A Case for Safer Building Materials:
Lifecycle Concerns, Data Gaps, and Precautionary Decision-making

Ted Schettler MD, MPH

Science and Environmental Health Network

Berkeley CA

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Topics

- Growing variety of building materials
- Exposures to chemical ingredients
- Hazard information; examples
- Health-related consequences throughout the product life cycle
  - Material manufacturers, construction workers, occupants, end of life considerations
  - Focus on chemicals; not radiation, mold, pests, etc.
- Data gaps; precautionary decision-making

Rationale for considering health and environmental impacts of buildings

- Use 40% of raw material globally (3 billion tons annually)
- Consume 65% of total U.S. electricity
- Construction and operations responsible for ~45% of total U.S. greenhouse gas emissions (includes electricity use)
- Building construction accounts for about 2-3% of chemical use in US

Conventional Building Materials

- Wood
- Stone
- Cement
- Metal
- Glass
- Straw
- Ceramics

Synthetic Building Materials

- Adhesives
- Sealants
- Caulks
- Paints
- Foams
- Binders
- Insulation
- Wood composites
- Wallpapers
- Carpets
- Plastics
- New kinds of concrete

Synthetic building materials

- Protective coatings, sealers, caulks and adhesives are the largest segments
- Others: cement and asphalt additives (rapidly growing), grout and mortar, polymer flooring, sprayed polyurethane foam
- $7.7 billion annually in US; 3.4% annual growth

Synthetic building materials

- Many are complex mixtures of multiple chemicals designed primarily for function and performance
- Many constituents are known hazards
- Others are inadequately tested for safety
- Exposures throughout the life cycle often poorly characterized

Who/what is at risk of exposure?

- Materials and product manufacturers
- Fence line communities
- Construction workers
- Building occupants
- End-of-life (discarded construction debris, recycled material)

Workers, families, communities, wildlife, general environment

Exposure pathways

- Dermal contact and absorption
- Inhalation
- Ingestion
  - Hand to mouth transfer
  - Dust ingestion: especially children
    - phthalates, alkylphenols, brominated flame retardants, organo-tins, other metals, perfluorinated surfactants, bisphenol A, etc.
  - Diet

Determinants of indoor environmental quality

- Temperature; temperature gradients; microenvironments
- Heating and ventilation
- Dampness and humidity
- Chemicals in building materials
- VOCs have received most attention until now
- Maintenance: e.g. cleaning materials and practices; pest control

Volatile organic compounds (VOCs)

- Aliphatic hydrocarbons, aromatic hydrocarbons, halogenated hydrocarbons, alcohols, ketones, aldehydes, esters, ethers, terpenes
- Examples: formaldehyde, toluene, xylene, benzene
- Generally highest soon after manufacture and construction
- Novel compounds formed by chemical reactions on site
- Contribute to building-related symptoms; "sick building syndrome"

Indoor sources of VOCs

- Consumer and commercial products—cleaning agents, pesticides, office supplies, etc.
- Paints and associated supplies
- Adhesives
- Building materials
- Furnishings and clothing
- Combustion appliances
- Outdoor air pollutants

Examples of Chemicals of Concern

Material	Chemicals	Life-cycle hazard concerns
Foam Insulation: polystyrene, polyurethane	styrene Isocyanates	Reasonably anticipated to be a carcinogen; asthmagen asthmagen
Paints, coatings	cadmium, cobalt, VOCs	developmental toxicants, neurotoxicants
Binders, laminates, particle board	Phenol-, urea-, melamine-formaldehyde resins	carcinogen, neurotoxin, skin irritant, asthmagen
Sealants, adhesives	Various resins, curing agents, solvents	Likely carcinogens, endocrine disruptors, reproductive/developmental toxicants, asthmagens
Carpets, windows, doors, wall coverings	phthalates, flame retardants	developmental toxicants, endocrine disruption
Roofing, flashing	lead	reproductive -, neuro-toxicity
Textiles, furnishings, insulating foam	brominated flame retardants	endocrine disruption, neurodevelopmental toxicity

Occupational asthma

- Estimated to represent 10-25% of cases of new onset asthma in the US; often unrecognized
- Sensitizer induced
  - High molecular weight compounds (e.g. animal allergens, latex, etc.)
  - Low molecular weight compounds (e.g. isocyanates)
- Irritant induced
- Mixed
- Significant problem in many industries
- What about the general public?

Asthmagens

- In foam insulation, paints, adhesives, floors and carpets, or other interior materials
  - Acid anhydrides (hardeners in epoxy resins, powder paints)
  - Acrylates (paints, coatings, plastic polymers)
  - Ammonium hydroxide (chalkboard paints, acrylic adhesives)
  - Bisphenol A diglycidyl ether [BADGE] (resins, adhesives)
  - Ethanolamines (cleaners, flexible foam mfg., coatings, etc)
  - Formaldehyde (phenol-formaldehyde resin)
  - Isocyanates (urethane spray foam, hardeners in urethane paints and adhesives)
  - Polyfunctional aziridine (hardening agent)
  - Styrene (carpets, rubber flooring, polystyrene insulation)
  - Phthalates (suspected)

Flame retardants

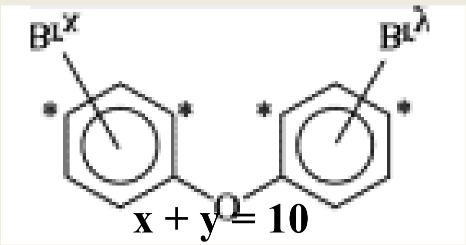
- Halogenated flame retardants (with bromine or chlorine)
  - PBDEs, TBBPA, HBCD, chlorinated tris (TDCP, TCEP), Declorane plus
- Phosphorus based
- Nitrogen based
- Inorganic (e.g. aluminum, magnesium oxides)

Halogenated flame retardants

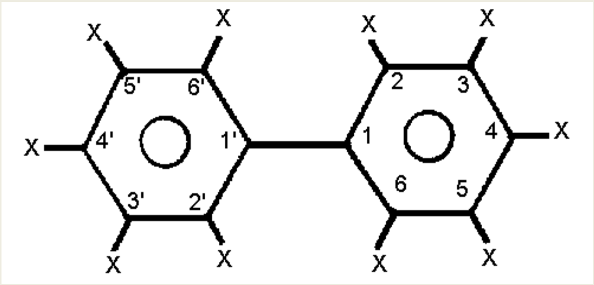
- Polybrominated diphenyl ethers (PBDEs)
  - In humans, associations with:
    - Neurodevelopmental toxicity
    - Thyroid disruption
    - Abnormal reproductive tract development
    - Increased time to pregnancy
  - decaBDE: possible human carcinogen (EPA)

Some of the most commonly used BFRs resemble PCBs

Over 150 million pounds produced annually until recently



PBDEs



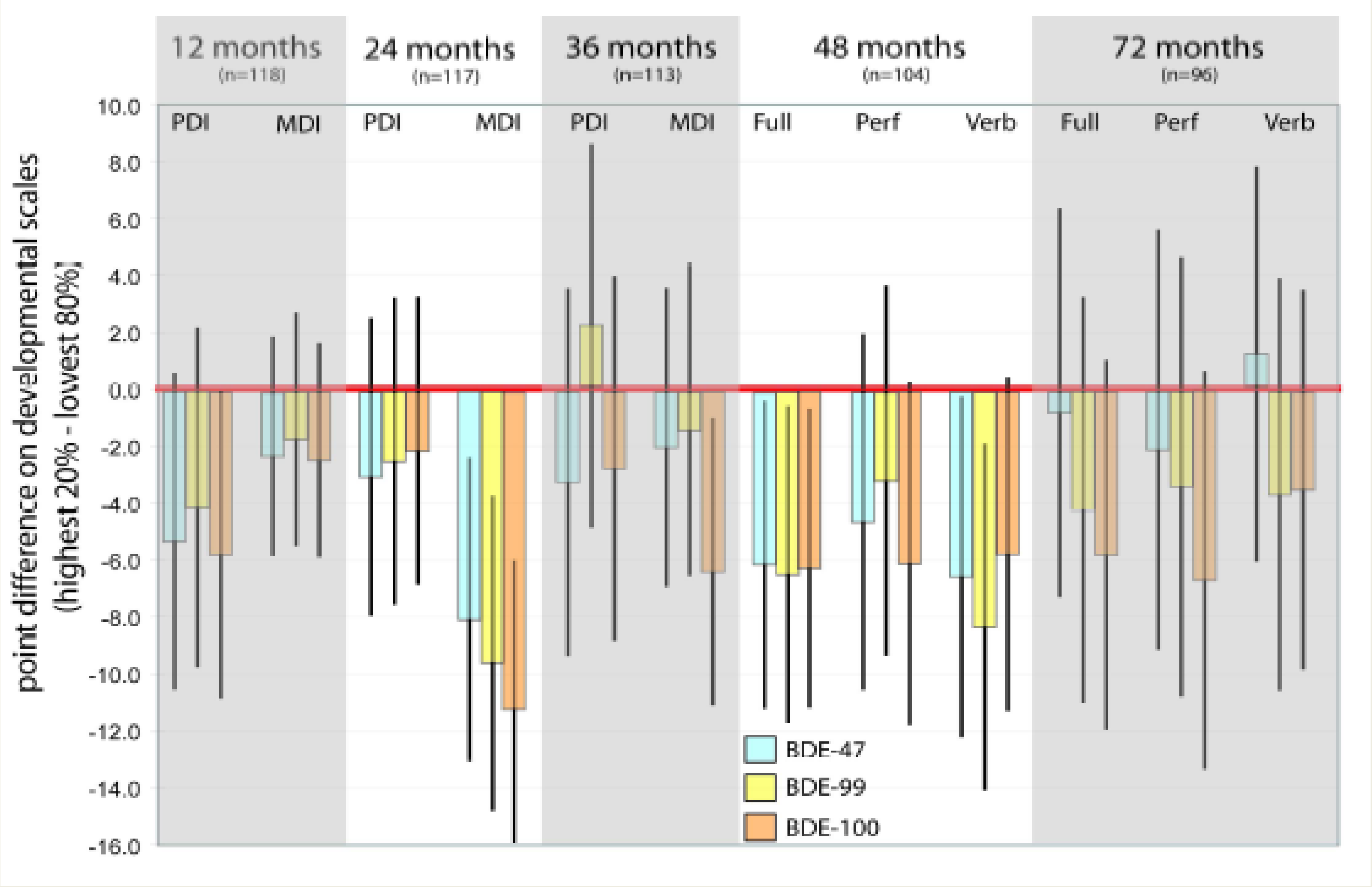
PCBs

Production banned in 1977;
Neurodevelopmental toxicity concerns began to surface in early 1980s;

Multiple longitudinal studies in cohorts around the world confirm adverse impacts on developing brains of children

Prenatal exposure to PBDEs and neurodevelopment

n = 329; adjusted for multiple confounders; co-variables; effect modifiers; Bayley Scales of Infant Development; Wechsler Scale of Intelligence



Herbstman, EHP, Jan 2010

Replacement HFRs

- *hexabromocyclododecane (*HBCD): persistent organic pollutant (POP); developmental neurotoxicant; UN recommends phase out (used in polystyrene foam insulation; worker/occupant exposures [dust])
- Chlorinated tris and related compounds: neurotoxic, probably carcinogenic, inadequately tested (used in foam, furniture)
- Newer flame retardants showing up in household dust (Dodson, EST, 2012)
- Sources and toxicity often not well understood

Polyurethane foams

- Two part system:
  - Amines, glycols, and phosphate (toxicity variable and for some, unknown)
  - Isocyanates (toluene diisocyanate (TDI), methylene diphenyl diisocyanate (MDI), others
- Curing time is variable (hours to days)
- Isocyanates: respiratory tract sensitizers; MDI less volatile than TDI; respiratory exposures, dermal absorption (workers, occupants)
- Isocyanate-free polyurethane foams being developed

Polyvinylchloride (PVC)

- Polymer of vinyl chloride (a carcinogen)
- Includes additives: stabilizers (metals; e.g.Pb, organotins, Cd), anti-oxidants, pigments, plasticzers (e.g. phthalates), flame retardants depending on application
- Siding, roof material, flooring, pipes, wall coverings, interior furnishings

PVC

- Manufacture:
  - chlorine plus ethylene > ethylene dichloride (EDC) (reasonably anticipated carcinogen)
  - EDC > vinyl chloride (carcinogen)
  - Toxic organochlorine compounds in waste stream
  - Worker exposures (incl. phthalates [Fong, 2014])
- Use: concerns about exposure to plasticizers (e.g. phthalates) and metal stabilizers
  - PVC flooring, wall coverings, phthalate levels and asthma, wheezing, allergic symptoms

(Jaakkola, 2004; Oie, 1999; Bornehag, 2004; Tuomainen, 2004; Shu 2013)

PVC

- Disposal: accidental or intentional burning > dioxins, furans, other toxic organochlorine substances (PBTs)
- Accidents: vinyl chloride; chlorine gas
- Difficult to recycle

Epoxy resin: (BADGE) bisphenol A diglycidyl ether

- BPA plus epichlorohydrin > BADGE
- Varying proportions > low- and high-molecular weight resins
- Other additives depending on the application
- Uses: High performance paints, coatings, adhesives

BADGE

- BPA: endocrine disruptor; multiple estrogen-like and effects that differ from estrogen
- Epichlorohydrin: probably carcinogenic to humans (IARC group 2A); reproductive toxicity (prop 65)
- Workers exposed to BADGE have higher levels of BPA in urine as a result of metabolism
- Association with lower sex hormone levels (Zhou, 2013)
- Indoor dust contaminated with BPA and BPA-analogues; sources unclear; exposures estimated 2-13 ng/kg/day; highest in toddlers (Liao, 2012)

Can we rely on government standards?

- Regulations and standards only cover a small proportion of chemicals in products
- Many occupational and consumer product health standards are out of date
- Most standards are risk-based relying on exposure controls rather than hazard prevention
- Government enforcement is limited
- Increasingly responsibility for chemical safety is shifting to the market

Risk- vs. hazard-based approaches

- Long-standing, inherent tension
- Historic privileging of function, performance, cost in building materials
- Health concerns have typically been addressed by efforts at exposure control rather than hazard elimination
- Alternatives assessment methods: contested territory

Hierarchy of hazard controls:

A basic principle of occupational safety and health

- In order of decreasing effectiveness:
  - Elimination
  - Substitution
  - Engineering
  - Administration
  - Personal protective equipment

Hazard-based Alternatives Assessment

- A process for identifying and comparing potential chemical and non-chemical alternatives that could replace chemicals or technologies of concern on the basis of their hazards, performance, and economic viability

- Avoid regrettable substitution!

Chemical Information Transparency

- Identifying chemicals in products and materials is not easy
  - Chemical information does not readily flow in supply chains
  - Businesses are often reluctant to disclose chemical information for both competitive and liability reasons
  - Chemical information is often difficult to interpret

- We need new chemical information disclosure systems:
  - To identify chemicals in products and materials
  - To track the use of those chemicals throughout product and material lifecycles

Safer Building Materials

- Many safer building materials and products are already available ; e.g. low VOC paints, PVC-free carpeting, formaldehyde-free fiber board, water based caulks, etc.
- Architects and designers can encourage safer materials and products through <u>informed and targeted specifications</u>
- Suppliers can and will respond if the demand is strong enough.
- Selecting safer materials will require increased focus on:
  - Transparency
  - Disclosure
  - Attention to hazards
  - Assessment of alternatives

An upstream, precautionary approach to safer materials

- When possible, eliminate hazards in chemicals, materials, and products by preferentially purchasing safer alternatives.
- Consider entire lifecycle
- Untested chemicals and materials should not be presumed to be safe; require data
- Act on early warnings; learn from old lessons

Acknowledgement

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