

# Indoor Air Pollutants, Health Effects, and Mitigation

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## I. Introduction

According to the EPA, “In the last several years, a growing body of scientific evidence has indicated that the air within homes and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. Other research indicates that people spend approximately 90 percent of their time indoors. Thus, for many people, the risks to health may be greater due to exposure to air pollution indoors than outdoors.” In fact the EPA claims “Indoor air levels of many pollutants may be 2-5 times, and occasionally, more than 100 times higher than outdoor levels.”<sup>2,3</sup>

Pollutants infiltrate the indoors by being pulled in by HVAC systems from the outdoors or they are emitted from sources within the building (cleaning agents, new building materials, and more). Our current HVAC systems are inadequate at dealing with indoor air pollutants allowing them to build up to levels that affect our health. Due to energy consumption standards, buildings are being constructed with tighter envelopes and more energy efficient HVAC systems, allowing less outdoor air in to dilute indoor pollutant concentrations. Thus, buildings are becoming more reliant on these HVAC systems for control of indoor pollutants. If these systems are incapable of removing pollutants, pollutants continue to recirculate in homes and cause sickness. According to the American Academy of Asthma, Allergy, and Immunology, “A worldwide study of housing and

asthma identified ducted heating and air conditioning as 2 of the 5 housing characteristics associated with asthma and bronchial responsiveness.”<sup>4</sup>

The primary indoor air pollutants of concern<sup>5</sup> are:

- **Bioaerosols:** Aerosols are liquid or solid particles suspended in a gaseous medium with size ranges from 0.001 to 100  $\mu\text{m}$ . Bioaerosols consist of aerosols containing microorganisms (bacteria, fungi, viruses), organic compounds derived from microorganisms (endotoxins, metabolites, toxins and other microbial fragments), and other small particles of biological origin (animal dander, dust mite allergen, pollen)<sup>6</sup>.

- **Volatile Organic Compounds:** “At room temperature, volatile organic compounds are emitted as gases from certain solids or liquids.” Volatile organic compound (VOCs) indoor sources include solvents, floor adhesive, paint, cleaning products, furnishings, polishes, and room fresheners. “VOCs include a variety of chemicals (e.g., formaldehyde, benzene, perchloroethylene), some of which may have short- and long-term effects. Concentrations of many VOCs are consistently higher indoors than outdoors. A study by the EPA, covering six communities in various parts of the United States, found indoor levels up to ten times higher than those outdoors -- even in locations with significant outdoor air pollution sources, such as petrochemical plants.”<sup>7</sup>

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<sup>1</sup> <http://www.epa.gov/iaq/pubs/insidestory.html> Accessed 8/2015

<sup>2</sup> <http://www.epa.gov/air/basic.html> Accessed 8/2015

<sup>3</sup> US EPA. “Targeting Indoor Air Pollution: EPA’s Approach and Progress” EPA-400-R-92-012

<sup>4</sup> Zock JF, “Housing characteristics, reported mold exposure, and asthma in the European Community Respiratory Health Survey.” *J Allergy Clin Immunol* 2002;110:285–92.

<sup>5</sup> US EPA. “Indoor Air Pollution: An Introduction for Health Professionals” <http://www.epa.gov/iaq/pubs/hpguide.html#VOCs>

<sup>6</sup> Mandal, J.; Brandl, H. “Bioaerosols in Indoor Environments – A review with specific reference to residential and occupational locations” *The Open Environmental & Biological Monitoring Journal*, 2011, 4, 83-96.

<sup>7</sup> US EPA. “Indoor Air Pollution: An Introduction for Health Professionals” <http://www.epa.gov/iaq/pubs/hpguide.html#VOCs>

- Environmental tobacco smoke and other combustion products.

## II. Health Effects of Indoor Air Pollution

It has been established that “various allergens, airborne irritants, and infections trigger exacerbation of asthma”<sup>8</sup>. Additionally it has been shown that “exposure to airborne allergens of biological origin is an important risk factor for the development of allergic asthma and rhinitis.”<sup>9</sup> In 1999, the American Academy of Asthma, Allergy and Immunology published a position statement that recommended that physicians<sup>10</sup> include indoor allergen avoidance approaches as adjunctive therapy for patients with chronic allergic asthma. However the health effects of indoor air pollution are not limited to allergies and asthma. Additional health effects of indoor air pollution include rhinitis (nasal congestion), pharyngitis (cough), headaches, dizziness, lethargy, fatigue, nausea, vomiting, and fever.<sup>5</sup>

### Bioaerosols:

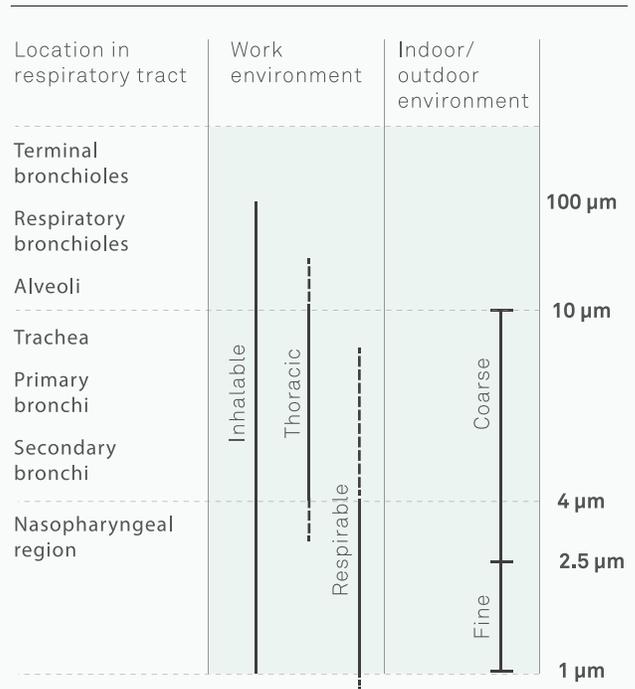
There are ranges of airborne bioaerosol particles that affect human health in various ways. Particles larger than 10 µm deposit in the nose and may induce hay fever, particles of 4 to 10 µm deposit in the lower airways and may cause asthma, and <4 µm particles can reach the alveoli and may cause allergic alveolitis.<sup>11</sup> The various types of airborne bioaerosol pollutants (dust mites, pollen, fungi / mold) range in size<sup>9</sup>:

**Dust Mite, Animal, and Cockroach Allergen:** Bioaerosols originating from dust mites, animals, and cockroaches have a strong link to development and exacerbation of allergic rhinitis and asthma.<sup>10</sup>

**Mold Spores:** “Studies conducted throughout the world indicate that fungal sensitivity is common among asthmatic

**Figure 1**

Interaction of respiratory tract and pollutants of varying sizes



Entry and interaction of particles of varying sizes with the respiratory tract

<sup>8</sup> Kanchongkittiphon, W. “Indoor Environmental Exposures and Exacerbation of Asthma: An Update to the 2000 Review by the Institute of Medicine” *Env. Health Perspectives* 2015. 123. 1. 6-20.

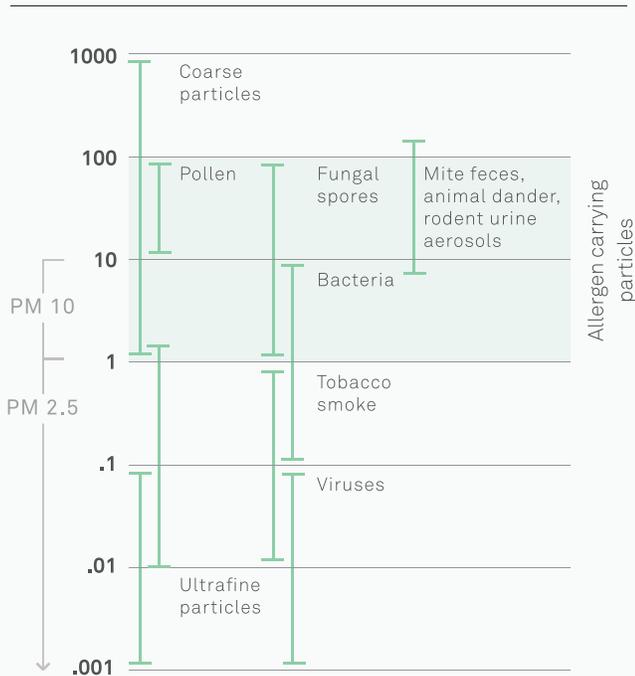
<sup>9</sup> Raulf, M. et al. *Monitoring of occupational and environmental aeroallergens – EAACI Position Paper. European Journal of Allergy and Clinical Immunology.* 30 May 2014

<sup>10</sup> Eggleston, P. et al. “Environmental allergen avoidance: An overview” *J Allergy Clin Immunol* 2001;107:S403-5

<sup>11</sup> Raulf, M. et al. *Monitoring of occupational and environmental aeroallergens – EAACI Position Paper. European Journal of Allergy and Clinical Immunology.* 30 May 2014

**Figure 2**

Particle size distribution of allergens



subjects. An accumulating body of evidence suggests that fungal sensitization, particularly to *Alternaria* species, is a risk factor for the development of asthma, increased severity of asthma, and asthma-induced fatalities”<sup>10</sup>

**Bacteria and Viruses:** The transmission of airborne infectious diseases has been difficult to control in the current built environment. “...there is strong and sufficient evidence to demonstrate the association between ventilation and the control of airflow directions in buildings and the transmission and spread of infectious diseases such as measles, TB, chickenpox, anthrax, influenza, smallpox, and SARS.”<sup>12</sup> In addition, legionnaire’s disease,

from the legionella strain of bacteria, is also primarily transmitted through aerosolized contaminated water spread by HVAC systems.

**Endotoxins:** “Toxicologic and epidemiologic studies have demonstrated that endotoxins cause inflammatory and atopic responses in nonasthmatic and asthmatic subjects... The available evidence shows a clear association of indoor endotoxin exposure with exacerbation among asthmatic individuals...”<sup>8</sup>

### Volatile Organic Compounds:

The most concerning health effect associated with VOCs is that some are well known carcinogens. For example benzene is a known human carcinogen, and is found in paints, environmental tobacco smoke, stored fuels, and car exhaust. Additionally exposure to very high levels of VOCs can be acutely toxic. Indoor exposure to VOCs has been related to asthma and asthmatic symptoms such as nocturnal breathlessness, increased bronchial responsiveness, and decreased lung function.<sup>13,14</sup>

### Current Air Cleaning Technologies:

Several commercialized technologies are available to improve indoor air quality:

- HEPA Filters (High Efficiency Particulate Air)
- Air Ozonation
- Electrostatic Filters / Air Ionizers
- Germicidal lamps (High Energy UV lights)
- Activated Carbon filters
- Photocatalytic Oxidation

The current technologies on the markets offer various solutions, however, come up short on dealing with the entire gamut of indoor air pollutants:

<sup>12</sup> Li, Y. et. al. “Role of ventilation in airborne transmission of infectious agents in the built environment – a multidisciplinary systematic review” *Indoor Air* 2007; 17: 2–18

<sup>13</sup> Norback D, Bjornsson E, Janson C, et al. Asthmatic symptoms and volatile organic compounds, formaldehyde, and carbon dioxide in dwellings. *Occup Environ Med* 1995;52:388–95

<sup>14</sup> Rumchev, K. et. al. “Association of domestic exposure to volatile organic compounds with asthma in young children” *Thorax* 2004;59:746–751

HEPA filters are densely packed fibers that are able to capture particles in air down to 0.3 micron in size. These filters are ineffective in removing viruses and VOCs (which are smaller than 0.3 microns in size). In addition, even after being captured on the filter surface, pollutants can get pulled back into the airstream. Certain microorganisms like mold can even colonize and breach these filters. Due to the densely packed fibers, HEPA filters create very large pressure drops and therefore require more powerful & energy consuming blowers to operate.

**Pros** - Does capture mold, bacteria, dust, pollen, and other large particles >0.3 microns in size.

**Cons** - Does not capture Viruses & VOCs or destroy any airborne pollutants. Can be colonized and breached by mold & bacteria.

Germicidal Lamps or High UV energy lights are proven to be effective on disinfecting surfaces not in disinfecting airflow. They are slow to disinfect surfaces. They are ineffective at destroying VOCs. They can pose a danger to humans if directly exposed.

**Pros** - Can destroy harmful microorganisms (bacteria & viruses) on surfaces.

**Con** - Slow to disinfect, ineffective in purifying the air.

Electrostatic Filters Ionizers work by charging particles in air and collecting them on a subsequent oppositely charged flat plate. work by dispersing charged ions into the air. These ions attach to airborne particles, which places a charge on these particles. Particles then attach to nearby surfaces (i.e. walls or furniture). However, ionizers produce unsafe byproducts like ozone, a lung irritant, and other ultrafine particles (less than 0.1 microns in size).

**Pros** - Captures some particles with minimum pressure drop.

**Cons** - Ionizers produce unsafe byproducts. Electrostatic filters & Ionizers are not capable of destroying bioaerosols.

Activated Carbon filter adsorbs VOC and large microorganisms such as mites, which stick to dust particles in the air, but does not remove other microorganisms from the air. In addition, once the activated carbon becomes saturated, the captured pollutants can release back into the air.

**Pros**- Removes VOCs and odors

**Cons** - Does not destroy any airborne pollutants

Ozonators, use high-energy UV lamps or electrical discharges to produce ozone, these react with chemical and biological pollutants to transform them into harmless substances. However, they introduce additional contaminants, ozone. Ozone can irritate eyes, dry the throat and stress lungs (according to consumer report 1996)

**Pros** - Removes VOCs and odors

**Cons** - Does not destroy any airborne pollutants

Photocatalytic Oxidation (PCO) is the first generation of Photocatalysis technologies. This process breaks pollutants down in air, but reaction rate are extremely low. This is due to the low quantum efficiency of the process. While PCO can destroy both bioaerosols and VOCs, the reaction rate is often too low to keep up with the production of these pollutants indoors.

**Pros** - Destroys both bioaerosols and VOCs.

**Cons** - Extremely slow in disinfection

NONE of these technologies are proven to be completely effective in quickly removing bioaerosols and VOCs from indoor air.