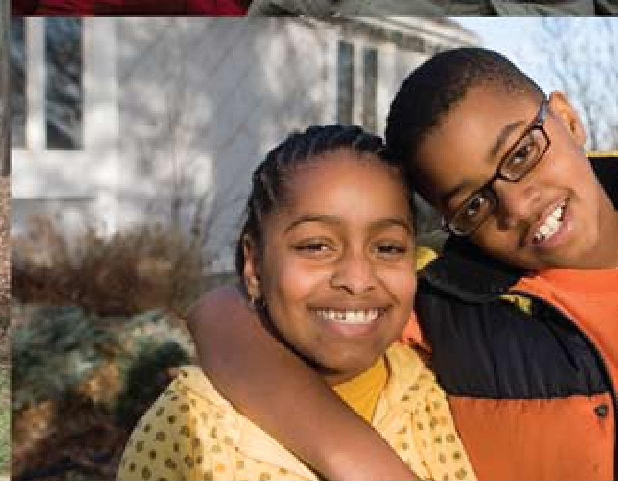
National Center for Healthy Housing

Housing Interventions and Health:

A Review of the Evidence



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DRAFT

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Introduction

Our housing and our health are at once inseparable and distinct. Together, they reflect two of our most basic needs for individual and collective identity, privacy, social progress and indeed survival itself. Yet scientific research in both fields historically has been hampered by a fragmented approach that has made ready identification of common avenues of improvement problematic. There are many reasons for this, including the large number of variables involved and the research process itself.

Nevertheless, the fact that improved housing means improved health in a general way has been accepted for well over a century (Lowry 1991). The advent of improved sanitation in the form of indoor plumbing, separation of housing from industrial emissions through zoning, and improvements in housing durability, among others, all led to demonstrable health gains by eliminating or controlling cholera, typhoid, tuberculosis, injuries and other diseases and conditions. Such health gains led to the first efforts to regulate housing quality.

Today, housing and health care are both in a state of crisis, particularly for families with limited means. A scientific examination of the efficacy of healthy housing interventions can help to improve both health and housing, reducing the cost of health care services.

As attention has shifted from communicable disease to more chronic afflictions, such as asthma, cancer, lead poisoning, injuries and mental health disorders such as anxiety and depression, the link between housing and health has received new appreciation and further investigation. Several reviews of how housing is linked to health in the modern era have been completed in the past decade (Sandel et al. 1999; Matte and Jacobs 2000; Krieger and Higgins 2002; Breysse et al. 2004; World Health Organization 2006). Increased recognition of this link has led to important developments both nationally (U.S. Department of Housing and Urban Development 1999; U.S. Department of Health and Human Services 2005) and internationally (World Health Organization 2005; Warwick University School of Law 2008).

While these reviews have amply demonstrated the many links between housing and health, until now there has been no attempt to assess the scientific literature on how housing and neighborhood-level interventions to improve housing affect health status. Saegert (2003) reviewed 72 studies of housing interventions aimed at improving health and found that the vast majority addressed only a single condition, most often lead poisoning, asthma or injury. Importantly, the review found that 68% of the studies showed statistically significant results; 61% had a comparison group; and 81% were able to document improvements in either health or environmental outcomes (Saegert et al. 2003).

As important as it is, the link between housing conditions and health effects constitutes only half of the knowledge needed. For example, to recognize the link between exposure to mold and increased risk of asthma does not necessarily provide information on how specific methods of reducing mold exposures do (or do not) improve asthma status. An intervention may have either unintended consequences or the link between a given housing condition and a given health outcome may in fact be spurious. We need a better understanding of the housing interventions that demonstrably improve health. Such an understanding can lead to policies and programs that will substantially improve our quality of life. In addition, such an understanding can also be used to develop a research agenda in this field. Furthermore, there is an economy of scale to this approach: one intervention can address multiple hazards. For example, the replacement of a rotted handrail covered with deteriorated lead paint addresses both lead poisoning and injury prevention.

This paper helps to close the gap in understanding about a vast array of housing interventions and their impact on health status.

Methods

The association between housing and health is complex, and causal relationships can be hidden or otherwise influenced by a host of confounding variables and effect modifiers. Several different frameworks have been proposed to characterize this relationship (Northridge et al. 2003; World Health Organization 2006; Miles and Jacobs 2007). These frameworks show that both proximate and distal factors are important to understanding the relationship between housing and health.

In assessing the scientific evidence, we used two broad categories of evidence: clinical evidence and environmental or housing measurements. Each of these sources of evidence has strengths and weaknesses. Clinical evidence (or other health data such as self-reported health) is likely to be the most direct measure of health status. Yet many health conditions do not have adequate biomarkers, or have long time horizons before an adverse health event occurs, making clinical evidence problematic. For example, lung cancer from radon exposure may not be clinically observable for many years, yet there is good evidence that radon environmental measurements can be linked reliably to risk of lung cancer. Similarly, asthma is a complex set of symptoms for which a single, reliable biomarker has yet to be identified. Thus, an intervention that successfully reduces environmental exposures for which there is good evidence of a dose-response relationship may be judged successful. Ideally of course, both clinical and environmental data can make the most compelling case for a given intervention. In this review, we analyzed studies that contained clinical, health, or environmental measurements, or a combination of these.

This report is the product of an exhaustive review of healthy housing intervention research. The review was carried out by a panel of experts at a December 2007 meeting convened in Atlanta, GA, through a cooperative agreement between the Centers for Disease Control and Prevention (CDC), National Center for Environmental Health/Agency for Toxic Substances and Disease Registry and the National Center for Healthy Housing (NCHH) (see Appendix A for the minutes of the meeting).

NCHH and CDC identified experts for five broad areas of healthy housing research.

- Interior Biological Agents (Toxins) Interventions
- Interior Chemical Agents (Toxics) Interventions
- External Exposures (Drinking water and sewage treatment)
- Structural Deficiencies
- Intersection Between Housing and Community

CDC carried out a preliminary literature review using relevant key words and search terms to search Medline, a public health database. This search covered articles added between 1990 and December 2007. The general terms and keywords used for all the panels included the following: public housing; housing; home; intervention studies; health effects; mitigation; program evaluation; prevention; primary prevention; clinical trials, randomized controlled trials; and domestic. In addition, the search included the specific terms and keywords for each of the five panels:

- **Panel 1:** Allergens; Dust; Mites; Asthma; Cockroaches; Animals, Domestic; Mice; Rats.
- **Panel 2:** Water; Air; Air Pollution; Integrated Pest Management; Pesticides; safe chemical storage; storage; Pest Control; Particulate Matter; Filtration; Ventilation; VOCs; Formaldehyde; Organic Chemicals; Air Pollution; Radon; Lead.
- **Panel 3:** Water; Water Supply; Drinking Water; In-Home Filtration; Waste Water Treatment; Sewage; Waste Management; Water Pollutants; Water Purification; Water Filters.
- **Panel 4:** Burns; Burn Prevention; Accident Prevention; Accidents, Home; Protective Devices; Accidental Falls; Fall Prevention; Falls; Accidents, Self-Help Devices.
- **Panel 5:** Environmental Justice; Universal Design; Ordinances; Law; Law Enforcement; Public Policy.

Additional literature was identified from the references in relevant papers. The expert panelists also identified additional literature, which was added to the review after the December meeting.

The literature review was limited to studies that were published in English. Although the majority of studies reviewed by the five panels were conducted in the U.S., the panels did include some relevant international studies, particularly in areas where little research has been conducted in the U.S. and where the international literature significantly strengthened the panels' recommendations.

The literature was divided into the five broad healthy housing research areas listed above. Within these broad areas, studies of interventions were grouped together according to recommendations in the Guide to Community Prevention Services (Community Guide), which identifies similarities in: (1) the type of intervention (e.g., activities undertaken, content, and scope); (2) the delivery of the intervention (e.g., who delivers it, time period, frequency, and duration); (3) target population (e.g., high risk population or general population); and (4) the setting of the intervention. (See *http://www.thecommunityguide.org/pubhealthpro.html*).

Each publication was reviewed by at least one reviewer; in some cases the publication was reviewed by two reviewers. The publications were evaluated using a structured review instrument and review procedure, adapted from the Community Guide. As noted in the Community Guide, the use of the standardized forms and data review procedure helps to provide a systematic approach that helps multiple reviewers ensure validity and reliability, while also allowing flexibility given the varying study designs and types of interventions.

The instrument (Appendix B) was used to score the following factors for each intervention study:

- Design/suitability
- Execution
- Study size and population
- Overall value
- Direction of effect and degree of impact

The experts assigned each of the interventions into one of four broad categories, based on the evidence in the literature:

- Sufficient evidence
- Needs more field evaluation
- Needs formative research
- No evidence of effectiveness

In order to consider an intervention effective, the Community Guide recommends that an intervention results in "improvements in health or leads to changes in behaviors or other factors that have been shown to result in better health." Additionally, interventions must demonstrate independent impacts on health or key factors that will result in better health. As described in the Community Guide, sufficient evidence can be determined through a small number of well designed, well executed and consistent studies, or through a larger group of studies that may be less strong in design, execution, and effect but when taken together provide convincing evidence for an intervention.

The study reviews were the primary evidence used to determine effectiveness. Reviewers did not, for example, consider other factors such as implementation barriers or economic analyses. While the Community Guide also allows for the use of expert opinion, the guide notes that expert opinion is seldom used for the recommendation of intervention effectiveness. Following this precedent, the panels did not recommend interventions based solely on expert opinion.

Respectively, the categories of 1) sufficient evidence, 2) needs more field evaluation, 3) needs more formative research, and 4) no evidence of effectiveness or evidence of harm are intended to be used in the following ways:

- Develop policy on those interventions that currently have sufficient evidence of effectiveness to recommend immediate implementation;
- Conduct research on those interventions where the evidence shows promising outcomes that need more testing and evaluation in the field prior to recommending widespread implementation, or interventions that have demonstrated success in non-residential settings, such as schools or offices, but need to be tested in homes;

- Implement formative research to determine the biologic plausibility of a link between a housing and health condition and an intervention's effectiveness; and
- Identify those interventions where the evidence is clear that the interventions should not be pursued.

The experts presented the results of their reviews to their respective panels to reach consensus on the category for the intervention. Each panel then presented its consensus assessment of the body of literature to the entire group of experts from the other four panels. Finally, the panels reviewed and discussed additional literature identified during the meeting deliberations. One exception to the process described above involves the effectiveness of lead hazard control, which has been extensively reviewed elsewhere and is summarized in the Panel 2 chapter.

The report provides the deliberations of the five panels, an overview of each panel's topical area, and the results of their reviews. Table 1 provides a summary of the interventions by category.

Table 1. Summary of Intervention Findings

Panel	Sufficient Evidence	Needs More Field Evaluation	Needs Formative Research	No Evidence or Ineffective
Panel 1: Interior Biological Agents (Toxins)	• Multi-faceted tailored asthma interventions • Integrated Pest Management (allergen reduction) • Moisture intrusion elimination	• Dehumidification • General & local exhaust ventilation (kitchens & baths) • Air cleaners (to reduce asthma) • Dry steam cleaning • Vacuuming	• Carpet treatments • One-time professional cleaning • Acaracides	• Bedding encasement alone • Sheet washing alone • Upholstery cleaning alone • Air cleaners releasing ozone
Panel 2: Interior Chemical Agents (Toxics)	• Radon air mitigation through active subslab depressurization • Integrated Pest Management (pesticide reduction) • Smoking bans • Lead hazard control	• Radon mitigation in drinking water • Portable HEPA air cleaners to reduce particulate • Attached garage sealing to limit VOC intrusion • Particulate control by envelope sealing	• Radon air mitigation using passive systems • Improved residential ventilation • VOC avoidance	• Portable HEPA air cleaners to reduce environmental tobacco smoke and formaldehyde • Air cleaners using or releasing ozone • Single professional cleaning to reduce long-term lead exposure
Panel 3: External Exposures (Drinking water & waste treatment)	• Voluntary drinking & wastewater treatment standards for small systems & private wells • Training for small system personnel • Guidelines for immuno-compromised individuals	• UV and other filtration point of use systems • Location of privies and failed drinking water and wastewater systems	• Training for planners and zoning officials • Control of pharmaceuticals and endocrine disruptors into drinking and wastewater systems • DNA analysis to track pathogen sources • Surveillance studies to define system failures	• UV/point of filtration research for systems that already comply with standards

Panel	Sufficient Evidence	Needs More Field Evaluation	Needs Formative Research	No Evidence or Ineffective
Panel 4: Structural Deficiencies (Injury)	• Installation of working smoke alarms • Isolation 4-sided pool fencing • Pre-set safe temperature hot water heaters	• Fall prevention by handrails, grab bars, stair-gates, window guards and improved lighting • Temperature-controlled water faucets • Safe ignition sources • Home modification to escape fires • Air conditioning during heat waves	• Ignition source controls (GCFI & AFCI) • Escape exit signage • Improved smoke alarm and faucet design • Behavior modification to escape fires • Automatic fire sprinkler systems for housing • Pool covers and alarms • Bathtub design to reduce falls • Stove and stove control design to prevent burns • Carbon monoxide exposure prevention through design and engineering • Improved enforcement of building and housing codes • Noise reduction	• 3-sided pool fencing
Panel 5: Intersection Between Housing & Community	• Rental vouchers (Housing Choice Voucher Program))	• Health Impact Assessment • Demolition and revitalization of poor or distressed public housing (HOPE VI) • Moving people from high-poverty to lower-poverty neighborhoods as a health intervention	• Universal design • Crime prevention through environmental design • Smart growth and connectivity designs • Residential siting away from highways • Noise interventions • Zoning • Density bonuses • Green space	

References

Breysse P, Farr N, Galke W, Lanphear B, Morley R, Bergofsky L, et al. 2004. The relationship between housing and health: children at risk. Environmental Health Perspectives 112(15): 1583–1588.

Krieger J., Higgins DL 2002. Housing and health: Time again for public health action. American Journal of Public Health 92(5): 758–768.

Lowry S. 1991. The Health of the Nation—Responses—Housing. British Medical Journal 303(6806): 838–840.

Matte TD, Jacobs DE. 2000. Housing and health—Current issues and implications for research and programs. Journal of Urban Health—Bulletin of the New York Academy of Medicine 77(1): 7–25.

Miles R, Jacobs DE. 2007. Future directions in housing and public health: Findings from Europe and implications for planners. Journal of the American Planning Association 74(1): 77–89.

Northridge ME, Sclar ED, Biswas P. 2003. Sorting out the connections between the built environment and health: A conceptual framework for navigating pathways and planning healthy cities. Journal of Urban Health-Bulletin of the New York Academy of Medicine 80(4): 556–568.

Saegert SC, Klitzman S, Freudenberg N, Cooperman-Mroczek J, Nassar S. 2003. Healthy housing: A structured review of published evaluations of US interventions to improve health by modifying housing in the United States, 1990–2001. American Journal of Public Health 93(9): 1471–1477.

Sandel M, Sharfstein J, Shaw R. 1999. There's no place like home: How America's housing crisis threatens our children. San Francisco: Doc4Kids project and Housing America.

U.S. Department of Health and Human Services. 2005. Report of the Surgeon General's Workshop on Healthy Indoor Environment. Washington, D.C.

U.S. Department of Housing and Urban Development. 1999. The Healthy Homes Initiative: A Report to Congress. Washington, D.C.: U.S. Department of Housing and Urban Development, Office of Lead Hazard Control.

Warwick University School of Law. 2008. Proceedings of the fifth annual healthy housing symposium. Accessible from: *http://www2.warwick.ac.uk/fac/soc/law/research/centres/shhru/conference/*

World Health Organization. 2005. Proceedings of the 2nd WHO International Housing and Health Symposium. Vilnius, Lithuania: World Health Organization, European Centre for Environment and Health. Accessible from: ?

World Health Organization. 2006. Technical meeting on quantifying disease from inadequate housing. Bonn, Germany. Accessible from: *http://www.euro.who.int/Document/HOH/EBD_Bonn_Report.pdf*

Panel 1: Indoor Biologic Agents

Excess moisture in a home can support the growth of mold and also provides an environment favorable to dust mites, cockroaches, mice, rats and other pests. Structural and plumbing deficiencies in a home are a source of water intrusion and also provide a mechanism for rodents, cockroaches and other pests to gain entry into the home (Ogg et al. 1995).

The National Academy of Sciences (2000) examined the current knowledge of the association between exposure to biologic agents in the home and the development and exacerbation of asthma. The review found sufficient evidence to establish a casual association between a number of respiratory conditions, including asthma exacerbation, and the presence of house dust mites, cockroaches, fungi (mold), and pet dander (Institute of Medicine 2000). This report found limited or insufficient evidence to support an association between rodents and asthma. However, subsequent studies have shown that rodents may be an important indoor allergen affecting inner-city and suburban children with asthma (Phipatanakul et al. 2000; Matsui et al. 2003).

Asthma prevalence has increased in the past few decades. It is unlikely that genetic changes could explain this increase and therefore much research has focused upon the indoor environment as a major precipitating factor (Miller 1999; Institute of Medicine 2000; Krieger et al. 2005). One of the strongest established risk factors for development of asthma is sensitization to one or more indoor allergens (Holt et al. 2005). Allergic sensitization occurs when the immune system produces antibodies against antigens (mainly glycoproteins) after the first exposure. Upon repeated exposures, the immune response is quicker and more intense and can result in a greater release of inflammatory agents. In some cases, the airways become affected; this can lead to allergic asthma which is characterized by bronchial hyper-reactivity, airways inflammation, and variable airflow (Holt et al. 2005). Not all asthma is driven by an allergic mechanism, with some authors pointing to respiratory irritants as contributors to asthma exacerbation (Pearce et al. 1999; Douwes et al. 2002; Salo et al. 2008)

The biologic agents related to housing structure that have received the most study include allergens from cockroaches, rodents, dust mites, fungi, and respiratory irritants including environmental tobacco smoke, cleaning agents, fungal cell wall components and VOCs, and oxides of nitrogen (Institute of Medicine 2000; Phipatanakul 2006).

House Dust Mites

Dust mites are found in the bedding, pillows, mattresses, carpets, and upholstered furniture of homes, where they feed on human skin scales, fungi, and other forms of organic material found in dust (Gravesen 1978; Tovey et al. 1981). Dust mite allergens primarily come from their fecal pellets, which can range in size from 10–40 microns (Tovey et al. 1981).When airborne, their large size leads them to settle quickly. Dust mites absorb water from the air and therefore require a relative humidity above 50% to survive (Arlian et al. 1992). This restricts the inhabitable environments for mites and is a major controlling factor in the geographical distribution of dust mites. In major cities of the northeastern U.S., multifamily buildings have low indoor humidity during winter, which helps to limit dust mite proliferation (Chew et al. 1999; van Strien et al. 2004). Mite genera vary geographically with Dermataphagoides being common in temperate climates and Blomia being found only in tropical climates (Arlian et al. 2002). A recent national survey found that over 80% of homes in the U.S. have detectable levels of house dust mite allergen in the bedroom (Arbes Jr. et al. 2003) and 45.8% had levels above sensitization thresholds for at least three allergens (Salo et al. 2008).

Dust mite allergens are the only class of inhalant allergens for which the National Academy of Sciences found sufficient evidence for a causal association between exposure and the development of asthma in children (Institute of Medicine 2000). Dust mite allergen exposure in the home appears to exhibit a dose-response curve, with those individuals exposed to more allergen more likely to become sensitized, especially among those with asthma or born to atopic mothers (Huss et al. 2001; Cole Johnson et al. 2004; Brussee et al. 2005; Illi et al. 2006). Further evidence for the causality of exposure to dust mite allergens exacerbating asthma comes from studies that have shown successful improvement in asthma patient symptoms when exposure to dust mite allergens were reduced (Platts-Mills and Mitchell 1982; Boner et al. 2002).

Cockroaches

There are five species of cockroaches commonly found in U.S. homes, all of which produce allergens. To date, only the German and American cockroaches have well-characterized allergens (Eggleston and Arruda 2001). Cockroach allergens are derived primarily from fecal material, saliva, secretions and body parts (Eggleston and Arruda 2001). Cockroach allergens are similar to dust mite allergens in that they are associated with fairly large (>10 microns) particles, and when aerosolized fall back to the ground relatively quickly. Heavy infestations in homes may create reservoirs of allergens in carpets, rugs, beds, and in difficult to reach areas around appliances and furniture (Eggleston and Arruda 2001). The humidity in a home may be an important factor in cockroach infestations for some species. The German and American cockroaches tend to aggregate in warm, humid areas such as those around water heaters, laundry, bathrooms, appliances, and plumbing fixtures, while the Oriental cockroach prefers damp areas such as basements, plumbing and sewers (Eggleston and Arruda 2001).

A detectable level of cockroach allergen is found in 63% of dwellings in the U.S. (Cohn et al. 2006) and 10.2% have cockroach allergen above a sensitization threshold (8 Units/g for bla g 1) (Salo et al. 2008). Cockroach allergens are important in asthma exacerbation (Chew et al. 2008), particularly in deteriorated homes where cockroach infestation is most common (Rauh et al. 2002). Examination of data from the National Survey of Lead and Allergens in Housing found that elevated concentrations of cockroach allergen were associated with high-rise buildings, urban settings, pre-1940 construction, and household incomes less than $20,000 (Cohn et al. 2006).

Based on a study of inner-city children with asthma, the combination of cockroach allergy and exposure to high levels of cockroach allergen resulted in greater odds of frequent asthma symptoms and hospital admissions for asthma (Rosenstreich et al. 1997). Cockroaches may also be an important factor in asthma exacerbation in rural and suburban homes (Garcia et al. 1994; Matsui et al. 2003). For example, in a study conducted among a suburban population, over 40% had levels of cockroach allergen in the home thought to be associated with sensitization (Matsui et al. 2003). In another example, the National Cooperative Inner City Asthma Study (a multi-site intervention study in the U.S.) found that among a group of inner-city children, cockroach allergens had greater effect on asthma morbidity than dust mites or pet allergens (Gruchalla et al. 2005). Nonetheless, only one prospective study has found an association between cockroach allergen exposure and development of asthma (Litonjua et al. 2001).

Fungi (Mold) and Excessive Moisture

There is a broad body of epidemiologic and laboratory evidence linking the presence of mold and moisture to poor health outcomes. National and international expert panels have reviewed the evidence, finding consistently that both mold and moisture are associated with a wide variety of adverse health effects in both the general population and in specific vulnerable segments of the population (Institute of Medicine 2000, 2004). From a public health and prevention perspective these clinical findings point to the importance of controlling moisture sources within the home, correcting water damage as soon as it occurs, fixing leaks promptly, and safely cleaning or removing mold-contaminated materials promptly.

In indoor environments, mold originates from two sources, including mold infiltrating from outdoors (e.g., through open windows), and mold colonization on the interior of the home. Molds obtain nutrients and moisture sufficient for growth from water-affected building materials such as wallboard and insulation materials, as well as carpets, furniture, and bedding (Institute of Medicine 2004; Woodcock et al. 2006). The features of a home that increase moisture levels and fungal growth include condensation on cool surfaces, water intrusion from outside, and interior leaks. Mold exposure occurs primarily as spores become aerosolized upon disturbance of a reservoir. Recent research has shown that fungal fragments also contribute to the respirable fraction of inhaled particles (Gorny et al. 2002; Green et al. 2005; Green et al. 2006).

The fraction of current asthma cases attributable to dampness and mold exposure in housing is estimated to be 21% (Mudarri and Fisk 2007). Although the precise causal pathway between mold exposure, allergic sensitization or irritant airway response and asthma development remains undetermined, exposure to mold is associated with the exacerbation of asthma-related symptoms in sensitized individuals (Institute of Medicine 2000, 2004). The IOM (2004) report did not find sufficient evidence of a causal relationship with any health outcome, and concluded there was insufficient evidence to determine an association with many health effects, including asthma development, dyspnea, airflow obstruction (in otherwise healthy persons), mucous membrane irritation syndrome, and pulmonary hemorrhage in infants. These results are not applicable to immuno-compromised persons, who are at increased risk for fungal colonization or opportunistic infections.

Molds not only have allergenic effects, but can also have toxic or irritant effects. Evidence from occupational studies suggests that exposure to mycotoxins can result in mucus membrane irritation, skin rashes, dizziness, nausea and immunosuppression (Burge and Ammann 1999). Fungi also produce irritants such as microbial volatile organic compounds (MVOCs) and (1→3)ß-D-glucans that may be responsible for some “sick building” symptoms (Douwes 2005; Walinder et al. 2005).

Rodents

Rodent allergy research on laboratory animal workers has mainly focused on mice and rats (Hollander et al. 1998; Lieutier-Colas et al. 2002), and it is allergens from these rodents that remained the focus for residential studies of allergy and asthma (Phipatanakul 2002). The rodent allergens are mainly found in urine and to some extent dander, and the allergens can be associated with small particles which remain airborne for long periods of time (Ohman et al. 1994; Phipatanakul 2002). Detectable levels of mouse allergen are found in 82% of dwellings in the U.S. (Cohn et al. 2004). The National Cooperative Inner-City Asthma study found 95% of all homes assessed had detectable mouse allergen in at least one room, suggesting that mouse allergens are widely distributed in inner-city homes (Phipatanakul W et al. 2000). Chew et al. observed that mouse allergen was common in low income, inner-city apartments, even where sightings were not reported (Chew et al. 2003).

In 2000, a study of 499 children in the U.S. with asthma found that 18% were allergic to mouse allergen and that those with exposure to Mus m 1 (an allergen in mouse urine) >1.6 μg/g in kitchen dust were more likely (OR=2.2) to become sensitized to the mouse allergen than those with a lower level of exposure (Phipatanakul et al. 2000). Among the same cohort of children, allergy to rats was also prevalent (21%), and those with sensitization and exposure to rat allergens experienced more unscheduled medical visits, hospitalizations and days with diminished activity due to asthma (Perry et al. 2003).

Panel 1 Decision Results

Panel 1 considered the following interventions:

- Multi-faceted tailored interventions for asthma
- Integrated Pest Management (IPM) as a means of reducing pest exposure
- Cockroach management
- Elimination of moisture intrusion
- Ventilation
- Air cleaners
- Carpet treatments
- Bedding and upholstery treatments
- Education
- One-time professional cleaning
- Acaracides
- Removal of moldy items and moisture control through dehumidification

Of these interventions, three are ready for implementation and have been shown to be effective, five need more field testing but are promising, three need formative research, and four are ineffective.

A. Sufficient Evidence

1. **Multi-faceted in-home interventions for asthma tailored to the individual, as exemplified by the National Cooperative Inner City Asthma Study, are effective in controlling asthma symptoms and reducing other measures of asthma morbidity. These interventions include home environmental assessment; education; use of mattress and pillow covers; use of HEPA vacuums and HEPA air filters; smoking cessation and reduction in environmental tobacco smoke exposure; cockroach and rodent management; minor repairs, and intensive household cleaning.**

Rationale: Studies by Morgan et al. 2004, Arlian et al. 2001, Becker et al. 2004, Schonberger et al. 2005, Eggleston et al. 2005, Krieger et al. 2005, and Arshad et al. 2003 provide the strongest clinical evidence that this multi-faceted tailored approach is effective. The panel found that all these studies were well-designed, had large numbers of subjects from appropriate populations and identified statistically significant improvements.

This is also consistent with a major recent systematic review of the evidence completed for the CDC Task Force on Community Preventive Services, which now recommends home-based multi-component multi-trigger interventions with an environmental focus for children with asthma based on strong evidence of effectiveness (Crocker et al. 2008). It is also consistent with more recent studies that were not available when the Panel convened (Parker et al. 2008; Krieger et al. Accepted for publication, 2008).

Other studies that did not incorporate these multi-faceted approaches were far less successful, or were unable to demonstrate significant clinical improvements. These are discussed in parts C and D of this section.

In short, the panel determined that the weight of the evidence in the studies cited above shows that individually tailored multi-faceted housing-based interventions are successful in controlling asthma severity, as measured by clinical outcomes. To date, housing interventions focused on single triggers, which were not tailored to the individual, have not been shown to be effective in improving clinical status, although it is possible to reduce environmental exposures to allergens through singular interventions.

2. **Cockroach control through Integrated Pest Management (IPM) was found to be an effective intervention in reducing exposures to pests, as well as reducing exposures to pesticides (the ability to reduce exposures to chemicals was reviewed by panel 2). IPM includes household cleaning and tool dispensing, professional cleaning, education of residents, baits and structural repairs and when necessary, intensive application of low-toxicity, non-spray pesticides.**

Rationale: The panel found evidence that IPM is effective in the Arlian, Arbes, Williams, Wang and Eggleston studies; most of the evidence is based on measurements of reduced exposure to allergens and to cockroaches (Arlian et al. 2001; Arbes et al. 2003; Eggleston et al. 2005; Wang and Bennett 2006; Williams et al. 2006). Additional research also found benefits from IPM for roach control, but did not have the methodological rigor of these studies. For example, Levy and colleagues showed a positive benefit in reducing cockroaches only (Levy et al. 2006). The McConnell et al. 2003 study did not measure clinical outcomes, but showed that cockroach counts declined when bait traps with insecticides were used; it also showed that intensive cleaning can achieve significant reductions in allergen levels in homes with initially high levels (McConnell et al. 2003). The Sandel study demonstrated a positive outcome from IPM in reducing both mouse and cockroach allergen levels and in reducing reported "severe" or "very severe" asthma from 37% before IPM to 9% following IPM (p=0.002), but was weakened by a small number of subjects, absence of a control group and the use of rather subjective outcome measures, such as self-reported qualitative statements on IPM (Sandel et al.). The Sever study showed positive benefits of IPM in reducing prevalence of pests, but the study was rather small and the use of skilled entymologists may have confounded the effect of IPM because entymologists may exert a greater level of care than routine IPM practitioners (Sever et al. 2007). Miller and Meek found that IPM was initially more costly but also much more effective in reducing cockroaches, compared to traditional pesticide treatment (the traditional method left cockroach levels unchanged, but IPM achieved a reduction of 24.7 cockroaches/housing unit before IPM to 3.9 cockroaches/housing unit, which was sustained for at least 8 months. However, this study did not directly measure health outcomes (Miller and Meek 2004). Klitzman found significant reductions in cockroaches following IPM implementation (Klitzman et al. 2005).

In short, the weight of the evidence shows that IPM is an effective intervention for reducing exposure to both cockroaches and cockroach allergen.

3. **When implemented together, eliminating moisture intrusion and leaks and removal of moldy items were found to be effective in reducing asthma triggers and reducing exposures.**

Rationale: The panel found that the studies done to date provided limited but sufficient evidence of efficacy. According to the Community Guide, sufficient evidence can be determined through a small number of well designed, well executed and consistent studies, or through a larger group of studies which may be less strong in design, execution, and effect but that taken together provide convincing evidence for an intervention. For example, one of the strongest and best designed studies (Kercsmar et al. 2006) had only 25 participants in each arm. Another study examined the effect of prompt remediation, but it included only one house (Rockwell 2005). The Lignell study also showed a beneficial effect on children's health following mold and moisture remediation, although this study was in a school, not housing (Lignell et al. 2007). The Burr study also showed a beneficial effect on wheeze, perceived breathing ability, and perceived reduction in medication use following mold and moisture control, although there was no difference in peak expiratory flow rate (Burr et al. 2007). A small study of moisture and mold control in 4 homes where flood damage occurred showed that spore counts and endotoxin increased significantly during renovation work and declined significantly following the removal of moldy items and a multi-step clean-up process (Chew et al. 2006). However, there were no control homes for this limited study. An important limitation was that the studies were not geographically representative enough to draw conclusions about their application across diverse climate zones.

The panel found sufficient evidence to recommend implementation of multi-faceted interventions to control mold and moisture intrusion, although more data on climate-zone specific interventions are needed.

B. Promising Interventions That Need More Field Evaluation

Moisture control through dehumidification, improved general and local exhaust ventilation, use of air cleaning devices, repeated dry-steam cleaning, and repeated vacuuming were all identified as promising interventions that need more field testing.

Rationale: Each of these interventions has received some study, but the evidence is not conclusive. For example, a large randomized controlled trial of moisture control through building improvements associated with addition of insulation in New Zealand showed respiratory health improvements, but the effect of moisture control may be confounded by the addition of insulation and improved thermal benefits (Howden-Chapman et al. 2007). Similarly, a small study of intensive vacuuming and steam cleaning of carpeting and furnishings had no control groups, but did show sustained reductions in mite concentrations (Vojta et al. 2001), making this a promising intervention. This is also supported by a small study showing benefits from steam cleaning (Colloff et al. 1995). A study of moisture reduction in schools through renovation showed improvements in symptoms (Lignell et al. 2007). There are a number of challenges that remain demanding further study. The U.S. comprises a very large geographic area with diverse climates, building systems and ages of the building stock. Better definitions of interventions for differing climates are needed. Further delineation of the approaches best suited to the differing circumstances encountered in new construction and rehabilitation is needed.

Evaluation of HEPA air filtration has yielded mixed results. A randomized controlled trial examining the control of cat allergen using HEPA air filtration did not control for the presence of carpets and other soft surfaces and did not show a significant clinical effect (Wood et al. 1998). Another randomized trial showed a decline in airborne particulate and improvement in active rhinitis or asthma with sensitivity to dust mites (Reisman et al. 1990) using air cleaners. Use of steam cleaners and HEPA and non-HEPA vacuum cleaners did not show a clear health or environmental benefit (Colloff et al. 1995; Gore et al. 2006; Sercombe et al. 2007). However, one review article did show improvement for reducing pet airborne allergens (Wood 2002). Van der Heide showed a statistically significant reduction in particulate matter from use of HEPA air cleaners, when compared to non-HEPA air cleaners (van der Heide et al. 1999), but a review article suggested otherwise (Kilburn et al. 2003). Ventilation and air cleaners are considered further in Panel 2.

C. Interventions in Need of Formative Research

Carpet treatments, one-time professional cleaning and use of acaracides were identified as housing interventions in need of more formative research.

Rationale: A study of treatment of carpets with chemicals to reduce allergens using differing methods provided mixed results and did not demonstrate the longevity of the treatment (Woodfolk et al. 1995).

D. Interventions Shown to be Ineffective

Evaluations of bedding encasement, sheet washing and upholstery cleaning each by themselves in isolation from other interventions have demonstrated only limited (if any) benefit. In addition, so-called air cleaners that release high levels of ozone should not be used due to problems with ozone exposure.

Rationale: Studies that focused on specific interventions to control asthma triggers without the multi-faceted approach described above either did not find benefit from single-focus interventions or tended to suffer from methodological deficiencies, which limited the ability to show clear results. Two well-designed evaluations of bedding encasements did not find associated improvements in clinical measures (Terreehorst et al. 2003; Woodcock et al. 2003). The Levy study had a smaller study size and could not statistically show that improvement in asthma status was significantly related to reduced allergen exposures, although the study was able to demonstrate effective cockroach allergen control (Levy et al. 2006). The Williams study had a large loss to follow-up, making it possible to identify improvements in only 25% of the population that was most severely affected at baseline (Williams et al. 2006). A number of studies evaluated single-focus interventions by their ability to reduce allergens, but without clinical outcomes (Vojta et al. 2001; McConnell et al. 2003; Mihrshahi et al. 2003). Another study that evaluated efficacy of mattress covers suffered from poor retention, limited covariate data, and no effect on clinical status (Rijssenbeek-Nouwens et al. 2002). A study that examined controlling cat allergen only using central versus traditional vacuum cleaners failed to demonstrate an effect and was small (n=12 houses) (van Strien et al. 2004). The Shapiro study did not control allergens other than cockroach and had a small sample size (Shapiro et al. 1999); the van den Bemt, Luczynska and Carter studies also had small sample sizes and did not demonstrate an effect (Carter et al. 2001; Luczynska et al. 2003; van den Bemt et al. 2004). The importance of targeting the intervention to allergens to which children are sensitized is demonstrated by the Carter study, because it had a null effect and did not perform such targeting. The Marks study did not show an effect, possibly because it targeted only a single allergen, in contrast to the multi-faceted studies cited above (Marks et al. 2006). One multi-faceted study showed that there was increased sensitization in the intervention group, although Specific Airway Resistance (sRaw) also improved in children at age 3 years (Woodcock et al. 2004). Studies of pet allergen reduction suffered from small sample size (n=9) (Green et al. 1999) or did not show a reduction in allergens (Francis et al. 2003).

A small study showed no significant improvement in asthma symptoms or forced expiratory volume (FEV), but did show a significant decline in mouse allergens (Phipatanakul et al. 2004). One small study, which treated pillow cases only, reduced dust mites, dust and glucan, but only very slightly (Siebers et al. 2007). A meta-analysis focusing only on control of dust mites with chemicals in 23 studies found no effect (Gotzsche et al. 1998).

References: Panel 1

Arbes Jr. SJ, Cohn RD, Yin M, Muilenberg ML, Burge HA, Friedman W, et al. 2003. House dust mite allergen in US beds: results from the First National Survey of Lead and Allergens in Housing. J Allergy Clin Immunol 111(2): 408–414.

Arbes SJ, Sever M, Archer J, Long EH, Gore JC, Schal C, et al. 2003. Abatement of cockroach allergen (Bla g 1) in low-income, urban housing: A randomized controlled trial. Journal of Allergy and Clinical Immunology 112(2): 339–345.

Arlian L, Neal J, Morgan M, Vyszenski-Moher D, Rapp C, Alexander A. 2001. Reducing relative humidity is a practical way to control dust mites and their allergens in homes in temperate climates. Journal of Allergy and Clinical Immunology 107(1): 99–104.

Arlian LG, Bernstein D, Bernstein IL, Friedman S, Grant A, Lieberman P, et al. 1992. Prevalence of dust mites in the homes of people with asthma living in eight different geographic areas of the United States. J Allergy Clin Immunol 90: 292–300.

Arlian LG, Morgan MS, Neal JS. 2002. Dust mite allergens: ecology and distribution. Current allergy and asthma reports 2(5): 401–411.

Boner A, Pescollderungg L, Silverman M. 2002. The role of house dust mite elimination in the management of childhood asthma: an unresolved issue. Allergy 57 Suppl 74: 23–31.

Brussee JE, Smit HA, van Strien RT, Corver K, Kerkhof M, Wijga AH, et al. 2005. Allergen exposure in infancy and the development of sensitization, wheeze, and asthma at 4 years. J Allergy Clin Immunol 115(5): 946–952.

Burge HA, Ammann HA. 1999. Fungal toxins and B (1, 3)-D-glucans. In: Bioaerosols: Assessment and Control. (J. Macher, ed.). American Conference of Governmental and Industrial Hygienists, Cincinnati, Ohio.

Burr ML, Matthews IP, Arthur RA, Watson HL, Gregory CJ, Dunstan FDJ, et al. 2007. Effects on patients with asthma of eradicating visible indoor mould: a randomised controlled trial. Thorax 62(9): 766–771.

Carter MC, Perzanowski MS, Raymond A, Platts-Mills TAE. 2001. Home intervention in the treatment of asthma among inner-city children. Journal of Allergy and Clinical Immunology 108(5): 732–737.

Chew G, Perzanowski M, Canfield S, Goldstein I, Mellins R, Hoepner L, et al. 2008. Cockroach allergen levels and associations with cockroach-specific IgE. J Allergy Clin Immunol 121(1): 240–245.

Chew GL, Higgins KM, Muilenberg ML, Gold DR, Burge HA. 1999. Monthly measurements of indoor allergens and the influence of housing type in a northeastern US city. Allergy 54(10): 1058–1066.

Chew GL, Perzanowski MS, Miller RL, Correa JC, Hoepner LA, Jusino CM, et al. 2003. Distribution and determinants of mouse allergen exposure in low-income New York City apartments. Environ Health Perspect 111(10): 1348–1351.

Chew GL, Wilson J, Rabito FA, Grimsley F, Iqbal S, Reponen T, et al. 2006. Mold and endotoxin levels in the aftermath of Hurricane Katrina: A pilot project of homes in New Orleans undergoing renovation. Environmental Health Perspectives 114(12): 1883–1889.

Cohn RD, Arbes SJ, Jr., Jaramillo R, Reid LH, Zeldin DC, Cohn RD, et al. 2006. National prevalence and exposure risk for cockroach allergen in U.S. households. Environ Health Perspect 114(4): 522–526.

Cohn RD, Arbes SJ, Jr., Yin M, Jaramillo R, Zeldin DC, Cohn RD, et al. 2004. National prevalence and exposure risk for mouse allergen in US households. Journal of Allergy & Clinical Immunology 113(6): 1167–1171.

Cole Johnson C, Ownby DR, Havstad SL, Peterson EL. 2004. Family history, dust mite exposure in early childhood, and risk for pediatric atopy and asthma. J Allergy Clin Immunol 114(1): 105–110.

Colloff MJ, Taylor C, Merrett TG. 1995. The Use of Domestic Steam Cleaning for the Control of House-Dust Mites. Clinical and Experimental Allergy 25(11): 1061–1066.

Crocker D, Hopkins D, Kinyota S, Dumitru G, Ligon C, Lawrence B. 2008. Home-Based Interventions to Reduce Asthma Morbidity and Mortality. In: Presentation to the Task Force on Community Preventive Services. Atlanta, GA.

Douwes J. 2005. (1→3)-Beta-D-glucans and respiratory health: a review of the scientific evidence. Indoor Air 15(3): 160–169.

Douwes J, Gibson P, Pekkanen J, Pearce N. 2002. Non-eosinophilic asthma: importance and possible mechanisms. Thorax 57(7): 643–648.

Eggleston PA, Arruda LK. 2001. Ecology and elimination of cockroaches and allergens in the home. Journal of Allergy and Clinical Immunology 107(3 Suppl): S422–429.

Eggleston PA, Butz A, Rand C, Curtin-Brosnan J, Kanchanaraksa S, Swartz L, et al. 2005. Home environmental intervention in inner-city asthma: a randomized controlled clinical trial. Annals of Allergy Asthma & Immunology 95(6): 518–524.

Francis H, Fletcher G, Anthony C, Pickering C, Oldham L, Hadley E, et al. 2003. Clinical effects of air filters in homes of asthmatic adults sensitized and exposed to pet allergens. Clinical and Experimental Allergy 33(1): 101–105.

Garcia DP, Corbett JL, Sublett SJ, Pollard JF, Meiners JM, Karibo HL, et al. 1994. Cockroach allergy in Kentucky: a comparison of inner-city, suburban, and rural small town populations. Annal of Allergy 72: 203–208.

Gore RB, Durrell B, Bishop S, Curbishley L, Woodcock A, Custovic A. 2006. High-efficiency vacuum cleaners increase personal mite allergen exposure, but only slightly. Allergy 61(1): 119–123.

Gorny RL, Reponen T, Willeke K, Schmechel D, Robine E, Boissier M, et al. 2002. Fungal fragments as indoor air biocontaminants. Appl Environ Microbiol 68(7): 3522–3531.

Gotzsche PC, Hammarquist C, Burr M. 1998. House dust mite control measures in the management of asthma: meta-analysis. British Medical Journal 317(7166): 1105–1110.

Gravesen S. 1978. Identification and prevalence of culturable mesophilic microfungi in house dust from 100 Danish homes; comparison between airborne and dust-bound fungi. Allergy 33: 268–272.

Green BJ, Sercombe JK, Tovey ER, Green BJ, Sercombe JK, Tovey ER. 2005. Fungal fragments and undocumented conidia function as new aeroallergen sources. Journal of Allergy and Clinical Immunology 115(5): 1043–1048.

Green BJ, Tovey ER, Sercombe JK, Blachere FM, Beezhold DH, Schmechel D, et al. 2006. Airborne fungal fragments and allergenicity. Med Mycol 44 Suppl 1: S245–255.

Green R, Simpson A, Custovic A, Faragher B, Chapman M, Woodcock A. 1999. The effect of air filtration on airborne dog allergen. Allergy 54(5): 484–488.

Gruchalla RS, Pongracic J, Plaut M, Evans R, 3rd, Visness CM, Walter M, et al. 2005. Inner City Asthma Study: relationships among sensitivity, allergen exposure, and asthma morbidity. Journal of Allergy and Clinical Immunology 115(3): 478–485.

Hollander A, Heederik D, Doekes G, Kromhout H. 1998. Determinants of airborne rat and mouse urinary allergen exposure. Scand J Work Environ Health 24(3): 228–235.

Holt PG, Upham JW, Sly PD. 2005. Contemporaneous maturation of immunologic and respiratory functions during early childhood: implications for development of asthma prevention strategies. J Allergy Clin Immunol 116(1): 16–24; quiz 25.

Howden-Chapman P, Matheson A, Crane J, Viggers H, Cunningham M, Blakely T, et al. 2007. Effect of insulating existing houses on health inequality: cluster randomised study in the community. British Medical Journal 334(7591): 460–464.

Huss K, Adkinson NF, Jr., Eggleston PA, Dawson C, Van Natta ML, Hamilton RG. 2001. House dust mite and cockroach exposure are strong risk factors for positive allergy skin test responses in the Childhood Asthma Management Program. J Allergy Clin Immunol 107(1): 48–54.

Illi S, von Mutius E, Lau S, Niggemann B, Gruber C, Wahn U, et al. 2006. Perennial allergen sensitisation early in life and chronic asthma in children: a birth cohort study. Lancet 368(9537): 763–770.

Institute of Medicine. 2000. Clearing the Air: Asthma and Indoor Air Exposures. Washington, DC: National Academy Press.

Institute of Medicin.e. 2004. Damp Indoor Spaces and Health. Washington, DC: National Academy Press.

Kercsmar CM, Dearborn DG, Schluchter M, Xue L, Kirchner HL, Sobolewski J, et al. 2006. Reduction in asthma morbidity in children as a result of home remediation aimed at moisture sources. Environmental Health Perspectives 114(10): 1574–1580.

Kilburn S, Lasserson TJ, McKean M. 2003. Pet allergen control measures for allergic asthma in children and adults. Cochrane Database Syst Rev(1): CD002989.

Klitzman S, Caravanos J, Belanoff C, Rothenberg L. 2005. A multihazard, multistrategy approach to home remediation: results of a pilot study. Enriron Res Nov;99(3): 294–306.

Krieger JW, Takaro T, Song L, Beaudet N, Edwards K. Accepted for publication, 2008. The Seattle-King County Healthy Homes II Project: A Randomized Controlled Trial of Asthma Self-Management Support Comparing Clinic-Based Nurses and In-Home Community Health Workers. Archives of Pediatric and Adolescent Medicine.

Krieger JW, Takaro TK, Song L, Weaver M. 2005. The Seattle-King County Healthy Homes Project: A randomized, controlled trial of a community health worker intervention to decrease exposure to indoor asthma triggers. American Journal of Public Health 95(4): 652–659.

Levy JI, Brugge D, Peters JL, Clougherty JE, Saddler SS. 2006. A community-based participatory research study of multifaceted in-home environmental interventions for pediatric asthmatics in public housing. Social Science & Medicine 63(8): 2191–2203.

Lieutier-Colas F, Meyer P, Pons F, Hedelin G, Larsson P, Malmberg P, et al. 2002. Prevalence of symptoms, sensitization to rats, and airborne exposure to major rat allergen (Rat n 1) and to endotoxin in rat-exposed workers: a cross-sectional study. Clin Exp Allergy 32(10): 1424–1429.

Lignell U, Meklin T, Putus T, Rintala H, Vepsalainen A, Kalliokoski P, et al. 2007. Effects of moisture damage and renovation on microbial conditions and pupils' health in two schools - a longitudinal analysis of five years. Journal of Environmental Monitoring 9(3): 225–233.

Litonjua AA, Carey VJ, Burge HA, Weiss ST, Gold DR. 2001. Exposure to cockroach allergen in the home is associated with incident doctor-diagnosed asthma and recurrent wheezing. J Allergy Clin Immunol 107(1): 41–47.

Luczynska C, Tredwell E, Smeeton N, Burney P. 2003. A randomized controlled trial of mite allergen-impermeable bed covers in adult mite-sensitized asthmatics. Clinical and Experimental Allergy 33(12): 1648–1653.

Marks GB, Mihrshahi S, Kemp AS, Tovey ER, Webb K, Almqvist C, et al. 2006. Prevention of asthma during the first 5 years of life: A randomized controlled trial. Journal of Allergy and Clinical Immunology 118(1): 53–61.

Matsui EC, Wood RA, Rand C, Kanchanaraksa S, Swartz L, Curtin-Brosnan J, et al. 2003. Cockroach allergen exposure and sensitization in suburban middle-class children with asthma. J Allergy Clin Immunol 112(1): 87–92.

McConnell R, Jones C, Milam J, Gonzalez P, Berhane K, Clement L, et al. 2003. Cockroach counts and house dust allergen concentrations after professional cockroach control and cleaning. Annals of Allergy Asthma & Immunology 91(6): 546–552.

Mihrshahi S, Marks GB, Criss S, Tovey ER, Vanlaar CH, Peat JK, et al. 2003. Effectiveness of an intervention to reduce house dust mite allergen levels in children's beds. Allergy 58(8): 784–789.

Miller DM, Meek F. 2004. Cost and efficacy comparison of integrated pest management strategies with monthly spray insecticide applications for German cockroach (Dictyoptera : Blattellidae) control in public housing. Journal of Economic Entomology 97(2): 559–569.

Miller RL. 1999. Breathing freely: the need for asthma research on gene-environment interactions. Am J Public Health 89(6): 819–822.

Mudarri D, Fisk WJ. 2007. Public health and economic impact of dampness and mold. [erratum appears in Indoor Air. 2007 Aug;17(4):334]. Indoor Air 17(3): 226–235.

Ogg B, Ferraro D, Ogg C. 1995. Cockroach control manual. Lincoln, NE: University of Nebraska-Lincoln, 1–91.

Ohman JL, Hagberg K, MacDonald MR, Jones RR, Paigen BJ, Kacergis JB. 1994. Distribution of airborne mouse allergen in a major breeding facility. J Allergy Clin Immunol 94: 810–817.

Parker EA, Israel BA, Robins TG, Mentz G, Lin XH, Brakefield-Caldwell W, et al. 2008. Evaluation of community action against asthma: A community health worker intervention to improve children's asthma-related health by reducing household environmental triggers for asthma. Health Education & Behavior 35(3): 376–395.

Pearce N, Pekkanen J, Beasley R. 1999. How much asthma is really attributable to atopy? Thorax 54(3): 268–272.

Perry T, Matsui E, Merriman B, Duong T, Eggleston P, Perry T, et al. 2003. The prevalence of rat allergen in inner-city homes and its relationship to sensitization and asthma morbidity. Journal of Allergy and Clinical Immunology 112(2): 346–352.

Phipatanakul W. 2002. Rodent allergens. Curr Allergy Asthma Rep 2(5): 412–416.

Phipatanakul W. 2006. Environmental factors and childhood asthma. Pediatric annals 35(9): 646–656.

Phipatanakul W, Eggleston P. A., Wright E. C., Wood R. A., Phipatanakul W., Eggleston P. A., et al. 2000. Mouse allergen. I. The prevalence of mouse allergen in inner-city homes. The National Cooperative Inner-City Asthma Study. Journal of Allergy and Clinical Immunology 106(6): 1070–1074.

Phipatanakul W, Cronin B, Wood RA, Eggleston PA, Shih MC, Song L, et al. 2004. Effect of environmental intervention on mouse allergen levels in homes of inner-city Boston children with asthma. Annals of Allergy Asthma & Immunology 92(4): 420–425.

Phipatanakul W, Eggleston P, Wright E, Wood R. 2000. Mouse allergen. II. The relationship of mouse allergen exposure to mouse sensitization and asthma morbidity in inner-city children with asthma. J Allergy Clin Immunol 106(6): 1075–1080.

Platts-Mills TA, Mitchell EB. 1982. House dust mite avoidance. Lancet 2(8311): 1334.

Rauh VA, Chew GL, Garfinkel RS. 2002. Deteriorated housing contributes to high cockroach allergen levels in inner-city households. Environ Health Perspect 110(2): 323–327.

Reisman RE, Mauriello PM, Davis GB, Georgitis JW, Demasi JM. 1990. A Double-Blind-Study of the Effectiveness of a High-Efficiency Particulat Air (HEPA) Filter in the Treatment of Patients with Perennial Allergic Rhinitis and Asthma. Journal of Allergy and Clinical Immunology 85(6): 1050–1057.

Rijssenbeek-Nouwens LHM, Oosting AJ, de Bruin-Weller MS, Bregman I, de Monchy JGR, Postma DS. 2002. Clinical evaluation of the effect of anti-allergic mattress covers in patients with moderate to severe asthma and house dust mite allergy: a randomised double blind placebo controlled study. Thorax 57(9): 784–790.

Rockwell W. 2005. Prompt remediation of water intrusion corrects the resultant mold contamination in a home. Allergy and Asthma Proceedings 26(4): 316–318.

Rosenstreich DL, Eggleston P, Kattan M, Baker D, Slavin RG, Gergen P, et al. 1997. The role of cockroach allergy and exposure to cockroach allergen in causing morbidity among inner-city children with asthma. [see comment]. N Engl J Med 336(19): 1356–1363.

Salo PM, Arbes SJ, Crockett PW, Thorne PS, Cohn RD, Zelding DC. 2008. Exposure to multiple indoor allergens in US homes and its relationship to asthma. J Allergy Clin Immunolo 121: 678–684.

Sandel M, Batcheller A, Richman I, Hendrick E, Troxell-Dorgan A, Reid M, et al. Can Integrated Pest Management Impact Urban Children with Asthma?

Sercombe JK, Liu-Brennan D, Causer SM, Tovey ER. 2007. The vertical distribution of house dust mite allergen in carpet and the effect of dry vacuum cleaning. International Journal of Hygiene and Environmental Health 210(1): 43–50.

Sever ML, Arbes SJ, Gore JC, Santangelo RG, Vaughn B, Mitchell H, et al. 2007. Cockroach allergen reduction by cockroach control alone in low-income urban homes: A randomized control trial. Journal of Allergy and Clinical Immunology 120: 849–855.

Shapiro GG, Wighton TG, Chinn T, Zuckerman J, Eliassen AH, Picciano JF, et al. 1999. House dust mite avoidance for children with asthma in homes of low-income families. Journal of Allergy and Clinical Immunology 103(6): 1069–1074.

Siebers R, Parkes A, Miller JD, Crane J. 2007. Effect of allergen-impermeable covers on beta-(1,3)-glucan content of pillows. Allergy 62(4): 451–452.

Terreehorst I, Hak E, Oosting AJ, Tempels-Pavlica Z, de Monchy JGR, Bruijnzeel-Koomen C, et al. 2003. Evaluation of impermeable covers for bedding in patients with allergic rhinitis. New England Journal of Medicine 349(3): 237–246.

Tovey ER, Chapman MD, Platts-Mills TA. 1981. Mite faeces are a major source of house dust allergens. Nature 289(5798): 592–593.

van den Bemt L, van Knapen L, de Vries MP, Jansen M, Cloosterman S, van Schayck CP. 2004. Clinical effectiveness of a mite allergen-impermeable bed-covering system in asthmatic mite-sensitive patients. Journal of Allergy and Clinical Immunology 114(4): 858–862.

van der Heide S, van Aalderen WMC, Kauffman HF, Dubois AEJ, de Monchy JGR. 1999. Clinical effects of air cleaners in homes of asthmatic children sensitized to pet allergens. Journal of Allergy and Clinical Immunology 104(2): 447–451.

van Strien RT, Driessen MNBM, Oldenweining M, Doekes G, Brunekreef B. 2004. Do central vacuum cleaners produce less indoor airborne dust or airborne cat allergen, during and after vacuuming, compared with regular vacuum cleaners? Indoor Air 14(3): 174–177.

Vojta PJ, Randels SP, Stout J, Muilenberg M, Burge HA, Lynn H, et al. 2001. Effects of physical interventions on house dust mite allergen levels in carpet, bed, and upholstery dust in low-income, urban homes. Environmental Health Perspectives 109(8): 815–819.

Walinder R, Ernstgard L, Johanson G, Norback D, Venge P, Wieslander G, et al. 2005. Acute effects of a fungal volatile compound. [see comment]. Environ Health Perspect 113(12): 1775–1778.

Wang CL, Bennett GW. 2006. Comparative study of integrated pest management and baiting for German cockroach management in public housing. Journal of Economic Entomology 99(3): 879–885.

Williams SG, Brown CM, Falter KH, Alverson CJ, Gotway-Crawford C, Homa D, et al. 2006. Does a multifaceted environmental intervention alter the impact of asthma on inner-city children? Journal of the National Medical Association 98(2): 249–260.

Wood RA. 2002. Air filtration devices in the control of indoor allergens. Curr Allergy Asthma Rep 2(5): 397–400.

Wood RA, Johnson EF, Van Natta ML, Chen PH, Eggleston PA. 1998. A placebo-controlled trial of a HEPA air cleaner in the treatment of cat allergy. American Journal of Respiratory and Critical Care Medicine 158(1): 115–120.

Woodcock A, Forster L, Matthews E, Martin J, Letley L, Vickers M, et al. 2003. Control of exposure to mite allergen and allergen-impermeable bed covers for adults with asthma. New England Journal of Medicine 349(3): 225–236.

Woodcock A, Lowe LA, Murray CS, Simpson BM, Pipis SD, Kissen P, et al. 2004. Early life environmental control—Effect on symptoms, sensitization, and lung function at age 3 years. American Journal of Respiratory and Critical Care Medicine 170(4): 433–439.

Woodcock AA, Steel N, Moore CB, Howard SJ, Custovic A, Denning DW. 2006. Fungal contamination of bedding. Allergy 61: 140–142.

Woodfolk JA, Hayden ML, Couture N, Platts-Mills TAE. 1995. Chemical Treatment of Carpets to Reduce Allergen - Comparison of the Effects of Tannic-Acid and Other Treatments on Proteins Derived from Dust Mites and Cats. Journal of Allergy and Clinical Immunology 96(3): 325–333.

Panel 2: Indoor Chemical Agents

Indoor chemical agents have been associated with neurotoxicity and developmental disorders, asthma and other respiratory illnesses, and cancer (U.S. Environmental Protection Agency 1992a; Institute of Medicine 2000; Whyatt et al. 2002; Bellinger and Needleman 2003; Canfield et al. 2003; Darby et al. 2005; Lanphear et al. 2005; Krewski et al. 2006). Indoor chemical agents include lead, pesticides, environmental tobacco smoke, carbon monoxide, volatile organic compounds, radon and others. Exposure to high levels of substances such as carbon monoxide has been associated with fatalities. Structural deficiencies, gas stoves, introduction of source materials that off-gas or otherwise release toxic agents are all housing factors that can increase the presence of chemical agents in or around a dwelling. Because most homes in the U.S. do not have a planned supply of fresh air delivered to the building space and instead rely on operation of windows and intermittent or inadequate building leakage, indoor airborne contaminants can increase. The absence of smooth and cleanable surfaces can also contribute to increases in pesticide residues, lead contaminated house dust and other accumulated toxicants.

Lead

Lead toxicity affects the brain, neurodevelopment processes, and many other organ systems and is one of the best studied toxic substances (Commission on Life Sciences 1993; Agency for Toxic Substances and Disease Registry 2007). Some of its effects are irreversible. No safe level of lead exposure has been identified (Centers for Disease Control and Prevention 1991; Bellinger and Needleman 2003; Canfield et al. 2003; Lanphear et al. 2005; Centers for Disease Control and Prevention 2007). Public health efforts over the past several decades have produced significant declines in the mean blood lead concentration of U.S. children, yet lead poisoning continues to be a serious health risk for young children (Levin et al. 2008). About 250,000 children under age 6 have blood lead levels >10mg/dL in 1999–2002 (Jones et al. Accepted for publication 2008). Low-income children and black and Hispanic children are at higher risk (Centers for Disease Control and Prevention 2005a). Based on results from the National Survey of Lead and Allergens in Housing, approximately 40% of housing units (38 million) in the U.S. contain lead-based paint and of those, 24 million have significant lead-based paint hazards in the form of deteriorated lead-based paint, lead contaminated house dust and lead-contaminated bare soil (Clickner et al. 2001; Jacobs et al. 2002). The panel did not review the effectiveness of lead hazard control, but a summary is included below.

Environmental Tobacco Smoke (ETS)

The U.S. Environmental Protection Agency (EPA) estimates that Environmental Tobacco Smoke (ETS) causes approximately 3,000 lung cancer deaths in nonsmokers each year (U.S. Environmental Protection Agency 1992b). Fetal and infant exposure to tobacco smoke also has been associated with prematurity, low birth weight, low Apgar scores, poor early growth of infants, and dysfunctional behavior (Bauman et al. 1991; Fergusson et al. 1993; Eskenazi and Trupin 1995; Williams et al. 1998). Environmental tobacco smoke contains over 4,000 substances, more than 40 of which are known to cause cancer; many are strong respiratory irritants (U.S. Environmental Protection Agency 1992b)

Analysis of the NHANES III (1988 to 1994) investigated the relationship between ETS exposure and cognitive abilities among U.S. children and adolescents 6 to 16 years of age. Serum cotinine, used as a biomarker of ETS exposure, indicated an inverse association between ETS exposure and cognitive deficits among children, even at extremely low levels of exposure (Yolton et al. 2005). The National Academy of Sciences' (NAS) review of exposures in the home and asthma found sufficient evidence for a causal relationship between ETS exposure and the exacerbation of asthma in preschool-aged children, and an association between ETS exposure and the development of asthma in younger children (Institute of Medicine 2000). Evidence released in the Surgeon General's report The Health Consequences of Involuntary Exposure to Tobacco Smoke found children exposed to ETS are at greater risk for sudden infant death syndrome, acute respiratory disease, ear problems, and more severe asthma episodes. The report concluded that there is no risk-free level of exposure to second hand ETS (Lord et al. 2006).

Carbon Monoxide (CO)

Sixty-four percent of non-fatal carbon monoxide (CO) exposures occur in the home (Centers for Disease Control and Prevention 2005b). Major sources of CO in the home include tobacco smoke, malfunctioning or inadequately vented gas appliances, oil or wood burning appliances, and unvented appliances that are designed for outdoor use, such as gasoline-powered electricity generators. Hundreds of unintentional deaths and thousands of non-fatal poisonings occur annually in the U.S. from CO (Centers for Disease Control and Prevention 2005b). Because CO interferes with oxygen metabolism, both acute exposures (short-term exposures to high concentrations of CO), and chronic exposures (lower level, repeated) can result in serious health effects. Survivors of CO poisoning may have long-term neurological effects such as personality changes, memory deficits, impaired judgment, poor concentration, and other adverse health effects (U.S. Environmental Protection Agency 2001).

Pesticides

Pesticides are any agent used to suppress pests such as insects, rodents, weeds, fungi, and bacteria. Exposure to pesticides occurs through diet, dermal absorption, and through inhalation of airborne pesticides either as an aerosol or adsorbed on dust particles (Institute of Medicine 2000). In 2000, 75% of U.S. households used at least one pesticide indoors during the past year, and 80% of most people's exposure to pesticides occurred indoors (U.S. Environmental Protection Agency 2004). Pesticides are a particular concern for low income, inner-city neighborhoods where pest infestations (e.g., cockroaches, mice, and rats) are higher (Berkowitz et al. 2003; Whyatt et al. 2003). Pesticides can remain in a home for years after use has stopped and have been found in indoor air, carpet dust, and on surfaces with settled dust. Animal data and in-vitro studies suggest that chronic exposure to pesticides may be linked to attention and behavior problems and other neuropsychological deficits, but the health effects of chronic exposure are not well understood (Chanda and Pope 1996; Rice and Barone 2000). The NAS report on asthma found inadequate evidence of an association between residential pesticide exposure and the development or exacerbation of asthma (Institute of Medicine 2000). Inert ingredients, not typically included in risk assessments, are also potentially hazardous and may contribute to the effects from the active ingredients (Watson et al. 2003; U.S. Environmental Protection Agency 2005). Pesticides often target the nervous system, and there may be a cumulative risk from exposure to multiple pesticides.

Volatile Organic Compounds (VOCs)

Volatile Organic Compounds (VOCs) are organic chemicals that are gases at normal room temperature and pressure. Common household items that can release VOCs include paint, varnish, and wax, as well as cleaning, disinfecting, cosmetic, and degreasing products, products containing particle board and plywood, so-called "air fresheners," and hobby products. VOCs that commonly pollute indoor air include toluene, styrene, xylene, benzene, tricholoethylene, formaldehyde and other aldehydes. Semi-volatile compounds such as phthalates may also be important. The health effects of VOCs are varied. Elevated indoor concentrations of VOC mixtures may play a role in the constellation of symptoms known as sick building syndrome (e.g., headaches, fatigue, eye and upper respiratory irritation). Formaldehyde is a component of some building materials, such as particle board and plywood adhesives and may be found at high levels in many new buildings. Levels of formaldehyde decline over time due to continued off-gassing (ATSDR 1999). The NAS review found limited evidence of an association between formaldehyde exposure, wheezing and other respiratory symptoms (Institute of Medicine 2000). The report found insufficient evidence of an association between indoor residential VOC exposures and the development or exacerbation of asthma (Institute of Medicine 2000). At higher levels of exposure, however, the threat of sensitization, cancer, respiratory and other problems is pronounced (Agency for Toxic Substances and Disease Registry 1999). The International Agency for Research on Cancer has classified formaldehyde as a "known human carcinogen." One study has demonstrated an association between formaldehyde exposure and increased prevalence of asthma and chronic bronchitis (Krzyzanowski et al. 1990).

Radon

Exposure to radon is the leading cause of lung cancer among nonsmokers and the second leading cause of lung cancer overall, causing 21,000 deaths annually in the U.S. (U.S. Environmental Protection Agency 2003). Combined data from several previous residential studies show definitive evidence of an association between residential radon exposure and lung cancer (Darby et al. 2005; Krewski et al. 2006; Samet 2006). A decay product of uranium, radon is a colorless, odorless gas that occurs naturally in soil and rock. It moves through fractures and porous substrates in the foundations of buildings and can collect in high concentrations in certain areas. Radon may also enter a house through water systems in communities where groundwater is the main water supply. This is most common in small public systems and private wells that are typically closed systems which do not allow radon to escape. Housing with high radon concentrations is more prevalent in certain regions of the country, but any house, regardless of region, can contain dangerous or unhealthy levels of radon; EPA has mapped high risk radon areas (U.S. Environmental Protection Agency 1992a).

Panel 2 Decision Results

Panel 2 considered the following interventions:

- Radon in air mitigation (both passive and active)
- Radon in drinking water mitigation
- Integrated Pest Management (as pesticide exposure reduction)
- Tobacco Smoke bans
- HEPA Air Cleaners
- Reductions of Volatile Organic Compounds
- Garage sealing
- Particulate reduction by envelope sealing
- Residential Lead Hazard Control
- Air cleaners releasing ozone

Of these interventions, four are ready for implementation and have been shown to be effective, four need more field testing but are promising, three need formative research, and two are ineffective.

A. Sufficient Evidence

1. Active radon mitigation in high-risk areas is effective in reducing exposure to radon in air to less than 4 pCi/L.

Rationale: The evidence for this finding comes from the following studies: Groves-Kirkby et al. 2006, Brodhead 1995, Burkhart 1991, Huber et al. 2004, Tuccillo and Rauch 1994, and Dehmel 1993. Each of these studies enrolled a relatively large number of housing units, ranging from 73 to 238 units. In particular, Groves-Kirkby and the Burkhart studies had well-characterized control groups and were able to demonstrate significant reductions in radon exposures using active soil depressurization systems. The Groves-Kirkby study showed that active soil depressurization systems were far more effective than installation of membranes during construction (Groves-Kirkby et al. 2006). An EPA review concluded that 97% of houses with high baseline radon levels (76% had baseline radon levels ≥10 pCi/L) could be remediated with active soil depressurization systems to less than 4 pCi/L (Burkhart and Kladder 1991). The Brodhead study, which was a national survey, showed that 95% of remediated homes were <4 pCi/L and 69% were actually <2 pCi/L (n=238 houses) (Brodhead 1995). The durability of these active systems has been assessed in relatively small studies, with the exception of the large Dehmel study, which showed that 95% of houses were <4 pCi/L 18 months after installation (Dehmel 1993). Kladder found that 11 of 13 houses evaluated were below 4 pCi/L two years after installation (Kladder and Jelinek 1993). It is worth noting that, with the exception of the Groves-Kirkby study, many of the studies cited above were peer-reviewed by the U.S. EPA, published as agency reports and are available from the agency, but were apparently never published in the literature. Nevertheless, the evidence is clear that radon mitigation in the form of active soil depressurization is an effective housing intervention.

2. **IPM is effective as a means of reducing exposure to pesticide residues.**

Rationale: The evidence for this finding comes from the Williams study, which showed that both cockroach infestations and levels of pyrethroid insecticides in indoor air samples decreased significantly ($p=0.016$), compared to a control group (Williams et al. 2006). Additionally, pesticides were not detected in the maternal blood samples in the intervention group and were either significantly different ($p=0.008$) or of borderline significance ($p=0.1$) when comparing the intervention and control groups. The efficacy of IPM as a means of controlling exposure to pests and their allergens was discussed in the Panel One findings above. This provides further evidence that IPM is an effective intervention.

3. **Smoking bans are effective in reducing exposure to environmental tobacco smoke.**

Rationale: The evidence for this finding comes from the following studies: (Allwright et al. 2005; Farrelly et al. 2005; Fong et al. 2006; Haw and Gruer 2007). While these studies were of non-residential smoking bans, it is logical that residential smoking bans would achieve the same result as non-residential smoking bans. Because no studies of smoking bans in the residential setting were identified, the panel believes that further study is warranted, but that the evidence is sufficiently clear to recommend implementation of residential smoking bans, based on the strength of the findings of the effectiveness of bans in non-residential settings.

4. **Residential lead hazard control is effective in reducing exposure to deteriorated lead-based paint, dust lead and soil lead.**

Rationale: The evidence that residential lead hazard control is effective in reducing environmental lead contamination comes from numerous studies, which have been reviewed extensively elsewhere (National Center for Healthy Housing 1993; Jacobs 1995; U.S. Environmental Protection Agency 1998). The largest study on lead hazard control occurred in 14 jurisdictions and covered nearly 3,000 housing units enrolled in the lead hazard control program funded by the US Department of Housing and Urban Development (HUD). The results demonstrated that dust lead levels declined by 78%–95% over a 3-year period (National Center for Healthy Housing 2004). Further declines in dust lead levels on both floors and window sills occurred in a representative subset of homes selected for follow-up 6 years after hazard control (Wilson et al. 2006). While this study was able to control for a number of confounding influences and was nationwide in scope, one of its weaknesses was that it was not feasible to construct a control or comparison group. However, similar declines in dust lead levels have been observed in a number of other smaller studies following lead hazard control work where control or comparison groups were feasible (Duggan and Inskip 1985; Lanphear et al. 1998). For example, one such study that did have comparison groups showed that median dust lead levels following hazard control declined over 98% (Farfel et al. 1997).Yet another study showed that dust lead loadings 1.5 to 3.5 years post-abatement were only 16, 10, and 4% of pre-abatement levels for floors, window sills, and window wells, respectively (Farfel et al. 1994). The specific interventions for lead hazard control are multi-factorial and include a combination of building component replacement, paint stabilization, enclosure, encapsulation, education, limited paint removal, followed by specialized cleaning and clearance testing. These interventions for lead hazard control have been published and adopted for federally assisted housing and in many local jurisdictions (U.S. Department of Housing and Urban Development 1995).

The effectiveness of lead hazard control to reduce blood lead levels in children whose blood lead levels are elevated (i.e., blood lead levels ≥ 10 µg/dL) is less clear. A number of randomized controlled trials of interventions have found modest declines or no statistically significant decline in the blood lead levels of children whose families received an educational or environmental intervention (Charney et al. 1983; Lanphear et al. 1996; Rhoads et al. 1999; Brown et al. 2006); (Achengrau et al. 1997). However, this is most likely due to the release of significant amounts of lead from endogenous bone lead stores in children whose exogenous lead exposure source has been controlled. This will limit the ability to detect a reduction in blood lead levels in chronically exposed children (Gwiazda et al. 2005).

Dust lead and blood lead levels following lead hazard control have been extensively reviewed elsewhere (U.S. Environmental Protection Agency 1998). Because dust lead is known to be highly correlated with blood lead, dust lead levels may be a more useful metric of the effectiveness of interventions on paint, dust and soil (Jacobs 1995). Further, in at least one study, residential lead hazard control was found to significantly reduce the likelihood of subsequent lead poisoning cases in buildings where children had been poisoned in the past, indicating that lead hazard control is an effective prevention strategy (Brown et al. 2006).

B. Promising Interventions That Need More Field Evaluation

1. Radon mitigation for drinking water using activated charcoal and aeration

Rationale: The Mose study showed that large reductions of radon in drinking water, which can sometimes be quite high, are achievable through filtration and aeration or a combination of the two (Mose et al. 2001). However, the study also showed that even after filtration and aeration, radon can still be at levels above the relevant standards. This suggests that further evaluation of this promising method is needed.

2. Portable HEPA Air Cleaners for indoor particulate control

Rationale: The ability of air cleaners to remove particulate matter of certain size ranges from air is well-established. Specifically, air cleaners are known to be able to achieve a 30–70% reduction in the half-life of airborne particulate matter between 0.3 to 1 microns (Batterman et al. 2005). However, that study also showed the air cleaners did not reduce larger airborne particles, between 1 to 5 microns. Air cleaners are less effective as the particle size increases and they have not been demonstrated to reduce volatile organic compounds or other gases such as carbon monoxide, oxides of nitrogen and others (Shaughnessy and Sextro 2006). This led the National Academy of Sciences to conclude that there is only limited evidence that air cleaners are effective in reducing asthma (Institute of Medicine 2000), probably because allergens may be concentrated in the larger particle size ranges. Nevertheless, the fact that air cleaners can reduce small airborne particles shows that this intervention is a promising one requiring further field study. A recently published study that appeared after the panel's deliberations showed that portable HEPA air cleaning devices were capable of greatly reducing very small particles in the indoor environment during forest fires and wood burning (Barn et al. 2008), adding further support to the position that this is a promising intervention requiring further work. Source control for indoor particulate matter and gaseous pollutants is always far more effective (Shaughnessy and Sextro 2006). Therefore, the panel did not feel that further research is needed to determine if Environmental Tobacco Smoke could be controlled using portable particulate matter air filtration systems.

3. Garage sealing to reduce benzene and other VOC exposures

Rationale: The Batterman study showed that nearly all of the indoor exposure to benzene and other VOCs in the houses studied is due to migration from attached garages into the living space (Batterman et al. 2007). Possible interventions include garage sealing, maintaining a negative pressure in the garage with respect to the indoor living space, sealing penetrations from the living area into the garage, administrative measures (e.g., parking the car outside) and perhaps others. The risk of asthma tripled for every 10-unit increase in benzene exposure (Rumchev et al. 2004). The effect of such interventions on indoor exposures to benzene and other VOCs has yet to be demonstrated, but because attached garages account for most of the indoor exposure, sealing such garages is a promising intervention. Housing construction guidelines that separate garages from houses are also effective.

4. Particulate intrusion reduction and improved ventilation

Rationale: A study of a single home showed that the building shell was not effective at preventing infiltration of small particulate matter (Thatcher and Layton 1995), although earlier studies that did not account for resuspension in indoor air suggested that the building envelop had a filtering effect (Russell et al. 2005). Although it is likely that there is some reduction in larger particles due to the building envelope, the effectiveness of differing building envelopes in filtering smaller particles requires further field investigation.

C. Interventions in Need of Formative Research

1. Radon mitigation using passive systems

Rationale: Several studies demonstrate that mitigation of airborne radon levels using passive systems does not consistently reduce indoor radon levels adequately (Brennan et al. 1990; U.S. Environmental Protection Agency 1990; Najafi 1998; LaFollette and Dickey 2001; Groves-Kirkby et al. 2006). Passive systems have the advantage of not requiring maintenance of mechanical equipment, but they have yet to be shown to be consistently effective.

2. Residential ventilation

Rationale: While ventilation standards have been developed (ASHRAE 2004; Russell et al. 2005), and compliance with such standards is quite likely to be beneficial, too little is known about how ventilation levels affect health. Ventilation systems can be varied and may consist of nothing more than building leakage for supply of fresh air. Many single family housing units and low-rise units in the U.S. do not have a planned fresh air supply system and multi-family buildings may have unbalanced or otherwise inadequate air supply systems. Ventilation rates can be expressed as volumetric air supply (cubic feet per minute), air exchanges per hour, air velocity, pressure differentials, and other metrics, which also need to include filtration and distribution requirements. Despite the complexity involved, there is compelling evidence that inadequate ventilation adversely affects health. For example, one large study showed that the odds of bronchial obstructions were higher in people living in housing with lower air exchange rates (Oie et al. 1999). Another multi-level intervention study in new home construction showed that the use of increased fresh air supply, coupled with heat recovery systems for the exhaust air, produced statistically significant improvements in asthma symptom free days, quality of life, urgent clinical care, and asthma trigger exposure (Takaro et al. 2008). Inadequate ventilation is also associated with moisture problems (Kercsmar et al. 2006). The increasing emphasis on energy conservation requires that further research be done on how such energy conservation measures affect indoor air quality and health and the precise levels of fresh air supply and distribution needed to protect health.

3. Volatile Organic Compound interventions other than garage sealing

Rationale: The effectiveness of avoidance of building materials containing VOCs, "baking out" VOCs, or both, following new construction using short-term higher ventilation and temperature levels has not been adequately demonstrated to show a positive health effect and further study is needed to demonstrate the potential health benefits of product avoidance, ventilation, or a combination of the two. One notable exception to this finding is the use of particle board containing formaldehyde and urea/formaldehyde insulation and other similar products, which should be avoided until new, independent studies are completed demonstrating their safety. Recent studies of FEMA trailers in the Gulf region show that exposures to formaldehyde in closed trailers can be quite high (Centers for Disease Control and Prevention 2008). Finally, no peer reviewed literature was found demonstrating that sealing particle board with coatings or laminants sufficiently reduces formaldehyde emissions. This suggests that building materials containing added formaldehyde should be avoided until coatings or laminants have been shown to be effective.

Finally, there are many other classes of organic compounds in house dust including persistent organic pollutants (POPs), poly-brominated diphenyl ethers (PBDEs), benzo (a) pyrene, and others. It is possible that exposures to these other compounds will also be reduced by intensive cleaning and source control, as is the case for lead, but no papers were identified indicating such procedures were effective for this class of chemicals.

D. Interventions Shown To Be Ineffective

1. **Portable air cleaning filtration systems are ineffective in controlling exposures to environmental tobacco smoke and also formaldehyde, although it is possible that there may be some modest decline in exposure. Source control through smoking bans and, in the case of formaldehyde, product substitution has been shown to be effective. So-called air cleaners that**

produce significant amounts of ozone should not be used, because they result in increased exposure to ozone, which mimics the health effects of radiation exposure and is a known respiratory toxicant.

2. **Single professional cleaning regimens have been shown to be ineffective in controlling exposures to lead contaminated dust over the long term (Tohn et al. 2003).**

References: Panel 2

Agency for Toxic Substances and Disease Registry. 1999. Toxicological Profile: Formaldehyde. Atlanta, GA: U.S. Department of Health and Human Services.

Agency for Toxic Substances and Disease Registry. 2007. Toxicological Profile: Lead. Atlanta, GA: U.S. Department of Health and Human Services.

Allwright S, Paul G, Greiner B, Mullally BJ, Pursell L, Kelly A, et al. 2005. Legislation for smoke-free workplaces and health of bar workers in Ireland: before and after study. British Medical Journal 331(7525): 1117–1122.

Aschengrau A, Beiser A, Bellinger D, Copenhafer D, Weitzman M. 1997. *Residential lead-based-paint hazard remedication and soil lead abatement: their impact among children with mildly elevated blood lead levels.* Am J Public Health, Oct;87(10): 1698–702.

ASHRAE. 2004. Ventilation and acceptable indoor air quality in low-rise residential buildings. ASHRAE Standard 62.2. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Barn P, Larson T, Noullett M, Kennedy S, Copes R, Brauer M. 2008. Infiltration of forest fire and residential wood smoke: an evaluation of air cleaner effectiveness. Journal of Exposure Science and Environmental Epidemiology 18(5): 503–511.

Batterman S, Godwin C, Jia CR. 2005. Long duration tests of room air filters in cigarette smokers' homes. Environmental Science & Technology 39(18): 7260–7268.

Batterman S, Jia CR, Hatzivasilis G. 2007. Migration of volatile organic compounds from attached garages to residences: A major exposure source. Environmental Research 104(2): 224–240.

Bauman KE, Flewelling RL, LaPrelle J. 1991. Parental cigarette smoking and cognitive performance of children. Health Psychol 10(4): 282–288.

Bellinger DC, Needleman HL. 2003. Intellectual impairment and blood lead levels. New England Journal of Medicine 349(5): 500–502

Berkowitz GS, Obel J, Deych E, Lapinski R, Godbold J, Liu Z, et al. 2003. Exposure to indoor pesticides during pregnancy in a multiethnic, urban cohort. Environmental Health Perspectives 111(1): 79–84.

Brennan T, Clarkin M, Osborn MC, Brodhead B. 1990. Evaluation of Radon Resistant New Construction Techniques. In: 1990 International Symposium on Radon and Radon Reduction Technology Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development.

Brodhead B. 1995. Nationwide Survey of RCP Listed Mitigation Contractors. In: 1995 International Radon Symposium. Nashville, TN: American Association of Radiation Scientists and Technologists, III–5.1—III–5.14.

Brown MJ, McLaine P, Dixon S, Simon P. 2006. A randomized, community-based trial of home visiting to reduce blood lead levels in children. Pediatrics 117(1): 147–153.

Burkhart JF, Kladder DL. 1991. A Comparison of Indoor Radon Concentrations Between Preconstruction and Post-Construction Mitigated Single Family Dwellings. In: International Symposium of Radon and Radon Reduction Technology. Philadelphia, PA: US Environmental Protection Agency, Office of Research and Development. Accessible from: ?

Canfield RL, Henderson CR, Jr., Cory-Slechta DA, Cox C, Jusko TA, Lanphear BP. 2003. Intellectual impairment in children with blood lead concentrations below 10 microg per deciliter. New England Journal of Medicine 348(16): 1517–1526.

Centers for Disease Control and Prevention. 1991. Preventing Lead Poisoning in Young Children: A Statement by the Centers for Disease Control and Prevention. Atlanta, GA: U.S. Department of Health and Human Services.

Centers for Disease Control and Prevention. 2005a. Blood lead levels—United States, 1999–2002. MMWR Morb Mortal Wkly Rep 54(20): 513–516.

Centers for Disease Control and Prevention. 2005b. Unintentional non-fire-related carbon monoxide exposures—United States, 2001–2003. Atlanta, GA: U.S. Department of Health and Human Services.

Centers for Disease Control and Prevention. 2007. Interpreting and Managing Blood Lead Levels <10 μg/dL in Children and Reducing Childhood Exposures to Lead: Recommendations of CDC's Advisory Committee on Childhood Lead Poisoning Prevention. MMWR Recommendations and Reports 56: 1–14.

Centers for Disease Control and Prevention. 2008. Final Report on Formaldehyde Levels in FEMA-Supplied Travel Trailers, Park Models, and Mobile Homes. Atlanta, GA: U.S. Department of Health and Human Services.

Chanda SM, Pope CN. 1996. Neurochemical and neurobehavioral effects of repeated gestational exposure to chlorpyrifos in maternal and developing rats. Pharmacol Biochem Behav 53(4): 771–776.

Charney E, Kessler B, Farfel M, Jackson D. 1983. Childhood Lead-Poisoning—A Controlled Trial of the Effect of Dust-Control Measures on Blood Lead Levels. New England Journal of Medicine 309(18): 1089–1093.

Clickner RP, Marker D, Viet SM, Rogers J, Broene P. 2001. National Survey of Lead and Allergens in Housing, Final Report; Volume I: Analysis of Lead Hazards. Washington, DC: U.S. Department of Housing and Urban Development.

Commission on Life Sciences. 1993. Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations. Washington, DC: National Academy Press.

Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H, Bochicchio F, et al. 2005. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. [see comment]. Bmj 330(7485): 223.

Dehmel JCF. 1993. Private Mitigation System Durability Study: U.S. Environmental Protection Agency, Office of Research and Development.

Duggan MJ, Inskip MJ. 1985. Childhood Exposure to Lead in Surface Dust and Soil: A Community Health Problem. Public Health Reviews 13(1–2): 1–54.

Eskenazi B, Trupin LS. 1995. Passive and active maternal smoking during pregnancy, as measured by serum cotinine, and postnatal smoke exposure. II. Effects on neurodevelopment at age 5 years. American Journal of Epidemiology 142(9 Suppl): S19–29.

Farfel M, Chisolm JJ, Lees PSJ, Rohde C. 1997. Lead-Based Paint Abatement and Repair and Maintenance Study in Baltimore: Findings Based on Two Years of Follow-up. Washington, DC: U.S. Environmental Protection Agency.

Farfel MR, Chisolm JJ, Rohde CA. 1994. The Longer-Term Effectiveness of Residential Lead Paint Abatement. Environmental Research 66(2): 217–221.

Farrelly MC, Nonnemaker JM, Chou R, Hyland A, Peterson KK, Bauer UE. 2005. Changes in hospitality workers' exposure to secondhand smoke following the implementation of New York's smoke-free law. Tobacco Control 14(4): 236–241.

Fergusson DM, Horwood LJ, Lynskey MT. 1993. Maternal smoking before and after pregnancy: effects on behavioral outcomes in middle childhood. Pediatrics 92(6): 815–822.

Fong GT, Hyland A, Borland R, Hammond D, Hastings G, McNeill A, et al. 2006. Reductions in tobacco smoke pollution and increases in support for smoke-free public places following the implementation of comprehensive smoke-free workplace legislation in the Republic of Ireland: findings from the ITC Ireland/UK Survey. Tobacco Control 15: 51–58.

Groves-Kirkby CJ, Denman AR, Phillips PS, Crockett RGM, Woolridge AC, Tornberg R. 2006. Radon mitigation in domestic properties and its health implications—a comparison between during-construction and post-construction radon reduction. Environment International 32(4): 435–443.

Gwiazda R, Campbell C, Smith D. 2005. A noninvasive isotopic approach to estimate the bone lead contribution to blood in children: Implications for assessing the efficacy of lead abatement. Environmental Health Perspectives 113(1): 104–110.

Haw SJ, Gruer L. 2007. Changes in exposure of adult non-smokers to secondhand smoke after implementation of smoke-free legislation in Scotland: national cross sectional survey. British Medical Journal 335: 549–+.

Huber J, Ennemoser O, Schneider P. 2001. Quality control of mitigation methods for unusually high indoor radon concentrations. Health Physics 81(2): 156–162.

Institute of Medicine. 2000. Clearing the Air: Asthma and Indoor Air Exposures. Washington, DC: National Academy Press.

Jacobs D. 1995. Lead-Based Paint as a Major Source of Childhood Lead Poisoning: A Review of the Evidence. In: Lead In Paint, Soil and Dust: Health Risks, Exposure Studies, Control Measures and Quality Assurance. Philadelphia: American Society for Testing and Materials, 175–187.

Jacobs DE, Clickner RP, Zhou JY, Viet SM, Marker DA, Rogers JW, et al. 2002. The prevalence of lead-based paint hazards in U.S. housing. Environmental Health Perspectives 110(10): A599–606.

Jones R, Homa D, Meyer P, Brody D, Caldwell K, Pirkle J, et al. Accepted for publication 2008. Trends in blood lead levels and blood lead testing among U.S. children aged 1 to 5 years: 1998–2004. Pediatrics.

Kercsmar CM, Dearborn DG, Schluchter M, Xue L, Kirchner HL, Sobolewski J, et al. 2006. Reduction in asthma morbidity in children as a result of home remediation aimed at moisture sources. Environmental Health Perspectives 114(10): 1574–1580.

Kladder D, Jelinek S. 1993. Rocky Mountain Region Private Mitigation System Durability Study (New Construction): U.S. Environmental Protection Agency, Office of Research and Development.

Krewski D, Lubin JH, Zielinski JM, Alavanja M, Catalan VS, Field RW, et al. 2006. A combined analysis of North American case-control studies of residential radon and lung cancer. J Toxicol Environ Health A 69(7): 533–597.

Krzyzanowski M, Quackenboss JJ, Lebowitz MD. 1990. Chronic Respiratory Effects of Indoor Formaldehyde Exposure. Environmental Research 52(2): 117–125.

LaFollette S, Dickey T. 2001. Demonstrating effectiveness of passive radon-resistant new construction. Journal of the Air & Waste Management Association 51(1): 102–108.

Lanphear BP, Hornung R, Khoury J, Yolton K, Baghurst P, Bellinger DC, et al. 2005. Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. [see comment]. Environmental Health Perspectives 113(7): 894–899.

Lanphear BP, Matte TD, Rogers J, Clickner RP, Dietz B, Bornschein RL, et al. 1998. The contribution of lead-contaminated house dust and residential soil to children's blood lead levels. Environmental Research 79(1): 51–68.

Lanphear BP, Winter NL, Apetz L, Eberly S, Weitzman M. 1996. A randomized trial of the effect of dust control on children's blood lead levels. Pediatrics 98(1): 35–40.

Levin R, Brown M, Kashtock M, Jacobs D, Whelan E, Rodman J, et al. 2008. US Children's Lead Exposures, 2008: Implications for Prevention. Environmental Health Perspectives Online 19 May; doi:10.1289/ehp.11241.

Lord SR, Menz HB, Sherrington C. 2006. Home environment risk factors for falls in older people and the efficacy of home modifications. Age Ageing 35 Suppl 2: ii55–ii59.

Mose DG, Mushrush GW, Simoni FV. 2001. Variations of well water radon in Virginia and Maryland. Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering 36(9): 1647–1660.

Najafi FT. 1998. Radon reduction systems in the construction of new houses in Gainesvllle, Florida. Health Physics 75(5): 514–517.

National Center for Healthy Housing. 1993. Does Residential Lead Hazard Control Work? Columbia, MD.

National Center for Healthy Housing. 2004. Evaluation of the HUD Lead Hazard Control Grant Program: National Center for Healthy Housing and the University of Cincinnati.

Oie L, Nafstad P, Botten G, Magnus P, Jaakkola JKK. 1999. Ventilation in homes and bronchial obstruction in young children. Epidemiology 10(3): 294–299.

Rhoads GG, Ettinger AS, Weisel CP, Buckley TJ, Goldman KD, Adgate J, et al. 1999. The effect of dust lead control on blood lead in toddlers: A randomized trial. Pediatrics 103(3): 551–555.

Rice D, Barone S, Jr. 2000. Critical periods of vulnerability for the developing nervous system: evidence from humans and animal models. Environmental Health Perspectives 108 Suppl 3: 511–533.

Rumchev K, Spickett J, Bulsara M, Phillips M, Stick S. 2004. Association of domestic exposure to volatile organic compounds with asthma in young children. Thorax 59(9): 746–751.

Russell M, Sherman M, Rudd A. 2005. Review of residential ventilation technologies. LBNL 57730: Lawrence Berkeley National Laboratory.

Samet JM. 2006. Residential radon and lung cancer: end of the story? J Toxicol Environ Health A 69(7): 527–531.

Shaughnessy RJ, Sextro RG. 2006. What is an effective portable air cleaning device? A review. Journal of Occupational and Environmental Hygiene 3(4): 169–181.

Takaro T, Krieger J, Sharify D, Song L, Phillips T. 2008. Clinical response in asthma from improved housing design and Construction. In: American Thoracic Society Annual Meeting. Toronto, ON: Am J Resp Crit Care Med.

Thatcher TL, Layton DW. 1995. Depsotion, Resuspension, and Penetration of Particles within a Residence. Atmospheric Environment 29(13): 1487–1497.

Tohn ER, Dixon SL, Wilson JW, Galke WA, Clark CS. 2003. An evaluation of one-time professional cleaning in homes with lead-based paint hazards. Appl Occup Environ Hyg 18(2): 138–143.

Tuccillo K, Rauch FB. 1994. Evaluation and Enforcement of Radon Mitigation System Installations in New Jersey. In: 1994 International Radon Symposium. Atlantic City, NJ American Association of Radon Scientists and Technologists.

U.S. Department of Housing and Urban Development. 1995. Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing. Washington, DC: U.S. Department of Housing and Urban Development.

U.S. Environmental Protection Agency. 1990. Testing of Indoor Radon in 19 Maryland Homes EPA-600/8-90-056: U.S. EPA, Office of Radiation Programs.

U.S. Environmental Protection Agency. 1992a. A citizen’s guide to Radon: U.S. EPA, Office of Air and Radiation, Indoor Environments Division.

U.S. Environmental Protection Agency. 1992b. Health Effects of Passive Smoking. Washington, DC: U.S. EPA, Office of Research and Development.

U.S. Environmental Protection Agency. 1998. Review of Studies Addressing Lead Abatement Effectiveness: Updated Edition. Washington, DC: U.S. EPA.

U.S. Environmental Protection Agency. 2001. Air quality criteria for Carbon Monoxide: U.S. EPA, National Center for Environmental Assessment.

U.S. Environmental Protection Agency. 2003. Assessment of risks from Radon in Homes: Office of Air and Radiation, Indoor Environments Division.

U.S. Environmental Protection Agency. 2004. Pesticide industry sales and usage: 2000 and 2001 market estimates: U.S. EPA, Office of Prevention.

U.S. Environmental Protection Agency. 2005. Inert (other) ingredients in pesticide products.

Watson WA, Litovitz TL, Rodgers GC, Jr., Klein-Schwartz W, Youniss J, Rose SR, et al. 2003. 2002 annual report of the American Association of Poison Control Centers Toxic Exposure Surveillance System. Am J Emerg Med 21(5): 353–421.

Whyatt RM, Barr DB, Camann DE, Kinney PL, Barr JR, Andrews HF, et al. 2003. Contemporary-use pesticides in personal air samples during pregnancy and blood samples at delivery among urban minority mothers and newborns. Environmental Health Perspectives 111(5): 749–756.

Whyatt RM, Camann DE, Kinney PL, Reyes A, Ramirez J, Dietrich J, et al. 2002. Residential pesticide use during pregnancy among a cohort of urban minority women. Environmental Health Perspectives 110(5): 507–514.

Williams GM, O'Callaghan M, Najman JM, Bor W, Andersen MJ, Richards D, et al. 1998. Maternal cigarette smoking and child psychiatric morbidity: a longitudinal study. Pediatrics 102(1): e11.

Williams MK, Barr DB, Camann DE, Cruz LA, Carlton EJ, Borjas M, et al. 2006. An intervention to reduce residential insecticide exposure during pregnancy among an inner-city cohort. Environmental Health Perspectives 114(11): 1684–1689.

Wilson J, Pivetz T, Ashley P, Jacobs D, Strauss W, Menkedick J, et al. 2006. Evaluation of HUD-funded lead hazard control treatments at 6 years post-intervention. Environmental Research 102(2): 237–248.

Yolton K, Dietrich K, Auinger P, Lanphear BP, Hornung R. 2005. Exposure to environmental tobacco smoke and cognitive abilities among U.S. children and adolescents. [see comment]. Environmental Health Perspectives 113(1): 98–103.

Panel 3: External Exposures (Drinking Water)

Safe drinking water and the proper disposal of human waste have long been associated with protecting human health. External biological agents associated with private drinking water wells include Cryptosporidium, E. coli 0157:H7, and norovirus. External chemical agents related to private drinking water wells include radionuclides, radon, nitrates and nitrites, and heavy metals such as arsenic, cadmium, chromium, and lead. More recently pharmaceuticals and endocrine disruptors have been added to the list of concerns about chemicals in drinking water. Improper design, structural deficiencies, improper installation, inadequate regulations, variations in topography, and poor maintenance are all factors that can increase the risk of illness should the ground water become contaminated with these biological and chemical agents.

Drinking water

Approximately 15 percent of homes in the United States rely on their own private drinking water supplies. Although some state and local governments set rules to protect users of these wells, these supplies are not subject to EPA standards. Unlike public drinking water systems that serve many people, households that have private water supplies generally do not have experts who routinely check the water's source and its quality before it is sent to the tap. These households must take special precautions to ensure the protection and maintenance of their drinking water supplies.

In *A survey of the quality of water drawn from domestic wells in nine Midwest states*, the mean age of the wells was 27 years with a mean depth of 154 feet (Centers for Disease Control and Prevention 1995). Water samples from households with wells older than 25 years, shallower than 100 feet, or greater than six inches in diameter were more likely to have contaminants than samples from households with a newer, deeper, and smaller-diameter drilled or driven well (Centers for Disease Control and Prevention 1995). Water samples from households with bored or dug wells were 10 to 15 times more likely to contain coliform bacteria or E. coli than were samples from households with drilled or driven wells (Centers for Disease Control and Prevention 1995).

Norovirus has been associated with water-borne disease outbreaks due to contamination from sewage that emanates from septic systems (Anderson et al. 2003). Microbial and chemical contamination of private wells is associated with heavy rainfall, leakage of surface water into improperly sealed wells, and lack of disinfection during warm weather (Kross et al. 1992; Lamka et al. 1980). Prevention is important when dealing with health issues associated with private drinking water systems.

More recently, concerns have been raised about the presence of disposed pharmaceuticals and the presence of other endocrine disrupting chemicals in both public and private drinking water systems (Snyder et al. 2003). While no EPA standards have been developed, risk assessments that suggest allowable levels have been published (Schwab et al. 2005).

Of the 8 drinking water associated water borne disease outbreaks reported to CDC in 2005–2006, 2 (25%) were associated with individual, unregulated water systems. In both cases the source of the water was untreated ground water intended for drinking. (CDC 2008)

Decentralized or on-site waste disposal systems can provide years of adequate and safe disposal of human waste. Maintenance includes proper siting, design, construction, and routine maintenance. Poorly designed and maintained systems contribute to contamination of water supplies and increase the risk of illness. Areas with a high density of onsite disposal systems contribute to the contamination of watersheds and the subsurface transport of contaminated water to surface waters (Lipp EK et al. 2001). Direct contamination of private water supplies also has occurred (Anderson et al. 2003).

Between 1997 and 2001, over 27 percent of all new construction relied on septic or cesspool systems (U.S. Census Bureau 2002). As development continues to expand beyond urban areas and into rural areas, onsite wastewater systems are viewed as an economical treatment choice for homes and small neighborhoods.

The problems associated with failed systems include the potential for contamination of the drinking water, public health nuisances, and aesthetic degradation. As the reliance on onsite treatment systems increases, having systems that are properly designed, constructed, and maintained is of paramount importance.

Panel 3 Decision Results

Panel 3 considered the following interventions:

- National voluntary treatment standards for drinking water and wastewater in decentralized, unregulated systems
- Enhancement of training centers
- Guidelines for immuno-compromised individuals
- UV/filtration point of use water purification systems
- Tracking transmission of pathogens using DNA technology
- Location of failed water systems
- Eliminate privies
- Social marketing and outreach for key audiences
- Methods of controlling entry of endocrine disruptors/ pharmaceuticals into drinking water

Of these interventions, three are ready for implementation and have been shown to be effective, three need more field testing but are promising, three need formative research, and one is ineffective.

A. Sufficient Evidence

1. National voluntary treatment standards for drinking water and wastewater in decentralized, unregulated systems

Rationale: Standards exist for municipal systems, which are regulated by EPA and the States, but no such standards exist for private unregulated systems. The existing regulatory standards have been shown to be protective of human health (see NSF International at *http://www.nsf.org/business/mechanical_plumbing/standardsnum.asp?program=MechanicalPluSysCom*; also see EPA standards at: *http://www.epa.gov/safewater/sdwa/30th/factsheets/standard.html*). The absence of either voluntary or regulatory standards for private unregulated systems produces unnecessary and avoidable risk. Standards are also needed for pharmaceuticals and other chemicals that can disrupt the endocrine system. Risk assessments that result in proposed limits in drinking water for pharmaceuticals have been published (Schwab et al. 2005) but have yet to be included in regulatory standards.

2. Enhance training centers by providing on-site hands-on training

Rationale: Training curricula have been developed that should be made more available to planning and zoning officials, sewage enforcement officers and other professionals. Such training would facilitate more widespread compliance with standards.

3. Guidelines for immuno-compromised individuals

Rationale: Existing knowledge on enteric bacteria in drinking water, Legionnella in water and mold on interior surfaces can be used to develop guidelines for those individuals who may be more susceptible to water-related disease.

B. Promising Interventions That Need More Field Evaluation

1. UV and Other Filtration Point of Use Systems

Rationale: There is conflicting evidence that use of UV/ filtration point of use systems are effective in preventing disease. In a randomized controlled trial, Colford 2005 showed that a device with a 1 μm absolute ceramic filter plus UV treatment had no significant effect on “highly credible gastrointestinal illness” (Colford et al. 2005b). However, in a cluster randomized controlled trial in Kenya where a turbid water supply was present, an intervention consisting of water treatment using flocculant disinfection and use of sodium hypochlorite resulted in significantly fewer deaths (relative risk=0.58) and a decrease of 25% in diarrhea among children <2 years old (Crump et al. 2005). A study in Guatemala also showed a benefit from use of sodium hypochlorite (Rangel et al. 2003). These differences may be due to the quality of the source water. Another small study of HIV-positive patients in San Francisco found that a filtration plus UV device significantly reduced Highly Credible Gastrointestinal Illness; among those with a sham device, the relative risk was 3.34 (Colford et al. 2005a). Yet another study showed that nutshell carbon beds in drinking water filters significantly reduced trace metals (Ahmedna et al. 2004). These technologies require further investigation in the field to more fully characterize their effectiveness and long-term durability in water of varying quality.

2. Location of failed water systems and privies

Rationale: Systems that have failed should not be used until corrective measures have been put in place or the system is permanently abandoned. Currently, there is no surveillance system identifying such systems, which makes reuse of the systems without corrective measures a distinct possibility. Similarly, privies are still in use in some rural areas, despite the fact that they are known to be associated with substandard sanitation that can cause disease. The precise method of identifying both failed systems and privies requires further field investigation, but the results of such identification are promising in reducing water-borne diseases.

C. Interventions in Need of Formative Research

1. **Delivery of training and outreach messages to zoning, planning and other users whose work may impact drinking water quality in dwellings without access to public drinking water systems.**
2. **Methods of controlling entry of endocrine disruptors/pharmaceuticals into drinking water. One study in California showed that a ban in the pharmaceutical use of lindane for head lice and scabies resulted in a decline in drinking water concentration from a mean of 36 parts per trillion (ppt) to less than the detection limit (about 1 ppt) (Humphreys et al. 2008).**
3. **Studies should be performed on socioeconomic, demographic and other ecological factors to identify gaps in providing basic drinking water and wastewater services.**
4. **Surveillance studies on Legionellosis should be designed to determine the magnitude of cases and mortality in residential buildings. Regional surveillance should be performed in warm climate areas.**
5. **System failure rates should be assessed under various operating conditions and linked to health effects.**
6. **Water reuse.**
7. **A risk index for emergency response and public health incidents should be developed.**
8. **The impact of siting and locating HUD-funded housing projects in Indian country.**
9. **The CDC study, “A Survey of the Quality of Water Drawn from Domestic Wells in Nine States,” should be updated. The study was completed in 1998.**
10. **Use of DNA technology to track transmission of pathogens.**

D. Interventions Shown To Be Ineffective or For Which Further Study Is Not Needed

1. **UV/point of use filter devices in systems which meet safe drinking water standards.**

There is no need to determine if such systems work for public drinking water systems that already meet standards, because the systems are unnecessary. Therefore, no further study of these devices is needed.

References: Panel 3

Ahmedna M, Marshall WE, Husseiny AA, Rao RM and Goktepe I (2004). "The use of nutshell carbons in drinking water filters for removal of trace metals." Water Research 38(4): 1062–1068.

Anderson AD, Heryford AG, Sarisky JP, Higgins C, Monroe SS, Beard RS, et al. (2003). "A waterborne outbreak of Norwalk-like virus among snowmobilers-Wyoming, 2001." J Infect Dis 187(2): 303–6.

Centers for Disease Control and Prevention (1995). A survey of the quality of water drawn from domestic wells in nine Midwest states: U.S. Department of Health and Human Services.

Centers for Disease Control and Prevention Surveillance for Waterborne Disease and Outbreaks Associated with Drinking Water and Water not Intended for Drinking—United sates 2005–2006. Surveillance Summaries September 12, 2008. MMWR 2008;57 (No. SS–9)

Colford JM, Jr., Saha SR, Wade TJ, Wright CC, Vu M, Charles S, et al. (2005a). "A pilot randomized, controlled trial of an in-home drinking water intervention among HIV plus persons." Journal of Water and Health 3(2): 173–184.

Colford JM, Wade TJ, Sandhu SK, Wright CC, Lee S, Shaw S, et al. (2005b). "A randomized, controlled trial of in-home drinking water intervention to reduce gastrointestinal illness." American Journal of Epidemiology 161(5): 472–482.

Crump JA, Otieno PO, Slutsker L, Keswick BH, Rosen DH, Hoekstra RM, et al. (2005). "Household based treatment of drinking water with flocculant-disinfectant for preventing diarrhoea in areas with turbid source water in rural western Kenya: cluster randomised controlled trial." British Medical Journal 331(7515): 478–481.

Humphreys EH, Janssen S, Heil A, Hiatt P, Solomon G and Miller MD (2008). "Outcomes of the California ban on pharmaceutical lindane: Clinical and ecologic impacts." Environmental Health Perspectives 116: 297–302.

Kross B, Selim M, Hallberg G, Brunner D and Cherryholmes K (1992). "Pesticide contamination of private well water, a growing rural health concern." Environment International ENVIDV 18(3): 231–241.

Lamka K, LeChevallier M and Seidler R (1980). "Bacterial contamination of drinking water supplies in a modern rural neighborhood." Appl Environ Microbiol 39(4): 734–8.

Lipp EK, Farrah SA and Rose JB (2001). "Assessment and Impact of Microbial Fecal Pollution and Human Enteric Pathogens in a Coastal Community." Marine Pollution Bulletin 42(4): 286–293.

Rangel JM, Lopez B, Mejia MA, Mendoza C and Luby S (2003). "A novel technology to improve drinking water quality: A microbiological evaluation of in-home flocculation and chlorination in rural Guatemala." Journal of Water and Health 1(1): 15–22.

Schwab BW, Hayes EP, Fiori JM, Mastrocco FJ, Roden NM, Cragin D, et al. (2005). "Human pharmaceuticals in US surface waters: A human health risk assessment." Regulatory Toxicology and Pharmacology 42(3): 296–312.

Snyder SA, Westerhoff P, Yoon Y and Sedlak DL (2003). "Pharmaceuticals, personal care products, and endocrine disruptors in water: Implications for the water industry." Environmental Engineering Science 20(5): 449–469.

U.S. Census Bureau (2002). American Housing Survey for the United States, Current Housing Reports. Available at *www.census.gov/prod/2002pubs/h150-01.pdf*. Retrieved 4/2/08.

Panel 4: Structural Deficiencies

Residential injuries result in thousands of deaths and millions of emergency department visits each year. In 2003, one-third of all injury-related deaths resulted from home injuries (National Safety Council 2003). The rates of unintentional home injury death are highest in the youngest and oldest age groups (Agran et al. 2003; Runyan et al. 2005). For children less than 1 year old, 93% of all injury-related deaths occur in the home (Breysse et al. 2004). For infants, children, and young adults 0–19 years old, at least 55% of unintentional deaths (excluding motor vehicle accidents) occur in the home (Nagaraja et al. 2005; Phelan et al. 2005). Overall, preventable, unintentional residential injuries in US children less than 19 years result in more than 4 million visits to US emergency departments, resulting in more than 70,000 hospitalizations each year (Nagaraja et al. 2005; Phelan et al. 2005). Adults over the age of 75 years have the highest death rate due to unintentional home injury (National Safety Council 2003; Centers for Disease Control and Prevention 2006b). These unintentional deaths among the elderly account for a third of the total unintentional injury deaths across all age groups (National Safety Council 2003).

Structural and other deficiencies in housing are important causes of fatal and non-fatal injury and encompass factors related to construction, design, installation, and lack of maintenance. Structural deficiencies in a house can cause falls, fires, burns and scalds, carbon monoxide and other poisoning, drowning and other injuries.

Falls

Falls are the leading cause of nonfatal injuries for infants, children and youth, and older adults (Marshall et al. 2005; Centers for Disease Control and Prevention 2006b). Falls account for 45% of all injuries in the home that require medical attention (Runyan et al. 2005). Falls on or from stairs and steps, falls on the same level from slipping, tripping or stumbling, and falls from or out of the building are the most commonly reported causes of falls in the home (Home Safety Council 2004).

Falls are the most common cause of injury death among older Americans (Hornbrook et al. 1994; Hausdorff et al. 2001). Residential injury-related deaths for persons 65 years and older account for approximately 60% of all household deaths due to falls (Mathers and Weiss 1998). Structural residential hazards associated with falls among older adults include lack of handrails on stairs, lack of grab bars and non-slip surfaces in the bathroom, tripping or slipping hazards, waxed flooring, other outdoor steps, inadequate lighting, and the presence of electrical or telephone cords in the walkway (Carter et al. 1997) . Individual behaviors and physical ability levels also are important factors contributing to falls in older adults (Lord et al. 2006).

Falls also are a major cause of nonfatal injury in children and result in an estimated 2.7 million emergency room visits each year (Centers for Disease Control and Prevention 2006b). Residential hazards associated with falls among children include a lack of safety devices such as grab bars, safety gates and window guards, structural defects (e.g., uneven floors), and insufficient lighting over stairs and in other areas.

Fire-Related Injuries

Residential fires account for 80% of all civilian fire injuries and deaths in the U.S. (Karter 2007). In 2006, U.S. fire departments responded to 412,500 residential fires that resulted in 2,580 deaths, 12,925 injuries, and nearly 7 billion dollars in property damage (Karter 2007). Most fatalities are due to smoke or toxic gases, rather than burns (Hall 2001). Smoke inhalation accounts for the largest percentage of residential fire-related injuries.

Groups at increased risk of fire-related injury and death include infants, young children, and the elderly (0 to 4 years and 75 years and older), African-Americans, Native Americans, low-income Americans, persons in rural areas, and those living in manufactured (i.e., mobile) homes (particularly those built before 1976 when building codes changed) and substandard housing (Istre et al. 2001; Centers for Disease Control and Prevention 2003; National Safety Council 2003). Young children and older adults are at increased risk of fire-related death and injury due, in part, to lack of mobility and judgment, which may limit their ability to exit a house (Home Safety Council 2004).

Primary residential hazards associated with fire-related injuries are the lack of functional smoke alarms near or inside bedrooms and on every floor of a house, lack of fire extinguishers, and lack of arc fault circuit interrupters (AFCIs) (U.S. Department of Housing and Urban Development 2006). Some individual behaviors such as smoking are also risk factors (Mallonee et al. 1996; Diekman et al. 2008).

Annually, home-related electrical fires in the U.S. claim approximately 485 lives and injure 2,300 more (U.S. Fire Administration 2006). Some of these fires are caused by electrical system failures and appliance defects; many more are caused by the misuse and poor maintenance of electrical appliances, incorrectly installed wiring, and overloaded circuits and extension cords (U.S. Fire Administration 2006). Faulty electrical wiring causes twice as many fires as faulty electrical appliances (U.S. Fire Administration 2006). Impairment by alcohol and drugs also increases the likelihood of death and injury in residential fires (Runyan et al. 1992; Marshall et al. 1998; Centers for Disease Control and Prevention 2003).

Scald-Related Injuries

Scald burns commonly occur from contact with hot foods and liquids, and hot tap or bath water. In 1997, an estimated 12,400 children received scald burns; nearly a quarter of these burns were caused by hot tap water (Schieber et al. 2000). Most scald-related deaths occur in children younger than 4 years old (Simon and Baron 1994; Morrow et al. 1996). Other high-risk groups include the elderly and those with physical or mental disabilities (U.S. Department of Housing and Urban Development 2006). These high-risk groups account for nearly 90% of those burned by hot tap water (U.S. Department of Housing and Urban Development 2006). Burns as a result of scalding by hot tap water generally are more severe than other scalds, and occur most frequently in the bathtub or shower, but also may occur in the kitchen or bathroom sink. Primary residential deficiencies associated with scalds include lack of anti-scald devices for shower heads and faucets, and water heater thermostats that are set above 120ºF (U.S. Department of Housing and Urban Development 2006).

Drowning

Drowning is the fifth leading cause of home injury death in the U.S (Home Safety Council 2004). It is the second leading cause of injury death among children 1–14 years old, surpassed only by motor vehicle accidents (Centers for Disease Control and Prevention 2006b). The risk of drowning is also high for adults 70 years and older and an average of 823 drowning deaths (across all ages) occur in or on home premises each year (Home Safety Council 2004).

Drowning is defined as a fatal event when death results from suffocation within 24 hours of submersion in water; approximately one-fourth of them occur in the home or its surrounding premises (Home Safety Council 2004). Forty-five percent of drownings occur in swimming pools, 33% in bathroom tubs and showers, 17% are unspecified, and 4% occur while engaged in a sport or recreational activity (Home Safety Council 2004). For the period 1996 to 1999, the U.S. Consumer Product Safety Commission reported non-pool home drowning of 459 children under 5 years old, which were related to bathtubs, 5-gallon buckets, spas or hot tubs, toilets, and other water-holding products (U.S. Consumer Products Safety Commission 2002). The most frequent cause (292 deaths) was submersion in bathtubs and nearly half were children under 2 years old (U.S. Consumer Products Safety Commission 2002). In 2004, for every child under 15 years old who died from drowning, there were 5 children who received emergency room care for nonfatal submersion injuries, which can lead to brain damage and result in long term disability (Centers for Disease Control and Prevention 2006a).

Panel 4 Decision Results

The scope of this panel included structural deficiencies and behavior changes to correct those deficiencies. The scope also included monitoring to identify structural deficiencies (e.g., carbon monoxide detectors) and behavior changes to increase such monitoring. Structural deficiencies are defined as those deficiencies for which a builder or landlord or home owner would take responsibility (i.e., design, construction, installation, repair, monitoring). It thus excludes behaviors of household residents such as safely storing poisons or matches, affixing loose rugs, and purchasing non-slip bathmats.

Panel 4 considered the following interventions:

- Smoke alarms
- Isolation 4-sided and perimeter 3-sided pool fencing
- Safe hot water heater temperatures
- Installation of stair gates, window guards, handrails, grab bars, better stair design and improved lighting
- Temperature-controlled mixer (water) faucets
- Safe ignition sources (e.g., electrical and heating systems) and ignition source controls (Arc Fault Circuit Interrupters)
- Home modification to improve fire escape (e.g., egress windows and doors, exit signage, protected stairways)
- Automatic fire sprinkler systems
- Pool covers and pool alarms
- Bathtub design
- Stove and stove control design
- Carbon monoxide exposure prevention through design and engineering
- Housing and building code enforcement
- Air conditioning/cooling during heat waves
- Noise reduction

For each of these interventions, the panel considered evidence regarding the efficacy of the intervention itself (i.e., whether, when correctly implemented, it was efficacious in reducing injury). It also considered the effectiveness of methods to increase implementation, including legislation, regulation (e.g., building codes), home or community-based education, device distribution and installation programs, and multi-component programs.

Three interventions have been shown to be effective and are ready for implementation, although further field testing is needed to determine the optimal method(s) to promote implementation. Four interventions are promising but need more field testing. Formative research is needed on aspects of several proven and promising interventions, methods to implement a number of interventions, and other aspects of home modification for safety. In addition, one intervention reviewed here has been shown to be ineffective, and one method for implementing an intervention is less effective.

Sufficient Evidence

1. Installed, working smoke alarms

Rationale: The evidence that having working smoke alarms installed in the home reduces death and injuries from residential fires is from the following studies: (Runyan et al. 1992; DiGuiseppi et al. 1998; Marshall et al. 1998; Watson and Gamble 1999; Ahrens 2004). Homes with smoke alarms have a 40–50% lower fire death rate compared to homes without smoke alarms (Ahrens 2004). Furthermore, 70% of all home fire deaths occurred in homes without working smoke alarms (Ahrens 2004).

Further investigation is needed to determine the most effective method(s) of increasing the presence of working smoke alarms in the home. Two implementation methods that appear promising but require field testing are: a) community-based installation of smoke alarms, with education, in high-risk homes, and b) building codes, legislation, or both, requiring smoke alarms.

The evidence that community-based installation of smoke alarms, combined with education reduces fire-related injuries in high risk homes comes from a systematic review that described two relevant trials (DiGuiseppi and Higgins 2001)[1]. Based on these trials, the systematic review concluded that community-based programs that install free smoke alarms are significantly more effective than community-based programs that give away free smoke alarms (but do not install them) as a method to

[1] *This version first published online: 23 April 2001 in Issue 2, 2001. Re-published online with edits: 8 October 2008 in Issue 4, 2008. Last assessed as up-to-date: 16 September 2007. The updated version includes an additional author, Cynthia W Goss.*

increase the prevalence of installed, working smoke alarms in high-risk homes. In addition, one of the trials found significant reductions in the incidence of fire-related injuries in intervention areas, but not in control areas after installation of free alarms. However, due to methodological limitations in this trial, the panel recommended further field testing of this implementation method to increase the prevalence of installed working smoke alarms.

The rationale for using building codes and legislation to increase the prevalence of working smoke alarms comes from McLoughlin 1985. This controlled before-after study demonstrated a higher proportion of homes with working smoke alarms and greater reductions in fatal fires and fire deaths in one county after passage of legislation requiring smoke alarms in all homes, compared to a similar county without such legislation (McLoughlin et al. 1985). In both counties, homes built after implementation of building codes requiring smoke alarm installation had more working smoke alarms than homes built before the code was implemented. Confirmation of these findings in other settings, with attention to potential confounding by population differences, is needed.

2. Isolation 4-sided pool fencing

Rationale: The evidence that 4-sided pool fencing is effective in preventing drowning is from the following studies: Fergusson and Harwood 1984, Intergov 1988, Pitt and Balanda 1991 and a systematic review of available evidence by Thompson and Rivara 1998. The Fergusson study compared fenced and unfenced pools and reported an odds ratio of the risk of drowning in a fenced pool of 0.29, i.e., the risk of drowning in a fenced pool was about three times lower, compared to an unfenced pool (Fergusson and Horwood 1984). The Intergov study showed that 4-sided isolation fencing is about 5 times more effective than 3-sided perimeter fencing (odds ratio =0.17) (Intergov WA - Intergovernmental Working Party on Swimming Pool Safety 1988). The Pitt study reported similar odds ratios to those reported in the Fergusson study (Pitt and Balanda 1991). One study failed to show that an ordinance requiring pool fencing in Los Angeles reduced drowning significantly (Morgenstern et al. 2000), although it is possible that this study was confounded by a public education campaign, the fact that the legislation only required 3-sided fencing, possible inadequate enforcement, and other factors. Overall, the evidence shows that 4-sided isolation pool fencing significantly reduces childhood drowning, and that this type of fencing performs significantly better than 3-sided perimeter fencing.

A number of different methods for implementing 4-sided isolation fencing have been considered, such as ordinances, legislation, building codes, and home- or community-based education (Morgenstern et al. 2000; Thompson and Rivara 2000; Kendrick et al. 2007). However, available evidence does not establish the best method(s) for implementation. Hence, field testing is needed to establish the optimal implementation method(s) to increase the prevalence of 4-sided isolation fencing.

3. Pre-set safe temperature hot water heaters

Rationale: The evidence that pre-set safe temperature hot water heaters reduce scald burns comes primarily from Feldman 1978 and Erdmann 1991. Feldman determined through testing that 80% of children hospitalized for scald burns lived in homes with unsafe bathtub water temperatures of 130 degrees F or higher (Feldman et al. 1978). Five years after a 1983 Washington State law required new water heaters to be pre-set at 120 degrees F at the factory, 77% of homes tested had safe tap water temperatures and there was a reduction in the frequency, morbidity and mortality of tap water burn injuries in children (Erdmann et al. 1991). The effect of requesting manufacturers to voluntarily comply with the presetting of water heaters temperatures to a safe level, in the absence of legislation, has not been evaluated. But such voluntary compliance, with appropriate monitoring, is likely to be a promising approach that deserves field testing (Katcher 1998).

Field testing is needed to determine effective methods for implementation of safe hot water heater temperatures in homes with existing hot water heaters that are set at unsafe temperatures. One such method is educating parents to lower the temperature setting of their hot water heaters. Studies evaluating home education have been comprehensively reviewed by Kendrick et al. 2007, which found eleven studies evaluating home education to promote safe hot tap water temperatures. A meta-analysis of the results of these studies demonstrated that families receiving home safety education were more likely to have a safe hot tap water temperature than control group families (Kendrick et al. 2007). A subsequently published study also found a greater prevalence of safe water temperature following provision of a safety kit with a water temperature card, compared to a control group (OR=2.21) (Babul et al. 2007). However, there was a lack of evidence from these studies showing any effect of home education on scald burns. Hence, further field testing is needed to determine if implementation of home education to promote safe hot water heater temperature is effective.

B. Promising Interventions That Need More Field Evaluation

1. **Fall prevention through home modifications such as installation of stair gates, window guards, handrails, grab bars, window guards and improved lighting**

Rationale: The evidence that structural modifications, such as installation of handrails, grab bars, and improved lighting, are promising interventions for reducing risk of falls among older adults comes from two systematic reviews (Lyons et al. 2006; Gillespie et al. 2003.). Lyons et al. reviewed studies of home modification to reduce older adult falls and fall injuries. Three studies included in the review evaluated the independent effect of physically modifying the home to reduce fall hazards (Cumming et al. 1999; Stevens et al. 2001a; Day et al. 2002).

In the Cumming study, home modifications included installation of stair rails, non-slip mats and night-lights. Home hazards were significantly reduced after the intervention, relative to control homes (Cumming et al. 1999). This study reported a significant reduction in falls among those with a prior history of falls (RR=0.64; 95% CI: 0.5-0.83); however, among those without a history of falling, the intervention was not effective (relative risk=1.03, 95% CI=0.75–1.41) (Cumming et al. 1999). Home modifications in Day et al. (2002) included handrail installation and modified floor coverings. Day reported significantly reduced home hazards and a non-significant relative risk of 0.92 (95% CI=0.75–1.08) for falls, suggesting that structural interventions may be effective in reducing the risk of falls among the elderly (Day et al. 2002). Neither Cumming (1999) nor Day (2002) evaluated effects on injuries from falls. A third trial involved modifications such as installation of grab bars and improved lighting and, as in the other two studies, reported significantly fewer home hazards in intervention homes relative to control homes (Stevens et al. 2001b). Stevens et al. found no beneficial effect on the incidence of falls following intervention (adjusted rate ratio=1.11), although the rate of injurious falls among the intervention group was non-significantly reduced (adjusted rate ratio=0.92, 95% CI=0.73–1.14) (Stevens et al. 2001b). These studies demonstrate that home modification does reduce hazards and is therefore promising as a way to reduce falls and fall injuries, but additional, larger field evaluations are needed to test and identify the interventions likely to be consistently successful in reducing falls and fall injuries for both those with and without a history of falling.

Field testing is also needed to determine the best method for implementing home modification for older adult fall prevention, especially since home modification can be costly and labor intensive. Three implementation methods appear promising: 1) home assessment followed by recommendations for modifications, 2) multi-factorial interventions that encompass home modification along with other fall-prevention strategies such as exercise, medication review, nutritional supplements or mobility aids, and 3) community-based, coordinated, multi-strategy initiatives that include home hazard reduction. Several studies reviewed in Lyons et al. evaluated the effect of implementing home safety modification through home assessment followed by advice, recommendations and action plans (Lyons et al. 2006). Close et al. reported a significant reduction in falls and a non-significant reduction in hospital admissions among elderly people with a history of falling (Close et al. 1999). Another study reported a modest reduction in fall risk that was not statistically significant (RR=0.87, 95% CI=0.50–1.49) (Pardessus et al. 2002). The third study found no effect on falls, but did report a significant reduction in home hazards (Lyons et al. 2006). Among the trials of multi-factorial programs for fall prevention reviewed in Lyons et al., the majority of the studies showed reductions in falls, although only one showed a reduction in injuries after intervention, and two studies showed increased falls with implementation of the multi-factorial program (Lyons et al. 2006). The programs varied substantially in the types of interventions that were included, and it is likely that some combinations of fall prevention strategies are more effective than others, although the optimal combination has not been established. Evidence for community-based, coordinated, multi-strategy initiatives was reviewed by McClure et al. 2005a and McClure et al. 2005b. The review identified and described studies that reported changes in medically treated fall-related injuries among older people following the implementation of a controlled population-based intervention that included home modifications to prevent falls. Despite methodological limitations of the studies reviewed, there was consistency in the reported reductions in fall-related injuries across all five programs. These two systematic reviews suggest that all three of these types of implementation methods for the prevention of fall-related injury are promising, but further studies are needed to establish their effectiveness.

The evidence that window guards reduce childhood morbidity and mortality from falls comes primarily from dramatic results following a community-wide program to provide window guards in high-risk apartments, where falls declined 50% in the 2 years after the program's inception (Spiegel and Lindaman 1977). A cohort study by Kendrick et al. demonstrated a reduced risk of injury in homes with fitted stair gates and other safety devices, but suggested that this may reflect a generally 'safe' home, rather than a specific benefit from stair gates or similar interventions (Kendrick et al. 2005). Several methods for implementing these interventions have been evaluated. Kendrick et al. reviewed 37 studies and reported that home education produced a statistically significant increase in the odds that a home would have a fitted stair gate (OR=1.26; 95% CI 1.05, 1.51) and a modest, non-significant increase in the prevalence of installed window locks and other window guards (OR=1.16; 95% CI 0.84, 1.59), but at the same time did not show any change in child injury rates (Kendrick et al. 2007). Building codes that require window guards, safe stair and balcony design, and other modifications are likely to be effective for fall prevention since they remove the need for home dwellers to modify their home for safety (or to encourage their landlords to install such interventions). However, available evidence evaluating this intervention is lacking. Hence, these interventions are promising, but need more field investigation to demonstrate an effect on injury rates and to determine optimal methods for implementation and for obtaining compliance with consistent stair gate and window guard usage.

2. Temperature-controlled mixer faucets

Rationale: Temperature-controlled mixer faucets reduce the temperature of hot water from faucets in manufacturer's tests and in institutional settings (Stephen and Murray 1993; Katcher 1998). Because of the risk of scald burns from high tap water temperatures and the evidence for a benefit from hot water heaters that are preset to a safe temperature (described above), this would seem to be a valuable approach to scald burn prevention. However, one study showed that the majority of families who were given a thermostatic mixing valve removed the device within 9 months after installation (Fallat et al. 1993). In addition, in a recent community-based trial to promote installation of temperature mixing valves, there was no evidence of a significant reduction in hot water temperature or scald injury rates (Spallek et al. 2007). Hence, although the technology is promising, research is needed to improve the use and acceptability of temperature-controlled mixer faucets, and field testing is required to determine how to implement this technology successfully.

3. Safe ignition sources (e.g., electrical and heating systems)

Rationale: Evidence for the contribution of electrical and heating systems to residential fires in the U.S. has been reported by Hall 2008. Fires involving heating equipment (e.g., furnace, chimney) account for 22.1% of deaths in residential fires, while fires involving electrical distribution and lighting equipment (e.g., electrical wiring, plugs, lighting) account for 11.2% (Hall 2008). Based on the important contribution of these types of systems and, as above, the evidence of potential beneficial effects of building codes and legislation for fire and burn prevention (McLoughlin et al. 1985; Erdmann et al. 1991) this type of intervention is considered promising, but field research is required to evaluate it. Ignition source controls (Arc Fault Circuit Interrupters (AFCI) are one potential approach to improve safety of ignition sources, but methods to promote AFCI, such as building codes, legislation, or community-education, require research.

4. **Home modification to improve ability to escape fires (e.g., egress windows and doors, exit signage, protected stairways)**

While working smoke alarms reduce the risk of fire injury, their efficacy depends on the presence of safe egress from the home in the event of a fire (e.g., via access windows, fire escapes, or protected stairways). The potential benefits of building codes and legislation requiring safe exits from fire is supported by the evidence of effects of building codes and legislation on other aspects of home structural safety (McLoughlin et al. 1985; Erdmann et al. 1991). However, field testing of this intervention in the residential setting has not been conducted. In addition, there is a need for formative research examining escape behaviors during fires, in order to inform safe egress design.

5. **Working air conditioning during heat waves**

Rationale: The strongest protective factor in preventing heat-related mortality during the 1999 heat wave in Chicago was a working air conditioning system (OR=0.2) (Naughton et al. 2002). However, no evaluations have measured the effectiveness of legislating, mandating or promoting the installation of air conditioning to prevent heat-related mortality, hence field testing is needed.

C. Interventions in Need of Formative Research

The Panel identified a substantial number of areas where more formative research is needed, including both efficacy and design, as follows:

- Improved smoke alarm design (acceptability, long-term function)
- Improved design of temperature-controlled mixer faucets (acceptability, long-term function)
- Automatic fire sprinkler systems for housing
- Pool covers and alarms
- Bathtub design to reduce falls and drowning
- Stove and stove control design to prevent burns
- Design and engineering to reduce carbon monoxide (CO) exposure
- Noise reduction

In addition, the panel recommended formative research to improve the ability to implement potentially beneficial interventions, including:

- Ignition source controls (Arc Fault Circuit Interrupters)
- Behavioral and legislative interventions to reduce CO exposure
- Home- and community-based education and distribution programs to reduce ignition sources (e.g., updated wiring, clean chimneys, safe space heaters)
- Community-based education for safe hot water temperature (Turner et al. 2004)
- Community-based, coordinated, multi-strategy initiatives for burn prevention targeted to families with children aged <14 years (Turner et al. 2004)
- Understanding fire escape behavior to inform improved building design
- Enforcement and/or use of incentives to promote implementation of safety-related building and housing codes and legislation
- Community-based, coordinated, multi-strategy initiatives that include home hazard reduction for fall prevention, targeting children (McClure et al. 2005a, McClure et al. 2005b)

Finally, the panel recommended that formative research be conducted to evaluate interactions among a range of structural hazards (e.g., falls and CO), and to test innovations in residential design that could reduce hazards (e.g., laboratory-based testing of coatings on electrical wires to prevent arcing).

D. Interventions Shown To Be Ineffective

Use of 3-sided pool fences instead of complete 4-sided pool fencing is not effective and may actually increase risk because care-givers may believe the incomplete fencing is adequate (Intergov WA—Intergovernmental Working Party on Swimming Pool Safety 1988).

Community programs that give away smoke alarms without taking steps to make sure they are actually installed are less effective than programs that actually install alarms, and have not been proven to reduce injuries (DiGuiseppi and Higgins 2001).

References—Panel 4

Agran PF, Anderson C, Winn D, Trent R, Walton-Haynes L, Thayer S. 2003. Rates of pediatric injuries by 3-month intervals for children 0 to 3 years of age. Pediatrics 111(6 Pt 1): e683–692.

Ahrens M. 2004. U.S. experience with smoke alarms and other fire alarms. Quincy, MA: National Fire Protection Association.

Babul S, Olsen L, Janssen P, McIntee P, Raina P. 2007. A randomized trial to assess the effectiveness of an infant home safety programme. Int J Inj Contr Saf Promot 14(2): 109–117.

Breysse P, Farr N, Galke W, Lanphear B, Morley R, Bergofsky L. 2004. The relationship between housing and health: Children at risk. Environmental Health Perspectives 112(15): 1583–1588.

Carter SE, Campbell EM, Sanson-Fisher RW, Redman S, Gillespie WJ. 1997. Environmental hazards in the homes of older people. Age & Ageing 26(3): 195–202.

Centers for Disease Control and Prevention. 2003. Fire deaths and Injuries. Retrieved March 25, 2008, from *http://www.cdc.gov/ncipc/factsheets/fire.htm*. Atlanta, GA: U.S. Department of Health and Human Services.

Centers for Disease Control and Prevention. 2006a. Water-related injuries Fact Sheet. Accessed March 26, 2008. Atlanta, GA: U.S. Department of Health and Human Services.

Centers for Disease Control and Prevention. 2006b. Web-based injury statistics query and reporting system (WISQARS) [online]. Atlanta, GA: U.S. Department of Health and Human Services.

Close J, Ellis M, Hooper R, Glucksman E, Jackson S, Swift C. 1999. Prevention of falls in the elderly trial (PROFET): a randomised controlled trial. Lancet 353(9147): 93–97.

Cumming RG, Thomas M, Szonyi G, Salkeld G, O'Neill E, Westbury C, et al. 1999. Home visits by an occupational therapist for assessment and modification of environmental hazards: A randomized trial of falls prevention. Journal of the American Geriatrics Society 47(12): 1397–1402.

Day L, Fildes B, Gordon I, Fitzharris M, Flamer H, Lord S. 2002. Randomised factorial trial of falls prevention among older people living in their own homes. British Medical Journal 325(7356): 128–131.

Diekman ST, Ballesteros MF, Berger LR, Caraballo RS, Kegler SR. 2008. Ecological level analysis of the relationship between smoking and residential-fire mortality. Injury Prevention 14(4): 228–231.

DiGuiseppi C, Higgins JP. 2001. Interventions for promoting smoke alarm ownership and function. Cochrane Database Syst Rev(2): CD002246. Updated 2008.

DiGuiseppi C, Roberts I, Li L. 1998. Smoke alarm ownership and house fire death rates in children. Journal of Epidemiology and Community Health 52(11): 760–761.

Erdmann TC, Feldman KW, Rivara FP, Heimbach DM, Wall HA. 1991. Tap Water Burn Prevention—The Effect of Legislation. Pediatrics 88(3): 572–577.

Fallat ME, Rengers SJ, Bachulis BL, Pruitt BA. 1993. The Effect of Education and Safety Devices on Scald Burn Prevention. Journal of Trauma-Injury Infection and Critical Care 34(4): 560–564.

Feldman K, Schaller R, Feldman J, McMillon M. 1978. Tap water scald burns in children. Pediatrics 62: 1–7.

Fergusson DM, Horwood LJ. 1984. Risks of Drowning in Fenced and Unfenced Domestic Swimming Pools. New Zealand Medical Journal 97(767): 777–779.

Gillespie LD, Gillespie WJ, Robertson MC, Lamb SE, Cumming RG and Rowe BH (2003). Interventions for preventing falls in elderly people. Cochrane Database Syst Rev(4): CD000340

Hall 2001. Burns, toxic gases, and other hazards associated with fires: Deaths and injuries in fire and non-fire situations. Quincy, MA: National Fire Protection Association, Fire analysis and research division.

Hall 2008. Home Structure Fires Involving Equipment. Quincy, MA: National Fire Protection Association.

Hausdorff JM, Rios DA, Edelberg HK. 2001. Gait variability and fall risk in community-living older adults: a 1-year prospective study. Arch Phys Med Rehabil 82(8): 1050–1056.

Home Safety Council. 2004. The state of the Home Safety in America: Facts about unintentional injuries in the home, Second edition. Wilkesboro, NC: Home safety council.

Hornbrook MC, Stevens VJ, Wingfield DJ, Hollis JF, Greenlick MR, Ory MG. 1994. Preventing falls among community-dwelling older persons: results from a randomized trial. Gerontologist 34(1): 16–23.

Intergov WA - Intergovernmental Working Party on Swimming Pool Safety. 1988. Pre-School drowning in private swimming pools. Perth: Health Department of Western Australia.

Istre GR, McCoy MA, Osborn L, Barnard JJ, Bolton A. 2001. Deaths and injuries from house fires. [see comment]. New England Journal of Medicine 344(25): 1911–1916.

Karter MJ. 2007. Fire loss in the United States during 2006. Quincy, MA: National Fire Proctection Association, Fire Analysis and Research Division.

Katcher M. 1998. Tap water scald prevention: it's time for a worldwide effort. Inj Prev 4: 167–169.

Kendrick D, Coupland C, Mulvaney C, Simpson J, Smith SJ, Sutton A, et al. 2007. Home safety education and provision of safety equipment for injury prevention. Cochrane Database of Systematic Reviews(1).

Kendrick D, Watson M, Mulvaney C, Burton P. 2005. How useful are home safety behaviours for predicting childhood injury? A cohort study. Health Education Research 20(6): 709–718.

Lord SR, Menz HB, Sherrington C. 2006. Home environment risk factors for falls in older people and the efficacy of home modifications. Age Ageing 35 Suppl 2: ii55–ii59.

Lyons RA, John A, Brophy S, Jones SJ, Johansen A, Kemp A, et al. 2006. Modification of the home environment for the reduction of injuries. Cochrane Database of Systematic Reviews(4).

Mallonee S, Istre G, Rosenberg M, Douglas MR, Jordan F, Silverstein P, et al. 1996. Surveillance and prevention of residential-fire injuries. New England Journal of Medicine 335(1): 27–31.

Marshall S, Runyan C, Bangdiwala S, Linzer M, Sacks J, Butts J. 1998. Fatal residential fires: who dies and who survives? Jama 279(20): 1633–1637.

Marshall SW, Runyan CW, Yang J, Coyne-Beasley T, Waller AE, Johnson RM, et al. 2005. Prevalence of selected risk and protective factors for falls in the home. American Journal of Preventive Medicine 28(1): 95–101.

Mathers L, Weiss H. 1998. Incidence and characteristics of fall-related emergency department visits. Acad Emerg Med 5(11): 1064–1070.

McClure R, Nixon J, Spinks A, Turner C. 2005a. Community-based programmes to prevent falls in children: a systematic review. J. Paediatr. Child Health (2005) 41, 465–470).

McClure R, Turner C, Peel N, Spinks A, Eakin E, Hughes K. 2005b. Population-based interventions for the prevention of fall-related injuries in older people. Cochrane Database of Systematic Reviews 2005, Issue 1. Art.No.:CD004441. DOI: 10.1002/14651858. CD004441.pub2

McLoughlin E, Marchone M, Hanger SL, German PS, Baker SP. 1985. Smoke Detector Legislation—Its Effect on Owner-Occupied Homes. American Journal of Public Health 75(8): 858–862.

Morgenstern H, Bingham T, Reza A. 2000. Effects of pool-fencing ordinances and other factors on childhood drowning in Los Angeles County, 1990-1995. American Journal of Public Health 90(4): 595–601.

Morrow SE, Smith DL, Cairns BA, Howell PD, Nakayama DK, Peterson HD. 1996. Etiology and outcome of pediatric burns. J Pediatr Surg 31(3): 329–333.

Nagaraja J, Menkedick J, Phelan KJ, Ashley P, Zhang X, Lanphear BP. 2005. Deaths from residential injuries in US children and adolescents, 1985-1997. Pediatrics 116(2): 454–461.

National Safety Council. 2003. Injury Facts, 2003 edition. Itasca, IL: National Safety Council.

Naughton MP, Henderson A, Mirabelli MC, Kaiser R, Wilhelm JL, Kieszak SM, et al. 2002. Heat-related mortality during a 1999 heat wave in Chicago. American Journal of Preventive Medicine 22(4): 221–227.

Pardessus V, Puisieux F, Di Pompeo C, Gaudefroy C, Thevenon A, Dewailly P. 2002. Benefits of home visits for falls and autonomy in the elderly—A randomized trial study. American Journal of Physical Medicine & Rehabilitation 81(4): 247–252.

Phelan KJ, Khoury J, Kalkwarf H, Lanphear B. 2005. Residential injuries in U.S. children and adolescents. Public Health Rep 120(1): 63–70.

Pitt WR, Balanda KP. 1991. Childhood Drowning and Near-Drowning in Brisbane—The Contribution of Domestic Pools. Medical Journal of Australia 154(10): 661–665.

Runyan CW, Bangdiwala SI, Linzer MA, Sacks JJ, Butts J. 1992. Risk factors for fatal residential fires. [see comment]. New England Journal of Medicine 327(12): 859–863.

Runyan CW, Perkis D, Marshall SW, Johnson RM, Coyne-Beasley T, Waller AE, et al. 2005. Unintentional injuries in the home in the United States Part II: morbidity. American Journal of Preventive Medicine 28(1): 80–87.

Schieber RA, Gilchrist J, Sleet DA. 2000. Legislative and regulatory strategies to reduce childhood unintentional injuries. Future Child 10(1): 111–136.

Simon PA, Baron RC. 1994. Age as a risk factor for burn injury requiring hospitalization during early childhood. Archives of Pediatrics & Adolescent Medicine 148(4): 394–397.

Spallek M, Nixon J, Bain C, Purdie DM, Spinks A, Scott D, et al. 2007. Scald prevention campaigns: Do they work? Journal of Burn Care & Research 28(2): 328–333.

Spiegel C, Lindaman F. 1977. Children can't fly: a program to prevention childhood morbidity and mortality from window falls. American Journal of Public Health 67: 1143–1147.

Stephen FR, Murray JP. 1993. Prevention of Hot Tap Water Burns - A Comparative-Study of 3 Types of Automatic Mixing Valve. Burns 19(1): 56–62.

Stevens M, Holman CDJ, Bennett N. 2001a. Preventing falls in older people: Impact of an intervention to reduce environmental hazards in the home. Journal of the American Geriatrics Society 49(11): 1442–1447.

Stevens M, Holman CDJ, Bennett N, de Klerk N. 2001b. Preventing falls in older people: Outcome evaluation of a randomized controlled trial. Journal of the American Geriatrics Society 49(11): 1448–1455.

Thompson DC, Rivara FP. 1998. Pool fencing for preventing drowning in children. Cochrane Database Syst Rev(2): CD001047. Updated 2006

Turner C, Spinks A, McClure R, Nixon J. 2004. Community-based interventions for the prevention of burns and scalds in children. Cochrane Database Syst Rev(3): CD004335.

U.S. Consumer Products Safety Commission. 2002. Children and In-Home Drownings Vol. 6, No. 4.

U.S. Department of Housing and Urban Development. 2006. Healthy Homes Issues: Injury Hazards, Version 3.

U.S. Fire Administration. 2006. Home fire safety: On the safety circuit: A factsheet on home electrical fire prevention: U.S. Department of Homeland Security.

Watson L, Gamble J. 1999. Fire statistics: United Kingdom 1998. London, UK: Government Statistical Service.

Panel 5: Intersection between Neighborhoods and Housing

Neighborhoods, Housing, and Health

Residing in extreme-poverty neighborhoods can have an detrimental effect on health outcomes, including mortality, child and adult physical and mental health, and health behaviors (Macintyre & Ellaway, 2000; Ellen, Mijanovich & Dillman, 2001; Pickett & Pearl, 2001; Macintyre, Ellaway et al. 2002; Ellen & Turner, 2003; Kawachi & Berkman, 2003; Macintyre & Ellaway, 2003). "Extreme-poverty neighborhoods" are defined as those having more than 40% of their residents living below the federal poverty level (Berube and Katz, 2005). People of color reside disproportionately in these extreme-poverty neighborhoods. Nationwide, 18.6% of African-Americans living below the federal poverty level reside in extreme-poverty neighborhoods. In Miami, nearly 70% of African-Americans living below the poverty level reside in extreme-poverty neighborhoods.

Data from the National Health and Nutrition Examination Survey demonstrate higher risks of mortality for individuals living in areas with high poverty rates compared to those living in low-poverty neighborhoods, even after controlling for household income, education, race, marital status, personal behaviors such as exercise and smoking, and other potential confounding variables (Waitzman and Smith, 1998). Similar studies have confirmed higher rates of coronary heart disease for residents in high-poverty neighborhoods that are independent of individual-level risk factors (Diez-Roux et al. 1997).

Residence in extreme-poverty neighborhoods also has strong implications for residents' educational outcomes, employment prospects, safety, and access to neighborhood resources such as supermarkets and parks. Limited employment prospects and a lack of neighborhood resources can have cascading effects onto major issues of concern, such as homelessness and rising rates of obesity in the U.S. Children who experience housing instability or homelessness have 25% greater risk of poor health in adulthood, and experience higher mortality rates in adulthood than individuals who reside in stable housing as children (Marsh et al. 2000). Neighborhood characteristics such as perceived safety and limited access to essential resources also play a large role in the nation's obesity epidemic.

The physical design of neighborhoods can influence the mode of transportation chosen by residents, access to parks and open space, and access to healthy foods. People of color are less likely to have access to healthy foods, with fewer supermarkets available in predominately minority neighborhoods compared to white neighborhoods (Morland, 2002, #450). Safety concerns create major barriers to exercise for adults and children. Adults who consider their neighborhoods to be unsafe are less likely to be physically active than those who consider their neighborhood to be safe, and safety is ranked as the most important factor in whether or not children are allowed to play outdoors (CDC, 1996; Sallis, 1997).

This section describes the evidence for neighborhood-based policy interventions as they relate to health. In considering various interventions for the "sufficient evidence" category, the panel specifically examined neighborhood-level housing interventions or policies that resulted in improved health outcomes or mediating factors that can improve health. The lack of interventions categorized as having sufficient evidence thus reflects the absence of specific, measurable data on reductions in environmental exposures, improvements in health, or improvements in other variables that have been directly linked to improvements in health. It does not reflect a lack of support by the panel members for neighborhood-based policies that have been demonstrated to improve other key outcomes (e.g., the role of smart growth in reducing sprawl, the importance of health impact assessment as a tool for policy change and resident input, and racial desegregation as a means for promoting equality and justice). This report highlights the research gaps that need to be filled to demonstrate that such neighborhood-based policies can be expected to directly or indirectly (through other factors) improve health.

Finally, a central premise behind this panel report is that all individuals in the U.S. have a right to safe, healthy, accessible, and affordable housing. Maintaining and increasing the number of affordable housing units in the U.S. is of utmost priority. Moreover, we must be clear that the distressed public housing units that are described in this report are not to be confused with well-designed, well-maintained public housing units. These units indeed exist, and are an essential component in ensuring adequate affordable housing. The panelists do not support policies that directly or indirectly result in a net loss of affordable units in either the public or private housing market.

Panel 5 Results

Panel 5 considered the following interventions:

- Housing Choice Voucher Program
- Health Impact Assessment
- Moving to Opportunity Demonstration Program - Relocation to Low-Poverty Neighborhoods
- Housing Opportunities for People Everywhere VI – Demolition of Distressed Public Housing and Relocation of Residents
- Universal Design
- Crime Prevention through Environmental Design
- Smart Growth and Connectivity Designs
- Residential Siting away from Highways
- Window Replacement to Reduce Noise
- Zoning
- Density Bonuses
- Green Space around Housing

Of these interventions, one has sufficient evidence for immediate implementation, three require further field investigation, and eight require formative research.

A. Sufficient Evidence

1. Rental Vouchers

Rationale: The continued provision and expansion of the Housing Choice Voucher Program (Section 8) is recommended by Panel 5 based on evidence demonstrating that voucher holders are less likely to suffer from homelessness, overcrowding, and malnutrition due to food insecurity than non-voucher holders, as well as evidence demonstrating that voucher holders are less likely to reside in high-poverty neighborhoods than other families receiving housing assistance (public housing residents). The evidence to support this recommendation comes from an evaluation of the Welfare to Work Voucher Program (U.S. Department of Housing and Urban Development & Office of Policy Development and Research, 2006), the New York City (NYC) Housing and Vacancy Survey (Van Ryzin and Kambler, 2002) and a study by Meyers et al. which demonstrated that children whose families were receiving rent subsidies were significantly less likely to demonstrate growth impairment related to malnutrition compared to children whose families were not receiving rental assistance (Meyers et al. 2005)

The housing choice voucher program is the federal government's major program for assisting very low-income families, the elderly, and individuals with disabilities to afford decent, safe, and sanitary housing in the private market. Since housing assistance is provided on behalf of the family or individual, participants are able to find their own housing, including single-family homes, townhouses, and apartments. Participants are free to choose any housing that meets the requirements of the program and are not limited to units located in subsidized housing projects. Housing vouchers are the dominant strategy in the U.S. for reaching households who have the greatest needs for affordable housing (U.S. Department of Housing and Urban Development & Office of Policy Development and Research, 2000). The program currently assists approximately 1.95 million households (Center on Budget and Policy Priorities, 2007). It is estimated that only 1 out of every 4 households eligible for the voucher program receive federal housing assistance (Center on Budget and Policy Priorities, 2007).

A recent evaluation of the Welfare to Work Voucher Program demonstrated that voucher recipients are far less likely than non-recipients to become homeless or live in crowded conditions (U.S. Department of Housing and Urban Development & Office of Policy Development and Research, 2006). The negative impacts of homelessness on child health and development are well documented. Homeless children are twice as likely to visit an emergency room 2 times or more in a year than children who are not homeless (Weinreb et al. 1998). Homeless children are also more likely to be hospitalized, less likely to receive primary care services, more likely to experience hunger, more likely to repeat a grade, and more likely to need special education than children who are in stable housing conditions (Weinreb et al. 1998; Karr and Kline, 2004; Wood et al. 1990; Meyers et al. 2005; Rafferty et al. 2004; Zima et al. 1997).

Overcrowding in housing has a negative impact on the health of residents. One of the earliest connections made between housing conditions and health was the linkage of crowding with increased risk of tuberculosis (TB) transmission (Stein, 1950; Hawker et al. 1999; Elender et al. 1998). Overcrowding has also been demonstrated to impact child mental health and cognitive functioning. Independent of social class, children living in crowded homes have lower cognitive functioning and increased levels of psychological distress (Evans, 2006).

Vouchers allow households to find affordable housing in any neighborhood, instead of having to reside in deprived, racially segregated neighborhoods where many public housing projects are located. Indeed, while on average public housing residents live in neighborhoods that are 59% minority, households receiving Section 8 vouchers live in neighborhoods that are 39% minority (HUD, 1997). Similarly, individuals receiving section 8 vouchers are less likely to live in high poverty neighborhoods than individuals in public housing. In the late 1990s, 14.8% of voucher recipients lived in high-poverty neighborhoods (poverty rate>30%), compared with 53.6% of public housing residents (Turner, 1998).

Although the pathways through which individual-level poverty and concentrated neighborhood level poverty impact health are not entirely understood or agreed upon, there is a substantial body of literature linking low individual income, low family income, and high neighborhood poverty rates to negative health outcomes, including higher mortality rates from chronic diseases such as cancer, cardiovascular disease, and injuries as well as increased risk of low birth weight, pregnancy in adolescence, mental health problems, and other negative health outcomes (Duncan GJ, 1996; Sorlie et al. 1995; Marmot et al. 1987; Chow et al. 2005). The association between low incomes and higher mortality rates has been shown to be large even after controlling for education level, employment, household size, and other potential confounding factors (Sorlie et al. 1995).

Additional research has demonstrated independent effects of neighborhood level poverty on health. Diez Roux et al. (2001) used data from 4 study sites within the U.S. to demonstrate that residents in disadvantaged neighborhoods had a higher incidence of coronary heart disease (CHD) compared to residents of advantaged neighborhoods independent of individual income, education, occupation levels, and CHD personal risk factors. A review of 25 multilevel analyses of neighborhood economic contexts on health revealed that 23 of the studies demonstrated neighborhood level effects on health, independent of individual level socioeconomic status, despite the inconsistency in study designs among them (Pickett and Pearl, 2001).

Evidence from the New York City (NYC) Housing and Vacancy Survey further corroborates that the Housing Choice Voucher Program can provide overall better neighborhood and housing outcomes for low-income residents compared to other housing assistance programs (Ryzin and Kambler, 2002). Researchers used data from the 1996 NYC Housing and Vacancy Survey to compare 11 different housing options; including Section 8 vouchers, rent controlled housing, unregulated housing, and public housing. These data found that Section 8 vouchers resulted in less crowding, increased affordability, and increased mobility compared to unregulated housing for low-income individuals. The study also compared the number of housing maintenance deficiencies in the various housing options. The Section 8 voucher program showed slightly fewer maintenance deficiencies than unregulated housing, and although this figure was not statistically significant, many other housing programs (e.g., public housing and rent controlled housing) showed significantly higher numbers of deficiencies compared to unregulated housing. Although more research is needed to understand the relationships between poverty, concentrated poverty, and health outcomes, there is sufficient evidence of their associations to support policies that aim to decrease both individual level poverty and concentrated poverty.

Overall, these data reveal that voucher recipients are able to live in lower-poverty neighborhoods compared to their counterparts in public housing. Thus, as policy makers determine how to provide housing assistance to low-income individuals and families in the U.S., vouchers hold promise in their ability to increase the housing choice of residents and to avoid re-concentrating poverty within neighborhoods.

Finally, evidence suggests that rental assistance programs can assist families in providing sufficient amounts of food for their children. A study by Meyers et al. demonstrated that children whose families were receiving rent subsidies were significantly less likely to demonstrate growth impairment related to malnutrition compared to children whose families were not receiving rental assistance (Meyers et al. 2005). This study confirmed and strengthened earlier evidence of this association (Meyers et al. 1995) by utilizing a multi-site study design and a larger sample size.

The panel supports the categorization of rental vouchers in the "sufficient evidence" category due to its ability to reduce exposure to known risks such as homelessness, overcrowding, malnutrition, and concentrated poverty, all of which have demonstrable negative impacts on health. Due to the strength of the evidence linking these risk factors to poor health outcomes, the panel found sufficient evidence of vouchers' strength as a policy that is ready for widespread implementation.

B. Promising Interventions Needing More Field Testing

1. Health Impact Assessments (HIA)

Rationale: Addressing housing issues and improving access to good quality and affordable housing requires the effort of an array of agencies, including those in the public, private, and government sectors. HIA has been used during residential redevelopment and construction to ensure adequate housing conditions, stability, and affordability (Dannenberg, et al. 2008). There is substantial documentation of the use of HIA as a planning tool from studies by Bhatia, 2007; Davenport, 2006; Elliston, 2002; Pratt, 2008; and Dannenberg, et al. 2008. The Dannenberg study is an analysis of 27 HIA case studies in the U.S. HIA has been shown to be an effective planning and policy tool. However, additional data are needed to demonstrate the impact of HIA either directly or indirectly through other causal factors on health.

Health Impact Assessments are defined as "a combination of procedures, methods, and tools by which a policy, program, or project may be judged as to its potential effects on the health of the population, and the distribution of these effects within the population" (European Centre for Health Policy, World Health Organization Regional Office for Europe, 1999). Consequently, health impacts "are the overall effects, direct or indirect, of a policy, strategy, program, or project on the health of a population" (European Centre for Health Policy, World Health Organization Regional Office for Europe, 1999). The approach generally follows five steps: 1) identifying projects or policies that will benefit from the use of an HIA; 2) determining the health impacts to be assessed and the population that is affected; 3) appraising the magnitude and direction of the health impacts; 4) communicating the results to decision makers; and 5) monitoring HIA's impact on the decision making process (Dannenberg, 2006).

In Europe, HIA is largely used around urban regeneration schemes and local transport policy. For example, HIA was used in 1999 in a project known as Morice Town Home Zone in Plymouth, England, which was initiated to implement the reclamation of residential streets for equal use by all users for a wide array of activities (Elliston, 2002). HIA was used as part of a housing redevelopment project in the Devonport neighborhood of Plymouth, England. One of the poorest neighborhoods in Southwest England, the planned regeneration of Devonport included the demolition and redevelopment of about 450 homes. To assess the health impacts of the demolition plan, the development team persuaded the Plymouth Public Health Development Unit to conduct an HIA (Pratt, 2008). In both of these examples, the HIA resulted in the presentation of recommendations to key individuals involved in the planning of the redevelopment; however, at present no literature is available that documents any direct health or policy impacts stemming from the use of the HIA in these cases.

In the U.S., the San Francisco Department of Public Health (SFDPH) used HIA in two well documented projects—the Trinity Plaza housing redevelopment and the Rincon Hill Area Plan. The first project was a demolition project by private developers to replace 360 rent-controlled units with 1400 new condominiums (Dannenberg, 2008; Bhatia, 2007). Residents and tenant advocates raised concerns that the displacement would negatively impact the well-being of the residents and the community. The SFDPH held public hearings, convened focus groups, and conducted a literature review. The assessment found that the redevelopment proposal was associated with severe health impacts, including "increased psychological stress, fear, crowding, substandard living conditions due to limited affordable replacement housing" and "food insecurity due to increased rent burden" (Dannenberg, 2008). Based on the HIA evidence and recommendations provided by SFDPH, the developer revised the proposal to include replacement housing of the 360 rent-controlled units as well as continued leases for existing tenants.

In Rincon Hill, two projects to build new downtown condominiums were called under review by community organizations that were working to minimize resident displacement (Bhatia, 2007). The HIA reviewed the associations between real estate development and health. Although developers had already endorsed the advantages of building near public transits and jobs, there were concerns about the availability of affordable housing. SFDPH recommended that a "jobs-housing balance analysis" be conducted as part of a revised environmental impact report to ensure that sufficient workforce housing would be available (Dannenberg, 2008). SFDPH also argued that building a high-income neighborhood could result in segregation that could increase mortality and violent injury rates, while lowering opportunity for educational and economic success (Bhatia, 2007). Two major changes occurred as a part of the community concerns raised by the HIA: the designation of a higher proportion of the new condominiums as affordable units; and new zoning rules for the Rincon Hill planning area requiring construction of affordable housing in the areas most at risk for displacement. In addition, developer fees were set aside for community development projects and affordable housing (Bhatia, 2007).

2. The Moving to Opportunity Demonstration Program (MTO): Relocation to Low-poverty Neighborhoods

Rationale: Moving families from high- to low-poverty neighborhoods is a promising intervention in need of additional field testing. The primary data supporting this policy intervention is the MTO study. MTO used an experimental longitudinal design that randomly assigned very low-income public housing families to poor and non-poor neighborhoods, allowing reported effects on health to be attributed to differences in neighborhood environment (Leventhal & Brooks-Gunn, 2001; Goering, Feins & Richardson, 2002; Goering, 2003; Goering & Feins, 2003; Leventhal & Brooks-Gunn, 2003; Acevedo-Garcia et al. 2004). Given the inconsistency and complexity of the impact data, Panel 5 recommends that further study be conducted to better understand the full impact of housing mobility programs on specific subgroups such as adolescent boys and to identify ways to improve mobility programs to ensure successful take-up of vouchers and long-term residence in low-poverty neighborhoods. Additionally, the MTO Final Evaluation is currently being conducted and will help to assess whether the effects demonstrated at the time of the Interim Evaluation are sustained over the long-term.

MTO is perhaps the best example of a housing accessibility intervention that imparted health improvements. Sponsored by the U.S. Department of Housing and Urban Development (HUD) and begun in 1994, MTO was conceived as a housing mobility policy experiment. Participation in the MTO demonstration program was voluntary. Low-income families from central-city public housing located in high-poverty neighborhoods (i.e., poverty rate ≥40%) in five metropolitan areas (Baltimore, Boston, Chicago, Los Angeles, and New York) who volunteered were randomly assigned to 1 of 3 groups (Goering, 2003; Goering & Feins, 2003):

- The experimental group, which was offered Section 8 housing vouchers that could be used only in a low-poverty neighborhood (i.e., poverty rate ≤10%).
- The comparison group, which was offered geographically unrestricted Section 8 housing vouchers.
- The in-place control group, which did not receive vouchers, but remained eligible for public housing.

MTO found better health among members of the experimental group, and in some instances also in the health of the Section 8 voucher (comparison) group, compared to the control group of families that stayed in their public housing developments. Health improvements included a lower rate of adult obesity (body mass index (BMI) ≥30) in the experimental group (Orr et al. 2003). Lower obesity rates in adults may be partly due to healthier diets, as the experimental group showed increased consumption of fruits and vegetables (Orr et al. 2003), possibly due to improved access to food stores.

Adults and children moving to low-poverty neighborhoods reported increases in their perception of safety and reductions in the likelihood of observing and being victims of crime (Orr et al. 2003). Considerable stress in the neighborhoods of origin may have also resulted from chronic exposure to poor-quality housing and schools, two reasons why participants looked forward to moving out of those neighborhoods (Orr et al. 2003). In addition to improvements in adult mental health, girls in the experimental group, and in some instances also girls in the Section 8 comparison group reported improvements in their mental health, including reductions in psychological distress, depression, and generalized anxiety disorder (Orr et al. 2003). Girls aged 15–19 in the experimental group also had better health behaviors than their counterparts in public housing, such as lower rates of smoking and marijuana use (Orr et al. 2003).

Data from the MTO Interim Evaluation that demonstrate improved mental health outcomes are corroborated by evidence from single-site studies and other mobility studies. Adult women in the experimental group showed significant improvements in mental health in the 1–3.5 year, single-site, follow-up studies in New York (Leventhal & Brooks-Gunn, 2003; Leventhal & Brooks-Gunn, 2003) and Boston (Katz, Kling & Liebman, 2001). Non-experimental studies also indicate that residents of neighborhoods with a higher socio-economic status (SES) show a lower prevalence of mental health problems. The Yonkers Scattered-site Public Housing evaluation team documented recent violent victimization, depression and anxiety symptoms, and substance use among mothers in two groups (Briggs & Yonkers Family and Community Project, 1997; Briggs, Darden & Aidala, 1999). The group that moved to neighborhoods with new scattered-site public housing in higher SES neighborhoods reported lower prevalence of depression symptoms, problem drinking, marijuana use, and experience of violent or traumatic events compared with those who stayed in the segregated Yonkers public housing neighborhoods (Briggs & Yonkers Family and Community Project, 1997).

Moreover, evidence suggests that enhancing minority access to white, suburban neighborhoods may improve social and economic outcomes such as higher employment rates and increased access to education (Popkin et al.1989; Rosenbaum & Popkin, 1990; Rosenbaum & Popkin, 1991; Rosenbaum, 1994; Rosenbaum, 1995). The Chicago Gautreaux Program gave public housing resident volunteers the opportunity to move to areas that were less than 30% black in and around the city. Although the Gautreaux program did not measure health outcomes directly, panel 5 believed that the improvement in social determinants of health such as education, employment, and earnings demonstrated in evaluations of the Gautreaux program could have led to an improvement in health outcomes. A long-term evaluation of the Gautreaux program's impact on low-income African-American women revealed that women who moved to less segregated neighborhoods with high levels of neighborhood resources spent significantly less time on welfare and significantly more time employed, compared to women who were placed in highly segregated neighborhoods with low levels of resources (Duncan, 2006).

Ironically, health improvements were not among the stated goals of MTO. Yet they are currently among the most apparent gains realized by participating families. However, the panel believes MTO needs additional field evaluation for three reasons. First, although its experimental design eliminates selection bias, some other threats to internal validity remain (Orr, 1999). A methodological discussion of validity threats with respect to MTO and other housing mobility research is available elsewhere (Acevedo-Garcia, Osypuk et al. 2004).

Second, although the reductions in obesity and mental health problems are promising, the MTO demonstration at the latest follow-up did not find significant improvements in other health outcomes such as asthma, blood pressure, and alcohol use, all of which could also be influenced by neighborhood conditions (Acevedo-Garcia, Osypuk et al. 2004). Additionally, although much of the data from the Moving to Opportunity Study (MTO) shows great promise for the ability of housing mobility programs to improve health, there is some evidence of negative impacts for adolescent boys who participated in the MTO study (Kling JR, Liebman JB, and Katz LF, 2007).

Finally, as designed, the MTO demonstration program resulted in fairly low take-up of vouchers in the experimental group, and high rates of subsequent moves after the required one-year lease in a low-poverty neighborhood. Of the 1,820 families assigned to the experimental group, just under half (48%, or 860) found a willing landlord with a suitable rental unit and moved successfully. At the time of the interim evaluation, 66% of the families in the experimental groups had moved at least once after their initial lease expired. Those that had moved were more likely to live in a higher-poverty neighborhood than those who remained in the same census tract of their initial move with their MTO voucher. However, families in the MTO experimental group were still much more likely to be living in low-poverty areas (whether the original placement areas or other areas) compared to their Section 8 voucher or control family counterparts, and also had lived for longer periods of time in such areas, than families in the other two groups. These data draw attention to the need for housing mobility programs to both help participants move and to help them remain in low-poverty neighborhoods (Popkin, Leventhall, and Weissman, 2008).

3. HOPE VI – Demolition of Distressed Public Housing and Relocation of Residents

Rationale: Panel 5 recommends that the HOPE VI program continue to be evaluated to determine its long-term health benefits. The studies used to support this recommendation include the HOPE VI panel study, conducted by the Urban Institute. The longitudinal Panel Study evaluated the impact of HOPE VI including the living conditions of residents of severely distressed public housing at five sites at baseline and after relocation through data collected from the residents of five sites around the country. Baseline data were collected in 2003 and a follow-up survey was administered in 2005. The data from the HOPE VI Panel Study indicate that individuals and families who relocated to the private market derived the most benefit from relocation. Those who were relocated to other public housing saw decreases in violence and drug activity in their neighborhoods, but saw no change in their housing quality (Popkin SJ, Levy D, and Buron L, Forthcoming). The data also show that residents are still living in racially segregated neighborhoods, and that the program did not influence employment rates regardless of where an individual relocated (Popkin SJ, Levy D, and Buron L, Forthcoming). Finally, although a major goal of the HOPE VI program is for the original distressed public housing units to be rehabilitated or rebuilt into a mixed-income community, very few residents (5%) have been able to move back to a rehabilitated HOPE VI site. Thus, the HOPE VI research to date corroborates the evidence that rental vouchers provide more benefits than distressed public housing developments. It does not yet provide insight into the potential benefits of mixed-income housing.

HUD's HOPE VI Program (Housing Opportunities for People Everywhere) funds the demolition and revitalization of poor or distressed public housing throughout the country. This initiative involves relocating residents during revitalization. Some residents ultimately move back to the new, mixed-income community that replaced the development, while others receive vouchers or move to other public housing developments. The goals of the HOPE VI Program are to provide an improved living environment for residents of distressed public housing developments and to avoid or decrease concentrated poverty (Popkin SJ, Levy D, and Buron L, Forthcoming).

At baseline, HOPE VI residents were living in substandard housing (e.g., presences of lead paint and mold, inadequate heat, and pest infestations) and extremely dangerous neighborhood conditions (e.g., shootings and drug-related crime) (Popkin, Levy et al. 2002). At baseline, 33% of residents reported peeling paint or plaster in their units, 25% reported cockroach infestation, 42% reported water leaks, 33% reported inadequate heat, and 16% reported rat and mice infestations (Popkin, Levy et al, 2002). Additionally, 90% of residents reported serious problems with drug trafficking, drug use, and gang activity in their neighborhoods; and 75% reported that violent crimes were "big problems" in their neighborhoods (Popkin, Levy et al. 2002). At baseline, HOPE VI parents reported substantially lower health ratings for their children than those reported for children in national samples. Twenty-five percent of HOPE VI children aged 0–5 had been diagnosed with asthma at the baseline survey, more than 3 times the national average (Popkin, Levy et al. 2002).

At the time of the 2005 follow-up surveys, 84% of families in the HOPE VI Panel Study had relocated from their original public housing development (Popkin SJ, Levy D, and Buron L, Forthcoming). Forty-three percent of families had moved into private market housing with the assistance of a rental voucher, 22% had moved into other public housing developments, 10% were renting on the private market without voucher assistance, 4% were homeowners, and 1% were either homeless or in prison. Sixteen percent of the families were still living in their original public housing development.

Data from the 2005 follow-up surveys conducted through the HOPE VI Panel Study suggest that residents are benefitting from the relocation, particularly those who relocated to the private market with or without voucher assistance. Half of respondents living in private market units were living in neighborhoods with a poverty rate of less than 20% at the 2005 follow-up, compared to 0% at baseline (Popkin SJ, Levy D, and Buron L, Forthcoming). Additionally, individuals who had relocated reported significant reductions in shootings, violence, and drug activity in their neighborhoods. The percentage of respondents reporting "big problems" with drug sales in their neighborhood dropped dramatically, from 78% at baseline to 47% in 2003, and to 33% in 2005 (Popkin SJ, Levy D, and Buron L, Forthcoming). The dramatic decreases in violence and drug activity were even more pronounced among voucher holders or those renting unassisted housing in the private market (Popkin SJ, Levy D, and Buron L, Forthcoming).

However, data on health outcomes at follow-up did not reveal the same dramatic benefits as seen in housing quality and neighborhood safety. Self-rated health was still significantly worse than national averages, with 41% of HOPE VI study participants reporting fair or poor health, a figure more than 3 times the national average (Manjarrez, Popkin, and Guernsey 2007). Additionally, mental health problems persisted, with 29% of respondents reporting poor mental health (Popkin SJ, Levy D, and Buron L, Forthcoming). Chronic health problems presented the biggest barrier to employment among respondents, regardless of whether an individual had relocated to the private market (Popkin SJ, Levy D, and Buron L, Forthcoming).

Housing quality improved for those who relocated to the private housing market through the HOPE VI program. At the 2005 follow-up survey, 25% of residents living in private market units reported having 2 or more housing problems (e.g., leaks, peeling paint, broken appliances) compared to more than 50% at the 2001 baseline survey (Popkin SJ, Levy D, and Buron L, Forthcoming). These same benefits in housing quality improvement were not seen among those who relocated to other public housing units or those who stayed in their original public housing development (Comey, 2007).

C. Interventions in Need of Formative Research

1. Universal Design

Rationale: The panel was unable to locate any data linking the implementation of universal design standards to improved health outcomes. However, further research on and promotion of universal design standards is supported by a significant amount of local precedent as well as evidence that implementing universal design standards may decrease the need for home modifications later on. Additional work is needed to examine the link, if any, between implementation of universal design standards and improved health outcomes.

Universal design criteria promote access to the home for all persons regardless of age or physical ability. The criteria include accessibility features at new construction to avoid the need for later home modifications. These standards can include providing at least one entrance without stairs, a bathroom on the ground floor level, door widths that accommodate wheelchairs, and open work counters in kitchens and other areas that allow for use in wheelchairs or while seated.

A number of cities and jurisdictions are including universal design standards as part of city accessibility plans. For example, the city of Toronto implemented Accessibility Design Guidelines in 2004, and the Thomas Jefferson area of Central Virginia includes universal design guidelines in both new residential and new commercial construction as a part of its Livable for a Lifetime Initiative (Myerson, 2007). Similar universal design efforts have also been implemented as part of the "visitability movement," which aims to provide residents with disabilities access to single family homes in their communities (Nishita et al. 2007). The first city to implement such regulations was Atlanta, GA, passing an ordinance in 1992 that required basic accessibility standards in newly constructed single-family properties that used city funds for construction. These requirements include an entrance to the home without steps, wide interior doors, a wheelchair accessible route inside the home, accessible light switches and outlets, and reinforced bathroom walls to provide easy installment of grab bars if needed (Nishita et al. 2007). A number of jurisdictions have passed similar legislation, including the states of Texas, Georgia, Vermont, Minnesota, and Kansas and the cities of Austin, TX, Urbana, IL, Iowa City, IA, Naperville, IL, and Pima County, AZ. Given local precedents in support of universal design, simple accessibility standards that can be implemented during new residential construction appear to have the potential to avoid some costs for home modifications later on, as well as to provide more equal access to housing within communities for all persons, regardless of age or ability.

2. Crime Prevention through Environmental Design

Rationale: Crime Prevention through Environmental Design (CPTED) interventions need more formative research to determine the impact of specific architectural strategies on crime. Only one study was identified (Carter et al. (2003) which examined the impact of CPTED on crime. The study had a number of limitations. For example, the data do not support the evaluation of individual CPTED components and the study did not control for potential neighborhood-level confounders such as property improvements, nearby redevelopment efforts, or other social changes. More formative research is needed to replicate the findings of the Sarasota study in other geographic areas.

The design principles of CPTED are generally agreed upon in the field, and include: (1) design that incorporates "natural surveillance" by residents, neighbors, or others (e.g., by creating spaces that are more easily viewed by others, such as through improved lighting and building design); (2) design that encourages appropriate conduct and respect for the property and that also creates a sense of private space from which criminals are discouraged (e.g., the use of "symbolic barriers" such as steps and archways, and limiting the number of apartments accessed through one entrance); (3) design that encourages community building and limits social isolation (e.g., positioning doorways in both apartments and on streets that face each other and the use of porches to promote social interaction); and (4) design that protects frequent crime targets (e.g., placing and designing building entrances to limit accessibility to criminals) (Katyal, 2002). However, the scientific evidence behind the implementation of these principles is limited. Carter et al. (2003) evaluated the impact of community-wide CPTED interventions between 1990 and 1998 in the North Trail Corridor of Sarasota, FL. The interventions included high-visibility patrols to discourage prostitution, collaborative efforts with hotel and motel owners to arrest drug dealers, and the creation of a new zoning district requiring new development to be reviewed for alignment with CPTED principles. These principles encourage installation and maintenance of outside lighting in entrances, walkways, and parking lots as well as appropriate landscaping to provide improved visibility and pedestrian environments.

Police data from 1990–1998 comparing the North Trail Corridor and the remainder of the city of Sarasota revealed the following:

- Calls for service decreased in the North Trail Corridor and increased in the remainder of the city ($p < .005$);
- Reports of prostitution decreased in the North Trail Corridor and increased in the rest of the city ($p < .05$); and
- Narcotic crime rates increased more gradually in the North Trail Corridor ($p < .005$).

3. Smart Growth and Connectivity Designs

"New urbanism," "smart growth," and "connectivity" are emerging and related schools of thought concerned with the design of housing communities allowing easy access to services and community resources without driving. Urban planning strategies balanced with transportation considerations have been implemented to develop mixed land use and promote walking, access, and mixed demographics. The design of houses and accessible street grids are other components of connectivity. Smart growth strategies recommend (1) development of housing with heterogeneous designs in the same neighborhoods that are also close to transport and retail areas; (2) development of racially and demographically diverse neighborhoods; and (3) promotion of a mix of land uses, higher density, sidewalks, and building of public areas.

Smart growth and connectivity strategies are supported by research linking land use and design patterns with physical activity levels, as well as evidence that sprawl has a negative impact on health outcomes (Frumkin et. al, 2004). Sprawl has been linked to increased risks of obesity and hypertension and lower rates of physical activity (Ewing et al. 2003; Lopez, 2004). The Robert Wood Johnson Foundation's Active Living Research Program has compiled substantial amounts of peer-reviewed literature demonstrating the connections between land use and physical activity (see http://www.activelivingresearch.org/). Adults living in "walkable" neighborhoods (defined as neighborhoods where residents can walk to essential services such as grocery stores and other common destinations) are more likely to meet national physical activity guidelines than those living in the least walkable neighborhoods (Frank et al. 2005). Additionally, individuals living in mixed-use neighborhoods with easy walking access to shops and other services have been shown to have a 35% lower risk of obesity (Frank et al. 2004). Similar relationships have also been demonstrated for children. A literature review of the associations between the physical environment and children's physical activity revealed that children are more likely to be physically active when sidewalks are present and destinations are easily accessible (Davison and Researchers in Britain have begun to examine the specific components of built-environment interventions that are linked to increased physical activity. This research has demonstrated increased rates of physical activity following the implementation of traffic calming devices, additional cycling infrastructure, additional trail infrastructure, and the introduction of road tolls (NICE Public Health Collaborating Centre, 2006[a]; NICE Public Health Collaborating Centre, 2006[b]). In the U.S., research on a newly-constructed trail system in West Virginia demonstrated an increase in the proportion of people who reported being "regular exercisers" (exercising 3 or more times a week) following the construction of the trail (Gordon et al. 2004). The increase in exercise was most notable for those who had who not met recommended physical activity guidelines prior to the trail's construction.

Despite this evidence, the complexity of factors influencing physical activity within neighborhood environments and the heterogeneity of the population in the U.S. both call for additional research to separate the effects of the components of Smart Growth and their impacts on health, and to better understand potential confounding factors that make the implementation of certain strategies region- or population-specific. For example, some research findings conflict with the evidence demonstrating an association between sidewalk, trails, and increased physical activity (Huston et al, 2003). Additionally, other neighborhood factors such as crime rates and safety may hinder the success of certain neighborhood design characteristics and their impact on resident physical activity (Robert Wood Johnson Foundation, 2008; Davison and Lawson, 2006). Panel 5 recommends formative research in this area.

4. Residential Siting Away from Highways

Rationale: The evidence that freeway pollutants negatively impact the pulmonary and cardiac health of nearby residents has been previously reviewed (Brugge et al. 2007). While additional research is needed to more thoroughly and consistently control for key confounding variables (e.g., exposure to environmental tobacco smoke, pests, gas stoves), the literature connecting residential proximity to freeways and elevated risk of asthma in children warrants the support of policies that place a buffer zone between major freeways and new residences, schools, daycares, and other areas where children spend large amounts of time.

Research has demonstrated that elevated levels of ultrafine particulates (UFP), black carbon (BC), oxides of nitrogen (NOx), and carbon monoxide (CO) have been found near highways. The research has also found that individuals living within 30 meters from highways will be exposed to much higher levels of these pollutants than individuals living at least 200 meters away from highways (Brugge et al. 2007). Children living near major highways have been found to have higher rates of asthma and wheezing, and research has demonstrated that children living near freeways are more likely to have a lifetime diagnosis of asthma (Brugge et al. 2007).

The current research on cardiac health and lung cancer development suggests that exposure to elevated levels of particulate matter is associated with cardiac mortality and lung cancer rates (Brugge et al. 2007). A study by Holguin et al. found that ambient levels for PM 2.5 and ozone can reduce the high-frequency component of heart rate variability in elderly subjects living in Mexico City and that subjects with underlying hypertension are particularly susceptible to this effect (Holguin et al. 2003).

Approximately 11% of the current housing stock in the U.S. is located within 100 meters of a major highway (Brugge et al. 2007). As such, strategies are needed to reduce exposure to highway pollutants for current residents in these areas without reducing the numbers of available housing units.

Low-income communities are disproportionately exposed to air pollutants and environmental justice research has demonstrated that polluting industries disproportionately move into existing minority communities (Morello-Frosch et al. 2002), and that African-Americans and Hispanics in the U.S. are significantly more likely to live in neighborhoods that fail to meet national air quality standards (Brooks and Sethi, 1997; Rauth et al. 2008). Housing policies that reduce residents' exposure to air pollutants may be one pathway toward environmental justice.

5. Noise Interventions

Rationale: Data from the World Health Organization's Large Analysis and Review of European Housing and Health Status (LARES) study reveal that strong annoyance by neighborhood noise and noise-induced sleep disturbances are statistically associated with elevated risks of various health conditions (Niemann and Maschke, 2004). The panel was unable to locate studies in the U.S. or abroad that link noise interventions to improved health outcomes. Formative research is needed to demonstrate the effectiveness of noise interventions.

Among children, LARES data demonstrated significantly elevated risks for respiratory symptoms, migraine, and bronchitis with strong annoyance by neighborhood noise (Niemann and Maschke, 2004). Noise-induced sleep disturbances in children were found to be associated with elevated risks of respiratory symptoms, medical treatment associated with bronchitis, and indicators of depression (Niemann and Maschke, 2004). Health impacts related to noise were also demonstrated for adults and the elderly, with the elderly showing elevated risk of arthritic symptoms, stroke, gastric ulcers, and depression and adults showing elevated risks of allergies, arthritic symptoms, asthma, gastric ulcers, hypertension, and respiratory symptoms associated with noise annoyance and disturbances (Niemann and Maschke, 2004).

6. Zoning

Rationale: Despite the potential for zoning tools to improve health outcomes and decrease health disparities, the panel did not identify specific literature linking zoning with improved health outcomes and therefore recommends more formative research in this area.

Zoning is the use of local ordinances to specify permitted and prohibited land uses within certain areas (zones) within a jurisdiction. Zoning ordinances specify what types of development can occur in what areas (e.g., residential, industrial), maximum building height, building setback requirements, and other features intended to ensure that development occurs in a manner that will provide neighborhood consistency and protect resident health. Although some zoning and land-use policies have segregated neighborhoods and disproportionately burdened communities of color and low-income communities with harmful exposures (Agyeman and Evans, 2003), when combined with thoughtful city planning and community input, zoning codes could protect the health of individuals and reduce health disparities. In response to research linking greater availability of alcohol to liver cirrhosis, drunk driving, motor vehicle crashes, violence, and other alcohol-related issues, local zoning ordinances and conditional-use permits have been used to limit the locations and density of alcohol outlets. Such ordinances also have limited the proximity of these outlets to schools and playgrounds (Ashe et al. 2003). Recent research and concerns over the obesity epidemic have led some cities to take the same approach in regulating the concentration of fast food restaurants within neighborhoods (Ashe et al. 2003). Zoning can also be used to address air pollution or to create environmental health buffer zones to ensure that housing units, schools, and other sensitive land uses are located away from freeways (Coburn, 2005).

6. Density Bonuses

Rationale: Density bonuses require formative research to examine their potential as a public health intervention. No academic literature was located that specifically linked density bonuses as an urban planning tool to any health outcomes, however, studies have examined connections between residential densities and physical activity. Overall, there is a lack of concrete research linking density to improved health outcomes, and specifically a lack of evaluation of density bonuses as a tool for achieving improved health. Of note, the effects of density on health will likely be confounded by numerous other neighborhood and individual level factors, making it challenging to disentangle its direct and indirect impacts.

Density bonuses are land-use planning tools that enable developers to build at higher densities (the average number of people per one unit of land) than normally permitted in an area. These bonuses are often provided in exchange for the developers' contribution to desired public features, such as affordable housing or the preservation of open space or resource lands.

Research by Rodriguez et al. and Forsyth et al. found no statistically significant differences in physical activity between residents in denser neighborhoods compared to residents living in more traditional suburban neighborhoods (Rodriguez, 2006 and Forsyth, 2007). While Forsyth et al. did find that increased density is associated with the purpose of walking (i.e., walking more for transportation compared to leisure or exercise walking), the overall amount of walking was no different in higher density areas compared to suburban areas.

Other research has suggested that increased density may result in fewer vehicle miles traveled, reduced emissions, and improved air quality over time. A study of compact growth in selected Midwestern Metropolitan Statistical Areas (MSAs) on emissions and air quality by 2050 demonstrated that compact growth could produce between 5-6% fewer harmful emissions (of PM, NOx, CO, and VOC) than current growth patterns (Stone, 2007). Interestingly, the impact of increased density on reduced emissions and vehicle miles traveled was greater in urban areas than non-urban areas, suggesting compact growth strategies in urban areas could play a more significant role in regional air quality improvement.

7. Green Space around Housing

Rationale: To date, the majority of studies examining housing proximity to greenery have been generated from one research institution (Coley et al. 1997; Taylor et al. 1998), conducted with a specific population of public housing residents in Chicago, and with methodological limitations. Additional research is needed to examine if these effects can be generalized to other populations and to examine whether or not the planting of trees and vegetation as an intervention would result in improved physical or mental health outcomes for residents. Various studies of residents living in Chicago's public housing developments have provided evidence that the presence of trees and other vegetation surrounding public housing buildings and within public spaces can have a positive impact on residents. The researchers demonstrated that the presence of trees in public spaces resulted in higher use of the space by both children and adults, and that children's level of play as well as supervision by adults was twice of what was observed in barren public spaces without trees and grass (Coley et al. 1997; Taylor et al. 1998). Another study of public housing residents in Chicago revealed that residents' sense of safety was positively correlated with the density of trees and maintenance of grass in the residents' neighborhood (Kuo et al. 1998). Finally, a study of 145 women living in a Chicago Public Housing development and randomly assigned to buildings of high or low amounts of surrounding vegetation revealed that residents living in "barren" buildings surrounded with little to no vegetation reported higher levels of aggression and violence than residents in buildings surrounded with more vegetation (Kuo et al. 2001).

Conclusions and Future Research

A number of neighborhood-level interventions show tremendous potential for improving the health and well-being of individuals within neighborhoods across the U.S., despite the dearth in the empirical evidence. The challenge in examining neighborhood-level policies and interventions is that a vast majority of data reviewed by panel 5 are cross-sectional, making it impossible to suggest causality.

Of particular note is that the majority of interventions considered in this paper were not intended to improve health. For example, the Housing Choice Voucher Program is primarily intended to assist very low-income individuals and families in accessing housing and reducing rent burdens. Smart Growth and Connectivity Designs emerged to reduce emissions, increase use of public transportation, and increase walkability designs in the fight against global climate change. Finally, improved health was not stated as a program goal at the outset of the MTO, even though health impacts from this program are now a large area of research. The fact that there is some demonstrable evidence of associations between specific neighborhood-level interventions and improved health suggests strong potential for spillover health effects from a number of these policies. Improved research designs that specifically identify direct and indirect health improvements related to the policies discussed above are clearly needed.

This panel report is intended to explicitly describe the evidence for neighborhood-level housing interventions as they relate to improvements in health outcomes. Many of the policies discussed do not, at the present time, have sufficient evidence for widespread implementation solely based on their health benefits. However, many of the policies discussed have a demonstrated impact in other areas of social, economic, and environmental well-being.

Since the vast majority of studies have used non-experimental, cross-sectional research designs, in some instances it is not possible to rule out selection bias as a possible explanation for neighborhood effects (Oakes, 2004) or to rule out the effect of unmeasured factors that influence both neighborhood choice and health outcomes (e.g., association between neighborhood poverty level and health).

Many of the research questions that future studies should address are multilevel in nature and thus will require the application of multilevel analytic methods (Subramanian et al. 2003). For instance, given that improvements in neighborhood quality that result from mobility policies are conceivably accompanied by improvements in the quality of housing units, it is important to determine whether mobility policies result in improved health outcomes due to housing unit effects, neighborhood effects, or both.

Future studies should also include better measurement of health outcomes including baseline and follow-up measurements and triangulation of methods (i.e., biological measures, self-reported health measures, and validated scales). It would also be important to link participant data to health insurance claims data or medical records, given proper ethical and confidentiality protections, especially for diagnostic-specific information. Such data linking may be feasible for programs such as MTO if substantial proportions of participants were enrolled in Medicaid or State Children's Health Insurance Programs. Linking to administrative health data seems feasible, given that the MTO follow-up study plans to link to other administrative data systems, including welfare, arrest records, and schools (US Department of Housing and Urban Development et al. 2003). In addition to being uniform across all the study sites (the original survey instruments were not), the 2001–2002 follow-up MTO household survey prepared by Abt Associates partially addressed some of the above issues. For example, it included a detailed section on injuries, one on asthma symptoms, body mass index, and blood pressure measurement. Yet additional measures may include other health outcomes that may be associated with neighborhood conditions such as intimate partner violence and infectious diseases such as tuberculosis, HIV, and sexually-transmitted diseases (Acevedo-Garcia 2000; Kawachi & Berkman 2003; O'Campo et al. 1995).

In conclusion, efforts to improve neighborhood environments are a critical component in ensuring safe, healthy, and affordable housing for all individuals and families in the U.S. Moving forward, we recommend that key leaders and researchers in housing, health, economic, and environmental fields collaborate to identify key neighborhood-level policies that can be supported and evaluated for their impacts on various aspects of individual and neighborhood well-being. As these collaborations become stronger, researchers should challenge themselves to design multifactoral studies from the outset, recognizing that many of these policies may have positive spillover effects on health, social justice, and other arenas.

References: Panel 5

Acevedo-Garcia D, Osypuk TL, et al. (2004). "Does housing mobility policy improve health?" Housing Policy Debate 15(1): 49–98.

Agyeman J and Evans T (2003). "Toward Just Sustainability in Urban Communities: Building Equity Rights with Sustainable Solutions." The Annals of the American Academy of Political and Social Science 590: 35–53.

Ashe M, Jernigan D, et al. (2003). "Land Use Planning and the Control of Alcohol, Tobacco, Firearms, and Fast Food Restaurants." American Journal of Public Health 93(9): 1404–1408.

Bhatia R (2007). "Protecting health using an environmental impact assessment: a case study of San Francisco land use decisionmaking." American Journal of Public Health 97(3), 406–413.

Briggs XS, Darden JT, and Aidala A (1999). "In the Wake of Desegregation: Early Impacts of Scattered-Site Public Housing on Neighborhoods in Yonkers, New York." Journal of the American Planning Association 65: 27–49.

Briggs XS and Yonkers Family and Community Project (1997). "Yonkers Revisited: The Early Impacts of Scattered-Site Public Housing on Families and Neighborhoods." A Report to the Ford Foundation. New York, NY, Columbia University Teachers College, Harvard University and Michigan State University.

Brooks N and Sethi R (1997). "The distribution of pollution: community characteristics and exposure to air toxins." Journal of Environmental Economics and Management 32: 233–250.

Brugge D, Durant JL, and Rioux C (2007). "Near-highway pollutants in motor vehicle exhaust: A review of epidemiologic evidence of cardiac and pulmonary health risks." Environmental Health 6: 23–35.

Carter SP, Carter SL, and Dannenberg AL (2003). "Zoning Out Crime and Improving Community Health in Sarasota, Florida: 'Crime Prevention through Environmental Design.'" American Journal of Public Health 93(9): 1442–1445.

Center on Budget and Policy Priorities (2007). Bipartisan legislation would build on housing voucher program success. *www.cdpp.org*

Chow JC, Johnson MA, and Austin MJ (2005). "The Status of Low-Income Neighborhoods in the Post-Welfare Reform Environment: Mapping the Relationship between Poverty and Place." Journal of Health and Social Policy 21(1): 1–32.

Coley RL, Kuo FE, and Sullivan WC (1997). "Where does community grow? The social context created by nature in urban public housing." Environment and Behavior 29(4): 468–494.

Comey, J (2004). "An Improved Living Environment? Housing Quality Outcomes for HOPE VI Relocatees." A Roof Over Their Heads Policy Brief 2. Washington: Urban Institute. Available online at: *http://www.urban.org/UploadedPDF/311058_Roof_2.pdf*. Accessed August 25th, 2008.

Coburn, Jason (2005). "Urban Planning and Health Disparities: Implications for Research and Practice." Planning Practice and Research 20(2): 111–126.

Dannenberg AL, Bhatia R, et al (2006). "Growing the field of health impact assessment in the U.S.: An agenda for research and practice." American Journal of Public Health 96: 262–270.

Dannenberg AL, Bhatia R, et al (2008). "Use of health impact assessment in the US: 27 case studies, 1999-2007." American Journal of Preventive Medicine 34(3): 241–256.

Davenport C, Mathers J, and Parry J (2006). "Use of health impact assessment in incorporating health considerations in decision making." Journal of Epidemiology and Community Health 60: 196–201.

Davison KK and Lawson CT (2006). "Do attributes in the physical environment influence children's physical activity? A review of the literature." International Journal of Behavioral Nutrition and Physical Activity 3: 19–35.

Diez Roux AV, Stein Merkin S, et al. (2001). "Neighborhood of Residence and Incidence of Coronary Heart Disease." New England Journal of Medicine 345(2): 99–106.

Duncan GJ (1996). "Income dynamics and health." International Journal of Health Services 26: 419–44.

Elender F, Benthem G, et al. (1998). "Tuberculosis mortality in England and Wales during 1982-1992; its association with poverty, ethnicity and AIDS." Social Science and Medicine 46: 673–681.

Ellen IG, Mijanovich T and Dillman KN (2001). "Neighborhood Effects on Health: Exploring the Links and Assessing the Evidence." Journal of Urban Affairs 23(3-4): 391–408.

Ellen IG and Turner MA (2003). "Do neighborhoods matter and why?" In Goering J and Feins JD (ed.). Choosing a Better Life? Evaluating the Moving to Opportunity Social Experiment (pp. 313–338). Washington, DC, The Urban Institute Press.

Elliston K and Maconachie M (2002). "Morice Town Home Zone: A prospective Health Impact Assessment." Available online at: *http://www.who.int/hia/examples/en/Morice_Town_Home_Zone.pdf*. Accessed April 21, 2008.

European Centre for Health Policy and World Health Organization Regional Office for Europe (1999). "Health impact assessment: main concepts and suggested approach." Gothenburg Consensus Paper. Brussels, 1999. Available online at: *http://www.euro.who.int/document/PAE/Gothenburgpaper.pdf*. Accessed April 7, 2008.

Evans, GW (2006). "Child Development and the Physical Environment." Annual Review of Psychology 57: 423–451.

Ewing R, Schmid T, et al.(2003). "Relationship between urban sprawl and physical activity, obesity, and morbidity." American Journal of Health Promotion 18(1): 47–57.

Forsyth A, Oakes JM, et al. (2007). "Does Residential Density Increase Walking and Other Physical Activity?" Urban Studies 44(4): 679–697.

Frank LD, Andresen MA, and Schmid TL (2004). "Obesity relationships with community design, physical activity, and time spent in cars." American Journal of Preventive Medicine 27: 87–96.

Frank LD, Schmid TL, et al. (2005). "Linking objectively measured physical activity with objectively measured urban form: Findings from SMARTRAQ." American Journal of Preventive Medicine 28(2S2): 117–125.

Frumkin, Howard, Frank, Lawrence, and Jackson, Richard Joseph. Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities. Island Press. July 9, 2004.

Goering, J (2003). "The Impacts of New Neighborhoods on Poor Families: Evaluating the Policy Implications of the Moving to Opportunity Demonstration." FRBNY Economic Policy Review June, 2003: 113–140.

Goering J and Feins JD, Eds. (2003). Choosing a Better Life? Evaluating the Moving to Opportunity Social Experiment. Washington, DC, The Urban Institute Press.

Goering J, Feins JD, and Richardson TM (2002). "A Cross-Site Analysis of Initial Moving to Opportunity Demonstration Results." Journal of Housing Research 13(1): 1–30.

Gordon PM, Zizzi SJ, and Pauline J (2004). "Use of a community trail among new and habitual exercisers: A preliminary assessment." Preventing Chronic Disease 1: A11.

Hawker et al (1999). "Ecological analysis of ethnic differences in relation between tuberculosis and poverty." British Medical Journal 319: 1031–1034.

Holguín F, Téllez-Rojo MM, Hernández M, Cortez M, Chow JC, Watson JG, Mannino D, Romieu I.Air pollution and heart rate variability among the elderly in Mexico City. Epidemiology. 2003 Sep: 14 (5): 521–7.

Huston SL, Evenson KR, Bors P, Gizlice Z. Neighborhood environment, access to places for activity, and leisure-time physical activity in a diverse North Carolina population. Am J Health Promot. 2003 Sep-Oct;18(1): 58–69.

Karr C and Kline S (2004). "Homeless children: What every clinician should know." Pediatrics in Review 25(7): 235–241.

Katyal, NK (2002). "Architecture as Crime Control." Yale Law Journal 11: 1039–1139.

Kawachi I and Berkman LF, Eds. (2003). Neighborhoods and Health. New York, Oxford University Press.

Kuo FE, Bacaicoa M, and Sullivan WC (1998). "Transforming inner-city landscapes: trees, sense of safety, and preference." Environment and Behavior 30(1): 28–32.

Kuo FE and Sullivan WC (2001). "Aggression and Violence in the Inner City: Effects of Environment via Mental Fatigue." Environment and Behavior 33(4): 543–571.

Leventhal T and Brooks-Gunn J (2001). "Moving To Better Neighborhoods Improves Health And Family Life Among New York Families." Poverty Research News. New York, NY, Joint Center For Poverty Research. 5.

Leventhal T and Brooks-Gunn J (2003). "Moving to opportunity: an experimental study of neighborhood effects on mental health." American Journal of Public Health 93(9): 1576–1582.

Lopez R (2004). "Urban sprawl and the risk for being overweight or obese." American Journal of Public Health 94(9): 1574–1579.

Macintyre S and Ellaway A (2000). "Ecological Approaches: Rediscovering the Role of the Physical and Social Environment." In Berkman LF and Kawachi I (Eds.). Social Epidemiology (pp. 332–348). New York, Oxford University Press.

Macintyre S and Ellaway A (2003). "Neighborhoods and Health: An Overview." In Kawachi I and Berkman LF (Eds.). Neighborhoods and Health (pp. 20–42), Oxford University Press.

Macintyre S, Ellaway A and Cummins S (2002). "Place Effects on Health: How Can we Conceptualise, operationalise and measure them?" Social Science & Medicine 55: 125–139.

Marmot MG, Kogeniva M, Elston MA (1987). "Social-economic status and health." Annual Review of Public Health 8: 111–135.

Meyers A, Cutts D, et al (2005). "Subsidized housing and children's nutritional status: Data from a multisite surveillance study." Archives of Pediatric and Adolescent Medicine 159(6): 551–556.

Meyers A, Frank DA, et al (1995). "Housing subsidies and pediatric undernutrition." Archives of Pediatric and Adolescent Medicine 149: 1079–1084.

Moorman JE, Rudd RA, et al. (2007). "National surveillance for asthma – U.S., 1980-2004." MMWR Surveillance Summary 56: 1–54.

Morello-Frosch R, Pastor M, Porras C, and Sadd J (2002). "Environmental Justice and Regional Inequality in Southern California: Implications for Future Research." Environmental Health Perspectives 110(S2): 149–154.

Morland K, Wing S, Diez Roux A, Poole C. Neighborhood characteristics associated with the location of food stores and food service places. Am J Prev Med. 2002 Jan;22(1): 23–9.

Myerson D (2007). “The Ultimate in Accessibility.” Planning December 2007: 44–45.

National Institute for Health and Clinical Excellence (NICE) Public Health Collaborating Centre (2006a). “Physical Activity and the Environment: Transport Evidence Review.” Available online at: *http://www.nice.org.uk/nicemedia/pdf/word/Transport%20evidence%20review.doc*. Accessed September 2, 2008.

National Institute for Health and Clinical Excellence (NICE) Public Health Collaborating Centre (2006b). “Physical Activity and the Environment: Urban Planning and Design Evidence Review.” Available online at: *www.gserve.nice.org.uk/nicemedia/pdf/word/Urban%20planning%20and%20design%20evidence%20review%20summary.doc*. Accessed September 2, 2008.

Nishita CM, Liebig PS, et al. (2007). “Promoting Basic Accessibility in the Home: Analyzing Patterns in the Diffusion of Visitability Legislation.” Journal of Disability Policy Studies 18(1): 2–13.

Niemann H and Maschke C (2004). “WHO LARES: Final Report—Noise Effects and Morbidity.” Available online at: *http://www.euro.who.int/document/NOH/WHO_Lares.pdf*. Accessed September 4, 2008.

Orr, LL (1999). Social experiments: Evaluating public programs with experimental methods. Thousand Oaks, CA, Sage Publications.

Pickett KE and Pearl M (2001). “Multilevel analyses of neighborhood socioeconomic context and health outcomes: a critical review.” Journal of Epidemiology and Community Health 55: 111–122.

Popkin, Susan J., Diane Levy, and Larry Buron. Forthcoming. “Has HOPE VI Transformed Residents Lives? Evidence from the HOPE VI Panel Study.” Housing Studies.

Popkin SJ, Levy DK, et al. (2002). “HOPE VI Panel Study Baseline Report.” Washington: Urban Institute. Available online at: *http://www.urban.org/UploadedPDF/410590_HOPEVI_PanelStudy.pdf*. Accessed August 25, 2008.

Popkin, SJ, Rosenbaum JE, et al. (1989). “Neighborhood Satisfaction of Low-Income Blacks in Middle Class Suburbs.” Society for the Study of Social Problems.

Pratt A (2008). “A health impact assessment of social housing redevelopment in Devonport, Plymouth.” Available online at: *http://www.apho.org.uk/resource/item.aspx?RID=44134*. Accessed April 21, 2008.

Rafferty Y, Shinn M, et al. (2004). “Academic achievement among formerly homeless adolescents and their continuously housed peers.” Journal of School Psychology 42(3): 179–199.

Rauth VA, Landrigan PJ, and Claudio L (2008). “Housing and Health: Intersection of Poverty and Environmental Exposures.” Annals of the New York Academy of Science 1136: 276–288.

Robert Wood Johnson Foundation (2008). “Designing for Active Living Among Adults.” Active Living Research Summary, Spring 2008. Available online at: *http://www.activelivingresearch.org/files/Active_Adults.pdf*. Accessed September 2, 2008.

Rodríguez D, Khattak AJ, and Evenson KR (2006). “Can New Urbanism encourage physical activity? Comparing a New Urbanist neighborhood with conventional suburbs.” Journal of the American Planning Association 72(1): 43–56.

Rosenbaum, JE (1994). “Housing Mobility Strategies for Changing the Geography of Opportunity.” Evanston, IL, Working Paper, Institute for Policy Research, Northwestern University.

Rosenbaum, JE (1995). “Changing The Geography Of Opportunity By Expanding Residential Choice: Lessons From The Gautreaux Program.” Housing Policy Debate 6(1): 231–269.

Rosenbaum, JE and Popkin SJ (1990). “Economic and Social Impacts of Housing Integration.” Evanston, IL, Center for Urban Affairs and Policy Research.

Rosenbaum, JE and Popkin SJ (1991). "Employment and Earnings of Low-Income Blacks Who Move to Middle-Class Suburbs." In C. Jencks and P. E. Peterson (ed.). The Urban Underclass (pp. 342–56). Washington DC, Brookings.

Sorlie PD, Backlund E, and Keller JB (1995). "U.S. mortality by economic, demographic and social characteristics. The national longitudinal mortality study." American Journal of Public Health 85(7): 949–956.

Stein L (1950). A study of respiratory tuberculosis in relation to housing conditions. British Journal of Social Medicine 4: 143–169.

Stone B, Mednick AC, et al. (2007). "Is Compact Growth Good for Air Quality?" Journal of the American Planning Association 73(4): 404–418.

Taylor AF, Wiley A, et al. (1998). "Growing up in the inner city: Green spaces as places to grow." Environment and Behavior 30(1): 3–27.

Turner, MA (1998). "Moving Out of Poverty: Expanding Mobility and Choice through Tenant-Based Housing Assistance." Housing Policy Debate 9(2): 373–394.

U.S. Department of Housing and Urban Development (1997). "1997 Picture of Subsidized Households Quick Facts." Available online at: *http://www.huduser.org/datasets/assthsg/picqwik.html*. Accessed April 21, 2008.

U.S. Department of Housing and Urban Development (2000). "Unequal Burden: Income and Racial Disparities in Subprime Lending in America." Washington, DC, U.S. Department of Housing and Urban Development. Available online at: *http://www.huduser.org/publications/fairhsg/unequal.html*. Accessed April 21, 2008.

U.S. Department of Housing and Urban Development. (2006). "Effects of Housing Vouchers on Welfare Families: Part 1 and 2." Available online at: *http://www.huduser.org/publications/commdevl/hsgvouchers.html*. Accessed August 25, 2008.

U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Orr L, Feins JD, et al. (2003). "Moving to Opportunity for Fair Housing Demonstration Program. Interim Impacts Evaluation." Washington, DC, U.S. Department of Housing and Urban Development. Available online at: *http://www.huduser.org/publications/fairhsg/mtoFinal.html*. Accessed April 21, 2008.

Van Ryzin G and Kamber T (2002). "Subtenures and Housing Outcomes for Low Income Renters in New York City." Journal of Urban Affairs 24(2): 197–218.

Wood DL, Valdez R, et al. (1990). "Health of homeless children and housed poor children." Pediatrics 86(6): 858–866.

Zima BT, Bussing R, et al. (1997). "Sheltered homeless children: their eligibility and unmet need for special education evaluation." American Journal of Public Health 87(2): 236–240.

Bibliography

Panel 1: Interior Biological Agents

A. Moisture control

Mold

Cox-Ganser, J. M., White, S. K., Jones, R., Hilsbos, K., Storey, E., Enright, P. L., et al. (2005). Respiratory morbidity in office workers in a water-damaged building. Environmental Health Perspectives, 113(4), 485–490.

Cunningham, M. J., & Cunningham, M. J. (1998). Direct measurements of temperature and humidity in dust mite microhabitats. Clinical & Experimental Allergy, 28(9), 1104–1112.

de Blay, F., Fourgaut, G., Hedelin, G., Vervloet, D., Michel, F. B., Godard, P., et al. (2003). Medical Indoor Environment Counselor (MIEC): role in compliance with advice on mite allergen avoidance and on mite allergen exposure. Allergy, 58(1), 27–33.

HUD. Controlling and preventing household mold and moisture problems: lessons learned and strategies for disseminating best practices-a report to congress. *http://www.healthyhousing.org/clearinghouse/docs/Article0135.pdf*.

Kercsmar, CM. Dearborn, DG, Schluchter, M, Xue, L, Kirchner,HL, Sobelewski, J, Greenberg, S, Vesper, SJ, Allan, TM, Reduction in Asthma Morbidity in Children as a Result of Home Remediation Aimed at Moisture Sources, Environ Hlth Perspect, 2006, 114:1574–1580.

Lignell, U., Meklin, T., Putus, T., Rintala, H., Vepsalainen, A., Kalliokoski, P., et al. (2007). Effects of moisture damage and renovation on microbial conditions and pupils' health in two schools—a longitudinal analysis of five years. Journal of Environmental Monitoring, 9(3), 225–233

Miller, J. D., Naccara, L., Satinover, S., Platts-Mills, T. A., Miller, J. D., Naccara, L., et al. (2007). Nonwoven in contrast to woven mattress encasings accumulate mite and cat allergen. Journal of Allergy & Clinical Immunology, 120(4), 977–979.

Ormandy, David & Roger Burridge. (July 1988). Dampness. Environmental Health Standards in Housing.

Park, J. H., Cox-Ganser, J., Rao, C., Kreiss, K., Park, J. H., Cox-Ganser, J., et al.(2006). Fungal and endotoxin measurements in dust associated with respiratory symptoms in a water-damaged office building. Indoor Air, 16(3), 192–203.

Rockwell W. Prompt remediation of water intrusion corrects the resultant mold contamination in a home. *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=16270726*

Siebers, R., Parkes, A., Miller, J. D., Crane, J., Siebers, R., Parkes, A., et al. (2007). Effect of allergen-impermeable covers on beta-(1,3)-glucan content of pillows. Allergy, 62(4), 451–452.

B. Control/elimination of allergens

Asthma

Krieger, JW., Takaro, TK., Song, L., Weaver, M. The Seattle-King County Healthy Homes Project: a randomized, controlled trial of a community health worker intervention to decrease exposure to indoor asthma triggers. *http://www.ajph.org/cgi/content/abstract/95/4/652*

Levy, J. A community-based participatory research study of multifaceted in-home environmental interventions for pediatric asthmatics in public housing. *http://www.asthmaregionalcouncil.org/about/documents/EffectivenessofIPMhomeinterventionsonasthma.pdf*

Morgan, WJ., Crain EF., Gruchalla, RS., O'Connor, GT., Kattan, M., Evans, R. 3rd, Stout, J., Malindzak, G., Smartt, E., Plaut, M., Walter, M., Vaughn, B., Mitchell, H.; Inner-City Asthma Study Group. Results of a home-based environmental intervention among urban children with asthma. *http://content.nejm.org/cgi/content/abstract/351/11/1068*

Williams SG, Brown CM, Falter KH, Alverson CJ, Gotway-Crawford C, Homa D, Jones DS, Adams EK, Redd SC. Does a multifaceted environmental intervention alter the impact of asthma on inner-city children? J Natl Med Assoc. 2006 Feb;98(2): 249–60.

The following are background.

A Systematic Review and Meta Analysis of Interventions Aimed at Reducing Exposure to House dust on the Development and Severity of Asthma. Clare Russell, Anna Sternberg and Paul R. Hunter. Enviornmental Health Perspectives :10.1289/ehp.10382; Online 25 September 2007. *http://dx.doi.org/* (14 articles included).

The EPR 3 Guidelines on Asthma was developed by an expert panel commissioned by the National Asthma Education and Prevention Program (NAEPP) Coordinating Committee (CC), coordinated by the National Heart, Lung, and Blood Institute (NHLBI) of the National Institutes of Health. Using the 1997 EPR 2 guidelines and the 2004 update of EPR 2 as the framework, the expert panel organized the literature review and final guidelines report around four essential components of asthma care, namely: assessment and monitoring, patient education, control of factors contributing to asthma severity, and pharmacologic treatment. Subtopics were developed for each of these four broad categories.

Section 3, Component 3: Control of Environmental COMORBID Conditions that Affect Asthma. *http://www.nhlbi.nih.gov/guidelines/asthma/06_sec3_comp3.pdf*

Evidence Table 9. Control of Factors Affecting Asthma: Allergen Avoidance. *http://www.nhlbi.nih.gov/guidelines/asthma/evid_tbls/9_allegenaviod_tagged.pdf*

HUD. Healthy Homes Issues: Asthma. Version 3 March 2006.

Clougherty JE, Levy JI, Hynes HP, & Spengler JD. (2006). A Longitudinal Analysis of the Efficacy of Environmental Interventions on Asthma-Related Quality of Life and Symptoms Among Children in Urban Public Housing Journal of Asthma, 43(5), 335–343.

Vojta, P. J., Randels, S. P., Stout, J., Muilenberg, M., Burge, H. A., Lynn, H., et al. (2001). Effects of physical interventions on house dust mite allergen levels in carpet, bed, and upholstery dust in low-income, urban homes. Environmental Health Perspectives, 109(8), 815–819.

Sears, M. R., Greene, J. M., Willan, A. R., Wiecek, E. M., Taylor, D. R., Flannery, E. M., et al. (2003). A longitudinal, population-based, cohort study of childhood asthma followed to adulthood.[see comment]. New England Journal of Medicine, 349(15), 1414–1422.

Allergens

Environmental Interventions that show a reduction of environmental allergen levels

Arbes SJ Jr, Sever M, Archer J, Long EH, Gore JC, Schal C, Walter M, Nuebler B, Vaughn B, Mitchell H, Liu E, Collette N, Adler P, Sandel M, Zeldin DC.Abatement of cockroach allergen (Bla g 1) in low-income, urban housing: A randomized controlled trial. J Allergy Clin Immunol 2003; 112: 339–45.)

Simpson A, Simpson B, Custovic A, Craven M, Woodcock A. Stringent environmental control in pregnancy and early life: the long-term effects on mite, cat and dog allergen. Clin Exp Allergy 2003; 33: 1183–9

Williams SG, Brown CM, Falter KH, Alverson CJ, Gotway-Crawford C, Homa D, Jones DS, Adams EK, Redd SC. Does a multifaceted environmental intervention alter the impact of asthma on inner-city children? J Natl Med Assoc. 2006 Feb;98(2): 249–60.

Allergens-dust mites

Arlian, L. Reducing relative humidity is a practical way to control dust mites and their allergens in homes in temperate climates *http://www.ncbi.nlm.nih.gov/sites/entrez?cmd=Retrieve&db=PubMed&list_uids=11149998&dopt=Abstract*

Colloff, M. J., Taylor, C., Merrett, T. G., Colloff, M. J., Taylor, C., & Merrett, T. G. (1995). The use of domestic steam cleaning for the control of house dust mites. Clinical & Experimental Allergy, 25(11), 1061–1066.

de Blay, F., Fourgaut, G., Hedelin, G., Vervloet, D., Michel, F. B., Godard, P., et al. (2003). Medical Indoor Environment Counselor (MIEC): role in compliance with advice on mite allergen avoidance and on mite allergen exposure. Allergy, 58(1), 27–33.

Gore, R. B., Durrell, B., Bishop, S., Curbishley, L., Woodcock, A., Custovic, A., et al. (2006). High-efficiency vacuum cleaners increase personal mite allergen exposure, but only slightly. Allergy, 61(1), 119–123.

Gotzsche P, Hammarquist C, Burr M. House dust mite control measures in the management of asthma: metaanalysis. BMJ 1998: 317: 1105–10.

Mihrshahi, S. Effectiveness of an intervention to reduce house dust mite allergen levels in children's beds. *http://www.blackwell-synergy.com/doi/pdf/10.1034/j.13989995.2003.00194.x?cookieSet=1*

Rijssenbeek, L. Clinical evaluation of the effect of anti-allergic mattress covers in patients with moderate to severe asthma and house dust mite allergy: a randomized double blind placebo controlled study. *http://www.ncbi.nlm.nih.gov/sites/entrez?cmd=Retrieve&db=PubMed&list_uids=12200523&dopt=Abstract*

Sercombe, J. K., Liu-Brennan, D., Causer, S. M., Tovey, E. R., Sercombe, J. K., Liu-Brennan, D., et al. (2007). The vertical distribution of house dust mite allergen in carpet and the effect ofdry vacuum cleaning. International Journal of Hygiene & Environmental Health, 210(1), 43–50.

Siebers, R., Parkes, A., Miller, J. D., Crane, J., Siebers, R., Parkes, A., et al. (2007). Effect of allergen-impermeable covers on beta-(1,3)-glucan content of pillows. Allergy, 62(4), 451–452.

Vojta, P. J., Randels, S. P., Stout, J., Muilenberg, M., Burge, H. A., Lynn, H., et al. (2001). Effects of physical interventions on house dust mite allergen levels in carpet, bed, and upholstery dust in low-income, urban homes. Environmental Health Perspectives, 109(8), 815–819.

Warner, J. A., Frederick, J. M., Bryant, T. N., Weich, C., Raw, G. J., Hunter, C., et al. (2000). Mechanical ventilation and high-efficiency vacuum cleaning: A combined strategy of mite and mite allergen reduction in the control of mite-sensitive asthma. Journal of Allergy & Clinical Immunology, 105(1 Pt 1), 75–82.

Woodfolk, J. A., Hayden, M. L., Couture, N., Platts-Mills, T. A., Woodfolk, J. A., Hayden, M. L., et al. (1995). Chemical treatment of carpets to reduce allergen: comparison of the effects of tannic acid and other treatments on proteins derived from dust mites and cats. Journal of Allergy & Clinical Immunology, 96(3), 325–333

Allergens-cockroaches

McConnell, R., Jones, C., Milam, J., Gonzalez, P., Berhane, K., Clement, L., et al. (2003). Cockroach counts and house dust allergen concentrations after professional cockroach control and cleaning.[see comment]. Annals of Allergy, Asthma, & Immunology, 91(6), 546–552.

McConnell R, Milam J, Richardson J, Galvan J, Jones C, Thorne PS, Berhane K. Educational intervention to control cockroach allergen exposure in the homes of Hispanic children in Los Angeles: results of the La Casa study. *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=15836749*

Sever, M. L., Arbes, S. J., Jr., Gore, J. C., Santangelo, R. G., Vaughn, B., Mitchell, H., et al. (2007). Cockroach allergen reduction by cockroach control alone in low-income urban homes: a randomized control trial. Journal of Allergy & Clinical Immunology, 120(4), 849–855.

Wang, C., Scharf, M. E., Bennett, G. W., Wang, C., Scharf, M. E., & Bennett, G. W. (2004). Behavioral and physiological resistance of the German cockroach to gel baits (Blattodea: Blattellidae). Journal of Economic Entomology, 97(6), 2067–2072.

Allergens-mice and rats

Phipatanakul, W., Cronin, B., Wood, R. A., Eggleston, P. A., Shih, M. C., Song, L., et al. (2004). Effect of environmental intervention on mouse allergen levels in homes of inner-city Boston children with asthma. Annals of Allergy, Asthma, & Immunology, 92(4), 420–425.

Woodfolk, J. A., Hayden, M. L., Couture, N., Platts-Mills, T. A., Woodfolk, J. A., Hayden, M. L., et al. (1995). Chemical treatment of carpets to reduce allergen: comparison of the effects of tannic acid and other treatments on proteins derived from dust mites and cats. Journal of Allergy & Clinical Immunology, 96(3), 325–333

Indoor air

van Strien RT, Driessen MN, Oldenwening M, Doekes G, Brunekreef B.Do central vacuum cleaners produce less indoor airborne dust or airborne cat allergen, during and after vacuuming, compared with regular vacuum cleaners? *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=15104784*

C. Control/elimination of pests (e.g., integrated pest management)

Miller, D. M., Meek, F., Miller, D. M., & Meek, F. (2004). Cost and efficacy comparison of integrated pest management strategies with monthly spray insecticide applications for German cockroach (Dictyoptera: Blattellidae) control in public housing. Journal of Economic Entomology, 97(2), 559–569.

Sandel, M. Can Integrated Pest Management Impact Urban Children with Asthma? *http://www.healthyhousing.org/clearinghouse/docs/Article0334.pdf*

Sever, M. L., Arbes, S. J., Jr., Gore, J. C., Santangelo, R. G., Vaughn, B., Mitchell, H., et al. (2007). Cockroach allergen reduction by cockroach control alone in low-income urban homes: a randomized control trial. Journal of Allergy & Clinical Immunology, 120(4), 849–855.

Wang, C., Bennett, G. W., Wang, C., & Bennett, G. W. (2006). Comparative study of integrated pest management and baiting for German cockroach management in public housing. Journal of Economic Entomology, 99(3), 879–885.

D. Hygiene (e.g., control of water temperature for sanitation and safety, frequency of cleaning, changing bedding, use of effective vacuum cleaners, etc.)

Reduction in environmental triggers show Improved morbidity

Arshad SH, Bateman B, Matthews SM. Primary prevention of asthma and atopy during childhood by allergen avoidance in infancy: a randomised controlled study. Thorax, 2003;58: 489–93

Becker A, Watson W, Ferguson A, Dimich-Ward H, Chan-Yeung M. The Canadian asthma primary prevention study: outcomes at 2 years of age. J Allergy Clin Immunol. 2004 Apr;113(4): 650–6.

Carter MC, Perzanowski MS, Raymond A, Platts-Mills TA. Home intervention in the treatment of asthma among inner-city children. J Allergy Clin Immunol, 2001;108: 732–7.

Eggleston PA, Butz A, Rand C, Curtin-Brosnan J, Kanchanaraksa S, Swartz L, Breysse P, Buckley T, Diette G, Merriman B, Krishnan JA. Home environmental intervention in inner-city asthma: a randomized controlled clinical trial. Ann Allergy Asthma Immunol 2005;95: 496–7.

Kattan M, Stearns SC, Crain EF, Stout JW, Gergen PJ, Evans R 3rd, Visness CM, Gruchalla RS, Morgan WJ, O'Connor GT, Mastin JP, Mitchell HE. Cost-effectiveness of a home-based environmental intervention for inner-city children with asthma. J Allergy Clin Immunol, 2005;116: 1058–63.

Morgan WJ, Crain EF, Gruchalla RS, O'Connor GT, Kattan M, Evans R 3rd, Stout J, Malindzak G, Smartt E, Plaut M, Walter M, Vaughn B, Mitchell H; Inner-City Asthma Study Group. Results of a home-based environmental intervention among urban children with asthma. N Engl J Med 2004;351: 1068–80.

Shapiro GG, Wighton TG, Chinn T, Zuckrman J, Eliassen AH, Picciano JF, Platts-Mills TA. House dust mite avoidance for children with asthma in homes of low-income families. J Allergy Clin Immunol, 1999;103: 1069–74.

van den Bemt L, van Knapen L, de Vries MP, Jansen M, Cloosterman S, van Schayck CP. Clinical effectiveness of a mite allergen-impermeable bed-covering system in asthmatic mite-sensitive patients. J Allergy Clin Immunol, 2004;114: 858–62.

Woodcock, A., Lowe, L. A., Murray, C. S., Simpson, B. M., Pipis, S. D., Kissen, P., et al. (2004). Early life environmental control: effect on symptoms, sensitization, and lung function at age 3 years. American Journal of Respiratory & Critical Care Medicine, 170(4), 433–439.

E. Structural Changes to the Home

Insulation

Howden-Chapman, P., Matheson, A., Crane, J., Viggers, H., Cunningham, M., Blakely, T., et al. (2007). Effect of insulating existing houses on health inequality: cluster randomised study in the community.[see comment]. BMJ, 334(7591), 460.

Waipara, Ralph Chapman and Gabrielle Davie Kay Saville-Smith, Des O'Dea, Martin Kennedy, Michael Baker, Nick Malcolm Cunningham, Tony Blakely, Chris Cunningham, Alistair Woodward, Philippa Howden-Chapman, Anna Matheson, Julian Crane, Helen Viggers. Effect of insulating existing housings on health inequality: clustered randomized study in the community. BMJ 2007; 334; 460–;

Air Filters

Antonicelli, L., Bilo, M. B., Pucci, S., Schou, C., Bonifazi, F., Antonicelli, L., et al. (1991). Efficacy of an air-cleaning device equipped with a high efficiency particulate air filter in house dust mite respiratory allergy. Allergy, 46(8), 594–600.

Francis, H., Fletcher, G., Anthony, C., Pickering, C., Oldham, L., Hadley, E., et al. (2003). Clinical effects of air filters in homes of asthmatic adults sensitized and exposed to pet allergens. Clinical & Experimental Allergy, 33(1), 101–105.

Gore, R. B., Bishop, S., Durrell, B., Curbishley, L., Woodcock, A., Custovic, A., et al. (2003). Air filtration units in homes with cats: can they reduce personal exposure to cat allergen? Clinical & Experimental Allergy, 33(6), 765–769.

Green, R., Simpson, A., Custovic, A., Faragher, B., Chapman, M., Woodcock, A., et al. (1999). The effect of air filtration on airborne dog allergen. Allergy, 54(5), 484–488.

Kilburn, S., Lasserson, T. J., McKean, M., Kilburn, S., Lasserson, T. J., & McKean, M. (2003). Pet allergen control measures for allergic asthma in children and adults. Cochrane Database of Systematic Reviews(1), CD002989.

McDonald, E., Cook, D., Newman, T., Griffith, L., Cox, G., Guyatt, G., et al. (2002). Effect of air filtration systems on asthma: a systematic review of randomized trials. [see comment]. Chest, 122(5), 1535–1542.

Reisman, R. E., Mauriello, P. M., Davis, G. B., Georgitis, J. W., DeMasi, J. M., Reisman, R. E., et al. (1990). A double-blind study of the effectiveness of a high-efficiency particulate air (HEPA) filter in the treatment of patients with perennial allergic rhinitis and asthma.[see comment]. Journal of Allergy & Clinical Immunology, 85(6), 1050–1057.

Reisman, R. E., & Reisman, R. E. (2001). Do air cleaners make a difference in treating allergic disease in homes? Annals of Allergy, Asthma, & Immunology, 87(6 Suppl 3), 41–43.

van der Heide, S., van Aalderen, W. M., Kauffman, H. F., Dubois, A. E., de Monchy, J. G., van der Heide, S., et al. (1999). Clinical effects of air cleaners in homes of asthmatic children sensitized to pet allergens. Journal of Allergy & Clinical Immunology, 104(2 Pt 1), 447–451.

Warburton, C. J., Niven, R. M., Pickering, C. A., Fletcher, A. M., Hepworth, J., Francis, H. C., et al. (1994). Domiciliary air filtration units, symptoms and lung function in atopic asthmatics. Respiratory Medicine, 88(10), 771–776.

Wood, R. A., Johnson, E. F., Van Natta, M. L., Chen, P. H., Eggleston, P. A., Wood, R. A., et al. (1998). A placebo-controlled trial of a HEPA air cleaner in the treatment of cat allergy. American Journal of Respiratory & Critical Care Medicine, 158(1), 115–120.

Wood, R. A., & Wood, R. A. (2002). Air filtration devices in the control of indoor allergens. Current Allergy & Asthma Reports, 2(5), 397–400.

Carpets

Causer, S. M., Lewis, R. D., Batek, J. M., Sr., Ong, K. H., Causer, S. M., Lewis, R. D., et al. (2004). Influence of wear, pile height, and cleaning method on removal of mite allergen from carpet. Journal of Occupational & Environmental Hygiene, 1(4), 237–242.

Colloff, M. J., Taylor, C., Merrett, T. G., Colloff, M. J., Taylor, C., & Merrett, T. G. (1995). The use of domestic steam cleaning for the control of house dust mites. Clinical & Experimental Allergy, 25(11), 1061–1066.

Gore, R. B., Durrell, B., Bishop, S., Curbishley, L., Woodcock, A., Custovic, A., et al. (2006). High-efficiency vacuum cleaners increase personal mite allergen exposure, but only slightly. Allergy, 61(1), 119–123.

Htut, T., Higenbottam, T. W., Gill, G. W., Darwin, R., Anderson, P. B., Syed, N., et al. (2001). Eradication of house dust mite from homes of atopic asthmatic subjects: a double-blind trial. Journal of Allergy & Clinical Immunology, 107(1), 55–60.

Lewis, R. D., Breysse, P. N., Lees, P. S., Diener-West, M., Hamilton, R. G., Eggleston, P., et al. (1998). Factors affecting the retention of dust mite allergen on carpet. American Industrial Hygiene Association Journal, 59(9), 606–613.

McConnell, R., Jones, C., Milam, J., Gonzalez, P., Berhane, K., Clement, L., et al. (2003). Cockroach counts and house dust allergen concentrations after professional cockroach control and cleaning.[see comment]. Annals of Allergy, Asthma, & Immunology, 91(6), 546–552.

Munir, A. K., Einarsson, R., Dreborg, S. K., Munir, A. K., Einarsson, R., & Dreborg, S. K. (1993). Vacuum cleaning decreases the levels of mite allergens in house dust. Pediatric Allergy & Immunology, 4(3), 136–143.

Phipatanakul, W., Cronin, B., Wood, R. A., Eggleston, P. A., Shih, M. C., Song, L., et al. (2004). Effect of environmental intervention on mouse allergen levels in homes of inner-city Boston children with asthma. Annals of Allergy, Asthma, & Immunology, 92(4), 420–425.

Popplewell, E. J., Innes, V. A., Lloyd-Hughes, S., Jenkins, E. L., Khdir, K., Bryant, T. N., et al. (2000). The effect of high-efficiency and standard vacuum-cleaners on mite, cat and dog allergen levels and clinical progress. Pediatric Allergy & Immunology, 11(3), 142–148.

Reisman, R. E., & Reisman, R. E. (2001). Do air cleaners make a difference in treating allergic disease in homes? Annals of Allergy, Asthma, & Immunology, 87(6 Suppl 3), 41–43. – Don't have hard copy yet

Sercombe, J. K., Liu-Brennan, D., Causer, S. M., Tovey, E. R., Sercombe, J. K., Liu-Brennan, D., et al. (2007). The vertical distribution of house dust mite allergen in carpet and the effect of dry vacuum cleaning. International Journal of Hygiene & Environmental Health, 210(1), 43–50.

Warner, J. A., Frederick, J. M., Bryant, T. N., Weich, C., Raw, G. J., Hunter, C., et al. (2000). Mechanical ventilation and high-efficiency vacuum cleaning: A combined strategy of mite and mite allergen reduction in the control of mite-sensitive asthma. Journal of Allergy & Clinical Immunology, 105(1 Pt 1), 75–82.

Woodfolk, J. A., Hayden, M. L., Couture, N., Platts-Mills, T. A., Woodfolk, J. A., Hayden, M. L., et al. (1995). Chemical treatment of carpets to reduce allergen: comparison of the effects of tannic acid and other treatments on proteins derived from dust mites and cats. Journal of Allergy & Clinical Immunology, 96(3), 325–333.

Heaters

Phoa, L. L., Toelle, B. G., Ng, K., Marks, G. B., Phoa, L. L., Toelle, B. G., et al. (2004). Effects of gas and other fume emitting heaters on the development of asthma during childhood. Thorax, 59(9), 741–745.

Education

Leung, R., Koenig, J. Q., Simcox, N., van Belle, G., Fenske, R., Gilbert, S. G., et al. (1997). Behavioral changes following participation in a home health promotional program in King County, Washington. Environmental Health Perspectives, 105(10), 1132–1135.

Persky, V., Coover, L., Hernandez, E., Contreras, A., Slezak, J., Piorkowski, J., et al. (1999). Chicago community-based asthma intervention trial: feasibility of delivering peer education in an inner-city population. Chest, 116(4 Suppl 1), 216S–223S.

Primomo, J., Johnston, S., DiBiase, F., Nodolf, J., Noren, L., Primomo, J., et al. (2006). Evaluation of a community-based outreach worker program for children with asthma. Pub.Hlth Nursing, 23(3), 234–241.

Schonberger, H. J., Maas, T., Dompeling, E., Knottnerus, J. A., van Weel, C., van Schayck, C. P., et al. (2004). Compliance of asthmatic families with a primary prevention programme of asthma and effectiveness of measures to reduce inhalant allergens—a randomized trial. Clinical & Experimental Allergy, 34(7), 1024–1031.

Schonberger, H. J., Dompeling, E., Knottnerus, J. A., Maas, T., Muris, J. W., van Weel, C., et al. (2005). The PREVASC study: the clinical effect of a multifaceted educational intervention to prevent childhood asthma. European Respiratory Journal, 25(4), 660–670.

Renovation

Lignell, U., Meklin, T., Putus, T., Rintala, H., Vepsalainen, A., Kalliokoski, P., et al. (2007). Effects of moisture damage and renovation on microbial conditions and pupils' health in two schools—a longitudinal analysis of five years. Journal of Environmental Monitoring, 9(3), 225–233.

Hurricane/Natural Disaster

Chew L., Wilson J., Rabito F.,Grimsley F., Iqbal S., Reponen T., et al. (2006). Mold and Endotoxin Levels in the Aftermath of Hurricane Katrina: A Pilot Project of Homes in New Orleans Undergoing Renovation. Environmental Health Perspectives, 14 (12), 1883–1889.

Environmental interventions that demonstrate no health benefit

Corver K, Kerkhof M, Brussee JE, Brunekreef B, van Strien RT, Vos AP, Smit HA, Gerritsen J, Neijens HJ, de Jongste JC. House dust mite allergen reduction and allergy at 4 yr: follow up of the PIAMA-study.Pediatr Allergy Immunol 2006;17: 329–36.

Horak F Jr, Matthews S, Ihorst G, Arshad SH, Frischer T, Kuehr J, Schwieger A, Forster J; The SPACE study group. Effect of mite-impermeable mattress encasings and an educational package on the development of allergies in a multinational randomized, controlled birth-cohort study—24 months results of the Study of Prevention of Allergy in Children in Europe. Clin Exp Allergy, Aug;34: 1220–5.

Klinnert MD, Liu AH, Pearson MR, Ellison MC, Budhiraja N, Robinson JL. Short-term impact of a randomized multifaceted intervention for wheezing infants in low-income families. Arch Pediatr Adolesc Med 2005;159: 75–82.

Luczynska C, Tredwell E, Smeeton N, Burney P. A randomized controlled trial of mite allergen-impermeable bed covers in adult mite-sensitized asthmatics. Clin Exp Allergy 2003;33: 1648–53.

Marks GB, Mihrshahi S, Kemp AS, Tovey ER, Webb K, Almqvist C, Ampon RD, Crisafulli D, Belousova EG, Mellis CM, Peat JK, Leeder SR. Prevention of asthma during the first 5 years of life: a randomized controlled trial. J Allergy Clin Immunol, 2006;118: 53–61.

The following is provided for background

Gotzsche PC, Hammarquist C, Burr M. House dust mite control measures in the management of asthma: meta-analysis. BMJ, 1998;317: 1105–10. (23 articles were included in this review.)

Panel 2: Interior Chemical Agents

A. Lead poisoning prevention

Brown, MJ. A randomized community based trial of home visiting to reduce blood lead levels in children. Centers for Disease Control. 2006.

Ettinger, A., Bornschein, R., Farfel, M., Campbell, C., Ragan, N., Rhoads, G., Brophy, M., Wilkins, S., Dockery, D. Assessment of cleaning to control lead dust in homes of children with moderate lead poisoning: treatment of lead-exposed children *http://www.healthyhousing.org/clearinghouse/docs/Article0011.pdf*

Haynes, E., Lanphear, B., Tohn, E., Farr, N., Rhoads, G. The effect of interior lead hazards controls on children's blood lead concentrations: a systematic evaluation *http://www.healthyhousing.org/clearinghouse/docs/Article0066.pdf*

Rich, D., Rhoads, G., Yiin, L. Comparison of home lead dust reduction techniques on hard surfaces: the NJ assessment of cleaning techniques trial *http://www.healthyhousing.org/clearinghouse/docs/Article0089.pdf*

Saegert, S. C., Klitzman, S., Freudenberg, N., Cooperman-Mroczek, J., Nassar, S., Saegert, S. C., et al. (2003). Healthy housing: a structured review of published evaluations of US interventions to improve health by modifying housing in the United States, 1990–2001. American Journal of Public Health, 93(9), 1471–1477.

Wilson, J., Dixon, S., Galke, W., McLaine, P. An investigation of dust lead sampling locations and children's blood lead levels *http://www.ncbi.nlm.nih.gov/sites/entrez?db=pubmed&list_uids=16823397&cmd=Retrieve&indexed=google*

Yiin LM, Yu CH, Ashley P, & G., R. (2008). Cleaning Efficacy of High-Efficiency Particulate Air-Filtered Vacuuming and "Dry Stream" Cleaning on Carpet. Journal of Occupational & Environmental Hygiene, 5, 94–99.

Zierold KM, Havlena J, Anderson H. Exposure to lead and length of time needed to make homes lead-safe for young children *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=17194869*

B. Radon mitigation

Cavallo A., Gadsby K., Reddy T.A., (1996). Comparison of natural and forced ventilation for radon mitigation in houses, Environmental International, 22(Supp 1), S1073–S1078.

Coskeran, T., Denman, A., Phillips, P., Tornberg, R., Coskeran, T., Denman, A., et al. (2006). A cost-effectiveness analysis of radon protection methods in domestic properties: a comparative case study in Brixworth, Northamptonshire, UK. Journal of Environmental Radioactivity, 91(1–2), 73–89.

Groves-Kirkby, C. J., Denman, A. R., Phillips, P. S., Crockett, R. G., Woolridge, A. C., Tornberg, R., et al. (2006). Radon mitigation in domestic properties and its health implications—a comparison between during-construction and post-construction radon reduction. Environment International, 32(4), 435–443.

Huber, J., Ennemoser, O., Schneider, P., Huber, J., Ennemoser, O., & Schneider, P. (2001). Quality control of mitigation methods for unusually high indoor radon concentrations.[see comment]. Health Physics, 81(2), 156–162.

LaFollette, S., Dickey, T., LaFollette, S., & Dickey, T. (2001). Demonstrating effectiveness of passive radon-resistant new construction. Journal of the Air & Waste Management Association, 51(1), 102–108.

Marley, F., Phillips, P. S., Marley, F., & Phillips, P. S. (2001). Investigation of the potential for radon mitigation by operation of mechanical systems affecting indoor air. Journal of Environmental Radioactivity, 54(2), 205–219.

Mose DG, Mushrush GW, Simoni FV. Variations of well water radon in Virginia and Maryland. *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=11688681*

Najafi, F. T., & Najafi, F. T. (1998). Radon reduction systems in the construction of new houses in Gainesville, Florida.[erratum appears in Health Phys 1999 Jan;76(1):78]. Health Physics, 75(5), 514–517.

C. Integrated pest management and safe chemical storage

Brenner, B. Integrated pest management in an urban community: a successful partnership for prevention *http://www.ehponline.org/docs/2003/6069/abstract.html*

Levy, J. A community-based participatory research study of multifaceted in-home environmental interventions for pediatric asthmatics in public housing. *http://www.asthmaregionalcouncil.org/about/documents/EffectivenessofIPMhomeinterventionsonasthma.pdf*

Peters, J. L., Levy, J. I., Muilenberg, M. L., Coull, B. A., Spengler, J.D. Peters, J. L., et al. (2007). Efficacy of integrated pest management in reducing cockroach allergen concentrations in urban public housing. Journal of Asthma, 44(6), 455–460.

Williams, M., An intervention to reduce residential insecticide exposure during pregnancy among an inner-city cohort. *http://www.asthmaregionalcouncil.org/about/documents/PesticideIntervention.pdf*

Pesticides

McCauley, L. A., Travers, R., Lasarev, M., Muniz, J., Nailon, R., McCauley, L. A., et al. (2006). Effectiveness of cleaning practices in removing pesticides from home environments. Journal of Agromedicine, 11(2), 81–88.

Miller, DM, Meek, F. Cost and Efficacy Comparison of Integrated Pest Management Strategies with Monthly Spray Insecticide Applications for German Cockroach (Dictyoptera: Blattellidae) Control in Public Housing. Journal of Economic Entomology; Volume 97, Issue 2 (April 2004); 559–569.

D. Environmental tobacco smoke (ETS) (e.g., establish smoke-free rules, smoke outdoors, change lease requirements, etc.)

Allwright, S., Paul, G., Greiner, B., Mullally, B. J., Pursell, L., Kelly, A., et al. (2005). Legislation for smoke-free workplaces and health of bar workers in Ireland: before and after study.[erratum appears in BMJ. 2006 Jan 21;332(7534):151]. BMJ, 331(7525), 1117.

Farrelly, M. C., Nonnemaker, J. M., Chou, R., Hyland, A., Peterson, K. K., Bauer, U. E., et al. (2005). Changes in hospitality workers' exposure to secondhand smoke following the implementation of New York's smoke-free law. Tobacco Control, 14(4), 236–241.

Fong, G. T., Hyland, A., Borland, R., Hammond, D., Hastings, G., McNeill, A., et al. (2006). Reductions in tobacco smoke pollution and increases in support for smoke-free public places following the implementation of comprehensive smoke-free workplace legislation in the Republic of Ireland: findings from the ITC Ireland/UK Survey. Tobacco Control, 15 Suppl 3, iii51–58.

Haw, S. J., Gruer, L., Haw, S. J., & Gruer, L. (2007). Changes in exposure of adult non-smokers to secondhand smoke after implementation of smoke-free legislation in Scotland: national cross sectional survey. [see comment]. BMJ, 335(7619), 549.

The following are provided for background

Gehrman, C. A., Hovell, M. F., Gehrman, C. A., & Hovell, M. F. (2003). Protecting children from environmental tobacco smoke (ETS) exposure: a critical review. Nicotine & Tobacco Research, 5(3), 289–301.

Saegert SC, Klitzman S, Freudenberg N, Cooperman-Mroczek J, Nassar S. Healthy housing: a structured review of published evaluations of US interventions to improve health by modifying housing in the United States, 1990–2001. Am J Public Health. Sep 2003;93(9): 1471–1477.

E. Particulate matter (e.g., install and maintain filtration and ventilation systems

Batterman, S., Godwin, C., Jia, C., Batterman, S., Godwin, C., & Jia, C. (2005). Long duration tests of room air filters in cigarette smokers' homes. Environmental Science & Technology, 39(18), 7260–7268.

Composite Panel Association. (2003). VOC emission barrier effects of laminates, overlays and coatings for particleboard, medium density fiberboard (MDF) and hardboard. Technical Bulletin.

Russell M, Sherman M, & Rudd, A. (2005). Review of Residential Ventilation Technologies. Ernest Orlando Lawrence Berkeley National Library.

F. Product and material selection (e.g., VOCs, formaldehyde

Batterman, S., Jia, C., & Hatzivasilis, G. (2007). Migration of volatile organic compounds from attached garages to residences: A major exposure source. Environmental Research, 104(2), 224–240.

Rumchev, K., Spickett, J., Bulsara, M., Phillips, M., Stick, S., Rumchev, K., et al. (2004). Association of domestic exposure to volatile organic compounds with asthma in young children.[see comment]. Thorax, 59(9), 746–751.

G. Particulate intrusion (e.g., sealing and filtration of buildings)

Canada Mortgage and Housing Corporation. (1992). Effectiveness of Clean up techniques for lead paint dust. g2 203 Technical Series.

Canada Mortgage and Housing Corporation. (2003). Indoor particulate and floor cleaning. Technical Series 03–104.

Canada Mortgage and Housing Corporation.(2004) The effects of improved residential filtration on particle exposure. Technical Series 99–108.

Canada Mortgage and Housing Corporation. (2005). Reduction of airborne particles in houses with occupants having respiratory ailments. Technical Report 05–114.

Canada Mortgage and Housing Corporation. (2006). Identifing and removing pollutants from heat recovery ventilators. Technical Series 06–103.

Oie, L., Nafstad, P., Botten, G., Magnus, P., Jaakkola, J. K., Oie, L., et al. (1999). Ventilation in homes and bronchial obstruction in young children. Epidemiology, 10(3), 294–299.

Rumchev, K., Spickett, J., Bulsara, M., Phillips, M., Stick, S., Rumchev, K., et al. (2004). Association of domestic exposure to volatile organic compounds with asthma in young children.[see comment]. Thorax, 59(9), 746–751.

Thatcher TL, & Layton DW. (1995). Deposition, Resuspension, and penetration of particles within a residence. Atmospheric Environment, 29(13), 1487–1497.

H. Traffic and Air Pollution

Samet, J. M., & Samet, J. M. (2007). Traffic, air pollution, and health. Inhalation Toxicology, 19(12), 1021–1027.

Panel 3: External Exposures

A. Drinking water safety

Ahmedna, M., Marshall, W. E., Husseiny, A. A., Rao, R. M., Goktepe, I. (2004). The use of nutshell carbons in drinking water filters for removal of trace metals. Water Research, 38(4), 1062–1068.

Calderon, R.Estimates of endemic waterborne risks from community-intervention studies. *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=16895087&ordinalpos=4&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_RVDocSum*

Colford, J.Participant Blinding and Gastrointestinal Illness in a Randomized, Controlled Trial of an In-Home Drinking Water Intervention. *http://www.cdc.gov/ncidod/eid/vol8no1/00-0481.htm*

Colford, J.M. Randomized, Controlled Trial of In-Home Drinking Water Intervention to Reduce Gastrointestinal Illness. *http://aje.oxfordjournals.org/cgi/content/full/161/5/472*

Colford, J.M. pilot randomized, controlled trial of an in-home drinking water intervention among HIV + persons. *http://www.ncbi.nlm.nih.gov/sites/entrez?cmd=Retrieve&db=PubMed&list_uids=16075942&dopt=Abstract*

Colford, J M, et.al. Participant Blinding and Gastrointestinal Illness in a Randomized, Controlled Trial of an In-Home Drinking Water Intervention Emerging Infectious Diseases 8(1), 2002 (2002) *http://www.medscape.com/viewarticle/423517_print*

Crump, J.A. et.al. Household based treatment of drinking water with flocculant-disinfectant for preventing diarrhea in areas with turbid source water in rural western Kenya: cluster randomized controlled trial. British Medical Journal 2005; 331: 478 (3 September) *http://www.bmj.com/cgi/content/full/331/7515/478*

Rangel, J. M., Lopez, B., Mejia, M. A., Mendoza, C., Luby, S., Rangel, J. M., et al. (2003). A novel technology to improve drinking water quality: a microbiological evaluation of in-home flocculation and chlorination in rural Guatemala. Journal of Water & Health, 1(1), 15–22. *http://www.environmental-expert.com/Files/5302/articles/5900/2.pdf*

B. On-site waste water treatment strategies

Anderson DL, Tyl MB, Otis RJ, Mayer TG, Sherman KM. 1998. Onsite wastewater nutrient reduction systems (OWNRS) for nutrient sensitive environments. In On-Site Wastewater Treatment, Sievers DM (ed.).

Proceedings of the Eighth National Symposium on Individual and Small Community Sewage Systems, 8–10 March, Orlando, Florida. American Society of Agricultural Engineers: Michigan; 436-445. *http://www.biomicrobics.com/downloads/Florida_OWNRS_Test_Summary.pdf*

Sinton, L.W. Microbial contamination of alluvial gravel aquifers by septic tank effluent Water, Air and Soil Pollution Vol. 28 No. 3 and 4; 407–425, 1986 *http://www.springerlink.com/content/p55h3222n5g85068/*

Background information.

Carpenter, L.Child Cares, Septic Systems and Public Health, *http://0-www.cdc.gov.mill1.sjlibrary.org/nceh/ehs/EPHLI/Reports/Carpenter.doc*

Siegrist, R.L., Tyler, E.J., Jenssen, P.D. Design and Performance of Onsite Wastewater Soil *http://www.wecf.de/download/WBreportSeptictanks.pdf*

Panel 4: Structural Deficiences

A. Burn prevention (e.g., shield hot surfaces, reduce hot water temperature, etc.)

Community-based education to reduce burns and scalds

Macarthur, C., & Macarthur, C. (2003). Evaluation of Safe Kids Week 2001: prevention of scald and burn injuries in young children. Injury Prevention, 9(2), 112–116.

Turner C. Spinks A. McClure R. Nixon J. Community-based interventions for the prevention of burns and scalds in children. Cochrane Database of Systematic Reviews. (3):CD004335, 2004. UI: 15266531.

Home safety education and provision of safety equipment to reduce burns and scalds

Kendrick D. Coupland C. Mulvaney C. Simpson J. Smith SJ. Sutton A. Watson M. Woods A. Home safety education and provision of safety equipment for injury prevention. Cochrane Database of Systematic Reviews. (1):CD005014, 2007.

B. Fall prevention (e.g., repair of floor and stair surfaces, install/repair railings, ladder safety, install non-slip rugs, etc.)

Injury—falls

Cohen, HH and LaRue, C. “Perception-Cognitive and Biomechanical Factors” in Pedestrian Falls (Chapter 19).

Johnson, DA; Measurement in Pedestrian Falls in Pedestrian Falls (Chapter 20).

Modification of the home environment to reduce home hazards, falls, and fall injuries

Lyons, R. A., A. John, et al. Modification of the home environment for the reduction of injuries (Review article—18 studies included) *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17054179*

Stevens, M., Holman, C. D., Bennett, N., (2001). Preventing falls in older people: impact of an intervention to reduce environmental hazards in the home. Journal of the American Geriatrics Society, 49(11), 1442–1447.

Stevens, M., Holman, C. D., Bennett, N., de Klerk, N., et al. (2001). Preventing falls in older people: outcome evaluation of a randomized controlled trial. Journal of the American Geriatrics Society, 49(11), 1448–1455.

Population-based interventions for prevention of fall-related injuries in older people

McClure R. Turner C. Peel N. Spinks A. Eakin E. Hughes K. Population-based interventions for the prevention of fall-related injuries in older people. Cochrane Database of Systematic Reviews. (1):CD004441, 2005.

Community-based interventions for prevention of fall-related injuries in children

McClure R. Nixon J. Spinks A. Turner C. Community-based programmes to prevent falls in children: a systematic review. Journal of Paediatrics & Child Health. 41(9–10): 465–70, 2005.

Home safety education and provision of safety equipment for prevention of fall-related injuries in children

Kendrick D. Coupland C. Mulvaney C. Simpson J. Smith SJ. Sutton A. Watson M. Woods A. Home safety education and provision of safety equipment for injury prevention. Cochrane Database of Systematic Reviews. (1):CD005014, 2007.

C. Fire prevention (e.g., use and maintenance of smoke, heat and carbon monoxide detectors/alarms, use of fire resistant materials)

Fire

Istre, G. R., McCoy, M. A., Osborn, L., Barnard, J. J., Bolton, A., Istre, G. R., et al. (2001). Deaths and injuries from house fires.[see comment]. New England Journal of Medicine, 344(25), 1911–1916.

Interventions to promote smoke alarms and fire guard

DiGuiseppi, C., Roberts, I., Wade, A., Sculpher, M., Edwards, P., Godward, C., et al. (2002). Incidence of fires and related injuries after giving out free smoke alarms: cluster randomised controlled trial.[see comment]. BMJ, 325(7371), 995.

DiGuiseppi C, Goss C, Higgins JP. Interventions for promoting smoke alarm ownership and function. Cochrane Database of Systematic Reviews. [in press]

Kendrick D. Coupland C. Mulvaney C. Simpson J. Smith SJ. Sutton A. Watson M. Woods A. Home safety education and provision of safety equipment for injury prevention. Cochrane Database of Systematic Reviews. (1):CD005014, 2007.

Mallonee, S., Istre, G. R., Rosenberg, M., Reddish-Douglas, M., Jordan, F., Silverstein, P., et al. (1996). Surveillance and prevention of residential-fire injuries. New England Journal of Medicine, 335(1), 27–31.

Home based education to promote CO detectors.

Posner J, Hawkins L, Garcia-Espana F, Durbin D. A randomized clinical trial of a home safety intervention based in an emergency department setting. Pediatrics 2004;113:1603.

Review Article

Public/Private Fire Safety Council. Home Smoke Alarms and Other Fire Detection and Alarm Equipment *http://www.firesafety.gov/downloads/pdf/white-paper-alarms.pdf*

D. Injury prevention in hazardous areas (e.g., drowning prevention education, retrofit bathtubs and showers to prevent falls, etc.)

Injury – General home injury

Modification of the home environment to prevent injuries

Lyons, R. A., A. John, et al. Modification of the home environment for the reduction of injuries (Review article—18 studies included) *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17054179*

Spinks A. Turner C. Nixon J. McClure R. The 'WHO Safe Communities' model for the prevention of injury in whole populations. Cochrane Database of Systematic Reviews. (2):CD004445, 2005. UI: 15846716

Modification of the home environment to prevent injuries

Lyons, R. A., A. John, et al. Modification of the home environment for the reduction of injuries (Review article—18 studies included) *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17054179*

Raw GJ, Cayless SM, Riley J, Cox SJ, & S., C. (2000). A risk assessment procedure for health and safety in buildings. BRE Center for Safety, Health and Environment. Loughborough University.

Housing Healthy and Safety Rating System, Housing Act 2004. Office of the Deputy Prime Minister: London. Feb 2006. Website with additional information: *www.communities.gov.uk/hhsrs*

Home safety education and provision of safety equipment for injury prevention.

Babul, S., Olsen, L., Janssen, P., McIntee, P., Raina, P., Babul, S., et al. (2007). A randomized trial to assess the effectiveness of an infant home safety programme. International Journal of Injury Control & Safety Promotion, 14(2), 109–117.

Kendrick D. Coupland C. Mulvaney C. Simpson J. Smith SJ. Sutton A. Watson M. Woods A. Home safety education and provision of safety equipment for injury prevention. Cochrane Database of Systematic Reviews. (1):CD005014, 2007.

Lyons, R. A., Newcombe, R. G., Jones, S. J., Patterson, J., Palmer, S. R., Jones, P., et al. (2006). Injuries in homes with certain built forms. American Journal of Preventive Medicine, 30(6), 513–520.

Posner, J. C., Hawkins, L. A., Garcia-Espana, F., Durbin, D. R., Posner, J. C., Hawkins, L. A., et al. (2004). A randomized, clinical trial of a home safety intervention based in an emergency department setting. Pediatrics, 113(6), 1603–1608.

Watson, M., Kendrick, D., Coupland, C., Woods, A., Futers, D., Robinson, J., et al. (2005). Providing child safety equipment to prevent injuries: randomised controlled trial. BMJ, 330(7484), 178.

Review Articles

MacKay, M., J. Vincenten, et al. Child Safety Good Practice Guide: Good investments in unintentional child injury prevention and safety promotion *www.actiononinjuries.org/csi/eurosafe2006.nsf/0/5C013FEF526F9157C12571AF002F0561/$file/GoodPracticeGuide-Draft7.pdf http://www.eurosafe.eu.com/csi/eurosafe2006.nsf/0/5C013FEF526F9157C12571AF002F0561/$file/GoodPracticeGuide-Draft7.pdf*

Towner, E., T. Dowswell, et al. Updating the evidence. A systematic review of what works in preventing childhood unintentional injuries: part 1 (Review article—37 articles) *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11428566*

Towner, E., T. Dowswell, et al. Updating the evidence. A systemic review of what works in preventing childhood unintentional injuries: Part 2 (Review article—28 articles) *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11565995*

Injury – Children

Johnston, B. D., Britt, J., D'Ambrosio, L., Mueller, B. A., Rivara, F. P., Johnston, B. D., et al. (2000). A preschool program for safety and injury prevention delivered by home visitors. Injury Prevention, 6(4), 305–309.

Nagaraja, J., Menkedick, J., Phelan, K. J., Ashley, P., Zhang, X., Lanphear, B. P., et al. (2005). Deaths from residential injuries in US children and adolescents, 1985–1997. Pediatrics, 116(2), 454–461.

Phelan, K. J., Khoury, J., Kalkwarf, H., Lanphear, B., Phelan, K. J., Khoury, J., et al. (2005). Residential injuries in U.S. children and adolescents. Public Health Reports, 120(1), 63–70.

Watson, M., Kendrick, D., Coupland, C., Woods, A., Futers, D., Robinson, J., et al. (2005). Providing child safety equipment to prevent injuries: randomized controlled trial. BMJ, 330(7484), 178.

Injury—Elderly

Modification of the home environment to reduce injuries

Lin MR, Wolf SL, Hwang HF, Gong SY, Chen CY. A randomized, controlled trial of fall prevention programs and quality of life in older fallers. *http://www.ncbi.nlm.nih.gov/sites/entrez?cmd=Retrieve&db=pubmed&dopt=Abstract&list_uids=17397426*

Lyons, R. A., A. John, et al. Modification of the home environment for the reduction of injuries (Review article—18 studies included) *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17054179*

Close, J., Ellis, M., Hooper, R., Glucksman, E., Jackson, S., Swift, C., et al. (1999). Prevention of falls in the elderly trial (PROFET): a randomised controlled trial.[see comment]. Lancet, 353(9147), 93–97.

Nikolaus, T., Bach, M., Nikolaus, T., & Bach, M. (2003). Preventing falls in community-dwelling frail older people using a home intervention team (HIT): results from the randomized Falls-HIT trial. Journal of the American Geriatrics Society, 51(3), 300–305.

Stevens, M., Holman, C. D., Bennett, N., Stevens, M., Holman, C. D., & Bennett, N. (2001). Preventing falls in older people: impact of an intervention to reduce environmental hazards in the home. Journal of the American Geriatrics Society, 49(11), 1442–1447.

Stevens, M., Holman, C. D., Bennett, N., de Klerk, N., Stevens, M., Holman, C. D., et al. (2001). Preventing falls in older people: outcome evaluation of a randomized controlled trial. Journal of the American Geriatrics Society, 49(11), 1448–1455.

Review Articles.

Lord, S. R., H. B. Menz, et al. Home environment risk factors for falls in older people and the efficacy of home modifications *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16926207* (Review article)

Rubenstein LZ, Josephson KR. Falls and their prevention in elderly people: what does the evidence show? (Review article) *http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16962843*

Rubenstein LZ, Falls in older people: epidemiology, risk factors and strategies for prevention. (Review article) *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=16926202*

Injury—Swimming pools

Efficacy of pool fences for preventing drowning

Thompson, D.Pool fencing for preventing drowning in children. (Review article, 3 articles) *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=10796742&ordinalpos=14&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_RVDocSum*

Interventions to influence use of pool fences and drowning rates

Morgenstern, H., Bingham, T., Reza, A., Morgenstern, H., Bingham, T., & Reza, A. (2000). Effects of pool-fencing ordinances and other factors on childhood drowning in Los Angeles County, 1990–1995. [see comment]. American Journal of Public Health, 90(4), 595–601.

Kendrick D. Coupland C. Mulvaney C. Simpson J. Smith SJ. Sutton A. Watson M. Woods A. Home safety education and provision of safety equipment for injury prevention. [Review] [170 refs] [Journal Article. Meta-Analysis. Review] Cochrane Database of Systematic Reviews. (1):CD005014, 2007.

Comparative efficacy of 3- vs. 4-sided pool fencing

Stevenson MR, Rimajova M, Edgecome D, Vickery K. Childhood drowning: barriers surrounding private swimming pools. Pediatrics 2003;111:115–9.

E. Temperature control (e.g., prevention of exposure to excessive heat and cold)

Naughton, M. P., Henderson, A., Mirabelli, M. C., Kaiser, R., Wilhelm, J. L., Kieszak, S. M., et al. (2002). Heat-related mortality during a 1999 heat wave in Chicago. [see comment]. American Journal of Preventive Medicine, 22(4), 221–227.

Panel 5: Intersection Between House and Community

A. Housing location and equity (e.g., environmental justice, avoid wetlands and industrial sites, evaluate brownfields)

Interventions for low-income/minority populations that reflect on Environmental Injustice:

Clougherty, J. E., Levy, J. I., Hynes, H. P., Spengler, J. D., Clougherty, J. E., Levy, J. I., et al. (2006). A longitudinal analysis of the efficacy of environmental interventions on asthma-related quality of life and symptoms among children in urban public housing. Journal of Asthma, 43(5), 335–343.

Hynes, H. P., Brugge, D., Osgood, N. D., Snell, J., Vallarino, J., Spengler, J., et al. (2003). "Where does the damp come from?" Investigations into the indoor environment and respiratory health in Boston public housing. Journal of Public Health Policy, 24(3–4), 401–426.

Krieger, J. K., Takaro, T. K., Allen, C., Song, L., Weaver, M., Chai, S., et al. (2002). The Seattle-King County healthy homes project: implementation of a comprehensive approach to improving indoor environmental quality for low-income children with asthma. Environmental Health Perspectives, 110 Suppl 2, 311–322.

Krieger, J. W., Takaro, T. K., Song, L., Weaver, M., Krieger, J. W., Takaro, T. K., et al. (2005). The Seattle-King County Healthy Homes Project: a randomized, controlled trial of a community health worker intervention to decrease exposure to indoor asthma triggers. American Journal of Public Health, 95(4), 652–659.

Poor Housing that reflect health disparities specifically for low-income populations

Environmental Justice Building

Agyeman, J., & Evans, T. (2003). Toward Just Sustainability in Urban Communities: Building Equity Rights with Sustainable Solutions. The Annals of the American Academy of Political and Social Science, 590, 35–53.

Maantay, J. (2002). Zoning law, health, and environmental justice: what's the connection? Journal of Law, Medicine & Ethics, 30(4), 572–593. *http://www.blackwell-synergy.com/doi/abs/10.1111/j.1748-720X.2002.tb00427.x*

Macey, G. P., Her, X., Reibling, E. T., Ericson, J., Macey, G. P., Her, X., et al. (2001). An investigation of environmental racism claims: testing environmental management approaches with a geographic information system. Environmental Management, 27(6), 893–907. *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=11393323*

Policy

Goldman, L., Falk, H., Landrigan, P. J., Balk, S. J., Reigart, J. R., Etzel, R. A., et al. (2004). Environmental pediatrics and its impact on government health policy. Pediatrics, 113(4 Suppl), 1146–1157. *http://pediatrics.aappublications.org/cgi/reprint/113/4/S1/1146?ck=nck*

Bhatia, R., & Bhatia, R. (2007). Protecting health using an environmental impact assessment: a case study of San Francisco land use decisionmaking. American Journal of Public Health, 97(3), 406-413. *http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=17267726*

Built Environment

Cummins, S. K., Jackson, R. J., Cummins, S. K., & Jackson, R. J. The built environment and children's health. Pediatric Clinics of North America, 48(5), 1241–1252.

Guite, H. F., Clark, C., Ackrill, G., Guite, H. F., Clark, C., & Ackrill, G. (2006). The impact of the physical and urban environment on mental well-being. Public Health, 120(12), 1117–1126.

Newcombe, R. G., Lyons, R. A., Jones, S. J., Patterson, J., Newcombe, R. G., Lyons, R. A., et al. (2005). Home injuries and built form—methodological issues and developments in database linkage. BMC Health Services Research, 5(1), 12.

Sheppard, E., Leitner, H., McMaster, R. B., Tian, H., Sheppard, E., Leitner, H., et al. (1999). GIS-based measures of environmental equity: exploring their sensitivity and significance. Journal of Exposure Analysis and Environmental Epidemiology, 9(1), 18–28.

Stevenson, M., & Stevenson, M. (2006). Building safer environments: injury, safety, and our surroundings. Injury Prevention, 12(1), 1–2.

Suburban and new urbanism areas

Baran, P. Rodríguez, D.A. and Khattak, A.J. In press. Space Syntax and Walking in a New Urbanist and Suburban Neighborhoods, Journal of Urban Design, 24 pages.

Brown, A.L., Khattak, A.J., and Rodríguez, D.A. 2008. Neighborhood Types, Travel and Body Mass: A Study of New Urbanist and Suburban Neighborhoods, Urban Studies, 45, 8.

Shay, E. Fan, Y. Rodríguez, D.A, Khattak, A.J. 2006. Drive or Walk? Utilitarian Trips within a Neo-Traditional Neighborhood, Transportation Research Record 1985, 154–161 4.

Rodríguez, D., Khattak, A.J., and Evenson, K.R. 2006. Can New Urbanism encourage physical activity? Comparing a New Urbanist neighborhood with conventional suburbs, Journal of the American Planning Association, 72:1, 43–56.

Khattak, A., and Rodríguez, D.A. 2005. Travel behavior in neo-traditional neighborhoods: A case study in USA. Transportation Research Part A, 39:6, 481–500. Don't have hard copy

B. Green space (e.g., eliminate conditions that have potential mental health impacts)

Farley, T. A., Meriwether, R. A., Baker, E. T., Watkins, L. T., Johnson, C. C., Webber, L. S., et al. (2007). Safe play spaces to promote physical activity in inner-city children: results from a pilot study of an environmental intervention. American Journal of Public Health, 97(9), 1625–1631.

Kling JR, L. J., Katz LF. (2007). Experimental analysis of neighborhood effects. Econometrica, 75(1), 83–119.

Kling JR, L. J., Katz LF. (2007). Supplement to "Experimental analysis of neighborhood effects"; Web appendix. Econometrica Supplmentary Material, 75(1), 83–119.

Klitzman, S., Caravanos, J., Belanoff, C., Rothenberg, L., Klitzman, S., Caravanos, J., et al. (2005). A multihazard, multistrategy approach to home remediation: results of a pilot study. Environmental Research, 99(3), 294–306. *http://www.ncbi.nlm.nih.gov/sites/entrez?cmd=Retrieve&db=PubMed&list_uids=16154560&dopt=Abstract*

Leventhal, T., Brooks-Gunn, J., Leventhal, T., & Brooks-Gunn, J. (2003). Moving to opportunity: an experimental study of neighborhood effects on mental health. American Journal of Public Health, 93(9), 1576–1582.

Semenza, J. C., Krishnasamy, P. V., Semenza, J. C., & Krishnasamy, P. V. (2007). Design of a health-promoting neighborhood intervention. Health Promotion Practice, 8(3), 243–256.

Wells, N. (2000). At Home With Nature: Effects of "Greenness" on Children's Cognitive Functioning. Environment and Behavior, 32(6), 775. *http://elib2.cdc.gov:2252/cgi/reprint/32/6/775*

C. Impact of local ordinances on housing quality

Breysse, J., Anderson, J., Dixon, S., Galke, W., Wilson, J., Breysse, J., et al. (2007). Immediate and one-year post-intervention effectiveness of Maryland's lead law treatments. Environmental Research, 105(2), 267–275.

Brown, M. J., Gardner, J., Sargent, J. D., Swartz, K., Hu, H., Timperi, R., et al. (2001). The effectiveness of housing policies in reducing children's lead exposure. American Journal of Public Health, 91(4), 621–624.

Brown, M. J., & Brown, M. J. (2002). Costs and benefits of enforcing housing policies to prevent childhood lead poisoning. Medical Decision Making, 22(6), 482–492.

Rabito, F. A., Shorter, C., White, L. E., Rabito, F. A., Shorter, C., & White, L. E. (2003). Lead levels among children who live in public housing.[see comment]. Epidemiology, 14(3), 263–268.

D. The following are provided for background

Acevedo-Garcia D, Osypuk TL, Werbel RE, Meara ER, Cutler DM, & LF, B. (2004). Does housing mobility policy improve health? Housing policy debate, 15(1), 49–98.

Carter, S. P., Carter, S. L., Dannenberg, A. L., Carter, S. P., Carter, S. L., & Dannenberg, A. L. (2003). Zoning out crime and improving community health in Sarasota, Florida: "Crime Prevention Through Environmental Design". American Journal of Public Health, 93(9), 1442–1445.

Dannenberg, A. L., Bhatia, R., Cole, B. L., Dora, C., Fielding, J. E., Kraft, K., et al. (2006). Growing the field of health impact assessment in the United States: an agenda for research and practice. American Journal of Public Health, 96(2), 262–270.

Dannenberg AL, Bhatia R, Cole BL, Heaton SK, Feldman JD, & Rutt CD. (Accepted for publication: to appear March 2008). Use of Health Impact Assessment in the United States: 27 Case Studies, 1999–2007. American Journal of Preventive Medicine.

Hynes HP, & Howe G. (2002). Urban Horticulture in the Contemporary United States: Personal and Community Benefits. Acta Horticulturae, 643.

Justice Policy Institute. (2007). Housing and Public Safety. *http://www.knowledgeplex.org/redir.html?url=http%3A%2F%2Fwww.justicepolicy.org%2Fimages%2Fupload%2F07-11_REP_HousingPublicSafety_AC-PS.pdf*

Manjarrez CA, P. S., Guernsey E. (June 2007). Poor Health: Adding Insult to Injury for Hope VI Families. Metropolitan Housing and Communities Center, Brief No. 5.

Newman, O. (1996). Creating Defensible Space. *http://www.huduser.org/periodicals/rrr/newman.html*

Popkin S, & Cove E. (2007). Safety is the most important thing. How Hope VI helped families. Metropolitan Housing and Communities Center, Brief No. 2.

Saegert, S. C., Klitzman, S., Freudenberg, N., Cooperman-Mroczek, J., Nassar, S., Saegert, S. C., et al. (2003). Healthy housing: a structured review of published evaluations of US interventions to improve health by modifying housing in the United States, 1990–2001. American Journal of Public Health, 93(9), 1471–1477. *http://www.ajph.org/cgi/content/abstract/93/9/1471*

Sampson RJ, Sharkey P, & Raudenbush SW. (2007). Durable effects of concentrated disadvantage on verbal ability among African-American children. Proc Natl Acad Sci USA.

U.S Department of Health and Human Services. National Institute of Health. National Heart, Lung and Blood Institute. (Dec 2003) Cardiovascular health small group discussion in Baltimore City public housing. Consumer Assessment for Community-Based Outreach and Education.

US Department of Housing and Urban Development. (2006). Effects of Housing Vouchers on Welfare Families. Part 1 and 2. *http://www.huduser.org/publications/commdevl/hsgvouchers.html*

Why Place Matters: Building a movement for healthier communities. Policy Link. 2007

Appendix A: Meeting Minutes

The Record of the Proceedings of the December 11–12, 2007 Healthy Homes Expert Panel

The National Center for Healthy Housing (NCHH) and the Centers for Disease Control and Prevention (CDC) convened a "Healthy Homes Expert Panel Meeting: Peer Review of Intervention Studies." The meeting was held at CDC's Century Center facility in Atlanta, Georgia, on December 11–12, 2007.

The sponsors of the meeting made opening remarks that provided a context for the proceedings. Keynote speakers included Dr. Mary Jean Brown, Chief of CDC's Lead Poisoning Prevention Branch, who explained the purpose of and process for the meeting; Dr. Thomas Sinks, Deputy Director of CDC's National Center for Environmental Health and the Agency for Toxic Substances and Disease Registry; Dr. David Jacobs, Director of Research, NCHH; and Ms. Rebecca Morley, Executive Director, NCHH. The opening session concluded by Dr. Brown providing the charge to the Expert Panel.

The Expert Panel was asked to compile practical and evidence-based information on housing interventions. Housing providers and others can use this information to make a difference in the lives of Americans and improve the quality of the housing stock in the United States. The Expert Panel reviewed healthy homes data and lessons learned in both the United States and other countries.

The articles reviewed by the Expert Panel were identified and compiled by CDC scientists with topical expertise. Only intervention research papers were included. The resultant literature was shared with planning committee members, who added additional intervention studies to the compilation for review. These studies were then sent to the Expert Panel members for review and feedback, based on their areas of expertise.

To fulfill the charge of evaluating the intervention studies, the Expert Panel was divided into five work groups (panels) based on the following broad topical areas:

1. Interior Biological Agents (Toxins) Interventions
2. Interior Chemical Agents (Toxics) Interventions
3. External Exposures
4. Structural Deficiencies
5. Intersection between Housing and Community

The panels placed each evidence-based study they reviewed into one of four categories or "intervention buckets" based the strength or weakness of the evidence.

- **Bucket 1:** interventions that currently have sufficient evidence of effectiveness to recommend immediate implementation (e.g., smoke alarms). lii
- **Bucket 2:** promising interventions that need more testing and evaluation in the field prior to recommending implementation.
- **Bucket 3:** interventions that need formative research to determine their effectiveness and biologic plausibility.
- **Bucket 4:** interventions with no demonstrated record of effectiveness.

The five panel chairs reported the findings of their respective groups. In addition to presenting evidence for the four intervention buckets, some panels also identified issues, research gaps, challenges, and concerns. Two of the panels created new intervention buckets for "studies that should be discarded" and "interventions in need of more literature or expertise." Time was allotted after each "report-out" for the Expert Panel members to make suggestions on collecting additional data and strengthening the evidence-based recommendations.

Of the four buckets, bucket 1, "interventions that currently have sufficient evidence of effectiveness to recommend immediate implementation," is the most important in implementing changes in the nation's housing stock. The following are examples of interventions that are ready for immediate implementation (see the report for a complete list):

(a) Multi-faceted tailored interventions for asthma, as exemplified by the Inner City Cooperative Asthma Study, are effective in controlling asthma symptoms and reducing asthma morbidity. The interventions include education that is based on the social learning theory; use of mattress and pillow covers; use of HEPA vacuums and air filters; smoking cessation; cockroach extermination; and bedroom cleaning.

(b) Integrated pest management studies show that household cleaning and tool dispensing, professional cleaning, education of residents, use of baits, use of low-toxicity pesticides and structural repairs are effective in lowering pests.

(c) A study on radon mitigation demonstrates the efficacy of active post-construction systems placed in homes in high-risk areas.

(d) Four studies demonstrate the efficacy of non-residential smoking bans to reduce exposure to environmental tobacco smoke.

(e) A study on working smoke alarms demonstrates their effectiveness in reducing the risk of death and injury from fires.

(f) A study on four-sided isolation fencing around pools demonstrates that such fencing reduces the risk of children drowning.

(g) A study on pre-set and safe water heater temperatures shows that setting thermostats at the manufacturer's recommendation of 120 degrees is effective in reducing the risk of scalds.

At the conclusion of the five panel "report-outs," all of the Expert Panel members made suggestions on actions that NCHH and CDC should consider to improve or advance the healthy homes peer review process in the future.

The Expert Panel was informed that the output from the meeting is expected to lead to development of a white paper that will be useful in the effort to establish a policy base for housing interventions for which the evidence shows that health gains will be achieved.

NCHH and CDC plan to compile a complete list of the key outcomes and findings from the meeting and assess the strength of evidence to support health-based housing interventions.

The Expert Panel and others will be asked to independently review these papers, as well as identify papers that have not been found during the initial literature search.

Post-meeting activities will include identifying missing literature; making decisions to incorporate new evidence; revising criteria for the intervention buckets, if necessary; discussing other documents and outcomes from the meeting; and clarifying and addressing any remaining issues.

There are plans for a policy meeting to be held in late spring 2008 for groups outside the research community for input on applying the Expert Panel's evidence-based guidance into actual practice. Participants of the policy meeting would include policymakers, housing advocates, home builders, architects, engineers, housing providers, medical and public health officials, and other practitioners in the field.

To read the full Record of the Proceedings and Follow-up Activities, please go to *www.nchh.org/Healthy_Homes_Expert_Panel_Meeting_Minutes_and_Final_Power_Points.pdf.*

Appendix B: Manuscript Review Instrument

Healthy Homes Expert Panel Meeting
Intervention Research Evaluation Form*

Reviewer:______________________________ **Page**____ **of** _____

Rating Factors: 5—Good 3—Fair 1—Poor

(1) (a) Research Area (b) Intervention (c) Title of Article (d) Primary Author	**(2)** Study Design/ Suitability	**(3)** Execution of Study	**(4a)** Study Size	**(4b)** Study Population Study	**(5)** Value of Intervention	**(6a)** Direction (+/-/null)	**(6b)** Degree of Impact	**(7)** Comments and Notes

*This form has been modified from "Assessing the strength of a body of evidence on effectiveness of population-based Interventions in the Guide to Community Prevention Services;" source: *http://www.thecommunityguide.org/pubhealthpro.html*