

An aerial night photograph of a city, likely Berkeley, California, showing a large domed building in the foreground and a dense urban area extending to the coast. The sky is a gradient of blue and yellow, suggesting dusk or dawn.

# **Indoor Residential Chemical Emissions as Risk Factors for Children's Respiratory Health**

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**Thanks to Al Hodgson for help understanding indoor chemicals.**

# Indoor Residential Chemical Emissions and Children's Health

- ❑ Introduction
- ❑ Available findings: indoor concentrations & sources
- ❑ Ventilation as modifier for risks from indoor sources
- ❑ Evaluation
- ❑ Existing conditions vs. risks
- ❑ Implications



# Indoor Residential Chemical Emissions and Children's Health

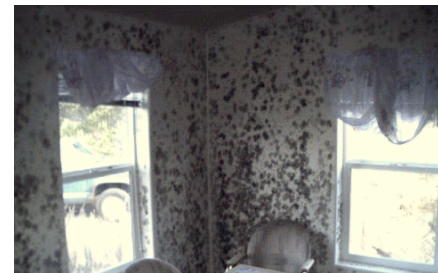
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# Indoor Chemical Emissions and Children's Health -- Introduction

## □ U.S. research on respiratory health effects of residential indoor air primarily on:

- allergens (dust mites, cockroach, animal dander)
- mold, moisture, endotoxin
- combustion products (ETS, cookstoves, heaters, outdoor pollutants)



# Indoor Chemical Emissions and Children's Health -- Introduction

- However, recent research outside U.S. shows associations between respiratory / allergic health effects and
  - indoor concentrations of chemicals
  - common indoor materials and finishes
- Most research, and strongest findings, in children
- Diverse findings not yet summarized

# Indoor Residential Chemical Emissions and Children's Health

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- ❑ **Available findings: indoor concentrations & sources**
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# Indoor Chemical Emissions and Children's Health – Available Findings

- Reported risk factors in 20 recent studies (last 10 yrs, except 2 U.S. 1989-90)
  - specific organic compounds –
    - formaldehyde
    - plasticizers
    - aromatic compounds
    - aliphatic compounds
  - indoor finishes or materials –
    - particleboard
    - flexible flooring and plastics
    - paint
    - carpet
    - Renovation
  - excluded ETS, combustion . . .





# Indoor Chemical Emissions and Children's Health: Available Findings



## ❑ Associated outcomes

- ❑ asthma-related
- ❑ allergy-related
- ❑ altered T-cell cytokine profiles
- ❑ pulmonary infections

# Indoor Chemical Emissions and Children's Health: Table 1a. Odds Ratios (OR) from Reported Studies

Risk Factors	Outcomes	
	Asthma-Related	Allergy/Atopy
<b>Plasticizers or Plastics</b>	<b>OR = 1.0 – 12.6*</b> (1.0, 1.1, 1.4*, 1.4*, 1.5, 1.9*, 1.9*, 2.4*, 2.9, 2.9*, 3.4*, 12.6*)	<b>OR = 1.3* – 3.0*</b> (1.3*, 1.6*, 2.0*, 2.6*, 3.0*)
<b>Formaldehyde or Composite Wood</b>	<b>OR = 1.2 - 8.0*</b> (1.2, 1.3, 1.3, 1.4, 1.4*, 1.4*, 1.4*, 1.6, 1.7*, 1.8*, 2.0*, 8.0*)	<b>OR = 1.5* - 4.1</b> (1.5*, 1.8, 2.4, 4.1)
<b>Paint or Painting</b>	<b>OR = 1.1 – 4.1*</b> (1.1, 1.2, 1.3, 1.7*, 1.9*, 4.1*, 4.1*)	<b>OR = 1.2*</b> (1.2*)

**KEY:** RANGE of ORs  
(specific reported ORs)

\* p-value <0.05



# Indoor Chemical Emissions and Children's Health: Table 1b. Odds Ratios (OR) from Reported Studies

Risk Factors	Outcomes		
	Asthma-Related	Allergy/Atopy	Altered T-Cell Cytokine Expression
<b>Aromatic VOCs</b>	<b>OR = 1.2*-10*</b>  (1.2*, 1.3*, 2.4*, 6.4*, 8.0*, 10*, 10*)	<b>OR = 3.0*-16*</b>  (3.0*, 3.3*, 3.6*, 5.0*, 5.9*, 5.9*, 8.0*, 9.3*, 11*, 13*, 16*)	<b>OR = 2.9*</b>  (2.9*)
<b>Non-aromatic VOCs</b>		<b>OR = 8.1*-16*</b>  (8.1*, 9.6*, 13*, 16*)	<b>OR = 2.9*-23*</b>  (2.9*, 3.3*, 14*, 20*, 23*)

**KEY:**      **RANGE of ORs**  
(specific reported ORs)

\* p-value <0.05



# Indoor Chemical Emissions and Children's Health: Available Findings

- ❑ Many specific risk factor/health outcome associations only single findings
- ❑ Most frequently identified risk factors:
  - ❑ Formaldehyde or particleboard
  - ❑ Plasticizers or plastic materials
  - ❑ Recent painting
- ❑ Selected single findings of interest
  - ❑ Aliphatic hydrocarbons (unclear interpretation)
  - ❑ Aromatic compounds (~ETS, vehicle emission?)

# Indoor Chemical Emissions and Children's Health: Specific Available Findings

## □ Risk factor

- Higher formaldehyde concentrations (>20, 22, 30, 36, 60, 61, 73  $\mu\text{g}/\text{m}^3$ ) or presence of particleboard

## □ → increased

- diagnosed asthma (3 studies)
- diagnosed chronic bronchitis (1 study)
- exhaled nitric oxide (1 study)
- wheeze, presence or frequency (2 studies)
- respiratory symptoms (1 study; not in 2)
- adverse changes in lung function (2 studies; not in 1)
- atopy or allergy (2 studies)

# Indoor Chemical Emissions and Children's Health: Specific Available Findings

## □ Example findings for formaldehyde

- Emergency treatment for asthma increased by 39% at formaldehyde concentrations  $>60 \mu\text{g}/\text{m}^3$ , or by an estimated 3% per  $10 \mu\text{g}/\text{m}^3$  increase over the observed range (Rumchev 2002)
- Proportion of diagnosed asthmatic children, in categories of peak indoor formaldehyde of  $<20$ ,  $20-50$ , and  $>50 \mu\text{g}/\text{m}^3$ , were 16%, 39%, and 44%, but  $p>0.05$  (Garrett 1999)

# Indoor Chemical Emissions and Children's Health: Specific Available Findings

## □ Risk factor

- Higher phthalate dust concentrations (BBzP >0.25 mg/g, DEHP >0.13 mg/g) or presence of plastic surfaces

## □ → increased

- diagnosed asthma (ns, 2 studies)
- bronchial obstruction (1 study)
- wheeze (2 studies; not in 1)
- cough (1 study)
- phlegm (1 study)
- allergy (2 studies)
- rhinitis (1 study)
- eczema (1 study)

**BBzP**= n-butyl benzyl phthalate

**DEHP**= diethyl hexyl phthalate

# Indoor Chemical Emissions and Children's Health: Specific Available Findings

## □ Risk factor

### □ Recent painting or renovation

## □ → increased

- wheeze (4 studies)
- obstructive bronchitis (1 study)
- pulmonary infection (1 study)
- allergy (2 studies)



# Indoor Chemical Emissions and Children's Health: Specific Available Findings

## □ Risk factor

- Higher concentrations of specific aliphatic hydrocarbon compounds (many intercorrelated)

## □ → increased

- food-specific IgE (1 study)  
(hexane, nonane, decane)
- T-cell cytokine expression → Th2 (1 study)  
(heptane, nonane, decane, dodecane)

# Indoor Chemical Emissions and Children's Health: Specific Available Findings

## □ Risk factor

- Higher concentrations of specific aromatic compounds (many intercorrelated)

## □ → increased

- diagnosed asthma (1 study)  
(benzene, toluene, dichlorobenzene, total aromatics)
- food-specific IgE (1 study)  
(toluene, m,p-xylene, 4-ethyltoluene, chlorobenzene)
- pulmonary infections (1 study)  
(benzene; styrene, not correlated with ETS)

# Indoor Chemical Emissions and Children's Health: Available Findings

## Strong associations for indoor materials / activities

Risk Factor	Age of Subjects	Outcome	Odds Ratio
Recent painting of newborn's room	6 wks	Pulmonary infections	5.6
Redecoration	up to age 2	Obstructive bronchitis	4.1
Plastic surfaces	up to age 2	Bronchial obstruction	2.9

# Indoor Chemical Emissions and Children's Health: Available Findings

## Strong associations for indoor chemical concentrations

Risk Factor	Age of Subjects	Outcome	Odds Ratio
<b>Formaldehyde</b> ( > 75 $\mu\text{g}/\text{m}^3$ )	6-15 yrs	Chronic bronchitis	8
<b>Decane</b> ( > 5.7 $\mu\text{g}/\text{m}^3$ )	3 yrs	Increased IgE, milk	9.6
	3 yrs	Reduced IFN- $\gamma$ producing T-cells	22.8
<b>Benzene</b> (above median)	6 mo-3 yrs	Diagnosed asthma	8
<b>DEHP in dust</b> (top quartile)	1-6 yrs	Diagnosed asthma	2.9

# Indoor Chemical Emissions and Children's Health: Available Findings

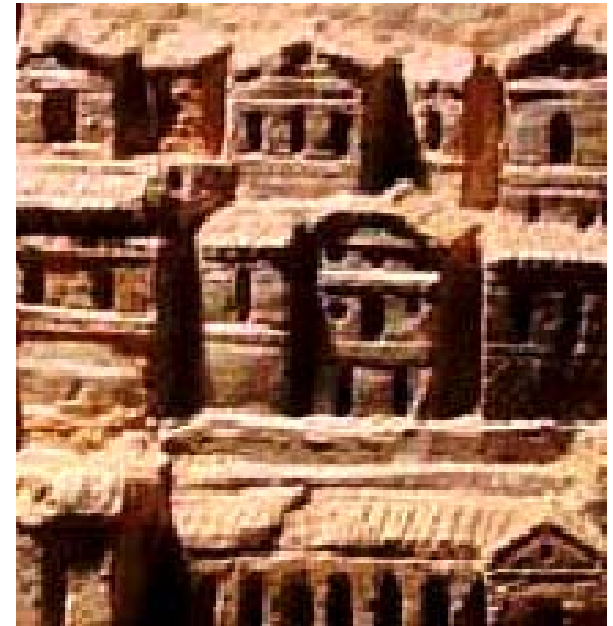
- ❑ **Example study of strong design:**
  - ❑ Oie, L, et al., Ventilation in homes and bronchial obstruction in young children. *Epidemiology*, 1999. 10:294-9.
  - ❑ Jaakkola, JJ, et al., Interior surface materials in the home and the development of bronchial obstruction in young children in Oslo, Norway. *Am J Public Health*, 1999. 89:188-92.
- ❑ **Nested case control study in infants 0-2 years old -- development of bronchial obstruction, w/excellent case ascertainment + validation**
- ❑ **Standardized environmental assessment**
  - ❑ **a priori index of child exposure to plasticizer emissions from indoor surfaces**
  - ❑ **ventilation measurements w/passive tracers**
- ❑ **Rigorous analysis adjusting for many confounders**

# Indoor Chemical Emissions and Children's Health: Available Findings

- **Results (Oie et al. 1999 and Jaakkola et al. 1999)**
  - **Plasticizer exposure index had dose-response relationship with risk of bronchial obstruction**
    - Categorical (below median, 3<sup>rd</sup> quartile, 4<sup>th</sup> quartile)  
ORs = 1.0, 1.34, 2.70\*
    - Continuous (per unit increase on 1-8 scale)  
OR = 1.65\*
    - For PVC flooring, OR=1.90\*
    - For PVC wallpaper, OR=0.72
  - **Risk of plasticizer exposure increased in homes with low ventilation rate (to be described)**

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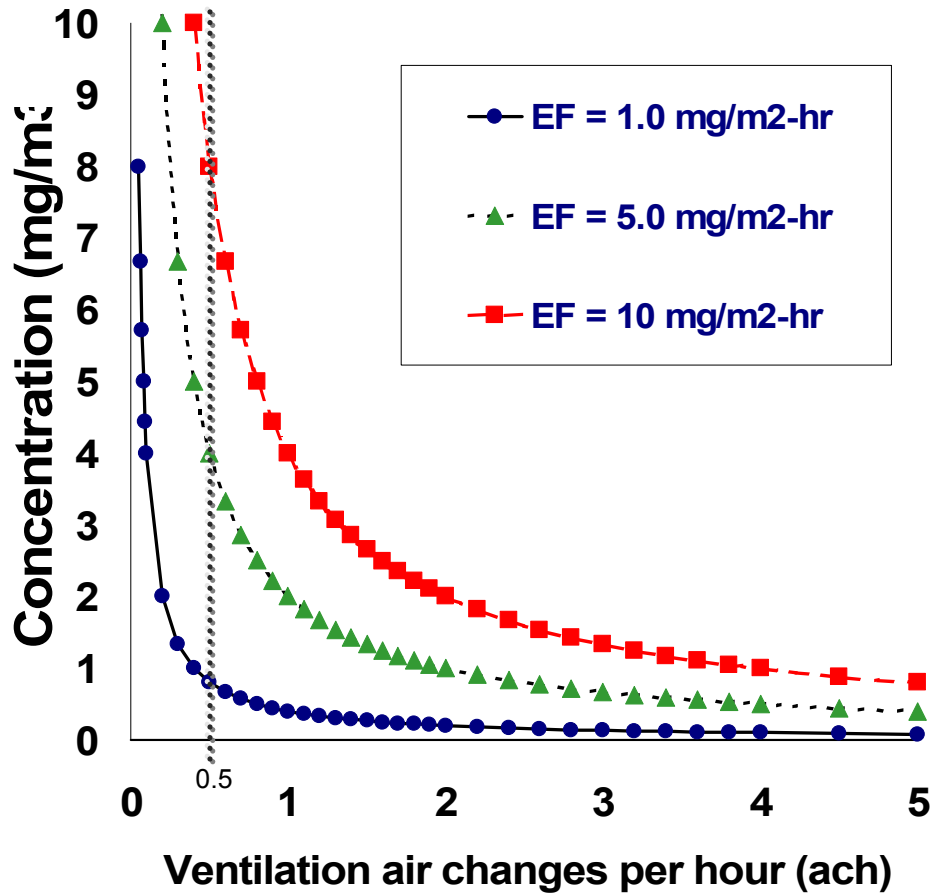
# **Indoor Chemical Emissions and Children's Health: Ventilation as modifier of risks from indoor sources**

- Risks from sources of indoor chemical emissions expected to increase at lower ventilation rates, because indoor concentrations would increase.**



# Indoor Chemical Emissions and Children's Health:

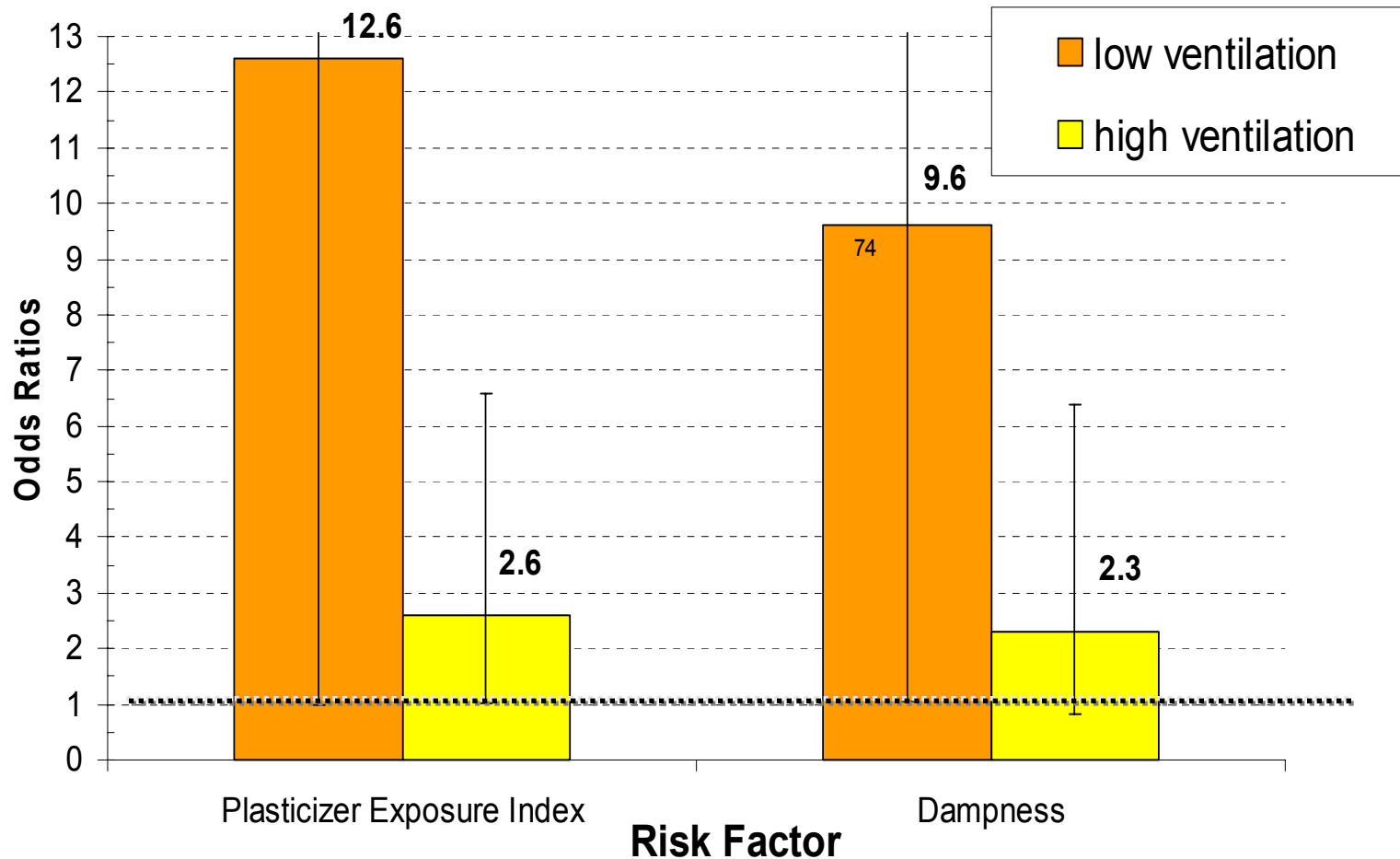
Modeled indoor air concentration of a chemical compound as ventilation rate varies, for different emission strengths (H. Levin)



# Indoor Chemical Emissions and Children's Health: Ventilation as modifier of risks from indoor sources

- ❑ Oie et al (1999) found the risk of bronchial obstruction in infants associated with indoor plasticizer-emitting materials was greatly *increased* in homes with low ventilation rates (less than 0.5 / hour)

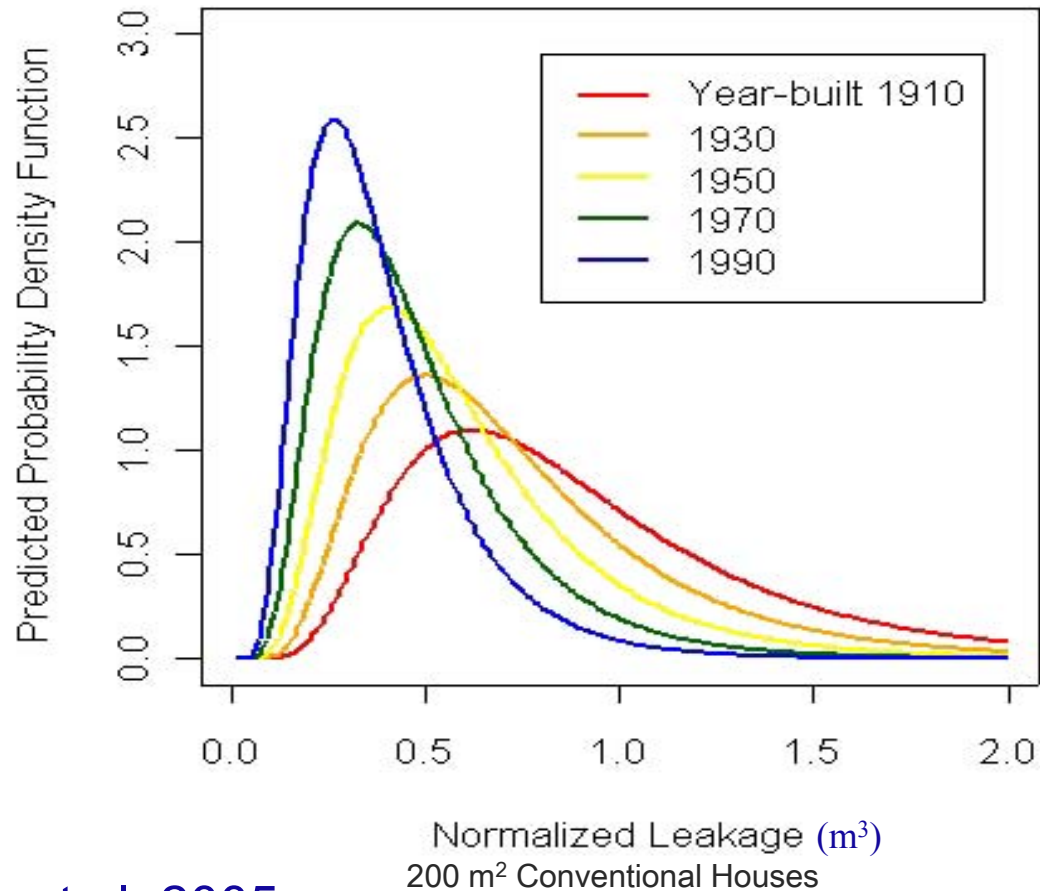
# Indoor Sources as Risks for Bronchial Obstruction in Infants, and Risk Modification by Residential Ventilation Rate (Oie et al. 1999)



# **Indoor Chemical Emissions and Children's Health: Ventilation as modifier of risks from indoor sources**

- Home ventilation rates decreasing over time, as newer houses built more tightly and older houses tightened, to save energy**
- Thus, average exposures from even unchanging sources likely to continue increasing over time**

# Evidence that Houses are Becoming More Air Tight: U.S. Houses 1910-1990\*



\* WR Chan et al, 2005

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# Indoor Chemical Emissions and Children's Health: Evaluation 1

## Explanation of findings?

- ❑ **Causal relationships with studied risk factors ??**
- ❑ **Strong correlation with unmeasured causal indoor exposures**
- ❑ **Confounding by non-indoor factors (SES . . . ?)**
- ❑ **Reporting bias on activities/materials (only for subjective reports in retrospective or cross-sect)**
- ❑ **Systematic measurement error**
- ❑ **Chance findings among multiple comparisons**

# Indoor Chemical Emissions and Children's Health: Evaluation 2

## ❑ Weaknesses

- ❑ All studies observational, with usual weaknesses
- ❑ multiple findings for only a few specific relationships
- ❑ Insufficient findings to distinguish causation/exacerbation
- ❑ Associations with specific risks often not adjusted for other potentially correlated indoor chemical risks (e.g., benzene – ETS, vehicle emissions)

## ❑ Strengths

- ❑ Many studies well-designed, without major flaws
  - ❑ Major common weakness = potential confounding by unmeasured indoor causal risk factors
- ❑ Difficult to identify alternative explanation not involving adverse effects by *some* indoor chemicals



# Indoor Chemical Emissions and Children's Health: Evaluation 3

- ❑ **Most persuasive findings (multiple, consistent, absence of plausible correlated alternatives)**
  1. **Formaldehyde**
- ❑ **Next most persuasive findings**
  2. **Plastics and plasticizers**
  3. **New paint**
- ❑ **Other suggestive findings**
  - ❑ **Aliphatic hydrocarbons (or correlated exposure)**
  - ❑ **Dichlorobenzene (no strong correlates)**

# Indoor Chemical Emissions and Children's Health: Evaluation 3

## □ Example mechanisms

- Respiratory tract inflammation (e.g., phthalates may have prostaglandin-like activity)
- Increased sensitization, non-inflammatory
- Direct effects on developing immune system (Th2 vs. Th1)

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# Indoor Chemical Emissions and Children's Health: Existing Conditions vs. Risks

## Formaldehyde

Study	Concentrations in air ( $\mu\text{g}/\text{m}^3$ )		
	Median	Mean	Max
<b>Existing conditions:</b>			
Garrett 1999	16		139
Venn 2003	22		
Krzyzanowski 1990		32	175
Rumchev 2002		30	224
Quackenboss 1989		35	
<b>Risks reported:</b>	<b>&gt; 20, 22, 30, 36, 60, 61, 73</b>		



# Indoor Chemical Emissions and Children's Health: Existing Conditions vs. Risks

## Phthalates

Phthalates*	Concentrations in dust (mg/g dust)		
	Median	90 <sup>th</sup> %	Max
<b>BBzP*</b>			
Existing conditions:	0.04	0.28	1.3
Risk reported:**		<b>&gt;0.25</b>	
<b>DEHP*</b>			
Existing conditions:	0.34	0.85	7.7
Risk reported:**	<b>&gt;0.13</b>		

\* Rudel 2003

\*\* Bornehag



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# Indoor Chemical Emissions and Children's Health: Implications

- ❑ **Some common materials and emissions in modern homes associated with adverse respiratory and allergic health effects in infants and children**
- ❑ **Findings most persuasive for formaldehyde, strongly suggestive for plastics/plasticizers and new paint, and suggestive for other risk factors**
- ❑ **Use of these products likely to increase, and home ventilation rates likely to decrease over time, increasing exposures and any true adverse effects**
- ❑ **Causal connections, biologic mechanisms, and role of these risk factors in recent rise of asthma and allergies is uncertain**

# Indoor Chemical Emissions and Children's Health: Implications

- ❑ These questions receiving no research attention in the U.S.
- ❑ Important to confirm or disprove
- ❑ *If* ubiquitous home exposures increase preventable, serious respiratory health effects in children, urgent need to –
  - ❑ identify causal exposures
  - ❑ quantify risks to motivate and guide policies or consumer choices
  - ❑ Identify preventive strategies

