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# Green Buildings and Indoor Air Quality: Lessons Learned from Household Exposure Studies

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## Introduction

•Standards for green building projects do not adequately consider effects on indoor environmental quality and health.

•People spend over 80% of their time indoors (Kleipeis, et al., 2001) and chemical concentrations indoors tend to be higher (Rudel, *et al.*, 2003; Rudel and Perovich, 2009).

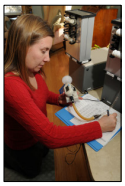
•Semivolatile organic compounds (SVOCs) are constantly released from indoor sources and can be found in indoor air and house dust, which acts as a reservoir and exposure pathway (Weschler and Nazaroff, 2008 and Weschler, 2009).

•Many SVOCs used in building materials, furnishings, and consumer products are classified as endocrine disrupting compounds (EDCs) because they interfere with hormones.

•Over 400 SVOCs have tentatively been identified in indoor air (Gale, *et al.,* 2009).

•Chemicals in house dust have been associated with health effects in some studies (Colt, *et al.,* 2005; Ward, *et al.,* 2009*).*

## Household Exposure Studies



**Cape Cod Household Exposure Study**

- •89 EDCs, including phthalates, alkylphenols, parabens, flame retardants, PCBs, and current-use and banned pesticides
- •Air and dust samples from 120 homes
- •First to report concentrations for over 30 suspected EDCs
- •67 EDCs detected in homes, averaging 24 per home

**California Household Exposure Study**

- •106 EDCs analzed in indoor air, outdoor air, and dust from 50 homes
- •66 target EDCs in indoor air, 42 in outdoor air, and 58 in house dust detected above method reporting limits
- •20 EDCs at significantly higher concentrations in indoor air than outdoor air

The green building movement provides a unique opportunity to translate lessons learned from household exposure studies to improve indoor air quality and health.

## Resources

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## Lessons Learned

### Building materials and furnishings containing vinyl (PVC) are a likely source of high phthalate concentrations

Phthalates, a class of EDCs associated with asthma and reproductive and developmental disorders (Bornehag, *et al.*, 2004; Swan, 2008), are among the most abundant EDCs in household air and dust, and in our household exposure studies were detected in every home. Maximum concentrations of DEHP – a primary phthalate plasticizer in vinyl – approached 8 mg/g in dust (Rudel, *et al.*, 2003).

Table 1. Most abundant chemicals (from Rudel, *et al., 2003)*

| Ten Chemicals with Highest 90th Percentile Concentrations | |
|---|---|
| air (ng/m³)[a] | dust (μg/g)[a] |
| diethyl phthalate (1,600) *100* | bis(2-ethylhexyl) phthalate (854) *100* |
| *o*-phenylphenol (440) *100* | benzyl butyl phthalate (277) *100* |
| di-*n*-butyl phthalate (430) *100* | di-*n*-butyl phthalate (43.9) *98* |
| 4-nonylphenol (230) *100* | nonylphenol diethoxylate (18.9) *86* |
| bis(2-ethylhexyl) phthalate (210) *68* | bis(2-ethylhexyl) adipate (16.6) *100* |
| diisobutyl phthalate (150) *100* | *trans*-permethrin (16.5) *53* |
| benzyl butyl phthalate (68) *44* | piperonyl butoxide (15.1) *66* |
| 4-*tert*-butylphenol (43) *100* | diethyl phthalate (10.8) *89* |
| nonylphenol monoethoxylate (41) *95* | nonylphenol monoethoxylate (8.55) *86* |
| bis(2-ethylhexyl) adipate (22) *99* | *cis*-permethrin (7.04) *45* |

[a] Percent detection in italics

### Brominated or chlorinated flame retardants in building materials and furnishings result in higher concentrations in homes and occupants

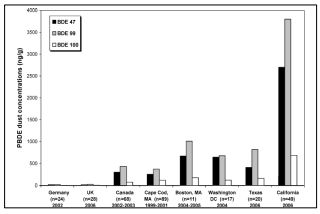


Figure 1. Median concentrations (ng/g) of BDE-47, -99, -100 in household dust from different locations. (Zota, *et al.*, 2008)

Many halogenated flame retardants are classfied as carcinogens or may lead to neurodevelopmental, reproductive or thyroid disruption effects (Lorber, 2008). Polybrominated biphenyl ethers (PBDEs) are a class of flame retardants used in polyurethane foam, textiles, plastics and electronic equipment. House dust penta-BDE levels are approximately 10 times higher in CA than elsewhere in US, likely due to stricter furniture flammability standards in CA's Technical Bulletin 117.

### Stain-resistant fabric treatments can release highly-persistent perfluorinated compounds

Stain-resistant fabric treatments are often made with perfluorinated compounds, which have been associated with cancer and reproductive and developmental effects (Betts, 2007). While perfluorooctane sulfonic acid (PFOS) is no longer produced by 3M Company, previously the sole producer, other polyfluorinated compounds continue to be produced and are often applied to furnishings and textiles for stain resistance and oil/water repellence (Betts, 2007). Manufacturers have promised to phase out a major perfluorinated compound, perfluorooctanoic acid, by 2015 (US EPA, 2009).

### Historically widely used floor finish likely source of PCBs

In our studies we found high levels of PCBs in a few residential air and dust and blood samples, and determined the likely source was a wood floor finish, Fabulon Bowling Alley Finish, widely used in the 1950s and 1960s (Rudel, *et al.*, 2008). Reclaimed building materials should be screened for previously banned chemicals such as PCBs and lead.

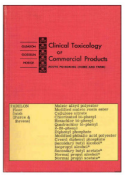


Figure 2. Entry for Fabulon floor finish from 1957 edition of Gleason et al. *Clinical Toxicology of Commercial Products* lists PCBs among the ingredients.

## Implementing Lessons Learned

### Expand indoor environmental quality considerations in building standards

Green building standards, such as the USGBC's LEED Standards and Green Globes, should more explicitly incorporate exposures to EDCs, which often exist as mixtures and act cumulatively. Also, exposures to EDCs need to be incorporated into various third-party certificate programs that are used to meet the standards (Bounds, 2009) as well as screening criteria for reclaimed materials. Criteria should be aimed at reducing the exposure burden to EDCs rather than establishing chemical-specific thresholds.

### Modernize US chemical policies

Rational decisions about green building materials can benefit from improved access to information. Chemical composition of products is not currently specified, chemicals are not evaluated for health effects, and exposures during product use are unknown. Furthermore, when one chemical is banned or withdrawn because of safety concerns, it is often replaced with other chemicals whose safety has not been evaluated. This recurring problem illustrates the limitations of current US regulations governing chemicals in commerce, and presents a barrier to achieving sustainability (Wilson and Schwarzman, 2009). Therefore, the green building and green chemistry movements, both of which can have substantial impact on improving public health, must develop in concert and promote one another.

### Beyond green buildings: Green the occupants

Rating systems need to move beyond as-designed criteria and also incorporate post-occupancy conditions. Occupant education programs and continued indoor monitoring, both areas of potential active research, will help protect occupant health over the lifetime of the building.

## Conclusions

Lessons from indoor environmental quality research can help builders think beyond existing standards to reduce exposures to potential harmful building materials and protect occupant health. Improved and validated certificate programs and green building standards can improve public environmental health and motivate modernization of US chemical policies.

## Acknowledgements

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