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Reducing chemical exposures at home: opportunities for action

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ABSTRACT

Indoor environments can influence human environmental chemical exposures and, ultimately, public health. Furniture, electronics, personal care and cleaning products, floor coverings and other consumer products contain chemicals that can end up in the indoor air and settled dust. Consumer product chemicals such as phthalates, phenols, flame retardants and per- and polyfluorinated alkyl substances are widely detected in the US general population, including vulnerable populations, and are associated with adverse health effects such as reproductive and endocrine toxicity. We discuss the implications of our recent meta-analysis describing the patterns of chemical exposures and the ubiquity of multiple chemicals in indoor environments. To reduce the likelihood of exposures to these toxic chemicals, we then discuss approaches for exposure mitigation: targeting individual behaviour change, household maintenance and purchasing decisions, consumer advocacy and corporate responsibility in consumer markets, and regulatory action via state/federal policies. There is a need to further develop evidence-based strategies for chemical exposure reduction in each of these areas, given the multi-factorial nature of the problem. Further identifying those at greatest risk; understanding the individual, household and community factors that influence indoor chemical exposures; and developing options for mitigation may substantially improve individuals' exposures and health.

INDOOR ENVIRONMENTS AND POPULATION HEALTH

Humans can be exposed to environmental contaminants from many different sources including the outdoor air, water, diet and the multiple environments where we spend time. Given that people in developed countries spend more than 90% of their time indoors,[1] indoor environments are substantial contributors to human environmental exposures and, ultimately, population health. Consumer products including furniture, electronics, personal care and cleaning products, and floor and wall coverings contain chemicals that can leach, migrate or off-gas from products and end up in indoor air and settled dust.[2 3] People can then inhale these chemicals, ingest small particles of dust containing these chemicals or even absorb these chemicals through their skin.[4] Infants and young children often have the highest exposures because of their activities (eg, hand-to-mouth play on the floor) and physiology (eg, higher breathing rates).[5] Consumer product chemicals such as phthalates, phenols, flame retardants and per- and polyfluorinated alkyl substances (PFASs) are widely detected in the US general population, including vulnerable populations such as pregnant women and children.[6 7]

Exposure to one or more of these chemical classes has been associated with adverse health effects including reproductive harm, endocrine disruption and impaired neurodevelopment in children.[8 9] Consequently, the economic burden of health impacts of endocrine-disrupting chemicals such as phthalates and flame retardants is estimated at more than $300 billion a year in the USA.[10] Many consumers assume that the chemicals in their products have been tested for toxicity before entering the marketplace, but this is a misconception. In most cases, limited pre-market safety testing took place,[11] and the chemical classes we describe here are widely used in common consumer goods despite evidence of potential health risks. Improvement in translating existing evidence into effective exposure reduction interventions is therefore needed.

Our recent meta-analysis of US indoor environments[12] underscores the scale and complexity of human exposure to indoor contaminants. We identified 45 consumer product chemicals from five chemical classes that have been measured in US indoor dust in three or more datasets. Some phthalates, a fragrance chemical, flame retardants and phenols were consistently found in at least 90% of dust samples across multiple studies, indicating ubiquitous presence in indoor environments. We focused on dust because it provides a window into which chemicals are present indoors, and chemical dust concentrations can be used in partitioning models to estimate indoor air concentrations and total residential intake with reasonable accuracy. Dust is a predominant exposure pathway, particularly for children, for some chemicals (eg, flame retardants). In our meta-analysis, phthalates occurred in the highest concentrations, followed by phenols, flame retardant chemicals, a fragrance and PFASs. Several phthalates and flame retardants had the highest residential intake estimates. The findings suggest that people, and especially children, are exposed on a daily basis to multiple chemicals in dust with known or suspected health effects. There is also potential for cumulative impacts since many of the chemicals co-occur in the indoor environment and may contribute to common adverse outcomes. Thus, there are reasons to be concerned about the exposure of the general population to these chemicals, which originate from a wide range of sources.

While it is well established that the physical–chemical properties of these compounds affect their concentration, distribution and lifetimes in any indoor environment,[13] the characteristics of our homes and how we occupy them is the starting point for reducing exposure and risk. Building characteristics, consumer product choices and product usage patterns also have an impact on environmental chemical levels indoors. All of these determinants are potentially modifiable through personal and institutional action.

Specific building materials are known contributors to indoor exposures. For example, homes constructed with polyvinyl chloride floor and wall covering materials have higher indoor levels of phthalates in dust.[14] Particular consumer products brought into the home are also likely to affect indoor environmental quality. Products containing polyurethane foam, such as baby products[15] and older couches,[16] along with electronics and household appliances,[17] are associated with higher flame retardant concentrations in dust. Stain repellent treatments for carpets may contribute to PFAS levels in house dust, and scented cleaning products likely contribute to synthetic fragrance exposures indoors.[3]

Human exposure levels are affected by the prevalence of chemical sources and by the way the environment is used and maintained. For example, in lower socioeconomic status (SES) communities, indoor environmental exposure profiles may be amplified by high outdoor exposure sources, dilapidated housing stock, older furniture, high occupant density and poor ventilation,[18] further exacerbating environmental justice concerns in these communities. Differences in chemical content related to the quality of less expensive furniture and other products may be another pathway by which low SES households experience elevated exposures.[19]

CHEMICAL EXPOSURE REDUCTION STRATEGIES

Because of the relative importance of the indoor environment on total exposures to many chemicals, identifying effective strategies for reducing these exposures may have substantial benefits for occupants. Given the multi-factorial nature of the problem, in this essay, we will discuss strategies that target individuals, households, consumer markets or state/federal policies. While we are relying on strategies that are evidence-based, there are significant data gaps in the effectiveness of these strategies across different populations and chemical classes.[20]

A number of strategies at the individual level have been developed around specific classes of chemicals, and they are likely applicable to other chemical classes with similar sources and physical–chemical properties. In some cases, individuals can alter behaviour to reduce exposures to contaminants already in the home. For example, hand washing, especially before mealtime, substantially reduces exposures to flame retardant chemicals and presumably other semivolatile organic compounds (SVOCs), particularly in children.[21] Making informed choices in personal care products can also reduce personal exposures. Individuals can choose to simplify their routines, thereby eliminating potential exposures (eg, avoiding fragranced products) or identify alternative products without chemicals of concern.[22] Several freely available consumer guides have been created to help consumers identify 'healthier' products in the marketplace; however, while these guides aggregate a tremendous amount of information for the consumer, they are often not price conscious and do not rely on independent testing but are beholden to the same product ingredient labels that have been shown to be inaccurate for some chemicals.[23] Because of these gaps, guides and mobile phone applications (apps) that have been designed to help consumers alter behaviours may be most effective at reducing exposures.

Exposure reduction strategies at the household level are important for all household members, particularly children. Using a damp cloth to wipe down surfaces can reduce dust loading and therefore reduce exposures to contaminants residing in dust.[24] Frequent cleaning of floors with damp mops or vacuums with high-efficiency particulate filters can also reduce dust levels.[25 26] Also, carefully choosing household products and building materials has been shown to be effective. For example, bare floors trap fewer contaminants than carpeted floors,[27] and carpeted floors have been implicated in worsening asthma symptoms.[28] However, children living in homes with phthalate-containing vinyl floors, an alternative to carpet, have worse asthma symptoms than children in homes without vinyl floors.[14 29] With this in mind, transparency in the marketplace is needed so that alternatives to chemicals of concern can be evaluated thoroughly for both efficacy and health impact in order to avoid regrettable substitutions. A regrettable substitution is the replacement of a known toxic chemical with another that proves to also be harmful to human health or the environment.

Unlike for volatile organic compounds, increased ventilation is not typically considered the primary strategy for reducing SVOC exposures indoors due to their physical properties and tendency to partition into non-airborne reservoirs such as household dust.[30 31] However, ventilation has more promise to remove SVOCs adsorbed to airborne particles and to remove fresh airborne emissions for sources that remain in use. While this approach may not effectively remediate levels in dust, it may reduce overall exposure to occupants. Physical–chemical properties and the proportion of chemical mass in air and dust will determine the phase-specific removal rates and ultimate effectiveness of ventilation in reducing exposures to particular SVOCs.[32]

While individual and household level action can be effective in reducing exposures, there are critical limitations. For ubiquitously used chemicals like phthalates, sources of exposure are complex, multiple and partially unknown, and even rigorous modification of product choices and individual actions may not fully reduce exposures.[33] As mentioned above, product label information may be inaccurate; further, in the USA, disclosure of chemical ingredients is not required for a wide variety of products that may contain chemicals of concern, including cleaning products, building materials and furniture. Market and regulatory strategies that can address these limitations are important approaches for population exposure reduction.

Phthalates in cosmetics and children's products have been the target of advocacy campaigns, and certain phthalates were prohibited in toys and childcare articles by legislation in 2008.[34] Analysis of national biomonitoring data shows significant reductions in population exposure to the prohibited phthalates after their partial phase-out. Unfortunately, at the same time, exposures to other phthalate chemicals are on the rise, and these appear to be regrettable substitutions because the substitute phthalates have similar toxicities to the prohibited phthalates.[35] To prevent regrettable substitutions and address emerging chemical concerns, a number of consumer product retailers and manufacturers have committed to removing entire classes of harmful chemicals, such as phthalates, flame retardants and fluorinated chemicals, from their supply chains.[36] Others have increased transparency by disclosing product ingredients online or on labels. Therefore, consumer advocacy targeted at chemicals or classes of concern can lead to meaningful policy change and reduce exposure at the population level.

To provide consumers with better information to make product choices, a number of states including California, Washington, Vermont and Maine have passed laws requiring disclosure of chemicals of concern in furniture or children's products.[37–40] Other states imposed bans on certain flame retardant chemicals in these products.[41] State regulatory actions likely contributed to the significant increase in furniture that did not contain flame retardants seen in recent testing data.[42] States are also developing frameworks for safer chemical substitution.[43] California's Safer Consumer Products Program is first in the nation to attempt to avoid regrettable substitutions with a regulatory requirement for companies to carefully choose the safest alternative to toxic chemicals.[44] Finally, at the federal level, there was a major revision in 2016 to the Toxic Substances Control Act (TSCA), the law that regulates the majority of industrial and consumer product chemicals.[45] Previously, TSCA was widely seen as outdated and ineffective[46]; the new law may result in better protections for human and environmental health, but this depends on how it is implemented. Importantly, state and federal policies restricting toxic chemicals and promoting safer substitutes are applicable across the board to all products, and therefore are an important part of exposure reduction strategies for the general population, especially lower SES communities.

What is already known?

- Indoor environments can influence human environmental chemical exposures and public health.
- Consumer product chemicals such as phthalates, phenols, flame retardants and per- and polyfluorinated alkyl substances are widely detected in the US general population, including vulnerable populations, and are associated with adverse health effects such as reproductive and endocrine toxicity.
- In most cases, although consumers assume chemicals have been tested, limited pre-market safety testing of commercial chemicals occurs.
- The chemical classes we describe here are widely used in common consumer goods despite evidence of potential health risks.

What this study adds?

- We recommend a multi-pronged strategy to reduce exposures to toxic chemicals that includes: targeting individual behaviour change, household maintenance and purchasing decisions, consumer advocacy and corporate responsibility in consumer markets, and regulatory action via state/federal policies.
- We call for major advancements in translating existing scientific evidence into effective exposure reduction interventions.
- Future research should further assess who is at greatest risk from these household environmental chemical exposures, the individual and community factors that influence these exposures, the available options for mitigation, and their effectiveness.
- To achieve the potential benefits to human health from research and mitigation, we need input from public, private and non-governmental sectors.

THE WAY FORWARD

The environmental health research community has devoted substantial resources to characterising human exposure and health effects of chemicals from consumer products and other in-home sources. On the basis of accumulated robust evidence of exposures and adverse health impacts related to environmental chemicals, health professionals, environmental health scientists and public health advocates have issued calls to action to prevent exposures to environmental chemicals that may threaten healthy reproduction and/or neurodevelopment.[47 48] It is now time to devote resources to developing evidence-based strategies for chemical exposure reduction. Effective and efficient interventions are needed at the individual, local, federal and global level and will likely have to be tailored to specific communities. In order to develop those interventions, we need a better understanding of who is at greatest risk, the individual and community factors that influence these exposures, and the available options for mitigation. One way to address these data gaps is through a deeper investigation of outliers, which often reflect unique sources of exposure among a few individuals. Another way is to increase the diversity of households in population health studies of consumer product chemicals along socioeconomic, racial, ethnic and geographical dimensions. Collectively, these approaches could help us identify and test effective strategies for exposure reduction, thereby increasing the evidence base for policy or action. Additional solutions-oriented research as well as cooperation and creativity from the public, private and non-governmental sectors have the potential to result in substantial benefits for human health.

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