

Volatile Organic Compounds in the Home:
Sources, Health Implications, and Solutions

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Overview

Volatile organic compounds (VOCs) are chemicals emitted as gases from certain solids or liquids. VOCs are released by a wide array of sources within the home (e.g., household products, building materials) and also migrate indoors from outdoor sources (e.g., industrial and mobile sources) and therefore, concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. Residential VOC exposures are associated with a variety of health outcomes, especially in young children. To lower the VOC burden in your home, there are a number of simple steps that can be taken, from choosing products that release fewer VOCs to helping to capture VOCs by using air purification, as well as increasing ventilation in the home, when products are used.

What are Volatile Organic Compounds (VOCs)?

Volatile organic compounds (VOCs) are a diverse class of chemical contaminants that are emitted from certain liquids and solids. Human exposure to VOCs occurs predominately through inhalation of air, particularly indoor air. As there are many indoor sources of VOCs, there may be up to 300 different VOCs found in indoor air. For some VOCs, high levels can be detected by smell, but other VOCs have no odor. Odor is not a good indication of the overall level of VOCs.

VOC Levels in the Home

Indoor air is impacted by both VOCs that are generated outdoors which migrate into the home and by VOCs which have sources within the home (EPA, 2012a). In some cases indoor sources of VOCs are the dominant sources contributing to the indoor concentrations and result in indoor levels up to 10 times higher than outdoors (EPA, 2012a). Therefore, while the outdoor VOCs levels in suburban and rural settings may be lower than those in urban settings, the indoor concentration of many VOCs could be higher in suburban or rural homes (Weisel, 2008).

Typical indoor VOC levels are in the low microgram/cubic meter ($\mu\text{g}/\text{m}^3$) range, though much higher concentrations have been measured where activities related to specific VOCs have been reported (Weisel, 2008). For example, levels far above typical VOC levels are associated with use of specific activities such as use of deodorizers (p-dichlorobenzene), washing clothes and dishes (chloroform), smoking (benzene, styrene), and painting and using paint remover (n-decane, n-undecane) (Wallace, 1989).

While there are hundreds of VOCs present in the home, studies tend to focus on chemicals that are present in the highest concentrations or those that present the largest health risk. In a study of homes in New Jersey, Texas and California, air was tested for 18 of the most common VOCs. While concentrations varied among location, the VOCs with the highest indoor concentrations were methyl tert-butyl ether (MTBE), toluene, α -pinene, d-limonene, formaldehyde, acetaldehyde, and acetone (Weisel, 2005).

Sources of VOCs in the Home

The most common indoor VOC emission sources include consumer products (e.g., cleaners, solvents, mothballs), building materials (e.g., floor and wall coverings, carpet, insulation, paint, wood finishing

products), combustion processes (e.g., smoking, cooking, home heating), personal care products (e.g., shampoo, soaps), attached garages, dry-cleaned clothing, and municipal tap water (Wallace, 1987; Batterman, 2007; Stocco, 2008; Blondel, 2011; Wheeler, 2013). Products can release VOCs while they are using them, and, to some degree, when they are stored (US EPA, 2012a).

Outdoor sources of VOCs including vehicles, industrial activities, coal and biomass combustion, evaporation processes associated with industry and transportation, or paints and solvents use (Watson, 2001; Ye, 2014). Certain VOCs, such as MTBE, benzene, carbon tetrachloride, and trichloroethylene, are also exclusively generated from mobile and industrial sources, 90 to 100% of the indoor concentrations of these chemicals generated by outdoor sources (Weisel, 2005). While outdoor sources continue to be a health issue, emissions of VOCs and other air pollutants have declined over the last 25 years in the U.S. due to regulations on stationary and mobile source (US EPA, 2014).

When evaluating all the VOCs found in indoor air in a range of non-smoking homes, over 70% of the total VOC burden was associated with indoor sources, where household products were the major contributor, followed by combustion processes, environmental tobacco smoke, deodorizers, and off-gassing of building materials. The major sources of VOCs from household products included bleach, dishwashing and laundry detergents, and glass cleaners. Other source groups included consumer products with fragrance (e.g. deodorizers, and personal care products), wood-based building materials, floor and wall coverings, paints and adhesives and others (Bari, 2015).

The indoor sources of VOCs discussed above produce a range of VOCs. Building materials, such as hardwood, plywood, laminate floorings, adhesives, paints and varnishes are most commonly associated with formaldehyde, benzene, toluene, ethylbenzene, and xylenes emissions (Cheng, 2015). Consumer products such as, laundry products and cleaners release, on average, 15 different VOCs, with the ethanol, acetone, and acetaldehyde being among the dominate chemicals (**Steinemann, 2015**). Fragranced products (e.g., products that smell like lemons or pine), give off VOCs called terpenes (e.g., limonene, α -pinene) among other VOCs. Terpenes chemically react with ozone (also found in indoor air) and can generate a range of secondary pollutants, including formaldehyde and ultrafine particles (Nazaroff, 2004).

Health Outcomes related to Indoor VOC Exposures

People spend most of their time indoors (Klepeis, 2001), and therefore the largest share of VOC exposure often results from the indoor environment. For example, a study evaluating the sources of VOC exposure, showed that exposures in the home were responsible for 42 to 73% of individual's total VOC exposure (Gokhale, 2008). Other areas where people are exposed to VOCs include time spent outdoors, traveling, and at work.

Many VOCs identified in homes have known toxicities, and it is well know that exposure to VOCs are strongly associated with both irritation of the eye, nose and throat irritation and impacts on the central nervous system, like headaches (US EPA, 2012b). The studies specifically evaluating health impacts of VOCs in the home, where overall concentrations may be lower than occupational settings, but the exposures are longer, indicate that residential exposures can result in negative health outcomes. In particular, residential exposure to VOCs has been linked to respiratory symptoms and asthma in young children (Bornehag, 2010; Choi, 2010; Henderson, 2008; Mendell, 2007; Nielson, 2007; Rumchev, 2004).

For example, in a study of children with asthma, VOCs (specifically propylene glycol and glycol ethers) sampled from air in the children's bedroom were associated with exacerbation or inducement of allergic symptoms, asthma, rhinitis, and eczema (Choi, 2010). In addition to studies on children, one study also evaluated the health impacts on pregnant women, where VOCs leaking into homes from contaminated soil under homes were associated with adverse birth outcomes (Forand, 2012).

Methods to Reduce VOC Exposure

While VOCs are consistently identified in residential air, the concentrations of the individual VOCs and what specific VOCs are identified in any one home vary considerably. This variation suggests that there are steps that can be taken to reduce VOCs levels within homes.

Effective strategies to lower indoor VOC levels are remove, replace, or relocate existing products and materials that release VOCs.

- Remove as many sources of the VOCs as possible, for example, using less cleaning products, buying smaller volumes of cleaning products, or storing them in a location outside the home (e.g., garage). Help remove VOCs from the air by increasing ventilation and by using an air purifier with an air cleaning system that includes a carbon filter.
- Replace typical consumer products and building materials with certified "green" products that generate lower VOCs or no VOCs (e.g., low VOC paint). When considering "green" products, care should be taken to evaluate them carefully, as many "green" claims are largely questioned.
- Relocate products that release VOCs to areas that are not inhabited like detached garages and sheds. Also, relocate the use of these products to outdoors, for example, painting furniture outside or in the garage.

As complete removal of products that release VOCs is likely to be impossible, keep in mind that ventilation is particularly important. If the exchange of outdoor air into the home is low, as is the case when homes are closed up due to the use of air conditioning or heating, indoor VOC levels will tend to be higher. Therefore, opening windows when possible will significantly reduce indoor VOC levels. In a study in Canadian homes, indoor VOC levels were about twice as high in the winter months (median concentration 1698 $\mu\text{g}/\text{m}^3$) compared to summer months (median concentration 915 $\mu\text{g}/\text{m}^3$) when windows were more likely to be open (Bari, 2015).

When increased ventilation is not be an option, the use of air filtration may reduce indoor VOC levels. For example, studies have shown that portable air purifier systems with charcoal filters can reduce benzene levels (by 52 to 73%) and nitrogen dioxide levels generated from cooking (Paulin, 2014; Polidori, 2013). These results are consistent with a review of air cleaning technologies that concluded that use of filters such as activated charcoal are effective at removing specific gaseous pollutants such as VOCs (Zhang, 2011).

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