

The Relationship between Housing and Health: Children at Risk Workshop

Report on the Workshop



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National Center for Healthy Housing

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Introduction

1

Background

There is a mounting body of scientific literature suggesting that children in America and around the world suffer from environmental health and safety risks. In 1998, the U.S. federal government interagency Task Force on Environmental Health Risks and Safety Risks to Children identified four major priority areas:

- Childhood asthma
- Unintentional injuries
- Developmental disorders
- Childhood cancer

Since children spend as much as 80 to 90 percent of their time indoors (Levy et al. 1998), the possible origins of many of these health risks can be traced to homes, schools, and other indoor environments. Much of this time is spent in the home environment. Prevention of these diseases in children has important social and economic benefits. Landrigan et al. (2002) recently estimated that the total annual costs for environmentally attributable childhood diseases in the U.S.—lead poisoning, asthma, and cancer—is \$54.9 billion. This amount is approximately 3 percent of total health care costs.

At the same time, there has been a rediscovery of the importance of housing as a determinant of health inequality, particularly within urban inner-city neighborhoods. In 1938 the American Public Health Association (APHA, 1938) addressed housing and health in a book

titled *Basic Principles of Healthful Housing*. In 1971 the APHA (APHA, 1971) identified knowledge gaps with respect to housing and health including the need “to understand and assess better the relative effects on humans of the various stresses which may exist in housing and its environment.” Increased concern about housing and health led the U.S. Department of Housing and Urban Development to implement its Healthy Homes Initiative in 1999 (Jacobs et al., 1999).

Measuring the direct impact of housing quality on health remains a difficult task, however, and this challenge is still with us today. In a recent study of the impact of housing on health, the investigators estimated that indices of urban residential quality explained up to 25 percent of the variability in health status in Japan (Takano and Nakamura, 2001). Housing quality remains an important component of health disparities in America and around the world.

Healthy housing is an evolving concept, a holistic approach to creating and maintaining home environments without elements harmful to health. Previous research on investigating and testing interventions, and evaluating results of prevention and remediation efforts has generally been categorical in nature, focusing on single agents (for example, lead, respiratory allergens, fire and injury prevention, and toxins). Healthy housing considers the home as a system. It is an umbrella concept under which all of these topics, and others, are brought together. The concept is stimulating shifts in thinking

and action approaches. By considering the entire housing environment, in terms of its physical and social context rather than one agent at a time, healthy housing programs are stimulating new approaches to housing and health issues.

The Workshop

The National Center for Healthy Housing held a two-day workshop to review the state of knowledge and to help promote the paradigm shift to healthy housing. The conference was held on November 7 and 8, 2002 in Annapolis, Maryland. The objectives of the conference were:

- To identify what is known and not known about the relationship between children's health and the residential environment.
- To identify current "best practices" to address residential health hazards, particularly those that can be readily applied in renovation and remodeling.
- To promote the development of a research agenda concerning residential health hazards and practical housing interventions.
- To identify policy and market options to promote healthy and affordable housing for the nation's children.

The workshop was divided into four sessions. The first three dealt with housing factors associated with 1) childhood asthma and other respiratory diseases, 2) neuro-developmental and behavioral problems, and 3) unintentional injuries. The final session focused on how to implement healthy housing programs. During the conference there were two or more invited presentations for each session (a total of 15 presentations for all four sessions) followed by a panel discussion. The agenda for the conference and list of participants are in Appendices A and B.

The format provided an opportunity for professionals in different topic areas to learn about causes, mechanisms, effects, remediation, and prevention for topics besides

their own specialty. It also allowed exploration of possible application of learning from one area to others—identifying commonalities, over-arching concepts, and ways to influence policy and guidelines.

The 60 participants included mainly administrators, managers, researchers, and technical experts from major universities and state and federal agencies related to health, housing, and the environment. Participants also included public health professionals, academics, and physicians specializing in allergens, pesticides, airborne pollutants, and injury prevention and control. Other participants represented non-profit organizations focusing on environmental health, housing, and legislative processes; state and federal legislative staff; and a few representatives of related industries (pharmaceuticals, construction).

History of the National Center for Healthy Housing

The National Center for Healthy Housing (formerly the National Center for Lead-Safe Housing) was founded as a non-profit organization in October 1992 to bring the public health, housing, and environmental communities together to combat childhood lead poisoning in the U.S. Recently the Center added other hazards in the home to its concerns, including allergens and irritants associated with asthma. The mission of the Center is "to develop and promote practical methods to protect children from residential environmental hazards while preserving the supply of affordable housing." The words "healthy housing" in the Center's new name signify this more holistic approach. The Center works to identify efficient and economical solutions to housing related health problems by sponsoring research, conducting scientific risk assessments, and promoting the adoption of these solutions by insurers, lenders, legislatures, community organizations, and the courts.

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The Relationship between Childhood Asthma and Housing

2

Introduction

Asthma prevalence, health service utilization, and mortality among children and young adults are increasing (Gergen, 1992; IOM, 2000). The causes of the increase in asthma are not well understood. However, a growing body of evidence suggests that agents and exposures found in indoor environments, housing in particular, are major determinants of asthma prevalence and morbidity. Asthma varies with race or ethnicity and urban location, with poor inner-city populations suffering disproportionately (IOM, 2000). Much of the variability in asthma rates is likely due to exposure to indoor environmental asthma triggers associated with living in substandard housing (Krieger et al., 2002). Pest infestation, crowding, moisture damage, and other structural deficits contribute to high levels of indoor asthma triggers. Such conditions are more common in inner-city, low-income environments. The link between substandard housing and asthma has not been widely recognized or addressed in the public health community, however. The purpose of this section of the workshop was to discuss:

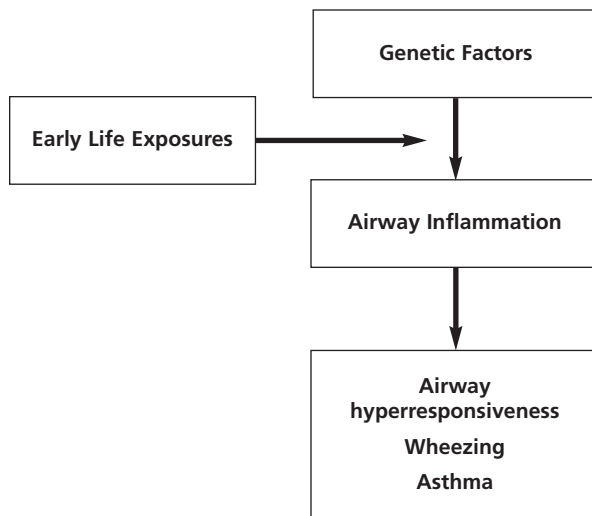
- 1) The current state of knowledge about the relationship between housing and asthma;
- 2) The translation of this knowledge into best practices to address housing-related determinants of asthma; and
- 3) The knowledge gaps and research needs.

Asthma varies with race or ethnicity and urban location with poor inner-city populations suffering disproportionately.

Current State of knowledge

Asthma, a chronic inflammatory condition of the lung airways, is the most common chronic disease among children today. Although asthma can be thought of as being caused by one or more mechanisms, there is general agreement that asthma is associated with airway inflammation and hyperresponsiveness. A general model for the development of asthma can be conceptualized according to Figure 1. Both environmental and genetic factors are thought to play a role in asthma initiation and exacerbation. Allergens are an established risk factor for asthma. After exposure to an allergen, the immune system can become sensitized and produces antibodies to allergen-specific proteins creating an inflammatory response that leads to airway hyperactivity. Children with atopy, a genetic predisposition to allergen sensitivity, are at higher risk of developing asthma. In a sensitized individual, small amounts of allergen can result in a large inflammatory response. Some individuals have non-allergic asthma that is also characterized by inflammation and airway hyperresponsiveness but without the specific immunoglobulin E (IgE) antibody response. It has been estimated that approximately 80% of asthma in children

Figure 1. Development of Asthma. (Adapted from Martinez, 2002).



is allergic asthma (IOM, 2000). Asthma rates are higher in children who are sensitized to allergens (Lau, 2000; Kattan, 1997; Nelson, 1999). It is important to note that once asthma has been established a variety of exposures, including allergens, can trigger an asthma attack or make asthma symptoms worse.

Wheezing is a common respiratory symptom in children, and understanding the natural history of the development of wheezing is important to understanding asthma. In a large birth cohort study conducted in Tucson, AZ, Martinez et al. found roughly half of children had wheezing at some point in childhood, about 20% had transient early onset wheezing, and 13% had persistent wheezing (Martinez et al., 1995). Based on the results of the Tucson Study, Castro-Rodriguez et al. have proposed that children who are at risk to developing asthma have early childhood wheezing and either one of two major risk factors (parental asthma or atopic dermatitis) or two of three minor risk factors (eosinophilia, wheezing without colds, or allergic rhinitis). Without other risk factors, 95% of those with early onset wheezing did not develop asthma.

However, 76% of those with early wheezing and other risk factors did develop asthma (Castro-Rodriguez et al., 2000).

Asthma often resolves as a child grows up; this happens for about half of children with asthma. However, the person will still have abnormal lung function later in life. In addition, asthma can recur in adulthood. One study suggests that adult reoccurrence occurs in about 20% of the cases (Blair, 1997).

The “Hygiene Hypothesis”

The hygiene hypothesis suggests that there is an inverse relationship between early childhood infections and the subsequent development of allergies and asthma (Martinez, 2001). This hypothesis has been invoked to explain why western lifestyle is associated with increased asthma. The hygiene hypothesis proposes that early exposure to viral respiratory infections may be protective against the development of asthma. Support for the hygiene hypothesis is provided in the Tucson study mentioned earlier. Results of this study suggest that exposure to older children, either at home or at day-care centers, protects against the development of asthma (Ball et al, 2000). Studies in Switzerland showed that farm children had higher exposures to endotoxins (from livestock) than non-farm children (von Mutius, 2000), and that farm children had lower rates of asthma and allergy (Braun-Fahrlanden, 1999). However, another study that controlled for many factors found higher levels of endotoxin was associated with slightly greater likelihood of wheeze in the first year of life, but whether asthma developed later in life was not presented (Park, 2001).

The hygiene hypothesis remains controversial and not widely accepted. Although some research suggests supporting this hypothesis, there are reasonable questions about its validity since it seems to be incongruent with the high rates of asthma among inner city children, who also have higher than average rates of both respiratory and other infections.

Allergens Associated with Housing

Chronic exposure to allergens in the indoor environment from mold, pets, mice and rats, cockroaches and dust mites, is associated with asthma. Moisture indoors contributes to sustaining mold and pests. It appears that there are different patterns of sensitization, due to different allergens in different indoor settings. Exposure to dust mites in homes has been associated with sensitization. For example, Wahn et al. presented a dose-response relationship between presence of dust mites and sensitization risk during the first three years of life (Wahn et al., 1997). For inner city home environments, exposure to cockroaches, mice, and rats is also related to asthma and allergic morbidity. Rosenstreich et al., for example, reported a cockroach sensitization rate of 36% in inner-city asthmatic children (Rosenstreich et al., 1997). Controlling them requires a community approach—eliminating them from an individual unit in multi-unit buildings and rowhouses isn't enough. The role of molds as a risk factor for allergic disease is not clearly understood. Exposure to damp housing and visual observation of mold growth has been identified as asthma risk factors (Billings and Howard 1998; Williamson et al., 1997). Little is known about the degree of mold exposure in housing environments, however (IOM, 2000; Dillon et al, 1999). Furthermore, the importance of mold-associated mycotoxins is not understood (Peltola et al., 2001; Dillon et al., 1999; IOM, 2000).

Indoor air pollutants have been associated with the development of asthma and exacerbation of asthma.

Household Moisture

The role of moisture in asthma needs to be delineated further, both as an independent factor and as a contributory factor to proliferation of other allergens. It is clear for example that high moisture environments favor dust mite growth as well as mold growth. The relationship between housing and asthma has been established almost entirely based on observational studies that note the presence of water damage or visible mold growth. Little is known about the role of moisture and mold in

housing and how mold and/or moisture might impact asthma. There are significant measurements issues associated with household moisture and mold assessment and their relationship to asthma etiology and prevention.

Indoor Air Pollution

Indoor air pollutants have been associated with the development of asthma and exacerbation of asthma. Due to cost and other practical limitations, there is relatively little data on the personal exposure to common indoor pollutants.

One of the most common indoor air pollutants is environmental tobacco smoke (ETS). ETS both stimulates and exacerbates asthma. ETS is a complex mixture of gaseous and particulate pollutants. The concentration of tobacco particles increases as smoking intensifies (Neas et al., 1994). Wheezing, cough, and asthma are more common among children with smoking than non-smoking parents (IOM, 2000). The effect is greater for 0–2 year olds (50–70%) than 6–15 year olds (30–40%). A mother's smoking is especially important as an irritant to young children. In a recent review of indoor air quality and asthma, the Institute of Medicine concluded that there is sufficient evidence to associate ETS exposure with the development and exacerbation of asthma (IOM, 2000).

Nitrogen dioxide (NO₂), a by-product of high temperature combustion, is associated with unvented or poorly vented combustion appliances such as gas stoves. Households with combustion sources can have NO₂ concentrations 2–3 times higher than those without. According the IOM review panel, there is suggestive evidence that NO₂ can exacerbate asthma, but there is inadequate evidence to support an association with development of asthma (IOM, 2000).

Volatile organic compounds (VOCs) include a wide variety of chemicals found in the home, including dry cleaning compound residues, plastics, products of combustion, paint thinners, and so on. One VOC, formaldehyde, has received research and public attention, but its role in the development or exacerbation of asthma is not clear. There is some evidence of an association with increased respiratory symptoms (that is, exacerbation of asthma); however, more epidemiologic data are needed (IOM, 2000).

Three outdoor pollutants—ozone (O₃), sulfur dioxide (SO₂), and fine particles are known to exacerbate asthma. Indoors, two of these (SO₂ and O₃) are adsorbed onto surfaces, readily taking them out of the air. As a result, there seems to be less of an indoor problem with these chemicals. The relationship between in-home particulate matter exposure and asthma is not well researched. Research is needed on the combined effects of indoor and outdoor pollutants. This area is largely unstudied.

Exposure Assessment

Measuring exposure to children presents a number of unique challenges and is limited in many cases by lack of good methods. There is a large amount of data on allergen concentration (µg/g of dust) reservoir dusts from homes. Data from the lead literature suggests that surface loading (µg/m²) may be a more appropriate exposure index. In addition, allergen exposure is assumed based on measurements of allergens in reservoir dust. How these measurements relate to actual inhaled doses of allergens is not known. Accepted methods of assessing airborne allergen concentrations do not exist except for animal dander allergens, which are readily aerosolized and stay airborne for extended periods of time.

Reducing exposure to allergens requires consistent application of various measures for years. Practical issues, including the cost of equipment and the time involved to keep a home sufficiently clean, can affect the ability to carry out recommended steps.

Few studies have quantified personal exposures of children to indoor air pollutants. Good methods for personal exposure assessment, using passive samplers, exist for gaseous pollutants (NO₂ and O₃) as well as volatile organic compounds. Measuring personal particulate matter exposures of children presents a greater challenge, particularly if size-selective exposure estimates are needed.

Best Practices to Address Housing-Related Asthma Risk Factors

Since allergy and exposure to allergens has been identified as a major source of airway inflammation, allergen avoidance has been the focus of asthma control efforts. Accordingly, the basic strategy to alleviate respiratory symptoms is to determine to which allergens a person is sensitive and then follow a set of steps to avoid the allergens. Since half of asthmatics have multiple (3+) sensitivities (Huss et. al., 2001; Eggleston, 2000), several actions may have to be undertaken over long periods of time.

Table 1 summarizes the usual steps that are recommended to avoid exposure to allergens that cause sensitization to allergens or trigger attacks.

Reducing exposure to allergens requires consistent application of various measures for years. Practical issues, including the cost of equipment and the time involved to keep a home sufficiently clean, can affect the ability to carry out recommended steps. Factors that determine initiating and sustaining behavior change need to be understood and incorporated into the design of interventions. Interventions should be promoted that are most likely to give positive results (i.e., reduced attacks, etc.) and encourage continued compliance.

There are compliance issues and questions of effectiveness with the steps usually recommended to avoid contact with allergens. It is easy to see that there would be challenges to maintain some of the methods listed above, particularly in low-income housing. Although the bedding steps have been found to be effective in reducing allergens, there is not much evidence for effectiveness of the steps shown for cockroaches.

Similar to allergen avoidance programs, preventing exposure to other asthma triggers, such as ETS smoke, is also recommended. Avoidance of ETS exposure has been identified as an important asthma control effort. These efforts include smoking cessation and passive smoke avoidance. Other than for ETS exposure, there is little evidence that reducing exposure to indoor air pollutants will have a significant impact on asthma morbidity.

Table 1. Summary of allergen avoidance steps taken to reduce asthma severity.

Usual recommendations to prevent asthma or reduce severity and frequency of asthma attacks	
<p>primary methods</p> <ul style="list-style-type: none"> • wash bedding weekly • use covers on mattresses and pillows • no stuffed animals • decrease humidity 	<p>secondary methods</p> <ul style="list-style-type: none"> • remove carpeting, upholstered furniture • use acaricides on fabrics • tannic acid
Steps to reduce cockroach allergen in the home	
<ul style="list-style-type: none"> • eliminate the source with pesticides • vacuum and wash home thoroughly • seal cracks and holes where cockroaches may enter home • wash dishes immediately after use • keep food in sealed containers • use bait stations 	

Two programs were mentioned as models of ways to convey information about healthy homes. The Master Home Environmentalist program is a community-based program that focuses on indoor sources of pollution, pesticides, and moisture. The American Lung Association has a program aimed at builders to help them build healthy homes.

Knowledge Gaps and Research Needs

Discussions during the workshop identified many knowledge gaps and research needs. These are summarized below.

Allergen mixtures. The complex mixture of allergens in the home setting presents several challenges. There could be interaction effects among allergens in terms of causing sensitization and attacks and worsening the condition. Along these lines, the concept of total allergen exposure was suggested. No such indicator presently exists. If it could be developed, it would have to be shown to correlate well with the development or exacerbation of asthma before its use could be promoted. Would it be possible to come up with a “total protein” measure that could serve as a proxy for measuring total allergen exposure?

Allergen measurement issues. Within the home, there are several measurement issues related to allergens. One issue is choice of sampling location within the home. The location of sample measurements can yield different levels, so there is need to give attention to choosing the most appropriate place for sampling. Allergen measurements from two locations can lead to different assessment of the degree of exposure. Another issue is the choice of the material to be sampled. Should samples be collected from either bare or carpeted floors or both. Yet another issue is the choice of the sampling method. A study done in Cincinnati found that the relationship between serum specific IgE and allergen concentration differed by vacuum used and allergen (Mansour et al. 2001). The establishment of the relationship between a surface allergen sample and the inhaled dose of an allergen is needed. This lack of understanding may result in exposure misclassification in health effects studies. For instance, there is a need to develop methodology to allow the determination of night time exposure of children to dust mite allergen in their bedding.

- Is it sufficient to just measure bedding to determine the exposure of children to dust mites?
- Is concentration or loading the most appropriate metric to use for predicting the health risk for asthma from allergens in the home?

Interactions and synergy among allergens; mixtures and multiple risk factors

- What are the synergistic effects among indoor/outdoor air pollutants and allergens? Do risk factors, when more than one is present, potentiate each other to cause or exacerbate asthma?
- What role do mice and rats play in asthma occurrence, especially in the inner city?
- Which are the most important pollutants when dealing with mixtures of chemical and biological pollutants and allergens?
 - Should tobacco smoke (in the inner city home environment) be a focus for prevention?
 - The role of volatile organic vapor exposure is not well understood. Less costly techniques to measure and analyze VOCs are needed to assist in these efforts.
- Are exposure effects cumulative for development of asthma (as exposure is for lead)?
- If a total allergen score is developed, what level should be defined to prevent an attack, or what level would be a trigger?

Mold related issues

To what extent is mold (indoor) a source of disease and allergy?

- What is the prevalence of mold allergens in the home, and what are acceptable levels to maintain health?
- Do molds, through the toxins they produce, directly cause disease (without going through IgE)?
- Molds release multiple chemicals to the atmosphere. What is the impact of the mixture of those chemicals on biologic systems? Is there a difference in children?
- How do climate, geography, housing and other local factors influence moisture levels and mold?
- Is moisture an important factor to control for respiratory problems?
- What is the relative contribution of various moisture sources (i.e., water intrusion from the exterior, interior humidity levels) to mold growth?

- How can we measure household moisture levels so the measure has meaning related to disease?

Social behavioral issues

- What are the optimal and feasible behavior change strategies to protect respiratory health?
- What are the barriers to compliance with drug therapies and/or recommended actions to reduce allergens in the home?

Effectiveness of interventions to reduce disease

- In situations with a complex mix of chemical (including ETS) and biological stimulants of allergic/asthmatic response, which interventions help the most to reduce asthma?
- Is it more efficient in the long run to reduce the total allergen burden in a house or will focusing on one or two allergens be sufficient?
- Does moving into a renovated home change a child's asthma status? Which is better—renovation (rehabilitation) or clean up only?
- What are successful interventions to reduce cockroaches over time?
- What is the relative importance of secondary prevention methods to stave off worsening of the condition?
- A comparative study of a drug-focused approach to control of asthma against aggressive home-environment allergen reduction strategy is needed.

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Environmental Neurotoxins in the Home

3

Introduction

Human and experimental studies indicate that the fetus and infant are more sensitive than adults to many environmental toxicants (Faustman et al., 2000). The developing neurological system is especially vulnerable to damage from environmental toxins such as lead and pesticides (Faustman et al., 2000). Of particular concern is the unidirectionality of the development of the central nervous system. This suggests the likelihood that a number of neurological deficits may be permanent once endured.

Despite over 30 years of research and public health attention, lead intoxication of children, particularly in the inner city, continues to be an important public health problem. The persistent concern about lead effects is magnified by the growing concern about the general impact of the environment on neuro-behavioral aspects of childhood development. Since children spend as much as 80 to 90% of their time in the home, the home is an important potential exposure environment for children. This section of the conference focused on lead, pesticides, and the neuro-developmental effects of tobacco smoke as they relate to housing. Although

Growth, learning and cognitive development, neuro-motor development, and behavior can all be affected by early childhood exposure.

our state of knowledge with respect to lead is more extensive, there is increasing concern about the use of pesticides as well as environmental tobacco smoke (ETS) exposure in the home (Faustman et al., 2000).

Current State of Knowledge

Lead

Lead toxicity affects the brain and neuro-developmental processes, and its effects are irreversible. Infancy (and the period *in utero*) is a peak period of vulnerability. Growth, learning and cognitive development, neuro-motor development, and behavior can all be affected by early childhood exposure. Early childhood lead exposure can result in the following:

- Deficits in visual-motor/visual-spatial and fine-motor coordination. Deficits such as these could adversely affect a child's ability to write, draw and construct (Dietrich et al., 1993).
- Poorer postural stability. This may result in clumsiness that could exclude children from fully engaging in sport and vocational activities requiring good gross-motor coordination (Bhattacharya et al., 1988; Bhattacharya et al., 2000).
- Attention problems and deficits in what psychologists call "executive functions" [planning, organization, anticipation of consequences]. Together, these effects

can lead to overall academic underachievement and behavioral problems in the classroom (Bellinger et al., 1994; Canfield et al., 2003).

- Conduct disorder and decreased impulse control leading to a higher risk of juvenile delinquency (Byers and Lord, 1943; Needleman et al., 1996; Dietrich et al., 2001).
- Reading disability placing a child at high-risk for academic failure and behavioral problems in the classroom (Needleman et al., 1990; Fergusson et al., 1997).
- Lower IQ (Needleman and Gatsonis, 1990; Schwartz 1994, Canfield et al., 2002).

The biological mechanisms involved in lead poisoning are not yet well understood (Silbergeld, 1992), although we know that it disrupts processes regulated by calcium and changes synapse formation (Bressler et al., 1999). In addition, it is possible that there are synergistic effects between lead and other neurotoxins such as ETS.

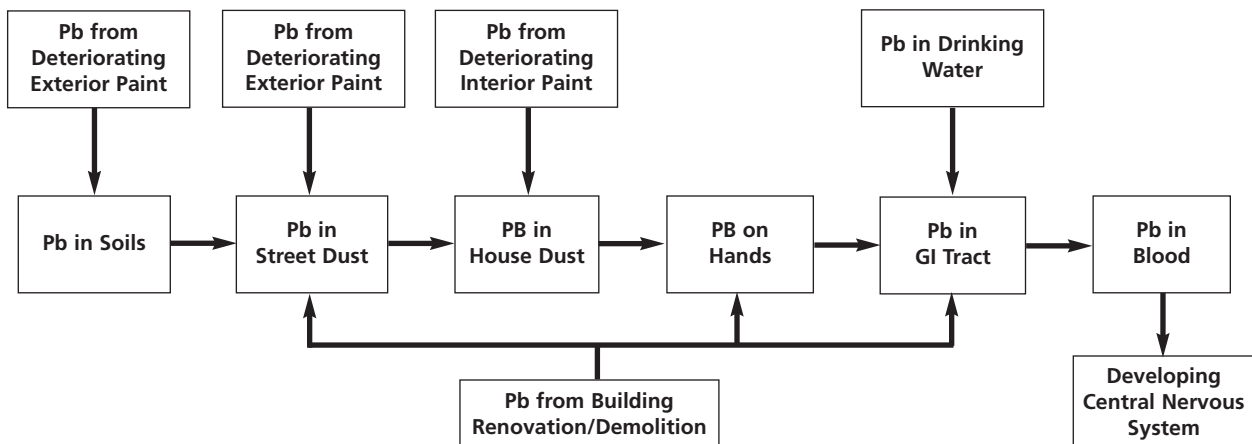
These neurological effects of lead have been linked to children's blood lead levels early in life. Therefore, children's blood lead levels can be thought of as an indicator of the current risk of neurological deficits due to lead

in the environment. Recent research suggests that there is probably no lower level threshold of blood lead; even at quite low levels (2.5 micrograms to 10 micrograms) deleterious effects can be detected. There is some evidence of decreases in cognitive and academic measures of children 6–16 years old, even with blood lead levels (BLL) less than 10 µg/dL (Lanphear et al., 2000).

Growing evidence suggests that current blood lead screening practices may be inadequate because the harmful effects of lead occur very early in life. Screening typically is done at about 24 months; by then irreversible damage has been done. In addition, only about a quarter of children are screened in the U.S., so there are many missed cases. Therefore, primary prevention is the optimal approach to lead poisoning.

Regulations have been quite successful in lowering exposures to lead (e.g. banning lead in gasoline and house paint (NHANES 1999–2000)). Those changes had both a primary and a secondary prevention aspect. The many governmental actions taken over the past quarter century have left old housing as the primary source of lead for children in this country. The following conceptual model illustrates the importance of housing in determining children's blood lead levels. It displays the reservoirs and pathways for children's exposure to lead in the urban environment.

Figure 2. Impact of Deteriorating Paint on Blood Lead Levels (Bornschein unpublished)



Lead paint dust is the main form of lead of concern in homes, rather than pieces of lead-based paint or soil lead (Lanphear et al. 1995; Lanphear, Burgoon et al., 1998; Lanphear, Matte et al., 1998). A meta-analysis of lead in dust and children's blood lead levels established a quantitative relationship between floor dust lead levels and children's blood lead levels (Lanphear, Matte et al., 1998). Recently established EPA hazard standards and HUD/EPA clearance standards for lead incorporated these findings in the decision-making process. Some analyses have shown that with floor dust lead levels greater than 25 µg/ft², there is a nine-fold greater risk of having blood lead levels greater than or equal to 10 µg/dL (Lanphear et al., 2002). This increase in risk occurs below the current standards and does not take into account the growing evidence of neurological effects at blood lead levels lower than 10 µg/dL.

It appears that children's blood levels, though they may be reduced through intervention, tend to remain at similar levels after remediation of the home.

It appears that children's blood levels, though they may be reduced through intervention, tend to remain at similar levels after remediation of the home. Low levels stay in the low range, and if starting at a high level, the blood lead levels will still be in that higher range (Haynes, 2001). This has important implications since these data suggest that to some degree BLL are refractory and difficult to reduce, suggesting that primary prevention will be much more successful.

The latest national survey of lead levels in the U.S. housing shows that 38 million homes had lead-based paint, a reduction from 64 million homes about 10 years earlier (Jacobs et al., 2002). Twenty-four million homes had significant lead-based paint hazards. Sixteen percent of homes had one or more lead dust hazards on either floors or window sills. Homes built before 1940 had much greater burdens of lead-based paint hazards than those built later.

Pesticides

Concern about the impact of pesticides on the health of children has been growing since the publication of the 1993 report "Pesticides in the Diets of Infants and Children" by the National Academy of Sciences (Landrigan et al., 1999). The mode of action of most pesticides is to affect the neurological system of the pests. It is reasonable to assume therefore that they will also have neurotoxic effects on humans. Pesticides include insecticides, fungicides, herbicides, and rodenticides. In the United States, the principal classes of insecticides in use today are the organophosphates, carbamates, and pyrethroids (Landrigan et al. 1999). The organo-phosphates and carbamates are toxic to the nervous system and cause cases of acute poisoning each year in the United States. The mode of action of these two classes is the inhibition of cholinesterase. There is a growing body of evidence suggesting that public exposure to cholinesterase inhibiting pesticides (organophosphates and carbamates) is a health concern (Whyatt et al., 2002). The impact of exposure of these pesticides on children has not been extensively researched. This is especially true for neurobehavioral effects.

In the United States residential use of pesticides is widespread with an estimated 80% to 90% of American households using them (Landrigan et al., 1999). In the inner city, indoor exposures to some pesticide toxins can be frequent and at high levels. Exposure is frequent because of cockroach and rodent problems. Whyatt et al., (2002) recently reported on the pesticide use of inner-city residents in New York City. This study documented widespread pesticide use and in the case of diazinon, the exposure for some women may have exceeded health-based levels. Eighty five percent of the women questioned as a part of this study reported that pest control measures were used in the home during pregnancy; 35% reported that their homes were sprayed by an exterminator; and of those, 45% said the spraying was done more than once per month. In addition, a number of organophosphate (chlorpyrifos and diazinon) and carbamate (propoxur) pesticides were detected in air samples, maternal blood, and cord blood samples (Perera et al., 2003).

In the New York City study, an association was noted between housing disrepair and the proportion of pregnant women reporting seeing pests in their home as well as with use of pesticides (Whyatt et al., 2002). Among women living in the housing in greatest disrepair the adjusted odds ratio of sighting pests and use of pesticides were 58 (95% CI, 9.1–378.3) and 6 (95% CI, 1.3–27.2)

Environmental Tobacco Smoke (ETS)

Tobacco smoke is listed as a Group A carcinogen by the International Agency for Research on Cancer. It has been shown to contain more than 4,000 chemicals, including 43 that have been identified themselves as being carcinogenic. Children may become exposed to tobacco smoke pre-natally or post-natally. Between 25% and 44% of female smokers continue to smoke while they are pregnant. Smoking cigarettes during pregnancy has effects on fetal development and the baby's health and development after birth. The smoking of mothers has been most closely associated with a child's exposure, probably because the child is with the mother for more time and in closer proximity. Children's blood cotinine levels have been shown to increase with increasing numbers of smokers in the household (Jordaan, 1999).

Exposure to tobacco smoke during pregnancy is associated with prematurity, low birth weight, low Apgar scores, and poor growth of infants (Dejmek, 2002; Horta et al., 1997). Several health problems of infants are associated with prenatal exposure as well as general developmental delay and several specific deficits. Currently, evidence related to child development and behavior is stronger for prenatal than post-natal exposure. All dimensions of IQ for children 9 to 12 years of age decline with increasing levels of prenatal exposure to tobacco (Fried, 1998), but other research has shown no effect of prenatal exposure (Bauman, 1991). Two studies show that postnatal ETS exposure resulted in lower IQ scores than for non-exposed children (Bauman, 1991; Eskenazi, 1995). Both of these studies show no effect or a positive effect of prenatal smoking, however, which raises questions of the methodology used to determine exposure, the need to use biomarkers, and sample size issues.

Recent research using blood cotinine levels as an indicator of exposure to ETS shows a robust inverse relationship between cotinine levels and cognitive scores (math and reading) in 6- to 16-year-old children. The relationship remains statistically significant after controlling for various characteristics. Significant declines in scores were found even at low levels of exposure. Postnatal exposure plays a role in these declines because the differences remained for two of the three cognitive tests after controlling for prenatal exposure (Yolton, unpublished).

Children exposed to ETS display a cluster of dysfunctional behaviors related to conduct, attention, and social harmony.

There is some evidence that smoking during pregnancy (Fergusson, 1993; Williams, 1998) and after pregnancy (Williams, 1998) is positively associated with various dysfunctional behaviors in young children. Children exposed to ETS display a cluster of dysfunctional behaviors related to conduct, attention, and social harmony. A dose-response relationship between ETS exposure and behavior problems for five year olds exists for each period of exposure, that is, during pregnancy, the first six months, and the first five years of life (Williams, 1998).

Best Practices to Address Exposure to Housing-Related Neurotoxins

The steps needed to prevent childhood exposures to neurotoxins are founded in core public health practice and include identifying sources of exposure, identifying unacceptable levels of exposure, developing and testing interventions, and finally implementing effective regulatory and screening programs. Intervention strategies include (in increasing order of effectiveness and cost) education, enforcement and engineering controls with an emphasis on primary prevention.

It is difficult to address detrimental neuro-development effects when children are exposed to multiple neurotoxins at the same time. It is common for inner city children to be exposed to lead, ETS, and pesticides both prena-

tally and postnatally. To be effective, intervention efforts should address these multiple exposures at the same time.

Lead

In the case of childhood lead exposure there is an extensive body of literature documenting the impact that various methods of lead hazard control have on dust and blood lead levels (Staes and Rinehart, 1995; Niemuth et al., 1998; Haynes et al., 2002; Galke et al. 2001; Tohn et al., 2003; Niemuth et al., 1998) summarized the literature from 1980 through 1998. Included in this report are both trials and observational studies. Generally, the studies report successful reductions in dust lead levels and in blood lead levels when initially above 20 µg/dL. Haynes et al (2002) published a systematic review of randomized controlled trials of dust control that were low cost. They reported no significant decline in mean blood lead levels among children receiving low-cost dust control interventions; however, they did find a significant reduction in the proportion of children who had blood lead concentrations greater than 15 and 20 µg/dL at the end of follow-up.

To date, the published data on the effectiveness of specific lead hazard control treatments has been too limited for proper conclusions to be drawn about the effectiveness of specific lead hazard control approaches.

Pesticides

Pesticide use in the home is common. Designing and implementing intervention strategies, however, is difficult due to the lack of basic toxicity testing information specific to neuro-developmental effects. Without adequate toxicity data, it is not possible to target control strategies. Basic toxicity testing for neuro-developmental effects as well as after-market health and exposure surveillance should be mandated. There needs to be a shift in programs away from screening of children to screening of homes. This will require the development of health-based screening guidelines similar to those developed for lead.

Environmental Tobacco Smoke (ETS)

Education and smoking cessation programs are the most commonly used interventions for ETS exposure (Chilmonczyk et al., 1992; Greenberg et al., 1994; Hovell et al., 2000, Hovell et al., 2002; McIntosh et al., 1994; Woodward et al., 1987). Only the most recent of these trials showed benefits of reduced exposure. Smokers need to be educated about the impact of ETS on children and the need to avoid smoking in their presence. In addition, educational efforts need to continue to target pregnant mothers to prevent prenatal exposure. The barriers to effective educational programs need further investigation to understand why some families take steps to reduce ETS exposure and others do not.

Besides the elimination of ETS, three methods of control—filtration of air, ventilation, and containment of smoke—could be used to reduce the presence of tobacco smoke in the home environment. A controlled study of HEPA-CPZ air cleaners has shown that they are able to reduce nicotine in the air (Aligne, unpublished, n.d.). Two practical issues were noted with this approach: 1) costs of the devices, and 2) possible compensatory behavior (i.e., smoking more) based on the belief that the filters would remove the smoke, which would defeat the purpose of the air cleaners.

Knowledge Gaps and Research Needs

Discussions during the workshop identified many knowledge gaps and research needs. These are summarized below.

Mixtures and Multiple Exposures

Laboratory studies are needed to increase knowledge about the active toxins. “Bench science” could also increase our knowledge about effects of environmental toxins like pesticides and environmental tobacco smoke, since epidemiological studies on populations may be very costly and take a long time. There are some limitations to laboratory studies, however. Animal tests may not be sensitive enough. Also, there are no animal

models for some human cognitive skills, such as reading, which are of concern with neurotoxicity.

Toxicity and Health Assessment Issues

Consistent measures of outcomes across studies (what to measure, agreed-upon cut-off points) are needed. Also, interactions and synergistic effects on neurodevelopment of multiple toxicant exposures need additional research. Finally, there is a need for testing home pesticides for neurotoxicity in children including pre-marketing (ethical issue: how to test children for exposures) and post-market surveillance. Additional research questions include the following:

- What are the mechanisms of lead toxicity on the brain, i.e., effects on brain structure itself, not just functional manifestations?
- Is there a threshold for lead neurotoxicity? What are the effects on children with BLL <25 µg/dL?
- With reference to neurotoxins, what are the critical periods for children's development and health?
- Do we know how to break out the different components of exposure (e.g. age, length, intensity, prenatal or postnatal exposure)?
- What are the specific mechanisms by which ETS affects child development and behavior, and during pregnancy?
- What is the relationship between exposures to toxins and the development of ADHD?
- What are the interaction effects with psychoactive drugs children take (e.g., Ritalin) for ADHD? Laboratory studies may be one approach to study such interactions.
- Does an intervention focused on one toxicant lead to reductions in other allergic irritants and toxins? (e.g., would cleaning meant for lead control make the home safer from other hazards like pesticides or allergens?)
- Can reading competency serve as an indicator of cognitive development?

Exposure Assessment

A number of measurement considerations were also raised during the workshop. These included appropriateness of measures, ability to detect differences and interpret them, and comparability across studies. Scientific agreement on the best measures of specific exposures and effects will make it easier to compare results of different studies and do meta-analysis. More precise measurement of actual exposures in the home environment will improve our ability to find effects and draw clear conclusions.

- Less costly techniques to measure and analyze exposures to pesticides need to be developed.
- The relationships between dust levels, airborne exposures, and biomarkers of exposure need to be established for children's pesticide exposures.
- Are pesticide levels in homes consistent across the country?
- Researchers need to look at generation of lead dust in communities—public areas of multi-unit buildings, other buildings in the community besides individual homes shed lead paint dust and chips.
- What are the key sources and determinants of intrauterine and postnatal exposure to pesticides in the residential environment?

Education

- Do educational programs and /or other interventions about ETS and pesticides result in lower use by pregnant women and after a child is born?
- How can the behavior effects of toxins be measured besides by reported behavior?

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Unintentional Injury of Children in the Home

4

Injury is defined as damage to cells and organs from energy exposure or depletion that have sudden discernible effects. “Injuries have a substantial impact on the lives of individual Americans, their families, and society. The consequences of injuries can be extensive and wide-ranging. They are physical, emotional and financial; in the case of disabling injuries, the consequences are enduring.” (National Center for Injury Prevention and Control, 2002).

“Injuries are the number one killer of children and young adults in the United States. They are the leading cause of years of potential life lost before age 65. More than 5 million people in the United States report suffering from chronic, injury related disabilities, and the lives of millions of others have been dramatically affected by injuries to themselves or someone they love.” (National Center for Injury Prevention and Control, 2002).

Injuries are a leading cause of emergency room visits, hospital admissions, and mortality for children in the U.S. The majority of injuries of children occur in the home.

Injuries manifest themselves by causing people to see their doctor, go to the emergency room, be admitted to a hospital, or perhaps die. Different data collection systems exist for each of these varying severity outcomes.

Injuries are a leading cause of emergency room visits, hospital admissions, and mortality for children in the U.S. The majority of injuries of children occur in the home (Pollack et al., 1988; Rivara et al., 1989; Scheidt et al., 1995). Falls are the most frequent cause of residential injuries to children, then injuries from objects in the home, followed by burns, poisoning, and animal bites.

Current State of Knowledge

By definition residential injuries are linked to the home environment. Because injuries, unlike diseases, tend not to be progressive, injuries of differing severity may be associated with different risk factors. Therefore, the different severity outcomes must be separately examined to define the set of risk factors that describe the linkage between a child's home and the injuries they might suffer. Some injuries may happen because of home design—stairs, lighting, flooring, railings, and windows. Others may happen because of poor maintenance of home design elements. Others are due to consumer products used in the home—toys, appliances, electrical equipment, chemicals. Interventions to reduce childhood injuries may focus on design changes, family behavior changes, and eventually regulation.

The proportion of injury deaths due to home injuries declines with age. A recent study reports that 80% to 90% of injury deaths among children under 5 years of

age occur in the home, compared to 80% for 5 to 9 year olds, and 60% for 10 to 14 year olds (Lanphear et al., 2003). Although the fatal injury death rate has been trending downward since 1985, the change is not significant. In addition, the trend line for injury death rates continues to be substantially higher for African-American children than other race groups, perhaps related to teen violence. Unlike injury death rates, residential injury rates by race are similar.

Over the period 1985 to 1997, fatal home injuries accounted for almost two-thirds of all fatal unintentional injuries occurring to U.S. children and adolescents. Mean residential death rates for children and adolescents over that period varied markedly by age. Children less than one year of age were at substantially greater risk. Male and black children had greater risk of fatal residential injuries. Fatal home injuries demonstrated wide geographic variability, being highest in the south. For children less than one year of age, 93.5% of all deaths occurred in the home. That proportion declined progressively with age through adolescence, falling to 38% for 15 to 19 year olds.

Data from the NHAMCS for 1993 to 1999 for children less than 20 years of age show that injuries accounted for 11 million visits to the emergency department (ED). Injuries occurring in the home accounted for 4 million visits (Phelan et al., 2003). Similar to fatal injuries, children in the youngest age groups had significantly higher ED visit rates. Residential injuries leading to emergency department visits were highest for children 1 to 4 years of age. The next highest age group was children under 1 year of age. Males had higher ED visit rates than females.

Falls. Injuries may also be classified by the mechanism (e.g., falls, poisonings, etc.) by which they occur. Falls are the leading type of residential injury for children. They account for an estimated 3 million visits to emergency departments. More than 40% of these visits are for infants, toddlers, and preschoolers. The severity of injuries due to falls can range from minor to severe injury or death. These injuries include fractures, spinal cord or brain injury, and death. Infants and children who fall from low heights are at substantial risk for head injuries while those falling from heights of 10 feet or

more may also sustain other multiple serious injuries. According to a report by Battelle (Battelle Memorial Institute, 2001), the primary residential hazards associated with falls are:

- Lack of grab-bars and non-slip surfaces in the bathroom
- Lack of non-slip backing on rugs and other unsecured flooring
- Lack of safety gates to block stairways and other dangerous areas
- Lack of window guards
- Structural defects in the home
- Insufficient lighting on stairs and other areas

Fires. With regard to deaths due to home fires, children under 5 years of age and the elderly are at higher risk than other age groups. Risk of death from fire is higher in the South and Southeast than in other regions of the U.S.

Scalds, non-fire burns, and poisoning. This type of residential injury occurs to children fairly often. Burns account for about 185,000 ED visits annually for children less than 20 years of age (Phelan et al., 2003), and 95 percent of scalds happen to children under 5 years of age (CDC, 2002, p. 24). Infants and toddlers are at higher risk of accidental poisoning that requires an ED visit than children 5 to 19.

Best Practices to Address Housing-related Injury Risk Factors

Research is needed about stair design to reduce falls of children. CDC is currently sponsoring research about floor compositions that could reduce the incidence and severity of falls.

A number of actions to prevent child injuries in the home are already well known. The most important home safety actions identified in the conference are given in the box above (Figure 3).

Figure 3

Recommendations to Prevent Unintentional Injuries of Children in the Home

- Reduce temperature of hot water heater to 120°F. to prevent scalding burns.
- Use stair fences.
- Install window guards, especially in high-rise buildings and upper stories of homes and apartment buildings.
- Install and maintain smoke alarms.
- Install and use cabinet locks.
- Segregate and lock away poisons.

Smoke alarms are a key means to prevent injury or death due to home fires. When homes have functioning smoke alarms, there is a 50 to 80 percent reduction in injury and death due to residential fires (CDC, 2002, p. 20). A pilot program for comprehensive residential fire prevention showed promising results, although an epidemiological approach to evaluating program impact has yet to be done. Components of the program included: installation of smoke alarms, educational activities, and cooperation among local health department, fire departments, community organizations, and media. The smoke alarm program found that 85 percent of alarms were operational when follow-up was done. This program approach might be a useful model for prevention of other types of residential injuries, but it should be tested for effectiveness.

Structural, product, and behavioral aspects are considerations for home fire safety. Testing of home construction materials, building codes and inspections (which focus on quality of home construction, repair, and renovation) and public education are strategies to prevent fires due to structural factors. Passive prevention methods integral to the home environment which don't require action to activate offer advantages over means that rely on education, awareness creation, and specific behavior. However, both approaches are probably needed for maximum effectiveness.

The prevention of scalds, non-fire burns, and poisoning has been shown to be possible in several different studies. Again, home design elements and consumer product design, as well as supervision, are key factors. Interventions include caretaker education and behavior change, and passive safety design and mechanisms. Several simple effective prevention steps are well known: locking cabinets for storage of poisonous materials, reducing the temperature of hot water heaters to 120°F.; child-proofing electrical outlets, drawers, and cabinet doors; and using child-proof caps on medicines and poisonous products in the home.

Knowledge Gaps and Research Needs

Data needs and uses

Some of the main data sources are National Health and Nutrition Examination Survey (NHANES) and hospital ED injury reports. Public health professionals can provide data on the risk of injuries due to these causes so that engineers can improve structures and materials and inspectors can direct their observation and regulatory work to the most important problems.

Many entities are sources of injury information, and they record different types of information. Improved reporting of product injuries has been mandated, and the Consumer Product Safety Commission is the main federal regulatory agency receiving these data. Data on non-fatal injuries are being reported more often through the NEISS. The National Fire Prevention Association collects data about residential fires. Despite the fact that injury data are collected, there are formidable obstacles to achieve more complete reporting because of the variability in what is collected and the fact that the data are scattered across many agencies. It is difficult to make injuries a "reportable" condition in the same way that some diseases are.

There is a general need for better data on residential injuries of children and for meaningful measures of injury outcomes. Questions on injuries and injury

prevention might be included in household surveys to better capture injuries that don't end up in hospital emergency rooms.

Three key questions about injury data and measurement are given below.

Data and Measurement Issues Related to Unintentional Residential Injuries of Children

- How can we improve surveillance of home injuries?
- How can we rapidly assess emerging hazards?
- Need to develop a system to get better information on causes of injuries and deaths from fire departments and fire marshals in order to identify where the real problem lies and what prevention activities can be done.

Research Needs

CDC has developed a five-year research agenda on injury prevention and control. A key issue in injury prevention, according to the CDC, is how to achieve broad dissemination of information about and adoption of preventive actions (CDC, 2002, p. 19). For example, the smoke alarm installation and education program described above was aimed to achieve some scale in dissemination and impact.

One challenging aspect of injury prevention is people's behavior—getting parents and caretakers to follow such recommendations. There is a need to understand what motivates and enables parents to take injury prevention measures in the home and to continue actions that need to be repeated over time.

Economic factors may shape preventive actions and their acceptance. Affordability is one economic element. Another economic factor is the interest of employers and insurers in loss reduction. Employers pay for the costs of injury through health and disability insurance and productivity losses; insurance companies, through

payment of claims. Both of these groups have a vested interest in reducing injuries, and this could lead to programs of incentives, discounts, and active education of employees.

Identifying moments of opportunity and points of leverage is an important strategy for injury prevention. This is a lesson learned from lead poisoning prevention strategies (for example, point of sale, new and renewing leases, and home sales contracts).

The agenda emphasizes applied research. For children, it includes attention to animal bites, drowning, fire, falls, and scalds and burns. The main research areas identified about residential injuries of children in the CDC research agenda are:

- **Falls:** determinants and consequences of fall injuries, biomechanics of falls, role of built environment, and testing innovations
- **A cross-cutting behavioral issue:** the role of supervision in prevention of injuries to children
- **Dog bites:** identification of modifiable risk factors for dog bites among children and testing of prevention programs
- **Scalds:** evaluation of prevention programs that focus on supervision and regulation of water tap temperature to prevent scald burns
- **Drowning:** testing unproven measures and testing means of dissemination of proven interventions to prevent drowning
- **Fire and burns:** testing interventions to prevent injury, barriers to adoption of fire prevention practices, behavioral aspects in causation and response, and large fires (mass trauma).

CDC's research agenda also recognizes five cross-cutting research priorities:

- Injury surveillance
- Costs and long-term consequences of injuries
- "Cross-cutting risks" of a behavioral nature (e.g., child abuse)
- Rapid assessment of emerging hazards

- Determining impact of legislation, litigation, and regulation.

The workshop participants identified research needs associated with home design, safety products and their use, behavior, obtaining better data on injuries of children, and risk factors. The reasons why African-American children have higher death rates from injury are not well understood. Severity of the injuries they have, blood lead levels as a risk factor, and the role of availability and quality of emergency medical services could be factors. There could be other risk factors that contribute to these higher rates.

Focused studies on a smaller scale would shed light on mechanisms of injury events—built environment and situational factors that contribute behavior that results in injury; and behavioral responses of victims, caretakers, health providers, and emergency personnel.

Stairs. Stairs are one element of home design associated particularly with falls. Stairs are not engineered to be safe for children. Most stair research and standards based on adults are not applicable to children. Investigation of stair rise, tread, incline, and number in relation to children's falls is needed from a "human factors" perspective. Factors that are associated with adoption or non-adoption of protective measures to prevent falls, and the extent of their use should be studied to identify effective behavior change communication programs.

Estimating the number of injuries that could be prevented through improved home design, safety devices, and consumer products with safety protection designed into the product would be useful to advocate for public attention and legislation.

CO detectors. In the discussion, a number of questions were raised about carbon monoxide (CO) detectors. There is a basic question as to whether they are actually effective in preventing injury and death. Appropriate guidelines for response to the sounding of a CO alarm

are needed both for the family and emergency agencies. Finally, there is a programmatic question which could be addressed in applied research as to whether they should be added to fire prevention (i.e., smoke alarm) programs.

Evaluation of interventions. Comparative studies of effectiveness of comprehensive residential fire prevention programs versus other approaches to residential fire prevention or no program are needed. Outcome measures for such studies would examine cost, injuries and death; persons who are protected from home fires, etc. In addition, operations research studies are needed to determine the most effective interventions to increase use of smoke alarms. Estimating the number of injuries that could be prevented through improved home design, safety devices, and consumer products with safety protection designed into the product would be useful to advocate for public attention and legislation.

Behavior. There are several behavioral questions for research. One is what do people do when smoke alarms go off. There are different responses, some facilitating escape and others leading to harm. Another human element is parental or caretaker guidance and supervision of children, both to prevent and respond effectively to a fire. A third question is what are the most effective communication and action interventions to bring about changes in parents' behavior to prevent injury of children at home.

The following table (Table 2) presents the questions which workshop participants raised by research type and injury topic area.

Strategies to Reduce Residential Injuries to Children

The workshop participants identified for future research several strategies to reduce injuries of children in the home (Figure 4).

Table 2. Research Needs Related to Residential Injuries of Children

Type of Injury	Type of Research			Dissemination of Prevention Methods (scaling up tested interventions)
	Foundational (risk factors, descriptive-analytic, design & testing of materials & technologies)	Developmental (design & initial trial of interventions, behavioral factors, enabling factors)	Efficacy (testing of interventions, cost-effectiveness, pilots)	
General (not specific to a type of injury or applies to several)	<p>What is the influence of housing stock (quality, characteristics) on injuries?</p>	<p>Is a combination of messages educating parents along with passive injury control more effective in reducing injuries than only passive control means? Need to test multi-pronged prevention strategies (because education alone is not enough).</p> <p>What is known about the effectiveness of outreach or education programs related to injury prevention?</p>	<p>What are the most important problems for home inspectors to observe? These need to be prioritized.</p>	
	<p>What is the influence of urbanization & crowding on childhood injuries?</p>	<p>What characteristics of parents are associated with reducing childhood injuries? Can these characteristics or behaviors be taught and developed in parents (without them) well enough to reduce the incidence of child injuries in the home?</p>		
	<p>What are the patterns of child injuries in day care environments by type of facility & type of injury; economic impact (including insurance cost); other costs (medical care, parent's or caretaker's work days lost).</p>	<p>There is need for tests of interventions, preferably controlled trials—in home design, construction, and maintenance, how home space is used—to assess their effectiveness in preventing injury.</p>		
	<p>What are the costs of child injuries?</p>		<p>What is the cost-effectiveness of injury prevention? How much money, pain, parents' time, etc. could be saved by prevention (include impact of legislation, regulation, litigation)?</p>	

Table 2. Research Needs Related to Residential Injuries of Children (continued)

Type of injury	Type of Research			Dissemination of Prevention Methods (scaling up tested interventions)
	Foundational (risk factors, descriptive-analytic, design & testing of materials & technologies)	Developmental (design & initial trial of interventions, behavioral factors, enabling factors)	Efficacy (testing of interventions, cost-effectiveness, pilots)	
Falls	What is the relationship between heights for stairs and children's falls on them?		What would be the optimal stair height and incline to prevent children's falls or reduce the severity of injury? Test other design options that may have been identified, also.	What standards should be set about stairways to reduce child injury on them?
Fire			<p>What incentives could be used to increase use of smoke alarms?</p> <p>↓ in home or renter's insurance,</p> <p>↓ which sectors of the population are most at risk, with greatest need and least ability to provide?</p> <p>↓ which sectors of the population are able to make changes in the home environment (use market forces, "loss reduction" strategy for insurance to encourage adoption)?</p> <p>Would a regulatory approach reach more homes about smoke alarms than the current approach (general education, voluntary), especially for rental housing?</p>	
Suffocation/Asphyxia	Can CO detectors be combined with smoke alarms into one unit?	Do CO detectors make a difference in preventing injury and/or death?		What would be the components of an effective CO detector program? Should it be linked to smoke alarm programs?

Figure 4.

- Strategies to Reduce Residential Injuries to Children**
- Choosing an injury to target for reduction in incidence that is frequent, relatively severe, and for which feasible prevention measures exist.
 - Shifting focus to “passive” built-in protection instead of education interventions.
 - Behavior change of parents and caretakers (positive deviance approach to identification of positive behavior to promote) and supportive interventions.
 - Testing of interventions, using the most rigorous methodology possible.
 - Applying the multi-faceted, participatory smoke alarm program strategy to other injury prevention measures.
 - Applying lessons learned from other public health problems related to housing.
 - Some injury prevention recommendations for older adults may apply to children as well.
 - Injury surveillance should be combined with other surveillance of residential health hazards and exposures.
 - Multiple types of actions and interventions may be required (from lead prevention programs), such as regulation, communities, leverage points, education, renovation, screening, and treatment.
 - Partnerships among government, research organizations, private sector.
 - Involving professionals in the fields of physical activity and the environment.
 - Social aspects (community and family) of child injury prevention.
 - Cross-training personnel of different programs that visit homes.
 - Developing cost-effective approaches for smoke alarms that will reach many more homes.
 - Cross-problem and cross-disciplinary, public-private coalitions for advocacy to state and federal legislatures—instead of a categorical approach—about codes, regulation, subsidies to enable installation or renovation to homes to reduce injury risk of children, and other approaches.
 - Exploring the possibility of establishing regional injury prevention research centers.

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Action for Healthy Homes: Translating Research into Action

5

Introduction

Understanding the relationships between residential environmental hazards and children's health problems and the most cost-effective techniques of assessing and controlling those hazards is a necessary precedent to prevention of those health problems. Equally important is an understanding of how to translate that knowledge into preventive action. This section suggests some of the activities that could lead to such action. They include:

- Increasing funding for research and demonstration projects on how best to assess and control hazards.
- Enforcing existing hazard elimination or control regulations and considering enacting new regulations.
- Pursuing market based approaches to eliminate or control hazards.
- Seizing opportunities to integrate healthy homes primary prevention and secondary prevention into state and local activities to build momentum and encourage early adopters.
- Persuading medical and policy organizations that eliminating or controlling hazards in housing should be given a high priority.

The hazard of lead in household dust is so clearly the primary cause of lead poisoning that even the medical profession has shifted its emphasis to a primary prevention approach.

Priority for hazard elimination or control

Physicians and hospitals have little or no experience with housing or hazards in housing. The medical establishment naturally focuses on treating the symptoms of diseases such as asthma, lead poisoning, and cancer with drugs rather than eliminating or reducing exposure to the hazards that at least partially cause the diseases. The hazard of lead in household dust is so clearly the primary cause of lead poisoning in young children that even the medical profession has shifted its emphasis to a primary prevention approach and supports controlling that hazard. Asthma and cancer are much more complex diseases, and the relationship of allergens, pests, pollutants, pesticide residue and other chemical and biological hazards in housing to disease is less clearly understood. Therefore, the research proposed in the preceding sections is critical to convincing the medical profession, the Congress, government agencies, foundations and other stakeholders that they should also focus on housing if those diseases are to be prevented. As research clarifies the importance of hazards in housing and as research and demonstrations show that assessing and treating those hazards can reduce the incidence and severity of disease, a concerted effort must be mounted to disseminate the data and conclusions to the medical profession and to other policy makers and funders.

Increase funding for research and demonstrations on housing hazards and their assessment and control

At present, the HUD Healthy Homes Initiative is the only source of funding dedicated to understanding how to prevent diseases associated with housing hazards. More research is needed to identify the specific characteristics and conditions of housing that either pose hazards to health or promote health. Effectiveness of various interventions needs to be established and their costs determined to allow cost-effectiveness to be assessed. Specific health impacts of indicators of building performance need to be investigated.

Because of the small appropriation for the Healthy Homes Initiative and the need for rapid results, HUD only funds two-year projects that are too short to develop definitive conclusions. Congress should provide HUD with a longer-term authorization and mission and it should direct other agencies, including EPA, CDC and NIEHS, to fund long-term studies, including randomized control studies. Those studies should be developed and managed by collaboratives of medical and public health schools and research-oriented housing organizations.

Such additional long-term funding will be available only if the interested scientific and advocacy communities make a major effort to provide the potential funders, including key legislators, with existing evidence that diseases can be prevented and money saved in the long run by supporting substantial expansion of the Healthy Homes effort.

Regulation and Demonstrations

Existing regulations. Federal, state and local legislation, regulations, and guidelines already exist that could materially reduce residential hazards. The existing comprehensive lead laws, regulations, and guidelines set the example. Most housing codes include provisions aimed at preventing excess moisture intrusion and pest infestation and requiring ventilation. Effective enforcement of those regulations would sharply reduce such allergens

as cockroaches, mold, and rat and mice dander. Requirements for smoke alarms reduce burns. Standards for stairs and window guard requirements reduce unintentional injuries.

For the most part, these requirements and their enforcement are aimed at individual hazards. Relatively minor changes in the rules could increase their cross hazard effectiveness. Cross training in healthy homes principles and practices of housing and sanitary code inspectors and home inspectors could increase efficiency and thoroughness in identifying hazards that make housing unsafe and unhealthy. Code inspectors and Public Housing Authority housing quality inspectors could detect lead hazards, pollutants, pests, and conditions that nurture allergens and mold. Lead inspectors and sanitarians could assess a wide range of potential hazards. Local agencies justifiably resist broadening the scope of their inspections because of resource and authority limits. Scientists and advocates should emphasize that comprehensive assessments would be more efficient and effective.

An overall assessment of current sanitary and building codes should be undertaken to identify points of leverage that can be exploited to promote healthy homes. The assessment should include identification of unique ideas, obvious gaps, and determination of the effectiveness of current healthy homes requirements. Also, current codes should be examined for points where future healthy homes equivalents of EPA's Energy Star and ARC certificates could be incorporated.

Education. Education alone designed to change parental behavior with respect, for example, to cleaning has been shown to be ineffective in reducing children's exposure to hazards. But education is needed after lead hazard or moisture control treatments have been carried out if the benefits of those treatments are to be maintained. Health and housing outreach workers and a variety of inspectors visit families in at-risk housing with some regularity. Cross training of those persons would help reinforce any educational program. As noted in earlier sections, research is needed to determine how family education can be more effective.

While difficult and slow, massive public education programs featuring the dangers of unsafe and unhealthy housing should be mounted to simulate demand for healthy market rate housing.

Demonstrations and evaluation research.

Government agencies should require that housing built or rehabilitated with government funds must incorporate basic healthy homes construction standards. Government should fund evaluations of the cost and effectiveness of these standards in increasing durability and reducing children's exposure to hazards. These evaluations must be large enough and last long enough to allow proper assessment of the long-term cost-effectiveness of these standards.

New laws, regulations and guidelines. Existing rules may well not be sufficient to make housing safe and healthy. But much more was known about lead hazards and lead poisoning when comprehensive lead laws were enacted than is now known about other residential hazards. So it would be premature to advocate for comprehensive regulation of other residential hazards at this time. In order to build the consensus on which a regulatory structure could be considered:

- The research and evaluations described above should be completed and the results disseminated widely.
- Federal and state agencies and/or private sector organizations should issue guidelines covering such noncontroversial matters as how to control moisture and how to control pest infestation without dangerous use of toxic pesticides.
- Consideration should be given to adding requirements for integrated pest management and moisture control to federally assisted housing (like the HUD Lead-Safe Housing Rule).
- Promote the adoption of healthy homes building practices by state housing finance authorities and other funding assisted housing rehabilitation.
- Promote ASHRAE 62.2 (new ventilation standard) adoption by states.

- Government agencies and private science based organizations should sponsor conferences at which medical organizations, congressional staff and foundation representatives would discuss the results of research and evaluations.
- Advocacy organizations should build grassroots understanding and interest to stimulate local programs and show support for government action.

Market Forces

Ideally, an informed market should induce homebuilders, renovators and remodelers to make housing safe and healthy. Informed market-rate homebuyers and renters should demand such housing. Affordable housing should meet the same standards. Unfortunately, buyers and renters value aesthetics and lower costs over health issues that they do not understand, and builders are unlikely to change their plans voluntarily, particularly if the change adds even marginally to costs.

Public education programs can be effective. Seat belts or airbags are now routine. Rachel Carson's "Silent Spring" launched the environment movement. Asthma is an expensive, uncomfortable disease even when controlled by drugs. Mold is dreaded in some parts of the country. While difficult and slow, massive public education programs featuring the dangers of unsafe and unhealthy housing should be mounted to simulate demand for healthy market-rate housing. Given the recognition that EPA's Energy Star program has gained in the public's eye, discussions should be undertaken with EPA about including health considerations in future implementations of the program.

Builders do not seem to be motivated by health concerns, absent effective demand for healthy housing. They are concerned with durability. It can and should be possible to demonstrate that moisture resistant housing is likely to reduce buyer complaints and lawsuits. Experimental programs to train builders in New England that simple moisture resistance techniques are practical and inexpensive were well received. Trained builders should perceive that they could use these techniques in

their marketing plans. The success of this approach should be followed up with attempts to convince the nation's large homebuilders of the message that healthy homes for small additional costs and their health benefits can be a successful marketing tool (e.g. Energy Star homes). Case studies with large builders could be developed and then used to promote these activities. A future goal would be to create a set of standards for housing with a simple name (e.g. essential maintenance practices for healthy housing) that can be used to promote a uniform application of healthy homes principles across the country thus helping build a national demand.

Owners and financiers of affordable rental housing also care about durability. Demonstrations that safe and healthy housing mean lower maintenance as well as healthy tenants should motivate owners, housing finance agencies, and even banks to include moisture-resistant techniques in their specifications and underwriting standards. Going beyond moisture control, general

healthy homes building guidance including costs should be provided to state housing finance agencies and Housing Authorities to promote adoption of healthy homes standards and practices by them.

Fear of liability induced property owners to accept lead safety standards. Publicity about illness apparently caused by mold has threatened the availability of insurance in parts of the country. So far there have been few if any law suits against rental property owners arising from exposure to allergens or pollutants, presumably because control of those hazards is considered to be the tenants' responsibility. As the relationship between structural conditions that cause excess moisture and disease become clearer, such lawsuits may become more common. Advocates should suggest that insurers and lenders include moisture resistance measures in their underwriting guidelines and that insurers consider discounts for healthy housing.

Appendix A Workshop Agenda

The Relationship Between Housing and Health: Children at Risk Workshop

Sponsored by the National Center for Healthy Housing
November 7 and 8, 2002
Maryland Inn
Annapolis, MD

Conference support for this Workshop was provided by the Centers for Disease Control and Prevention's National Center for Injury Prevention and Control.

Agenda

Thursday, November 7, 2002

8:00 – 9:00 **Registration and Continental Breakfast**

9:00 – 9:15 **Welcome and Introductions**
Nick Farr, JD, Former Executive Director
Rebecca Morley, MS, Executive Director
National Center for Healthy Housing

9:15 – 12:00 **Session I: Residential Determinants of Asthma and Other Respiratory Conditions**

9:15 – 9:20 Introduction of Speakers and Panel Discussants
Moderator: Patrick Breyse, PhD
 Professor
 Bloomberg School of Public Health
 Johns Hopkins University

9:20 – 9:45 “Research Associated with Allergens and Childhood Asthma”

Speaker: Peyton Eggleston, MD
Professor of Pediatrics
School of Medicine
Johns Hopkins University

9:45 – 10:10 “Residential Indoor Air Pollution and Childhood Asthma”

Speaker: Douglas Dockery, ScD
Professor of Environmental Health & Epidemiology
Director of the Environmental Epidemiology Program
Harvard School of Public Health

10:10 – 10:25 **Break**

10:25 – 11:30 Panel Discussion

Panelists: Timothy Buckley, PhD
Assistant Professor
Bloomberg School of Public Health
Johns Hopkins University
Peter Gergen, DrPH
Senior Medical Officer
Center for Primary Care and Research at the Agency for Health Care
Policy and Research
U.S. Dept. of Health and Human Services
Lance Wallace, PhD
Environmental Scientist
U.S. Environmental Protection Agency

11:30 – 12:00 **Keynote Address:**

“Lead Poisoning, Injuries, Asthma – Big Challenges for Lonely Specialists:
Confronting the Syndemic of Housing Caused Disease”

Speaker: Richard Jackson, MD
Director
National Center for Environmental Health
Centers for Disease Control and Prevention

12:00 – 1:00 **Lunch**

1:00 – 4:00 **Session II: Environmental Neurotoxins in the Residential Environment**

1:00 – 1:05 Introduction of Speakers and Panel Discussants

Moderator: Bruce Lanphear, MD, MPH
Sloan Professor of Children’s Environmental Health
Director, Children’s Environmental Health Center
Cincinnati Children’s Hospital Medical Center

- 1:05 – 1:30 “Framework for Understanding Neurotoxic Risks in the Residential Environment:
Lead as a Model”
Speaker: Kim Dietrich, PhD
Professor of Environmental Health and Pediatrics
Associate Director, Children’s Center for Environmental Health &
Disease Prevention
University of Cincinnati College of Medicine
- 1:30 – 1:55 “Pesticides in the Residential Environment”
Speaker: Robin M. Whyatt, PhD
Assistant Professor of Clinical Public Health
Division of Environmental Health Sciences
Mailman School of Public Health
Columbia University
- 1:55 – 2:20 “Environmental Tobacco Smoke in the Residential Environment”
Speaker: Kimberly Yolton, PhD
Research Associate in General & Community Pediatrics
General & Community Pediatrics Research Center
Cincinnati Children’s Hospital Medical Center
- 2:20 – 2:45 “Residential Interventions: Opportunities to Prevent Exposure to Environmental
Neurotoxins”
Speaker: Bruce Lanphear, MD, MPH
Sloan Professor of Children’s Environmental Health
Director, Children’s Environmental Health Center
Cincinnati Children’s Hospital Medical Center
- 2:45 – 3:00 **Break**
- 3:00 – 4:00 Panel Discussion
Panelist: Jerome A. Paulson, MD
Associate Professor of Pediatrics
Co-director of the Mid-Atlantic Center for Children’s Health and the
Environment
George Washington University School of Medicine
- 4:00 – 4:30 **Wrap Up**
- 6:30 – 7:30 **Dinner**

Friday, November 8, 2002

8:00 – 8:30 **Continental Breakfast**

8:30 – 10:40 **Session III – Residential Determinants of Unintentional Injuries**

- 8:30 – 8:35 Introduction of Speakers and Panel Discussants
Moderator: Warren Galke, PhD
Director of Science and Health
National Center for Healthy Housing
- 8:35 – 9:00 “Residential Characteristics and Conditions Associated with Unintentional Injuries”
Speaker: Kieran J. Phelan, MD, MSc
Assistant Professor of Pediatrics
Cincinnati Children’s Hospital Medical Center
- 9:00 – 9:20 “Residential Interventions to Minimize Risk of Unintentional Injuries”
Speaker: Mark Jackson, BS
Project Officer
Division of Unintentional Injury Prevention
National Center for Injury Prevention and Control
Centers for Disease Control and Prevention
- 9:20 – 9:30 “CDC’s Injury Research Agenda: Focus on the Residential Environment”
Speaker: David Sleet, PhD
Associate Director for Science
Division of Unintentional Injuries
National Center for Injury Prevention and Control
Centers for Disease Control and Prevention
- 9:30 – 9:45 **Break**
- 9:45 – 10:40 Panel Discussion
Panelists: Christine Branche, PhD
Director
Division of Unintentional Injury Prevention
National Center for Injury Prevention and Control
Centers for Disease Control and Prevention
Mary Jean Brown, ScD, RN
Assistant Professor
Department of Maternal & Child Health
Harvard School of Public Health

10:40 – 1:30 **Session IV – Translating Research Results into Positive Actions**

10:40 – 10:45 Introduction of Speakers and Panel Discussants

Moderator: Nick Farr, JD
Former Executive Director
National Center for Healthy Housing

10:45 – 11:10 “The Federal Role in Creating Healthy and Affordable Housing”

Speaker: David Jacobs, PhD, CIH
Director
Office of Healthy Homes and Lead Hazard Control
U.S. Dept. of Housing and Urban Development

11:10 – 11:25 “A Summary of the Healthy Homes Initiative”

Speaker: Ellen Taylor, MS
Director, Healthy Homes Division
Office of Healthy Homes and Lead Hazard Control
U.S. Dept. of Housing and Urban Development

11:25 – 11:55 “The Market Approach to Translating Research Results into Positive Action”

Speaker: Ellen Tohn, MCP
President
ERT Associates

12:00 – 1:00 **Lunch**

1:00 – 2:00 Panel Discussion

Panelists: Kara Stein, JD
Legal Counsel
Office of Senator Jack Reed, RI
Joshua Sharfstein, MD
Minority Professional Staff
Committee on Government Reform
Office of Rep. Henry Waxman, CA
Don Ryan, MURP
Executive Director
Alliance to End Childhood Lead Poisoning

2:00 – 2:30 **Wrap Up**

Moderator: Nick Farr, JD
Former Executive Director
National Center for Healthy Housing

Speaker: Tom Matte, MD
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