds as carbon monoxide, ozone, lead, nitrogen dioxide, sulfur dioxide, and particulate matter of different sizes.
- In indoors areas there are different types of air pollution. Some are well-known, like dust, virus, mold, fungi spores, cooking gasses, and cigarette smoke
- However, other sources of pollution may be surprising as they include standard equipment present in most homes, such as furniture, paints, glues, varnishes, coatings, and building materials.
- Pollution can also come from everyday objects, such as cleaning and personal care products, laundry detergents, or candles. All of those chemical substances are part of the VOCs (Volatile Organic Compounds), a group that includes all the typical indoor air pollutants.
- VOCs can cause respiratory problems, decreased lung function, asthma, and numerous other health problems.

# Indoor air pollution

In addition, recent studies suggest that indoor concentrations of air pollutants are increasing, driven by factors such as:



Indoor air quality is a global issue. Both short- and long-term exposure to indoor air pollution can cause a range of health issues. As one prominent example, the World Health Organization estimates 3.8 million people worldwide die every year from illnesses attributable to harmful indoor air from dirty cookstoves and fuel.

Certain populations may be affected more than others

- ✓ Children
- ✓ Older adults
- ✓ Individuals with preexisting conditions
- ✓ Households of low socioeconomic status are often exposed to higher levels of indoor pollutants



Like outdoor pollution the indoor air can have severe health impacts. **Short-term exposure** can lead to respiratory issues, headaches, and fatigue. In contrast, **long-term exposure** can result in chronic respiratory diseases, heart disease, lung cancer and even affect brain health and development in children.



# Types of Pollutants in Indoor air

Many factors contribute to poor indoor air quality. Indoor air includes pollutants that penetrate from the outdoors, as well as sources that are unique to the indoor environment.



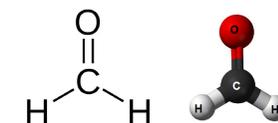
**Allergens** are substances that can trigger the immune system, causing an allergic reaction; they can circulate in air and remain on carpets and furniture for months.

**Asbestos** is a fibrous material formerly used for making incombustible or fireproof building materials, such as roof shingles, siding, and insulation. Asbestos-containing materials can release fibers, often too small to see, into the air. Asbestos is known to be a human carcinogen.

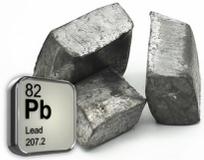


**Carbon monoxide** is an odorless and toxic gas. It is produced any time you burn fuel in cars or stoves, lanterns, grills, fireplaces, gas ranges, or furnaces. Proper venting or exhaust systems prevent build up in the air.

**Formaldehyde** is a strong-smelling chemical found in some pressed wood furniture, wood particle cabinets, flooring, carpets, and fabrics. It can also be a component of some glues, adhesives, paints, and coating products. Formaldehyde is known to be a human carcinogen.



## Types of Pollutants in Indoor air



**Lead** is a naturally occurring metal that has been used in a wide variety of indoor products including paint, plumbing pipes, ceramics, solders, batteries, and even cosmetics.



**Mold** are ubiquitous microorganism, they are a type of fungus that thrives in damp places; different molds are found often in indoors.



**Pesticides** are substances used to kill, repel, or control certain forms of plants or bugs that are considered to be pests.

**Radon** is a colorless, odorless, naturally occurring gas that comes from the decay of radioactive elements in soils. It can enter indoor spaces through cracks or gaps in buildings. Most exposures occur inside homes, schools, and workplaces. EPA estimates radon is responsible for about 21 thousand U.S. deaths from lung cancer annually.



**Smoke**, a byproduct of combustion processes, such as from cigarettes, cookstoves, contains toxic chemicals like formaldehyde and lead.

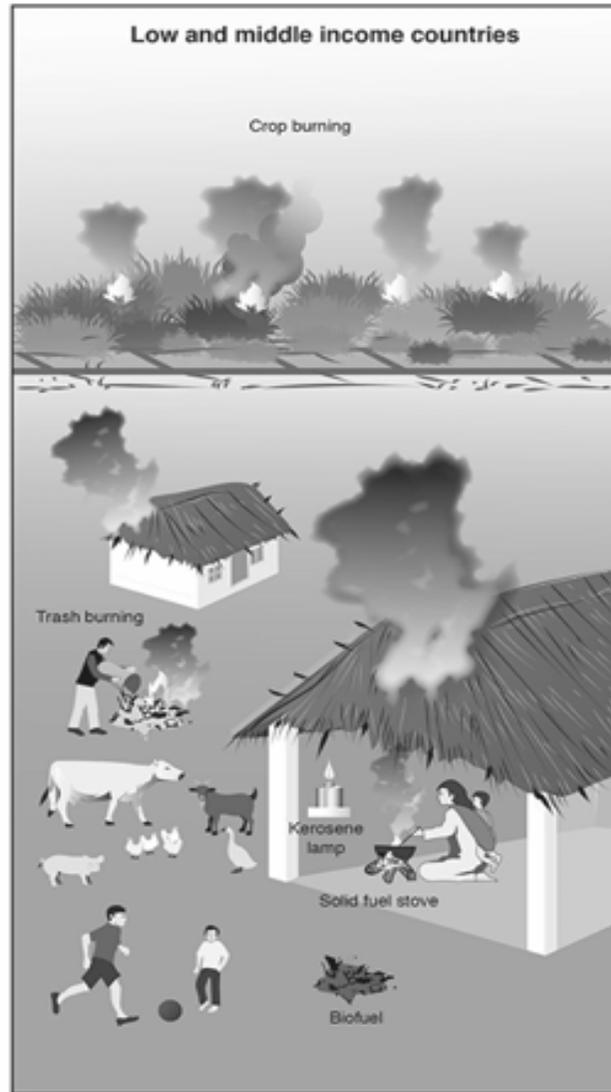


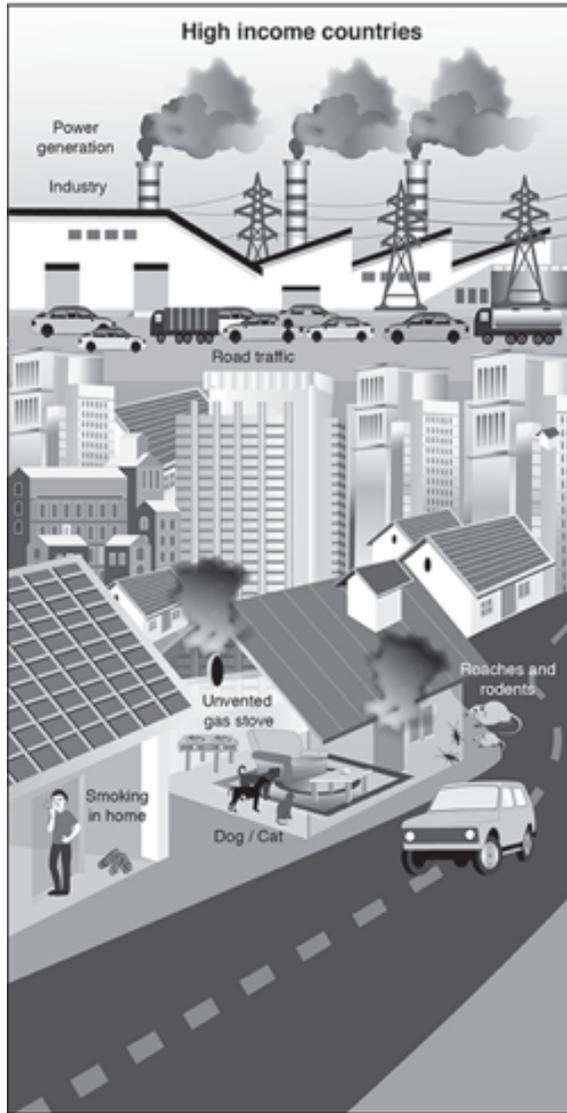
## Indoor air pollution in Low-Middle Income Countries

There are many differences in the Indoor air pollution in Low-Middle Income Countries than High Income Countries.

- ✓ In Low-Middle Income Countries, nearly 3 billion people rely on biomass fuels for cooking and heating daily.
- ✓ Biomass fuels, often referred to as solid fuels, include wood, dung, agricultural crop waste, and coal.
- ✓ Biomass is the main domestic energy source for ~40% of all households and ~90% of rural households in these countries.
- ✓ Solid fuels are often burned in inefficient and poorly vented combustion devices (i.e., open fires, traditional stoves).
- ✓ Multiple respiratory health outcomes have been associated with Household air pollution (HAP), including preterm birth; low birth weight and attenuated lung function; childhood respiratory infection;
- ✓ As well as increased risk for development of asthma, chronic obstructive pulmonary disease, lung cancer and exacerbations of existing diseases.

*Raju S et al. Clin Chest Med. 2020 Dec;41(4):825-843. doi: 10.1016/j.ccm.2020.08.014; Gordon et al. Lancet Respir Med. 2014;2(10):823-860. 10.1016/S2213-2600(14)70168-7.*





## Indoor air pollution in High Income Countries



**While respiratory health effects of pollution are most prominent in low-middle income countries, significant mortality has been observed at lower pollutant concentrations typical of high-income countries, including the US and Canada.**

Urbanization and the expanding built environment predispose individuals in high-income settings to other pollutants indoors, including indoor particulate matter (PM), environmental tobacco smoke, gases such as nitrogen dioxide from cooking and heating, allergens from indoor pests, toxic cleaning chemicals, and molds related to increased indoor humidity and dampness.

*Raju S et al. Clin Chest Med. 2020 Dec;41(4):825-843. doi: 10.1016/j.ccm.2020.08.014*

## Black Mold

There are possibly millions of Mold species on earth. The vast majority of these mold spores live in harmony with humans, rarely causing disease.

The rare species that does cause disease does so by triggering allergies or asthma or may be involved in hypersensitivity diseases such as allergic bronchopulmonary aspergillosis or allergic fungal sinusitis.

Other hypersensitivity diseases include those related to occupational or domiciliary exposures to certain mold species, as in the case of Farmer's lung disease or humidifier fever.

The final proven category of fungal diseases is through infection, as in the case of onchomycosis or coccidiomycosis.

**Black mold is a type of fungus that looks dark green or black. There are many kinds of black mold, but when most people refer to it, they're referring to *Stachybotrys chartarum* (*S. chartarum*).**

**It grows and spreads on materials that contain a lot of cellulose, including paper products, wood products and drywall. Cellulose is a part of fungal cell wall.**

# Black Mold



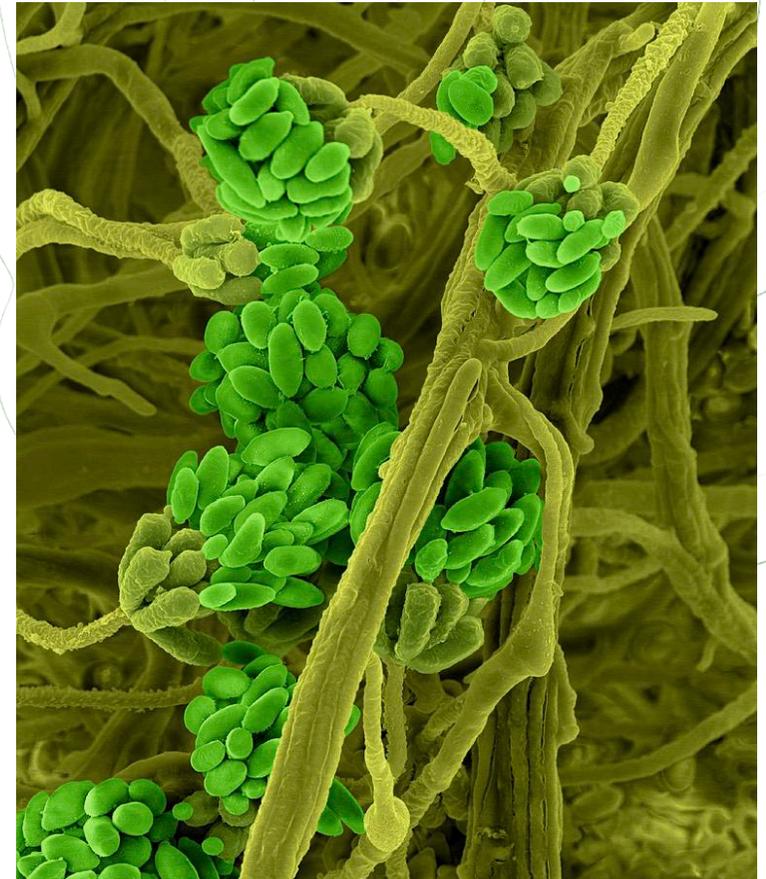
*Stachybotrys chartarum* growth



*In vitro* culture

*Stachybotrys chartarum* Photograph

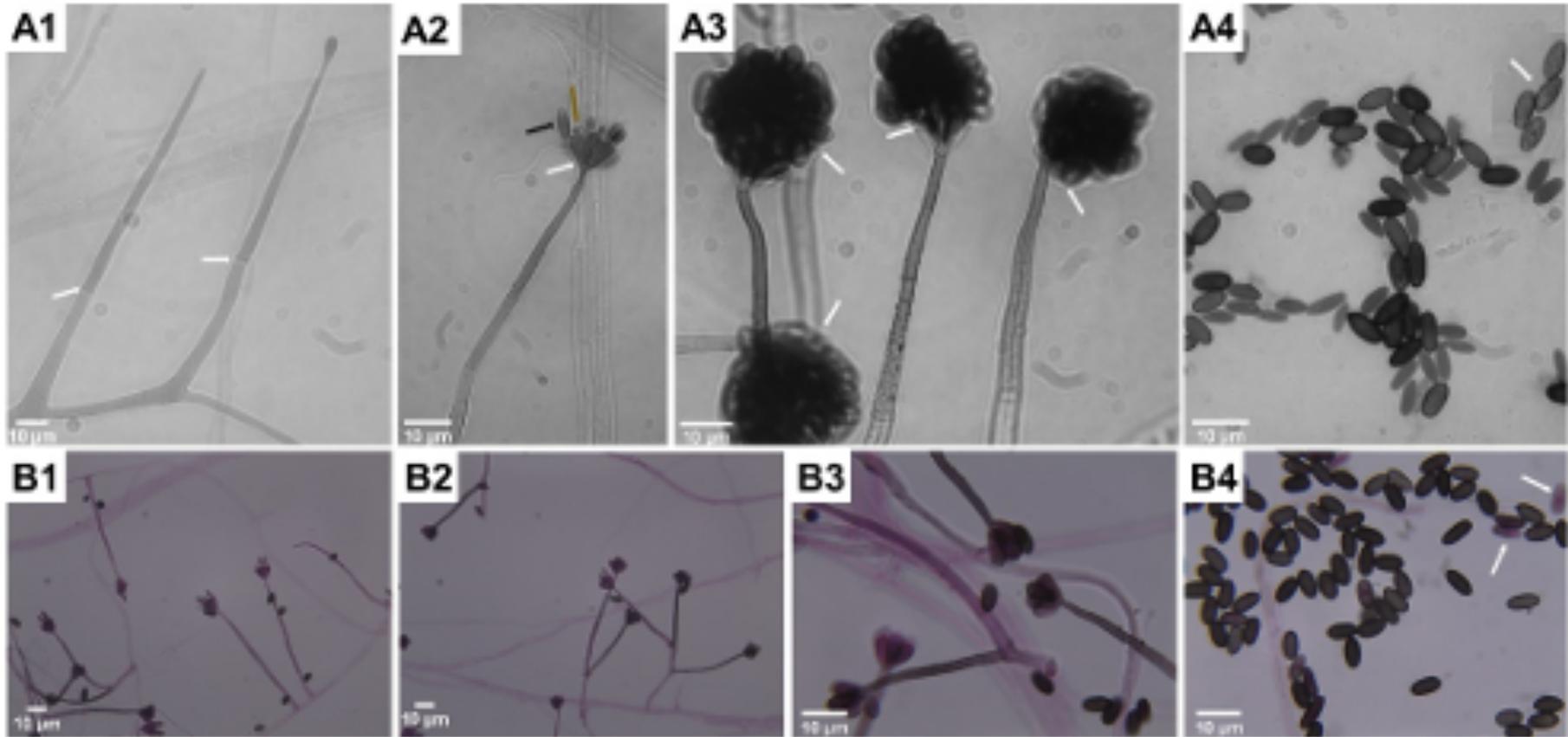
**Black mold needs warm temperatures and moisture to grow and spread. It commonly appears in damp or water-damaged areas of your home, such as basements, showers and windows.**



## Black Mold: growth condition

- ✓ *S. chartarum* is a typical saprophytic micromycete that has spread all over the world. In natural environments this fungus feeds as saprophyte by decomposing cellulose and other dead plant matter.
- ✓ This black mold is able to grow in a range of pH 3.0–9.8; with an optimal pH range of 5.6–6.0.
- ✓ The optimal temperature for growth is in the range of 20–25 °C, although can grow even at temperature of 2.5 °C.
- ✓ Although *S. chartarum* is capable of growing over a wide range of pH and temperatures, it is somewhat limited by the relative humidity (RH) of the air and activity water values.
- ✓ This is one of the key parameters limiting growth indoors. It is well known that growth of *S. chartarum* at room temperature (~25 °C) is possible with an RH value  $\geq 93\%$ , and mycotoxin production by this fungus occurs at activity water  $\geq 0.95$ .
- ✓ As it has already been shown experimentally, the release of conidia of *S. chartarum* is positively related to air flow rate, but negatively related to relative humidity, but also insects may play a role in spreading of conidia (asexual, non-motile spore of a fungus).
- ✓ However, drying is not a problem, and the fungus can survive unfavorable conditions and its conidia stay viable for years to decades.
- ✓ Even if the water source runs out, *S. chartarum* may continue to propagate because of catabolic reactions, which provide additional water.

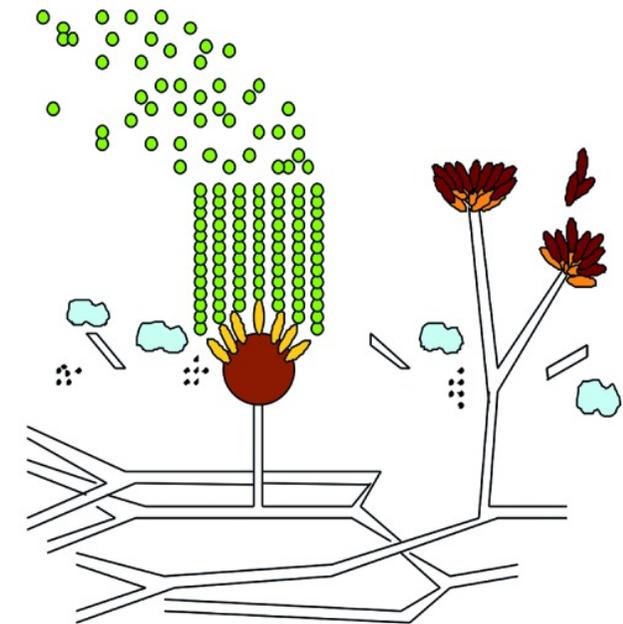
## Black Mold: growth condition



**These images represent *Stachybotrys chartarum*-specific mycelial structures typical for anamorphs visualized in light microscopy (saline wet mount microscopy, (A1–A4); fungal structures stained by lactofuchsin, (B1–B4)).**

## Black Mold: volatile microbial organic compounds

- ✓ Molds produce large amounts of volatile microbial organic compounds (MVOCs) including alcohols, aldehydes, ketones, esters, as well as sulfur and nitric compounds.
- ✓ MVOCs, in principle, are considered as products of primary metabolism during synthesis of DNAs, amino acids, and fatty acids.
- ✓ Although the distinction between primary and secondary metabolism is not clear, MVOCs might form during both stages.
- ✓ The products of MVOCs depend strongly on the substrate and environmental conditions; various compounds that define MVOCs might have a nonmicrobial origin.
- ✓ It is believed that fungal VOCs (FVOCs) may cause headaches, lack of concentration, inattentiveness, and dizziness.



 MVOC    Spores    Mycelium    Toxins

The most common symptoms of black mold exposure include:

- ✓ Sneezing
- ✓ Coughing
- ✓ Nasal congestion
- ✓ Postnasal drip
- ✓ Red eyes

Black mold exposure can also trigger or worsen asthma symptoms

**Allergy symptoms occur when immune system is hypersensitive to fungal spores. This results in your immune system releasing chemicals that cause inflammation in your nose, eyes and lungs. Even if you don't have allergies, you can still experience irritation from VOCs**

### Symptoms of Black Mold Exposure Include:



The infographic is a vertical rectangular graphic with a blue header and a light blue body. It is divided into several sections. The top section has a blue background with white text: "Symptoms of Black Mold Exposure Include:". Below this, there are two rows of three panels each. Each panel contains an illustration of a person or a body part and a label. The first row shows: 1. A woman sneezing into a tissue, labeled "Sneezing." 2. A man coughing into his elbow, labeled "Coughing." 3. A close-up of a red eye, labeled "Red eyes." The second row shows: 1. A man with a drip from his nose, labeled "Postnasal drip." 2. A woman holding her nose, labeled "Nasal congestion." Below these two rows is a dark blue horizontal bar with white text: "Black mold exposure can also trigger or worsen asthma symptoms, including." Below this bar is a third row of three panels. Each panel contains an illustration of a person and a label. The third row shows: 1. A man wheezing, labeled "Wheezing." 2. A woman with her hand to her chest, labeled "Shortness of breath (dyspnea)." 3. An older man coughing, labeled "Dry cough and chest tightness."

Sneezing.

Coughing.

Red eyes.

Postnasal drip.

Nasal congestion.

Black mold exposure can also trigger or worsen asthma symptoms, including.

Wheezing.

Shortness of breath (dyspnea).

Dry cough and chest tightness.

## Black Mold: Biology

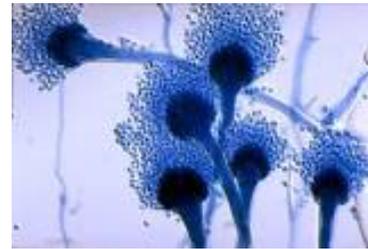
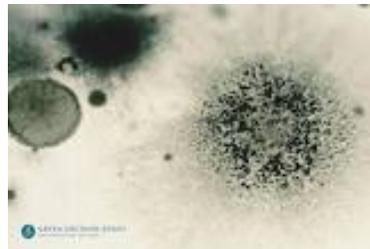
- ✓ People can be exposed to this fungus via dermal contact, ingestion and inhalation.
- ✓ Moreover *S. chartarum* is capable of producing secondary metabolites known mycotoxins, which can be divided into three structural groups, macrocyclic trichothecenes (MCTs, e.g., satratoxins), atranones and immunosuppressive phenylspiro drimanes (PSDs).
- ✓ Such compounds bind irreversibly to the 60S ribosomal subunit of mammalian cells and inhibit protein biosynthesis
- ✓ It is commonly known that most of the mycotoxins related with this species are very harmful for humans, they represent the most cytotoxic trichothecenes currently known.
- ✓ It should be noted, however, that the Centers for Disease Control and Prevention (CDC), due to the lack of complete documentation on pulmonary hemorrhage cases does not allow for the conclusion that *S. chartarum* unequivocally is the etiological agent for this ailment in infants.
- ✓ However, it is impossible not to notice that 91% of the cases of infant pulmonary hemorrhage described so far have been associated with the presence of *S. chartarum* in the homes of the selected patients

Ulrich et al. *Mycotoxin Res.* 2020 May;36(2):267. doi: 10.1007/s12550-020-00391-y; Dylag et al. *Biology (Basel)*. 2022 Feb 23;11(3):352. doi: 10.3390/biology11030352.



**Black Mold**

~~you~~  
are  
**NOT**  
alone



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## Aspergillus in indoor environments: a public health hazards

In addition to the well-known data on exposure to *S. chartarum*, several studies have previously revealed that exposure to indoor, air-borne fungi from moisture damaged buildings can result in adverse and severe health effects.

- ✓ *Aspergillus spp.* is one of the well documented mold known to cause health problems, may adversely affect human health based on toxicity, allergy, and infection.
- ✓ Some species of *Aspergillus* (*A. fumigatus*, *A. flavus* and *A. niger*) are known to be capable of producing secondary metabolites or mycotoxins.
- ✓ It is known that inhaling high concentrations of mixed organic dusts, including mycotoxins, VOCs, and allergens (Beta-glucans), are associated with sick building syndrome.

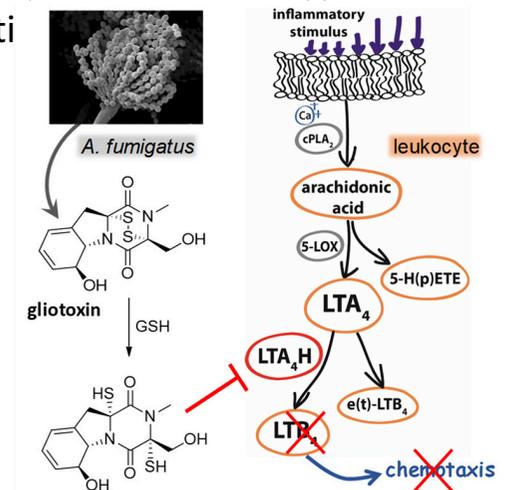
The term "sick building syndrome" (SBS) is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified.



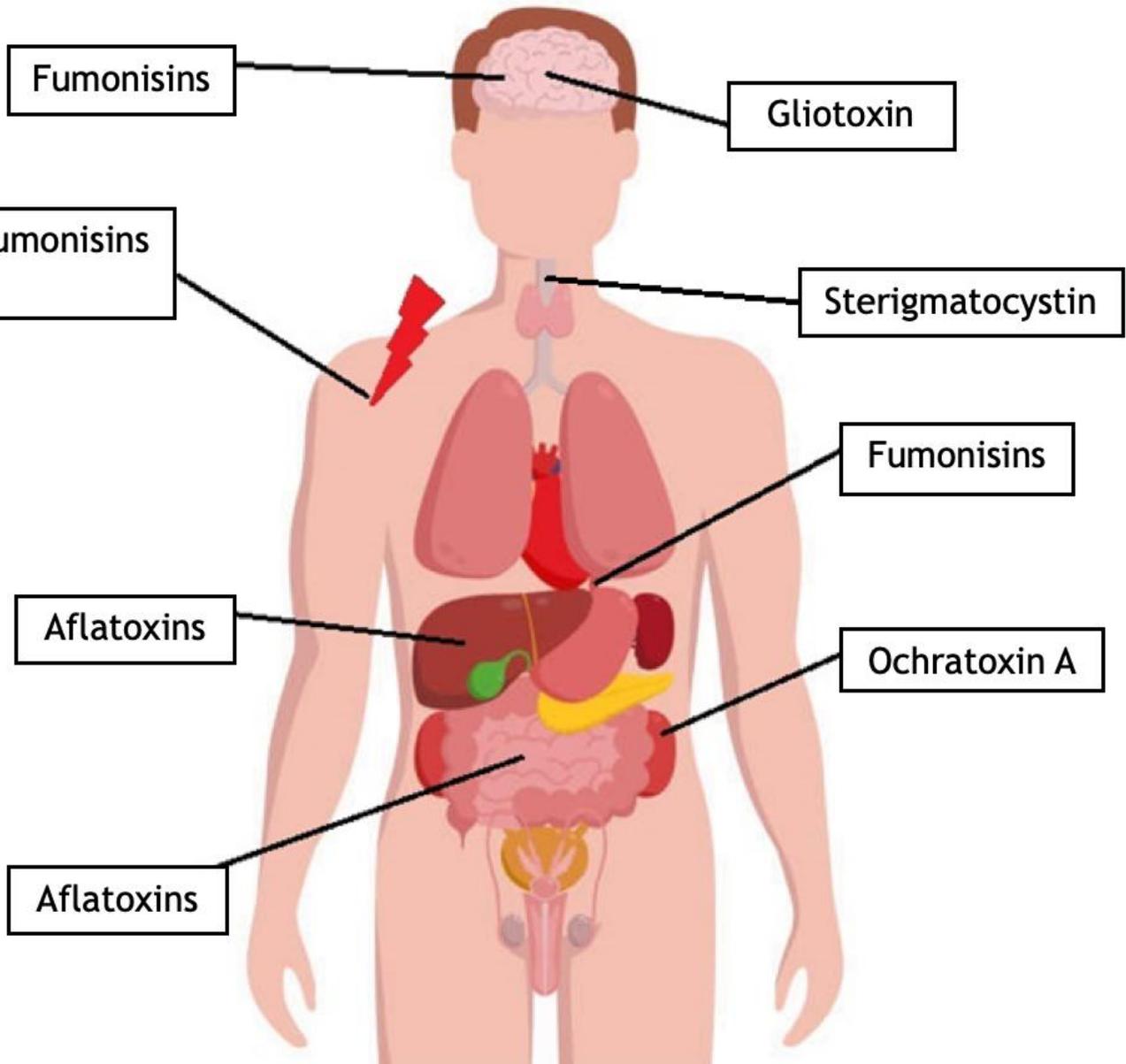
## *Aspergillus*: Mycotoxin production

- ✓ *Aspergillus spp.* mycotoxins are produced during consecutive enzyme reactions via several biochemically simple intermediary products from the primary metabolism of acetates (related metabolism of acetyl-CoA), mevalonates (involved in lipid synthesis), malonites, and some aminoacids.
- ✓ *Aspergillus* produces some of the most significant known mycotoxins including aflatoxin, gliotoxin, and ochratoxin A.
- ✓ The secondary metabolite gliotoxin has attracted the most interest on *A. fumigatus* because of its potent immunosuppressive and cytotoxic properties. In addition, it can be readily detected during experimental infection and in sera from patients with aspergillosis.
- ✓ Fungal metabolites may also impair phagocytic functions that would normally destroy conidial and hyphal forms, aflatoxin affects phagocytosis, intracellular killing, and spontaneous superoxide producti

- ✓ Gliotoxin reduces adherence and phagocytosis of fungal element and suppresses neutrophil (a type of white blood cell) influx and chemotaxis.



Recent studies have also highlighted that....



- ✓ *Aflatoxin metabolites can lead to chromosomal DNA strand breaks.*
- ✓ *Aflatoxins can inhibit cell proliferation.*
- ✓ *In the gut, mycotoxins can interfere with the regeneration of the gastrointestinal tract forming cells.*
- ✓ *Gliotoxin can penetrate the blood–brain barrier, and due to its cytotoxicity, it can damage the astrocytes.*

## The unknown risks of scented candles!



- ✓ A number of treatment options, such as aromatherapy, are used everyday to alleviate human psychological discomfort and promote healing of sick subject.
- ✓ Among such treatments, the use of scented candles has acquired a lot of consideration with the rapidly expanding interest in room decor and indoor air fresheners.
- ✓ The U.S. market for scented candles is estimated to be worth approximately 2 billion USD annually due to rising demand.
- ✓ When candles are lit indoors, several harmful gasses are released.
- ✓ The discharge of combustion gasses like carbon monoxide or nitrogen oxide would contaminate the interior environment, according to studies done in environmental test chambers.
- ✓ A number of polycyclic aromatic hydrocarbons that have been identified as carcinogens, such as naphthalene, anthracene, and pyrene, were also found in candle fumes that are products of wax, aroma substances, or combustion dyes.

The most common complaints from those who had been exposed to scented candles were....

**Vertigo**



**Headaches**



**Mucosa irritation**



**Respiratory issues**

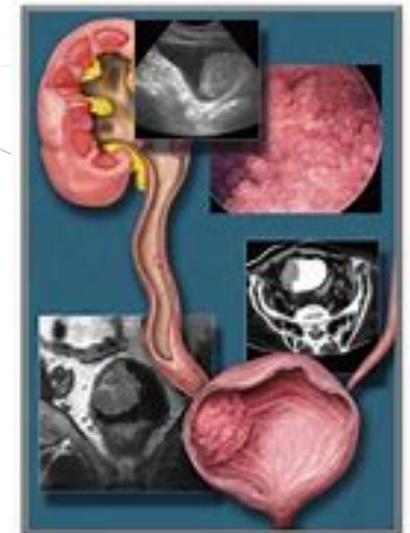
**....and also: watery eyes, sneezing, stuffy nose, chest tightness, and a dry or irritated throat!!!**

*Nazir et al. 2023 Nov 17;86(1):16-17. doi: 10.1097/MS9.0000000000001524.*

# The unknown risks of scented candles!



- ✓ When burning scented candles indoors, quantities of pollutants such as formaldehyde, CO<sub>2</sub>, and volatile organic compounds were measured that were higher than background levels, showing that the candles were one of the sources of indoor pollution
- ✓ Formaldehyde and aromatic hydrocarbons like toluene and benzopyrene may be released in large quantities from commonly available scented candles, especially the less expensive ones made from paraffin wax.
- ✓ In addition, Candle waxes are still stained using toluene derivatives and benzidine-based dyes, which have been associated with cancer development (urothelial cancer).
- ✓ Frequent consumption of scented candles for quite a long time and their use in inadequately ventilated rooms may increase the chance of developing cancer.



*Nazir et al. 2023 Nov 17;86(1):16-17. doi: 10.1097/MS9.0000000000001524.*

## Consequence of Indoor Air Pollution: Mechanisms

The respiratory consequences of household air pollution are wide ranging, affecting lung development in childhood, incidence of lower respiratory tract infection, and both disease development and morbidity for chronic obstructive pulmonary disease (COPD) and asthma.

There have been a number of mechanisms proposed by which indoor air pollution results in pulmonary disease and alters host immune responses, leading to chronic respiratory conditions.

Exposure to household air pollution results in:

**Pro-inflammatory states with associated increases in neutrophilic inflammation**

**Proteolytic activity of matrix metalloproteinases**

**Oxidative stress and apoptosis**

**Loss of lung function from prolonged exposure to air pollution has been proposed as a leading cause of COPD globally.**

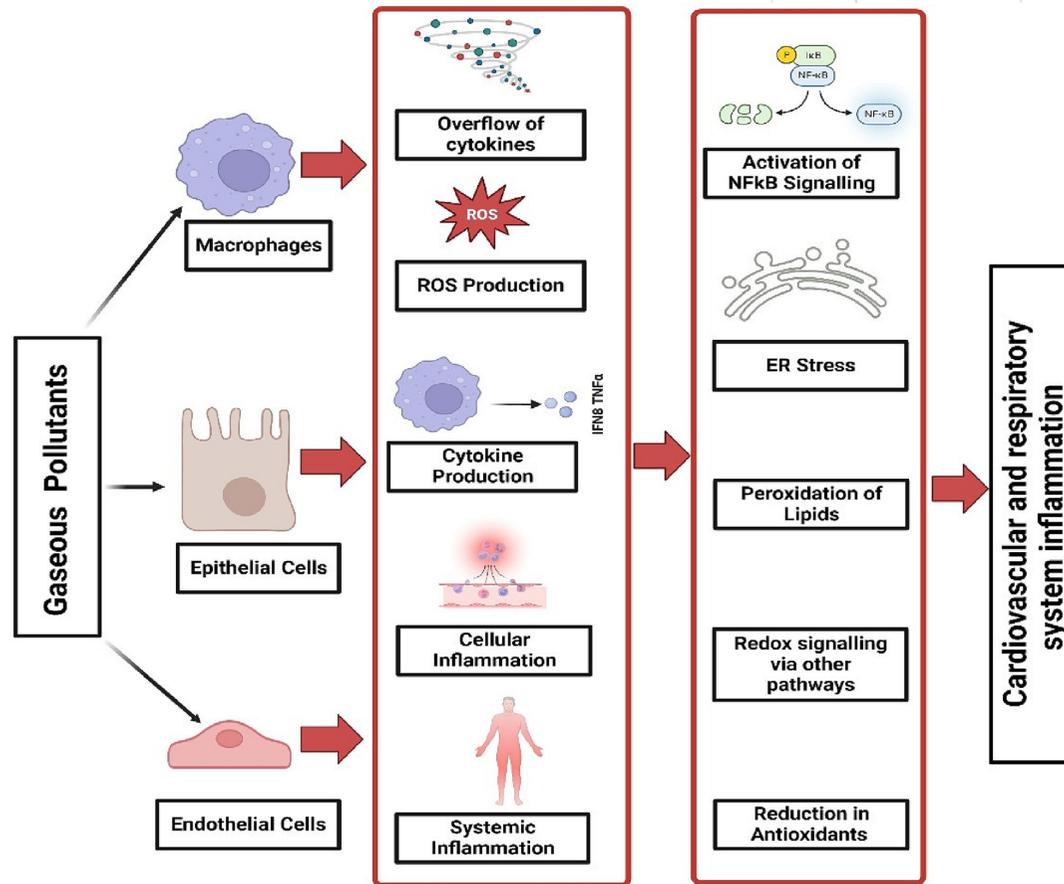
## Consequence of Indoor Air Pollution: Mechanisms



- In particular, when breathed in, particles enter the lungs, trachea, and bronchia are all reached by the nasal cavity as it descends the respiratory system.
- It is thought that the mucosa, or mucus layer underneath tissue cells, serves as the body's first line of defence against inhaled particles.
- The function of alveolar type 1 epithelial cells is the ingestion of small and extremely small particles.
- Endocytosis of pollution particles by alveolar type 1 epithelial cells results in cellular autophagy because of epithelial damage brought on by the particles.
- This mechanism causes the bronchial epithelial cells to become activated, followed by a mucus hypersecretion that is regulated by type 2 epithelial cells to maintain the dynamic equilibrium.
- A thin coating of pulmonary surfactant (PS), which is essential for both host defence and the lowering of surface tension, coats the inner surface of the respiratory tract.
- The deposition of pollution particles considerably changes the number of PS components, including proteins and phospholipids, which may cause pulmonary toxicity and lung inflammation.

*(Ali et al., 2017, Ali et al., 2019; Oberdörster et al., 2005; Schmid et al., 2009; Possmayer et al., 2010; Chen et al., 2016a, 2016b; Zuo et al., 1978)*

# Consequence of Indoor Air Pollution: Mechanisms



(Ali et al., 2021; Ali et al., 2017, Ali et al., 2019; Oberdörster et al., 2005; Schmid et al., 2009; Possmayer et al., 2010; Chen et al., 2016a, 2016b; Zuo et al., 1978)

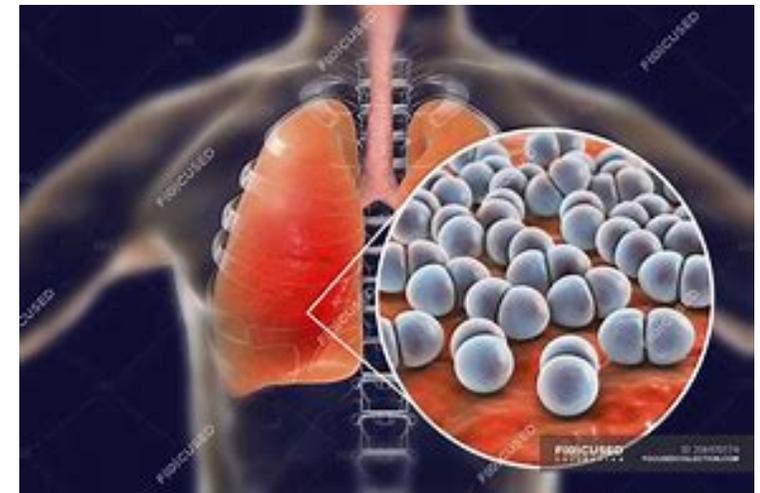
## Consequence of Indoor Air Pollution: Mechanisms

Additionally, recurrent respiratory infections have been associated with increased levels of household air pollution, likely due to underlying immune dysregulation.

Household air pollution has been demonstrated to impair macrophage phagocytosis and surface adherence, reduce bacterial and mucociliary clearance, and disrupt the alveolar-capillary barrier in the lungs.

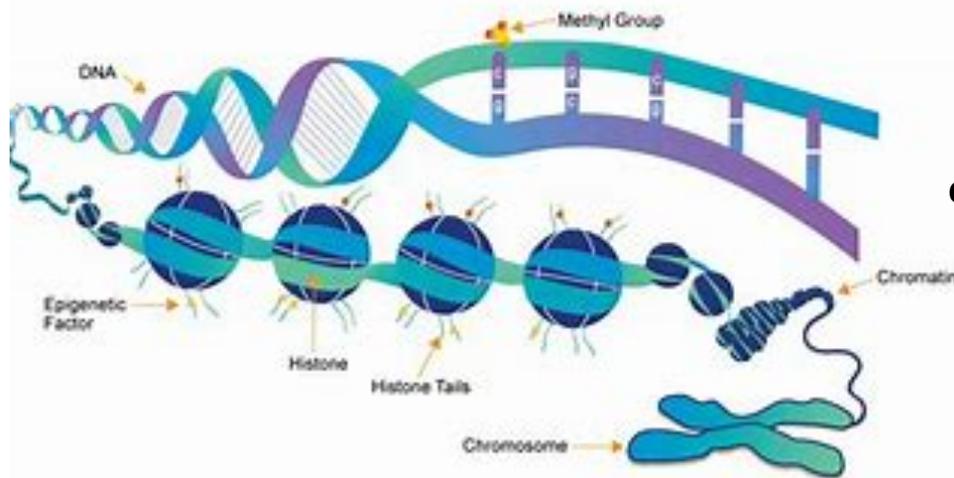
A number of effects also relate to alterations in the airway microbiome as well as immune dysregulation and host response to commensals.

**In particular *Streptococcus pneumoniae* carriage, the most common cause of bacterial pneumonia, is thought to be increased in individuals with high HAP exposure.**



## Consequence of Indoor Air Pollution: Mechanisms

- ✓ Additionally, as previously highlighted, immune responses to respiratory viruses may be impaired, with many literatures demonstrating that increased PM10 exposure can blunt alveolar macrophage responses to Respiratory syncytial virus (RSV).
- ✓ As a result, recent research has focused on the impacts of HAP on both viral and bacterial acute lower respiratory tract infection.



**Indoor air pollution additionally may result in genetic and epigenetic changes which alter inflammatory and oxidative stress responses even after the exposure is removed**

## Consequence of Indoor Air Pollution: Cognitive Effects



- ✓ Among different effects of indoor pollution, in the last decade it has been shown that indoor air pollutants, including particulate matter, allergens, oxides of nitrogen, endotoxin, and mold, have been associated with impaired cognitive health and performance in children and adults.
- ✓ Characterization of indoor air pollution in schools is a public health concern for children, given the large amount of time spent there, in particular for nitric oxide, that can affect...

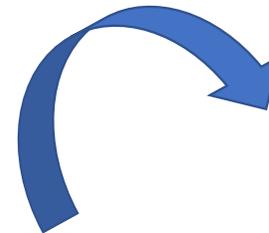
**Cognitive  
outcomes**

**Verbal abilities**

**Executive  
functioning**

**Physical and structural defects and lack of proper ventilation often contribute to the poor air quality in schools.**

**Different studies suggest that improving building conditions and facilities, as well as consideration of the school's outdoor surroundings, could create healthier environments.**



**Further, learning and memory impairment occurring in men and animals due to defective NO activity in the brain**

## Strategies for Reducing Household Air Pollution

Several strategies have been attempted to reduce pollutant exposure in diverse settings.

Interventions have been attempted to reduce a wide range of indoor pollutants including, particulate matter, gases, allergens, and mold. Certain strategies outlined focus on source reduction (i.e LPG stove interventions and smoking bans) while others focus on secondary reduction (air cleaner interventions).

### Common Strategies for Reducing Household Pollutants

Pollutant	Interventions
Particulate Matter (PM <sub>2.5</sub> , PM <sub>10</sub> )	Cookstove Exchanges (In homes burning biomass fuels), Air Cleaner Interventions, Woodstove Replacement
Gases (NO <sub>2</sub> )	Air Cleaners (HEPA with carbon filter), Gas Stove Replacement, Vented Hoods for Stoves
Allergens	Air Cleaners, Integrated Pest Management, Pest Education
Molds	Remediation of household dampness and humidity
Environmental Tobacco Smoke	Smoking Cessation, Indoor Smoking Bans

Raju S et al. *Clin Chest Med.* 2020 Dec;41(4):825-843. doi: 10.1016/j.ccm.2020.08.014

Indoor air pollution, from sources that include indoor tobacco smoke, the burning of solids fuels, and gases from cooking and heating, is associated with greater risk for chronic lung disease development and respiratory morbidity worldwide

While the impact is most pronounced in Low- and Middle Income countries, significant health effects are still observed at lower pollutant concentrations typical of high-income settings

Exposure to molds species that produce secondary or primary metabolites in the environment can promote health risks, and even small amounts of fungal contamination may lead to fatal outcomes in predisposed individuals

Thus, developing new techniques to determine the nature of these components is necessary, also to obtain a better understanding of the health implications of fungal exposure in indoor environments and to improve future diagnosis



*\*Take  
home message*

**It is important to raise awareness of common sources of pollution among clinicians, policy makers, and patients with chronic respiratory disease, in order to improve health education and promote efforts that can reduce pollutant exposure across households and address environmental health disparities**



*\*Take home message*

**While the long-term benefits of efforts to reduce indoor air pollution are yet to be defined, multiple intervention strategies at the household and community levels (including indoor smoking bans and air cleaner interventions) have been effective in reducing pollutant exposure.**

# ITINERIS

Future research may help to define optimal strategies for reducing indoor air pollution at the individual, household, community and population level to improve long-term lung health and reduce health disparities

# THANKS!



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