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# Healthy Residential Indoor Air Quality

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## Abstract

Healthy indoor environments are important components of sustainable housing. Creating such environments means avoiding health hazards from mold and other allergens, combustion pollutants, volatile organic compounds, radon, lead, and asbestos. Ways of doing so include use of water-managed building foundations, site drainage, adequate ventilation, informed selection of equipment for space conditioning and water heating, material choices, and sub-slab ventilation. Lead and asbestos are concerns in rehabilitating older homes and are addressed through well-established best practices. The purpose of this paper is to examine indoor environmental pollutants, their impacts on human health, and methods to avoid and mitigate exposure. The presence of asthma triggers in homes has become an increasingly serious indoor environmental issue and will be covered in more depth.

## Introduction

Human health can be adversely affected by a multitude of conditions in our constructed environments. These elements emanate from materials and techniques used in the construction process, from activities within such spaces, and from connections to the external environment. These factors are of particular concern when examining indoor air quality because most people in the U.S. spend about 90% of their time indoors [1], with some groups such as infants, the elderly, and infirm persons spending nearly all of their time indoors. A number of conditions contribute to typically higher levels of indoor pollutants than corresponding levels outdoors [2]. Numerous studies have documented the incidences of indoor air pollution and its negative impacts on children, especially with respect to lead, pesticides, radon, and asthma triggers [3] For physiological and behavioral reasons, children are at higher risk than adults for both exposure to environmental toxicants and for adverse health effects from those toxicants [4]. Children are more highly exposed to environmental pollutants than adults because they breathe more air per pound of body weight and chew or suck on toys and hands that have been in contact with pollutants [1],

Concerns about indoor air quality have led to indoor air management becoming a new consumer skill. Steps involved in this process include identifying a pollutant of concern, controlling it at its source, and if that fails, mitigation. The importance of widespread understanding of this issue is underscored by the fact that most indoor air pollutants are not regulated; and responsibility for their identification and mitigation lies with consumers. In addition to human health impacts that result from exposure to indoor air pollutants, financial costs are passed on to society.

## Materials and Methods

This research uses a review and summary method to provide a context for indoor environmental quality and its management. Materials used for this purpose include books, journal publications, and internet resources. The current state of knowledge pertaining to indoor environmental quality is described by categorizing indoor environmental toxicants by groups, explaining their impacts on human health, and providing solutions for avoidance or mitigation.

## Results and Discussion

### Biological Contaminants

Biological contaminants include mold, viruses, bacteria and dust mites. The term also applies to animal dander and pollen. Exposure to mold can cause allergic reactions, asthma, and other respiratory problems [5]. Mold spores are ubiquitous in indoor and outdoor air. The most practical way to prevent spores from colonizing in homes is to control moisture levels. Maintaining relative humidity to between

30 and 60 percent will minimize problems with mold [6]. This can be accomplished through adequate ventilation: exhaust fans ducted to the outdoors in bathrooms, an exhaust fan ducted to the outdoors over the kitchen range, and a clothes dryer that is vented according to the manufacturer's instructions. Preventing moisture entry from external sources is also important in preventing mold growth. This means quick repairs of leaks in roofs, siding, and other building components and maintaining dry basements and crawl spaces. Dust mites, pollen, and dander can be controlled in houses through regular cleaning [7].

### Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are carbon-based molecular compounds that evaporate at room temperature. In homes VOCs are emitted from certain building materials, paints, paint strippers, solvents, hobby supplies, air fresheners, and from smoking. They are also brought into a house from outdoor air [8]. Some VOCs are known and suspected human carcinogens and include acetone, benzene, ethylene glycol, formaldehyde, methylene chloride, perchloroethylene, toluene, and xylene [9]. Adequate ventilation should be provided when using VOC-containing products. Low- or no-VOC products are increasingly becoming available.

### Radon

Radon is a colorless, odorless, and tasteless radioactive gas. It comes from the decay of uranium, which is present in trace amounts in soils all over the world. Uranium decays to radium – both of these are solid elements. But radium decays to radon, which is a gas. Radon moves easily through soils, especially porous, sandy or gravelly soils. Radon can enter a house through foundation cracks and other openings. Once inside a house, radon decays to solid elements: lead, polonium and bismuth. These elements attach themselves to particles in the air. House occupants then inhale the particles into their lungs where they emit radiation, which eventually leads to lung cancer. Radon is the second-leading cause of lung cancer after cigarette smoking [10].

Radon's presence can only be confirmed through the use continuous- or long-term radon detectors. The U.S Environmental Protection Agency (EPA) recommends that mitigation systems be installed at or above the Action Level of 4 picoCuries per Liter (pCi/L) of air. In EPA-designated Zone 1 counties, or counties in which indoor radon levels are expected to be 4 PCi/L or higher, Radon-Resistant Construction Techniques are recommended for new homes [11].

Figure 1 is a map that depicts radon zones in the U.S. This map is broken down into three zones:

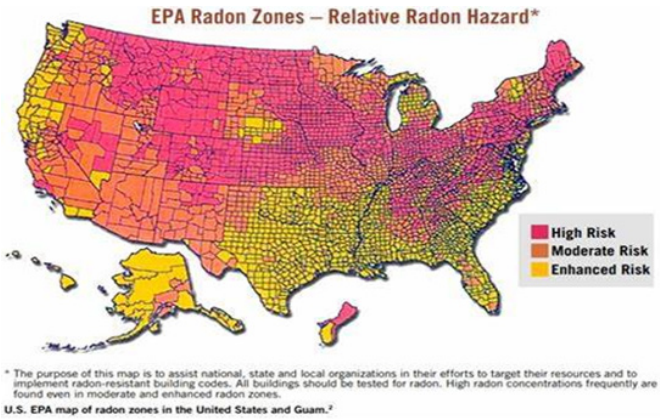


**Figure 1:** U.S. Map of Radon Zones

Source: Centers for Disease Control and Prevention, 2020:

https://www.cdc.gov/asthma/most_recent_national_asthma_data.htm

- Zone 1 (Red) – predicted amount of radon in a home will be 4 picocuries per liter of air (pc/L)or higher.
- Zone 2 (Orange) – predicted levels will be between 2 and 4 picocuries per liter.
- Zone 3 (Yellow) – predicted levels will be less than 2 picocuries per liter.

A picocurie is a unit of radioactive measurement that is commonly used for radon. The EPA defines the "action level" for radon at 4 picocuries per liter. This means that at this level and higher, action should be taken in a home to lower radon levels. Usually this action refers to the installation of a sub-slab ventilation system, sealing of cracks, and taking steps to eliminate sources of house depressurization.

### Combustion Pollutants

Combustion Pollutants are another category of indoor air pollutants. They consist of nitrogen oxides, sulfur dioxide, carbon monoxide, respirable particulates and water. Nitrogen oxides and sulfur dioxides are lung irritants, and carbon monoxide can kill. Recommendations for preventing the build-up of combustion pollutants include avoiding the use of unvented fuel-fired space heaters in homes, regular maintenance of fuel-fired heating systems and water heaters, the placement of an exterior-vented exhaust fan over a gas cooking range, and the avoidance of smoking indoors. In addition, every home should have a smoke detector and at least one carbon monoxide detector.

### Lead and Asbestos

Many older homes have lead and asbestos in them. Lead is present in the paint of a house, interior or exterior. It can also be present in the solder of copper plumbing systems. And some U.S. cities still have lead pipes that deliver water from utility companies to homes and businesses. Lead exposure is very dangerous, especially for pregnant women, because it can damage the developing fetus. In adults, it can damage the central nervous system. Asbestos was used as insulation on heating systems and heating ducts. In some older homes, it actually covers entire boilers. Exposure to asbestos causes asbestosis, a type of lung cancer, mesothelioma, which is cancer of the chest lining, and lung cancer. Abatement of both lead and asbestos are not do-it-yourself activities. The removal of these elements is regulated in the U.S., and must be performed by certified abatement contractors.

### Asthma Triggers

The Centers for Disease Control and Prevention reports that over 18 million adults and 4 million children in the U.S. have asthma, and these numbers increase annually [12]. Over 3,000 Americans die every year from asthma attacks (U.S. Centers for Disease Control and Prevention, 2016). Although asthma attacks can be prevented through medications and avoidance of asthma triggers, less than half of people suffering from asthma are taught how to avoid triggers [13].

Common asthma triggers include dust mites and mold spores, both of which can be minimized through moisture control. The use of special pillow and mattress covers and weekly washing of bed linens in 130-degree F water are further measures to control dust mites. Tobacco smoke is another asthma trigger that can be controlled by not allowing smoking in homes and cars. Cockroaches and mice are asthma triggers that can be controlled without resorting to chemical pesticides. Integrated Pest Management (IPM) is a practice that keeps these and other pests out of homes by preventing their access to food, water, and harborage. Animal dander from dogs and cats can also trigger asthma attacks; these pets may need to be kept out of an asthmatic's home. Particulates in house air can contain dust, pollen, mold spores, and outdoor air pollutants, all of which can be controlled through frequent cleaning with HEPA vacuums. In some cases the use of air cleaners may be warranted. Asthma triggers for some asthmatics also include colognes and perfumes. Other triggers to be avoided can include extreme temperatures, stress, emotions, and exercise. The Asthma and Allergy Foundation of America recommends that every asthmatic have an Asthma Action Plan in writing. Such a plan lists

prescribed medications, their amounts, and when to take them, as well as triggers to be avoided. Asthma Action Plans can be particularly helpful for children, as they can be shared with school administrators and nurses [14].

## Conclusion

Knowledge of potential indoor environmental hazards is key to their avoidance. Indoor air management techniques include pollutant identification, source control of such pollutants, and mitigation. As a public policy issue, human exposure to indoor environmental pollutants should be recognized for costs such exposure imposes on society. Fisk [14] demonstrated that indoor environmental improvements in the U.S. would reduce health care costs and improve human productivity substantially. He estimated savings of $6 to $14 billion from reductions in respiratory disease and $1 to $4 billion from decreases in allergies and asthma. Other social costs to consider are those imposed by intelligence losses and behavioral problems from lead exposure. These costs justify policy interventions that could range from public education about indoor environmental quality to financial assistance for pollutant mitigation for limited resource households.

Chi and Laquatra [15] observed a significant and negative relationship between income and radon exposure. This does not mean that low household income increases radon levels in a home, but that low-income households tend to live in lower-quality housing than do higher-income households. In areas prone to high radon levels, those lower-quality units are likely to have more radon pathways into the home. ln a study of indoor air quality in 23 low-income homes, Tsongas [16] reported that one-third of the homes had ovens that caused carbon monoxide levels exceeding 9 ppm in the cooking area. Tsongas also reported on several other studies that examined oven-produced carbon monoxide levels in homes. One recommendation from that research was the need to stress the importance of using exhaust fans while cooking to reduce carbon monoxide. This recommendation is not always practical, however, as many homes do not have operable kitchen exhaust fans. For its implications on public policy, the significant and negative correlation between oven-produced carbon monoxide and income warrants further study.

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