

# Housing-Related Health and Safety Hazard Assessment

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# 4

**H**ousing conditions should support the health and well-being of its residents; they should not cause injuries or illness.

This simple principle lies at the heart of healthy housing initiatives and recognizes interactions between housing and disease, injury, and overall well being. Identifying unhealthy housing conditions is a prerequisite to correcting them before they negatively impact health.

This chapter provides an overview of inspection and assessment methods, highlights specific tools, and lays the foundation for effective and efficient interventions addressed in Chapter 5. Home-based health hazards can be assessed by: (1) collecting information on occupants' health and housing concerns during resident interviews; (2) performing a visual assessment; and (3) for some hazards, collecting environmental measurements and samples (Figure 4.1). The visual assessment is the cornerstone of the assessment process and can be conducted alone or in combination with the resident interview and/or environmental

## Figure 4.1 Assessment Methods

There are three approaches to identifying health and safety hazards in the home environment:

- Resident Interviews.
- Visual Assessment.
- Environmental Sampling and Building Performance Testing.

## Key Messages

- There are three primary ways of identifying housing health and safety problems: resident interviews, visual assessments, and environmental sampling. Visual assessments are the foundation of the assessment process, while environmental sampling is usually limited because of cost constraints.
- Interviews with residents should be conducted by skilled individuals. The interview can help to inform the visual assessment and environmental sampling, as well as provide an education opportunity.
- Program staff performing these functions must be trained to carry them out properly, understand how to work as an integrated team, and know when to refer a problem to a more highly trained professional.
- Numerous interview and visual assessment tools have been developed. In general, new programs should not change validated, evidence-based tools. Use of common tools ensures consistency.
- The visual assessment covers moisture, ventilation, safety (injury) hazards, combustion safety, pest problems, and cleanliness. It usually begins with the exterior site (including garages), building exterior, common areas (if any), building equipment rooms, building penetrations and proceeds finally to living areas.

measurements. Environmental sampling should be used judiciously as it can be costly. The Department recognizes the need for local jurisdictions to tailor programs based on priorities and end users. While programs are encouraged to use the best tools to meet their needs, the Department is requiring grantees of the Healthy Homes Production Grant program to use HUD's Healthy Home Rating System in an effort to standardize assessment criteria. In order to be considered healthy, a home must support the health and well-being of its residents, and protect against harm caused by health and safety deficiencies. Unless common assessment criteria are used, these definitions are subject to interpretation and wide variability in practice.

Assessing and remediating health and safety risks in housing includes recognizing hazards, assessing their importance, and controlling or eliminating them. Proper assessment of hazards can help your program move to an evidence-based selection of intervention priorities and maximize the impact of limited resources for housing interventions. It can also enable you to determine when a housing unit is in such a

deteriorated state that it cannot be restored to a healthy living environment. Done properly, hazard assessment provides the foundation for detailing which interventions need to be prioritized based on consultations with construction and housing rehab specialists. (Figure 4.2).

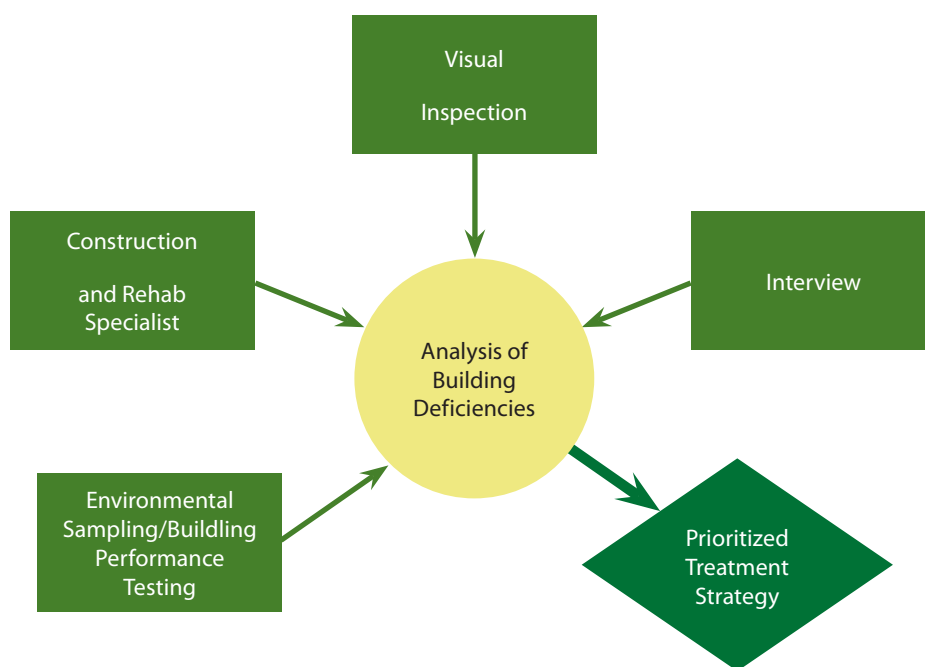
## Resident Interviews

### Purpose

Although some assessments are performed in vacant housing, most take place in occupied housing units. Gaining the residents' perception of the home environment and their health concerns are important sources of information and engages them in creating and maintaining a healthier living environment. A useful checklist for residents is available at: <http://www.surgeongeneral.gov/topics/healthyhomes/checklist.pdf>.<sup>a</sup> Residents'

<sup>a</sup>An additional item not included on the checklist is ascertaining the thermal comfort of the occupants where there may be excess heat or cold due to the lack of proper insulation or inadequate heating/air conditioning.

Figure 4.2 Assessing Building Deficiencies and Outcome



Note: The Prioritized Treatment Strategy reflects the focus of your program (e.g., asthma, energy efficiency, injury prevention) as well as other factors such as identifying imminent health hazards and risks to occupants, resources, intervention costs, and their relation to housing value and level of deterioration.

input can help focus the subsequent visual assessment and environmental measurements that, in turn, will determine intervention priorities.

Resident interviews that gather information on health and environmental problems are useful aids but should not replace a thorough visual assessment. Resident interviews can provide an important opportunity to educate residents on what they can do to improve and maintain a healthy home. Skilled interviewers not only collect data but provide information to residents that can motivate and reinforce good health behavior and discourage unhealthy practices.

## Past Experience

The report, *An Evaluation of HUD's Healthy Homes Initiative: Current Findings and Outcomes*,<sup>1</sup> examined over 50 Healthy Homes grantees from the first four rounds of grant funding (1999–2006). It found 83 percent of these programs routinely conducted multiple assessments and interviews of clients. Resident assessments and interviews usually focused on behavioral information (such as smoking or cleaning habits), health data (such as asthma symptoms), household/resident/family characteristics, and the client's knowledge of specific subject matter. The top three types of data routinely collected as part of the baseline interview were:

- Behavioral information (88 percent);
- Health data (83 percent); and
- Household/resident/family characteristics (81 percent).

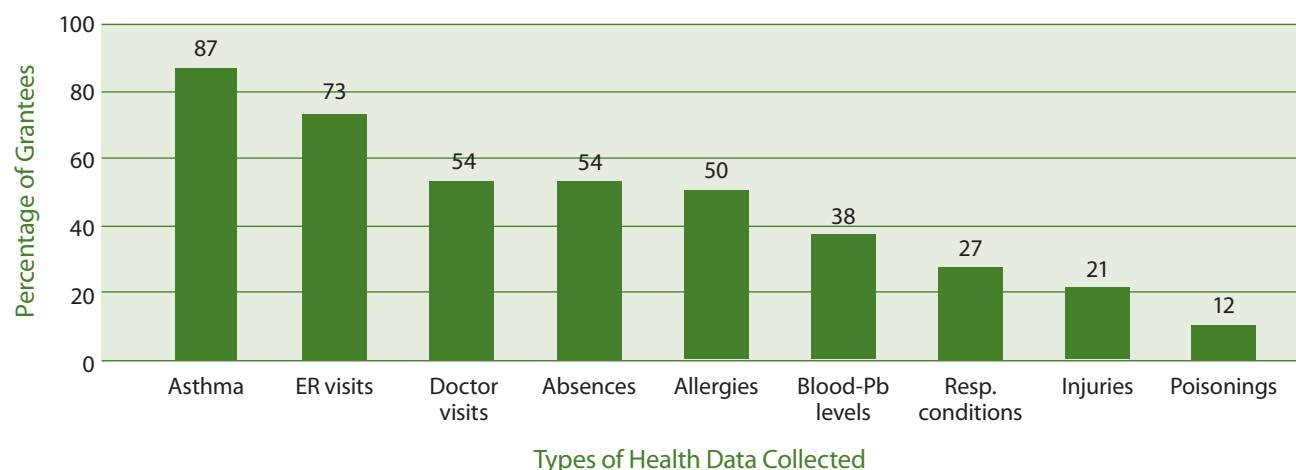
Data were collected most commonly on asthma, emergency department visits, doctor visits, and health-related absences from school or work (see Figure 4.3). These health data sets are often used to assess child and caregiver quality of life. Self-reported data, collected using a validated instrument during an interview, contain valuable information on health status and have proven to be an acceptable way to assess health outcomes associated with housing improvements.

## Interviewer Staffing

Consider carefully who will conduct the interview, keeping in mind the program design and local resources. Interview staff can be health educators, community health workers, community organizers, nurses, social workers, environmental health specialists, health inspectors, housing code inspectors, physicians, or other medical care providers.

Community health workers and organizers are outstanding resources for education and many aspects of research studies. All data collectors should be trained in how to protect confidential

Figure 4.3 HUD Healthy Homes Programs and Type of Data Collected (n=52)



Source: *An Evaluation of HUD's Healthy Homes Initiative* pp. 17–18 and A11–15.

information. It may be difficult for residents to share sensitive information with anyone other than an objective professional.

Many healthy homes programs use a team approach to conduct the assessment—with a health services staff person conducting the interview and a housing services staff person conducting the visual assessment. Some programs have integrated these functions within one person's job responsibilities with appropriate training and support (see Figure 4.4). In some communities, language translation services are required.

## Interviewer Training

It is essential that the person conducting the interview be trained to follow the protocol and prepared to handle various interview situations. Training should include content education,

### Figure 4.4 Examples of Healthy Homes Assessment Methods

Kansas City Children's Mercy Hospital Environmental Health Program's intensive assessment takes two hours to complete and is conducted by two staff members. While the environmental hygienist conducts environmental measurements and collects samples, another staff member (respiratory therapist, health educator or social worker) provides education and case management.

Healthy Homes and Babies Program in Cleveland uses computerized tools such as PDAs (personal data assistant) and tablet personal computers to collect environmental assessment data. The computerized assessment tool guides the inspection in each area of the home, documents building and behavioral conditions through drop-down alternatives to document observations, lists options for corrective actions, and can specify the responsible party for each.

Environmental Health Watch (EHW) in Cleveland uses visual assessments as an opportunity for occupant education. As EHW inspectors conduct the assessment, they are accompanied by the resident and provide education on identified hazards, intervention options, and resident responsibility.

role playing, an explanation and practice of standardized methods of documentation, and cultural competence. The training should also teach interviewers and other healthy homes professionals to understand the limits of their expertise, such as when to refer a suspected problem to a structural engineer or medical professional (see Figure 4.5).

## Interview Documentation

Documentation calls for recording information in a manner that is accurate, legible, and understandable so that others can interpret the results. The following guidelines are helpful:

- Entries onto interview data collection forms (and all other data collection forms) should be made in ink.
- Any corrections should be made with a single line through the mistaken entry and initialed by the interviewer.
- Interviewers should also sign and print their names on the forms in case clarifications are needed. This practice promotes a sense of the importance of the data collected.
- Provide a "notes" section on the form where any pertinent information, including deviations from the standard interview method, can be recorded. No interview form can fully capture all potentially important information.

Much of this data collection is now automated through the use of computer tablets and other

### Figure 4.5 Promotoras: Healthy Homes Training Model

Esperanza Community Housing Corporation in South Central Los Angeles employs community health promoters—promotoras—to conduct outreach, education, case management, and environmental assessments. Promotoras have been found to be effective in reaching underserved populations through peer education since they are members of the communities they serve and speak the same language. The promotoras participate in a six-month intensive Community Health Promoters Training program and receive ongoing specialized healthy homes education.

electronic data collection devices. This reduces the time needed for data entry and can also reduce data entry errors. Using a centralized database to upload data can also save time and prevent errors.

## Quality Control/Quality Assurance

A supervisor or project coordinator should review documentation periodically for completeness and conduct quality control site visits to observe interviews and provide training and support if needed. When interview information is entered into a database, quality control checks should be included in the data management protocol. This might include randomly reviewing data to ensure that the data entered match the data on the forms, double-keyed data entry (data entered twice), or using a statistical program that can be programmed to check data accuracy, such as ACCESS.

Quality assurance procedures should also be included in the interview process. For example, some interviews can be observed by a supervisor to determine whether the interview results are properly recorded, all questions are being asked, and if the interviewer has established a relaxed but thorough interaction with the person being interviewed.

More broadly, programs should have a Quality Assurance Plan (QAP) in place to ensure that all program activities are consistent with established program plans and carried out in the most effective and cost efficient manner possible. A QAP template that should be used by HUD Healthy Homes programs is available at <http://www.hud.gov/offices/lead/hhi/hhts.cfm>. The QAP, which is most appropriate for programs that are conducting rigorous outcome evaluations, has four components:

- Project Management Plan
- Measurement/Data Acquisition Procedures
- Assessment/Oversight Activities
- Data Verification and Usability Confirmation

## Managing Confidential Data and Resident Concerns for Privacy

The interview provides an opportunity to help residents understand the scope of the program

and what it will and will not do. It also points to housing conditions that will be considered for interventions. The interviewer should inform the resident about how the data will be used and delineate how private and confidential information will be protected. Although a research project involving an Institutional Review Board (IRB) will likely require more formalized protection of this information at a later date, the resident's expectation of confidentiality should be explicitly confirmed by the interviewer at the beginning. Regardless of whether a given project is under the purview of an IRB, which ensures the privacy and ethical nature of research studies, the interviewer should make it clear that residents are not required to answer any question they feel uncomfortable with, and that they can stop the interview at any time. Individuals attending the interview, including translators, should also understand the confidential nature of the process. The interview must be conducted in a professional, courteous manner that respects the resident's dignity and culture. Data should be securely stored and managed; access to the data should be limited and electronic data should be stored in secure, password protected files.

## Interview Tools

There are several healthy homes interview instruments that have been field-tested and found useful in characterizing health status and housing conditions (see Figure 4.6). One is the HUD/CDC Healthy Homes Inspection Manual.<sup>2</sup> A longer, more detailed instrument designed for research projects is drawn from the CDC National Health Interview Survey and other national surveys and was developed jointly by the National Center for Healthy Housing and CDC staff. Variations of this instrument have been used in two studies that document health improvements associated with green, healthy housing rehabilitation of low-income housing and elsewhere.

Each has strengths and weaknesses. Healthy homes programs should evaluate existing tools and methods to determine which elements of each can be adapted to their programs and local conditions. For example, the Seattle-King County interview is focused on asthma while Cleveland's interview focuses on mold and moisture. If existing tools are not used,



Figure 4.6 Examples of Healthy Homes Interview Instruments

- Healthy Homes Inspection Manual (Section 1)
- NCHH adaptation of National Health Interview Survey for Housing Conditions
- Boston, MA Healthy Homes Interview
- Cuyahoga County, OH (near Cleveland) Mold and Moisture Interview
- Seattle-King County, WA HomeBASE Interview
- New York State Healthy Neighborhoods
- Newport, RI Healthy Homes Health and Visual Assessment
- Healthy Homes Training Center: Pediatric Environmental Home Assessment.
- NIEHS Injury Assessment Questionnaire
- SF-8 Quality of Life Survey <http://www.sf-36.org/tools/sf8.shtml>
- Allies Against Asthma, Asthma Core Caregiver Survey [http://asthma.umich.edu/media/eval\\_autogen/core\\_caregiver.pdf](http://asthma.umich.edu/media/eval_autogen/core_caregiver.pdf)

interview instruments need to be developed with your program's housing intervention and desired outcome in mind. Be mindful that if you change a tool that has been widely used, your changes may compromise its reliability. In general, creating your own assessment tool is not recommended.

## Interview Data Security

Completed interview forms may contain personal information. To prevent inadvertent disclosures of this information, secure the data by keeping forms in a locked file cabinet or a locked room, limiting access to the data to specified staff, and establishing a data retention schedule to destroy the information at a designated time after the project ends. Unique identifiers can be used to protect an interviewee's identity. Finally, anyone who collects or has access to personal health information should sign a confidentiality agreement that such information should not be disclosed to unauthorized parties. Training

on protection of human subjects is available at: <http://phrp.nihtraining.com/users/login.php>.

## Visual Assessment

### Purpose—Identify Housing Defects and Causes

Visual assessments by trained individuals have emerged as the primary assessment tool for most housing conditions related to health (see Figure 4.7). This system works best for visible hazards such as missing or deteriorated building components and systems. It can also identify causes of hazards and how they are likely to be remediated. The visual assessment should be integrated with the interventions (discussed in Chapter 5). Missing hand railings, leaking pipes under a kitchen sink, and openings that permit pest entry are obvious examples of problems amenable to visual examination. There is an emerging consensus that most mold problems can be identified by a visual assessment. Of course, the eyes are not the only senses that should be used. For example, mold is often associated with a musty odor and has been linked with adverse respiratory health outcomes in large studies.<sup>3, 4</sup> The rotten-egg odor of hydrogen sulfide from sewer gas is also well known. The odor of natural gas can indicate a dangerous gas leak. Although some protocols have a simple “yes” or “no” response, most conditions require some assessment of the severity of each observed hazard. Digital photography of units can be helpful in documenting specific conditions. Programs should obtain permission from the resident to take photographs, which should then be included in the project file with other documentation.

### Limitations of Visual Assessment and Training Needed

Visual assessments should be performed only by trained personnel and criteria should be developed for enlisting specialized assistance (Figure 4.8 describes one source of available training). Some housing hazards are not amenable to sight and smell assessment. For example, the pipe leak under the kitchen sink may not be obvious if the leak begins three



levels up or the water is pooling behind a wall and the leak is sporadic, which might be the case for an infrequently used drain. Radon and carbon monoxide are examples of contaminants that cannot be assessed visually. To assess hidden structural defects, programs may need to employ engineers or electricians when problems include inadequate or missing grounding or other faulty wiring.

## Scope

Visual assessments can evaluate many structural, environmental, and behavioral risk factors. For example, many ventilation problems can be identified visually, such as inoperable bath or kitchen exhaust fans or disjointed flues on water heaters (a structural problem). However, if the bath fans are operational and there is still a large mold problem, it may be that the resident is not turning the exhaust fan on when needed or it may not be ducted to the exterior. Similarly, no amount of ventilation will prevent the health hazards associated with tobacco smoking (behavioral problem). In short, visual assessments can provide clues to occupant behavior that can cause or exacerbate hazards.

Visual assessments should document the tenure of the unit (rental versus owner-occupied),

if the unit is occupied or vacant, the type of structure (such as manufactured housing, or duplex, single- or multi-family housing), type of ventilation and air conditioning system, type of foundation, and whether the basement is treated as a living space.

How your program performs a visual assessment depends to some extent on your target housing. For example, assessing the structural condition of row homes may differ from stand-alone single family housing due to the presence of shared walls. If the dwelling is a multi-family home, the common areas (if present) should be included in the visual assessment. Similarly, if the dwelling is a mobile home, it might be prudent to check the tie-down systems. Tie-downs are an example of why the assessment should be driven by the type and location of housing. In earthquake zones, for example, seismic retrofits may be needed.

The type of water supply and sewage system should be determined. In rural areas, well water should be tested periodically to ensure it is potable and tile fields/septic systems may need assessment for adequate treatment of waste water. Crawl spaces and attics should also be included in the visual assessment.

## Sequencing Areas

Experience and studies have found a standardized sequence increases the accuracy of an assessment and reduces omissions when pinpointing building deficiencies. Checklists and/or documentation should mirror the sequence. Figure 4.9 and the

### Figure 4.7 Most Frequent Hazards Identified by Visual Assessments

An Evaluation of HUD's Healthy Homes Initiative: Current Findings and Outcomes reported 81 percent of 51 Demonstration and Technical Studies programs conducted visual assessments. The five most frequently reported hazards assessed included:

- Presence of visible mold and moisture problems (96 percent);
- Pest infestation (82 percent);
- Lead hazards/chipping peeling paint (72 percent);
- Fire hazards (69 percent); and
- Carbon monoxide hazards (67 percent).

An Evaluation of HUD's Healthy Homes Initiative, 2007, pp A9–11.

### Figure 4.8 Training for Healthy Homes Practitioners

The National Healthy Homes Training Center's Essentials for Healthy Homes Practitioners course provides an introduction to the concept of the house as a system. The course prepares participants for a comprehensive exam to receive National Environmental Health Association accreditation as a Healthy Homes Specialist. The training is not required to sit for the exam. See <http://www.nchh.org/Training/National-Healthy-Homes-Training-Center.aspx>

following discussion detail a recommended sequence enabling inspectors to examine areas methodically and assess common features efficiently.

First, examine the general site on which the building is located for common hazards such as pooling of water, damaged fencing (or lack of fencing, especially around swimming pools), erosion, extensive plant overgrowth, sidewalk cracks, and safety of play area equipment. Inspect garages and other structures during this phase of the inspection.

Second, examine the building envelope (walls, roofs, doors, windows, etc.) and exterior for items such as: leaks from deteriorated caulk; gaps in doors that might enable pest entry or water incursion; broken or inoperable windows; bulging walls; sagging rooflines; damaged or missing trim (fascia and soffits) or flashing; and problems with gutters.

Third, examine the “guts” of the home, which consists of the equipment room where the HVAC (heating, ventilation, and air conditioning), laundry, electrical, and other systems are located. Items such as fuel leaks, misaligned flue vents, the absence of makeup air (e.g., air that is supplied to a space to replace the air that is exhausted), damaged or frayed electrical wiring

or burn marks on fuse or electrical breaker boxes, and faulty fire protection systems (e.g., painted-over sprinkler heads) are examples of items to be examined.

Fourth, proceed into the living area of the house itself, which can be divided into “wet” rooms (kitchens and baths), bedrooms, and living areas. Some of the items to be assessed in these areas include leaks and drains; cracks in walls, floors and ceilings; water temperature (120° Fahrenheit or lower); trip hazards; paint condition; mold; overuse of extension cords (overloaded circuits); broken electrical sockets; presence of unvented fuel-fired space heaters; and inadequate food preparation, storage, and disposal facilities. Evidence of pests, such as mice and cockroach feces (frass), is typically assessed in these locations. Smoke and carbon monoxide alarm operation should always be tested. Visual assessment should include the stairways that service the living space.

Fifth, examine all penetrations into the house from the inside to the exterior. Healthy homes inspectors should be trained to recognize the limits of their expertise. For example, they should not touch electrical systems unless adequately trained. Inspectors should also avoid tracking contaminants, soil or dirt from one area to another (e.g., from crawl spaces into bedrooms). Some ventilation problems require specialized building science or engineering expertise. Training in lead risk assessment is recommended and required by most jurisdictions for assessment of lead-based paint hazards.

#### Figure 4.9 Recommended Sequence for Visual Assessments

1. Site (including entrance and egress).
2. Garages (attached and non-attached) and other site structures (e.g., sheds and fences) and facilities (e.g., swimming pools, play areas).
3. Building exterior.
4. Common areas (multifamily housing only).
5. Equipment rooms (HVAC, laundry, basements, crawl spaces, attics).
6. Kitchens.
7. Baths.
8. Living areas.
9. Bedrooms.

### Healthy Home Rating System

While programs are encouraged to use the best tools to meet their needs, HUD is requiring grantees of the Healthy Homes Production Grant program to use HUD’s Healthy Home Rating System (HHRS) in an effort to standardize assessment criteria. The HHRS is categorized in accordance with the American Public Health Association’s 1938 publication entitled, “Basic Principles of a Healthful Housing.” Using the HHRS, the assessor examines 29 hazards, or categories of hazards, and determines the risk to the occupant (i.e., the likelihood of hazard causing harm and the severity of the harm should it occur) for each hazard that is identified

(see Figure 4.10 and Operating Guidance at: <http://www.hud.gov/offices/lead/hhrs.cfm>). Each of the 29 hazards are assessed separately and weighted according to likelihood of occurrence and the severity of possible outcomes should the hazard result in harm (i.e., a risk-based approach in which a numerical value is generated for each hazard). The HHRS is available for use by those not receiving HUD grant funds, as well.

A priority ranking of hazards is generated based on the estimated risks of potential harm to the most vulnerable occupants. Inspections are essentially carried out in the traditional fashion (i.e., a physical assessment of the whole property for deficiencies) using a portable computer with specialized software. The HHRS follows the same approach to identifying health and safety hazards in the home as successfully implemented in the British “Housing Health and Safety Rating System” (<http://www.communities.gov.uk/publications/housing/housinghealth>). The basic principle is that the property should be safe and healthy for all occupants.

The assessment using the HHRS is made based on the condition of the whole dwelling. This means that, before such an assessment can be made, a thorough inspection of the dwelling must be carried out to collect the evidence of the condition. While this does not involve a new approach to the inspection

of dwellings, it does require an understanding and appreciation of the potential effects that could result from conditions and deficiencies that should have been identified during the inspection.

The HHRS concentrates on threats to health and safety. It is generally not concerned with matters of quality, comfort and convenience. However, in some cases, such matters could also have an impact on a person’s physical or mental health or safety and so can be considered. Also, as the Rating System is about the assessment of hazards (the potential effect of conditions), the form of construction and the type and age of the dwelling do not directly affect the approach taken in the assessment. The age of the dwelling would be a consideration when assessing for lead hazards, for example, but would not alter the overall approach taken in terms of evaluating the hazards present. Matters related to age and type of construction will be relevant to determining the cause(s) of any problem and so indicate the nature of any remedial action.

The HHRS has been devised and designed so that it can be applied to any form of dwelling. To achieve this, it is only necessary to inspect and assess the dwelling and those parts and areas (whether shared or not) that are associated with that unit.

Once the inspection has been completed, the

Figure 4.10 Healthy Home Rating System (HHRS)—Categorization of 29 Hazards

Physiological	Psychological	Infection	Safety
1. Dampness & Mold Growth	11. Crowding and Space	15. Domestic Hygiene, Pests, and Refuse	19. Falls in baths etc.
2. Excess Cold	12. Entry by Intruders	16. Food Safety	20. Falls on the level
3. Excess Heat	13. Lighting	17. Personal Hygiene	21. Falls on stairs etc.
4. Asbestos and man-made fibers	14. Noise	18. Water Supply	22. Falls from windows etc.
5. Biocides			23. Electrical hazards
6. Carbon Monoxide			24. Fire hazards
7. Lead-based paint			25. Hot surfaces etc.
8. Radiation			26. Collision/Entrapment
9. Un-combusted fuel			27. Ergonomics
10. Volatile organic compounds			28. Explosions
			29. Structural collapse

inspector makes the assessment. This involves:

- (a) determining whether there are any deficiencies present by assessing whether each dwelling element and the dwelling as a whole meets the relevant Ideal;
- (b) determining whether any deficiencies contribute to one or more hazards, and if so, which hazards; and
- (c) for each hazard which is obviously worse than average for that type and age of property, the inspector assesses:
  - i) the likelihood of an occurrence over the next twelve months; and
  - ii) the probable spread of harms which could result from such an occurrence.

It is important to note that the HHRS only assesses the physical aspects of the home; it does not collect information on occupant behavior that can contribute to some hazards (e.g., misuse of pesticides), nor does it incorporate environmental sampling results. If desired, programs can supplement the HHRS with a resident questionnaire and a plan for collecting environmental samples and measurements.

For more information on the Healthy Homes Rating System, refer to the Operating Guidance available at [www.hud.gov/healthyhomes](http://www.hud.gov/healthyhomes).

## Major Housing Conditions to Assess Visually

Conditions to be assessed visually include:

- Moisture
- Ventilation Systems and Combustion Sources
- Safety Hazards
- Structural Defects
- Insulation and Temperature Regulation
- Pest Infestation\*
- Cleanliness and Clutter

(\*Investigation of pest problems is also covered in the building performance section of this chapter, because it involves the use of certain traps and other tools. A more complete

discussion appears in the HUD/CDC Healthy Homes Inspection Manual<sup>5</sup> and the HUD/CDC Healthy Housing Reference Manual.<sup>6</sup> Additional technical information is available in EPA's Indoor airPLUS Construction Specifications: [www.epa.gov/indoorairplus/construction\\_specifications.html](http://www.epa.gov/indoorairplus/construction_specifications.html)).

## Moisture

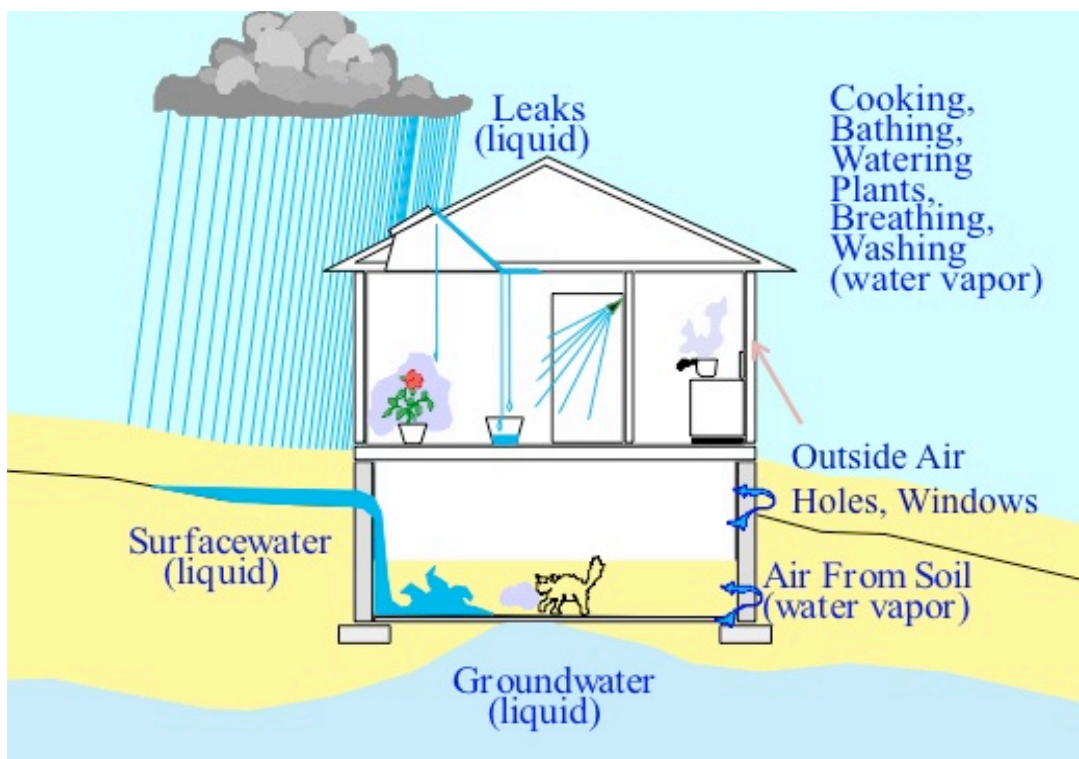
Excessive moisture in housing has been related to a number of adverse health outcomes. Structural rot, rust, and other degradation can result in physical injury hazards as well as slips and falls from slippery surfaces. Moisture in housing can amplify indoor levels of biological agents such as mold, dust mites, and pest populations, many of which can trigger asthma and allergy symptoms.<sup>7</sup> Excessive moisture is also one of the leading causes of deteriorating lead paint.

Many moisture problems can be identified visually:

- Look for discolored or wet walls ceiling and walls;
- Identify missing or damaged downspouts and gutters;
- Check for ponding near foundations;
- Examine exteriors for holes and cracks;
- Look underneath sinks for drain and plumbing leaks;
- Determine if air conditioner condensate drains are operating and sloped;
- If humidifiers are present, determine if they are clean;
- Look for condensation on windows in cold weather; and
- Look in basements for water damage and entry.

In addition, while there may not be obvious visible signs of moisture, the presence of a strong musty smell may indicate the presence of mold from excess moisture/water leaks. The National Academy of Sciences examined the association between exposures to biologic agents in the home and the development and exacerbation of asthma. The review found sufficient evidence to establish a causal association between asthma and dust mite exposure as well as between asthma exacerbation and the presence of

Figure 4.11 Ways in Which Water Can Enter a Building (Envelope leaks can occur from anywhere in the building roof, windows, walls, doors and penetrations)



dust mites, cockroaches, fungi (mold), and pet dander.<sup>8,9</sup> There is also evidence of associations between excessive moisture and other adverse respiratory outcomes.<sup>10</sup> Mice and cockroaches spread allergens that can trigger asthma suffered by both inner-city and suburban children.<sup>11, 12, 13</sup>

Moisture problems can be typically assessed by trained individuals through direct visual observation. The CDC/HUD Healthy Housing Inspection Manual identifies moisture-related building deficiencies such as discolored ceiling tiles, presence of visible condensation (may only occur in the winter), missing or damaged downspouts and gutters, pooling of water near foundations, presence of holes or cracks in building walls, plumbing systems that have inadequately insulated cold water pipes (leading to condensation), and sewage and water drain and supply leaks. Clearly, there are many ways in which water can enter a building (Figure 4.11). Some programs find that using a simple moisture meter helps identify moisture problems along with visual assessment (Figure 4.12).

Homes equipped with air conditioning systems or dehumidifying systems require attention to ensure that condensate drains do not become blocked or contain mold. Additionally, condensate pans need to be properly sloped so that the water runs to the drain and does not pool in other areas. Keeping coils clean can reduce contaminants in the air and also promote energy efficiency.

Figure 4.12 Moisture Meters as an Adjunct to Visual Assessment of Moisture Problems





Unvented combustion appliances, such as unvented space heaters and unvented fireplaces, can introduce substantial amounts of moisture and other combustion products (depending on whether the appliances are properly functioning) into the home whenever the devices are in use.

Some HVAC systems are equipped with humidifiers, especially in northern climates where indoor winter air can be very dry; sometimes individual rooms may be equipped with room humidifiers. In southern climates, the systems may be fitted with a dehumidifier to remove moisture before the conditioned air enters the home. In both cases, the water supply, water tank, water pads, water wheels, or other distribution systems need to be maintained. If the systems are not used regularly, they can breed biological agents such as mold and bacteria. Drafty homes are often too dry in the winter and too humid in the summer, depending on the climate region. The resident interview can help to determine if there is excessive dryness in the winter and whether boiling pots of water or other measures are used as “home-grown” humidifiers, which may lead to mold problems.

Aside from floods, sources of water and moisture in homes include structural leaks (e.g., roof leaks), plumbing leaks, condensation, damp foundations and crawl spaces, inadequate ventilation, and activities such as bathing and cooking. Condensation is often linked to inadequate insulation, inadequate vapor barriers (in cold climates) and/or poor ventilation. Unless moisture-laden air is exhausted from the home, building envelopes that are “tightened” for energy conservation purposes may lead to excessive indoor moisture levels.

Other sources of moisture can foster problems, such as capillary action that “wicks” moisture from basement floors up into certain types of walls (such as drywall, paneling, or other cellulose-based materials touching concrete basement floors). Excessive crowding may also produce high moisture levels.

Interior moisture levels are strongly influenced by exterior conditions, making a uniform definition of acceptable interior moisture levels dependent on climate zones. In general, maintaining an indoor relative humidity between 30–50 percent (lower in the winter and higher in the summer) optimizes comfort and improves indoor air quality

by reducing dust mite and mold growth. Water content (sometimes called “water activity”) of building components can be measured with a moisture meter (Figure 4.12) but be mindful of the fact that building materials have differing amounts of water activity. For example, plaster or concrete hold much more water than drywall, so interpreting moisture meter readings is typically dependent on the type of material.

Local exhaust ventilation for bathrooms and kitchens should be present and properly installed and maintained, and, of course, actually used. Many building codes do not require such systems if windows are present. However, if windows are kept shut during peak water use (such as bathing when the outdoor temperature is too cold or hot), moisture has nowhere to go other than the rest of the living area. Kitchens also benefit from local exhaust by removing excess moisture from cooking and by removing combustion gases from fuel-fired stoves and ovens.

If installing new fans, use quiet “low sone” Energy Star-rated products, because residents are less likely to use noisy fans. Moist air should be exhausted to the outside, never into a building cavity, attic, basement, or crawl space. New and rehabilitated houses increasingly equip local exhaust fans with timed humidistats that automatically operate the exhaust fans when moisture increases to a certain level. This conserves energy and reduces the need to rely on resident behavior. Fans should be properly sized (Figure 4.13).

#### Figure 4.13 Fans Should Fit the Building Configuration

The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommends that kitchen fans exhaust 100 cubic feet per minute (cfm) and bathroom fans exhaust 50 cfm (see <http://www.ashrae.org/technology/page/548>).

Actual fan performance depends on the duct configuration and other factors that contribute to the pressure drop (resistance) in the system. For example, a fan rated at 50 cfm located in a basement bathroom that has to push air through several stories before being exhausted may not move sufficient air.

When installing exhaust ventilation for kitchens and baths, the issue of supply (makeup) air matters. If sufficient makeup air is not available, it can create negative pressure in the home. If there are combustion appliances, this negative pressure can cause “backdrafting”—the reversal of airflow in chimneys, water heaters, and other devices. Backdrafting results in carbon monoxide and other combustion products being released into the living space. An example of makeup air is the passive or powered delivery of outside air into a basement that has a furnace, boiler, or gas water heater. Another is a heat recovery ventilator that permits tempering of the outside air supply using the energy of air being exhausted. Both examples involve a planned fresh air supply to replace the exhausted air (Figure 4.14).

### Exterior Grading and Pooling

Water penetration into a building often occurs at the foundation and ground level. Evidence of standing water, pooling, or erosion usually means failure to slope and grade the soil and ground properly around the foundation (Figure 4.15). Maintaining proper grading around a foundation can prevent moisture intrusion into basements and the need for expensive foundation waterproofing and excavation. Proper grading also supports the durability of the structure by reducing the prospect of settling that leads to cracks.

### Ground Treatment

Bare earth floors in a basement or crawl space should be covered with a durable vapor retarder—such as 6 mil or thicker polyethylene plastic—covering the

Figure 4.14 Backdraft Deficiencies

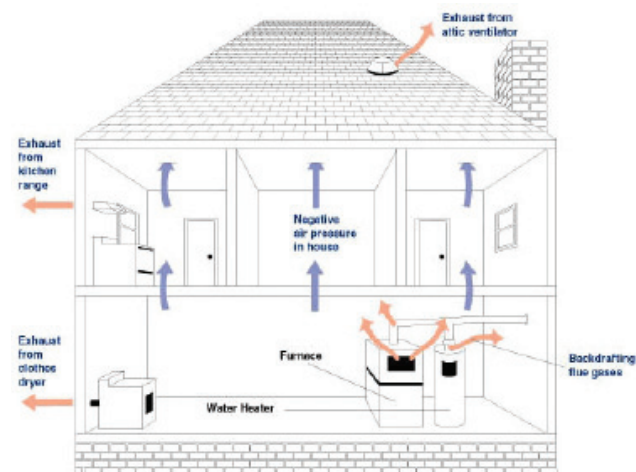


Figure 4.15 Moisture Problems Caused by Improper Ground Slopes



entire soil area and sealed to the foundation walls and piers. In some parts of the country, a thin concrete slab is poured over the poly to protect it. Called a “rat slab,” the concrete prevents rodents from burrowing through the poly and entering the space. The visual assessments should determine if the bare earth is covered.

### Water Pipes

Water pipes located in unconditioned areas should be insulated to prevent condensation. One way of detecting this problem is to look for areas of discoloration where condensation from pipes has dripped onto a lower surface. The same principle applies to ductwork that carries warm or cold air through air zones with a high temperature gradient.

### Ductwork

All ductwork should be sealed and well insulated. To prevent condensation, the insulation should be protected by a vapor retarder depending on the climate zone. Insulation should be applied to the exterior of the ductwork to keep insulation fibers out of the air stream and reduce the opportunities for dirt and debris to build up inside the ductwork, which creates a habitat for mold and other organisms. While insulation of ductwork is a simpler matter in new construction, poor insulation of ductwork in older housing can result in condensation and become a significant breeding ground for mold and other biological agents.

### Flashing

The absence or deterioration of flashing is a common building deficiency associated with



water leakage through the building envelope. Flashing refers to thin continuous pieces of sheet metal or other impervious material installed to prevent water from leaking into a structure through an angle or joint. Flashing is appropriate in numerous building situations:

- Roof penetrations such as chimneys;
- Places where walls meet a roof line;
- Valleys between opposing roof surfaces;
- Wall penetrations such as windows or ventilation hoods; and
- Other structural discontinuities such as additions.

When new building components such as windows are installed, they should be installed with flashing to prevent moisture intrusion. The key design requirement of flashing is its assembly in a manner that allows flashing layers to use gravity to shed water rather than rely on caulks or sealants. The principle of flashing should be extended to all penetrations in structures—i.e., they should be sealed to prevent moisture and pest incursion into the living space. Moisture meters and visual assessment can sometimes be used to assess the adequacy of flashing, although it is not always possible to see if flashing is present without removing building coverings, which is not recommended. If moisture meters or visual assessment results identify building components with excessive moisture, defective or absent flashing may be a cause.

### Condensation

Evidence of window condensation also deserves special consideration (Figure 4.15). Depending on the indoor and outdoor temperature and humidity levels, condensation may not be present at the time of an inspection. Condensation can occur when air that is sufficiently warm and moist comes in contact with a cold surface. The water created through condensation can lead to mold and other problems that create both health hazards and building decay.

Condensation often occurs on windows because the window is not adequately insulated and it is the coldest surface. Modern double- and triple-pane windows, some filled with inert gases between the panes, effectively eliminate condensation problems on windows when

properly configured for the specific building application, orientation, and climate. Such window replacement also has the benefit of removing a major source of lead-based paint exposure, as old single pane windows are known to have the highest levels of lead-contaminated dust and paint of any other building component. If old windows coated with lead-based paint are replaced, lead-safe work practices must be used.<sup>14</sup>

Sometimes condensation occurs within the walls, ceilings, and floors that separate the outside unconditioned air from the conditioned air inside the structure as warm moist air travels through the cavity. Crawl spaces, attics, and exterior walls can be subject to such condensation.

In some cases a vapor retarder—often called a vapor barrier—is recommended to inhibit condensation or other sources of moisture intrusion by reducing the movement of moisture-laden air into walls, ceilings and floors. However, vapor retarders require some careful thought and are dependent on climate zone and other factors. If an insulated wall has materials on both the interior and exterior surfaces that retard vapor movement, moisture can become trapped within the wall cavity and cause a serious problem. Walls should be designed to have the ability to dry in at least one direction. If a mold problem is identified, vapor retarder problems may be the cause.

### Drains

As important as entry of excess moisture into a building is, how water exits the housing structure is equally as important. Drains are often overlooked as important sources of moisture because the leak may be a slow one. Drain traps, like all plumbing, deteriorate over time. If drain traps are not kept full of water, harmful soil or sewer gases can enter the living area. If an odor is detected, dry drain traps may be the cause. Basement floor drain traps should be kept full by periodically adding water into them (Figure 4.16).

### Other Moisture Sources

Metal windows and door casings directly touching sheetrock can lead to moisture problems. Inadequate insulation or leaks from old caulking can be related to condensation and moisture problems. Furniture that is pushed up directly against exterior walls, especially in rooms

Figure 4.16 Floor Drain Traps



that are below grade, can foster mold growth by reducing air movement. Inadequate ventilation and moisture problems are often closely related. The following sections on ventilation and environmental sampling and building testing contain additional information on identifying moisture and ventilation problems.

### Ventilation System and Combustion Sources

Many ventilation system problems can be identified visually.

- Look for discoloration on carpets under doors. This suggests air pressure differences between the two rooms may be too high (i.e., the carpet is acting as a filter for the air as it moves from the higher to lower pressure space).
- Check for pooling or ponding of water near air intakes that may cause moisture to infiltrate the building.
- Check whether an attached garage has doors that lack seals or other holes between the garage and living space. This allows for carbon monoxide (CO) and other combustion by-products and Volatile Organic Chemicals (VOCs) to enter the living space.
- Identify whether an exhaust vent is located too close to a supply vent. If so, the air can be “short-circuited,” meaning that instead of mixing with the supply air and diluting contaminants, it enters the room and is immediately exhausted.

- Identify ducting problems (too many twists and turns), disconnected ducts, and leaky ductwork.
- Identify misaligned, cracked, corroded or disconnected chimney and water heater flues.
- Check that bathroom, dryer, kitchen, and bathrooms have exhaust systems.
- Make sure all the exhaust ducts go all the way through the building envelope to the exterior, especially clothes dryers and kitchen and bathroom exhaust.
- Identify any unvented combustion appliances and determine if all existing combustion appliances are vented properly.
- Make annual inspections of gas and wood and other fuel burning appliances and their venting systems to prevent poisoning by combustion gases.
- Assess homes for the presence of properly working carbon monoxide and smoke alarms located near all sleeping areas.
- Additional information on testing ventilation systems is covered in the Building Performance section of this chapter.

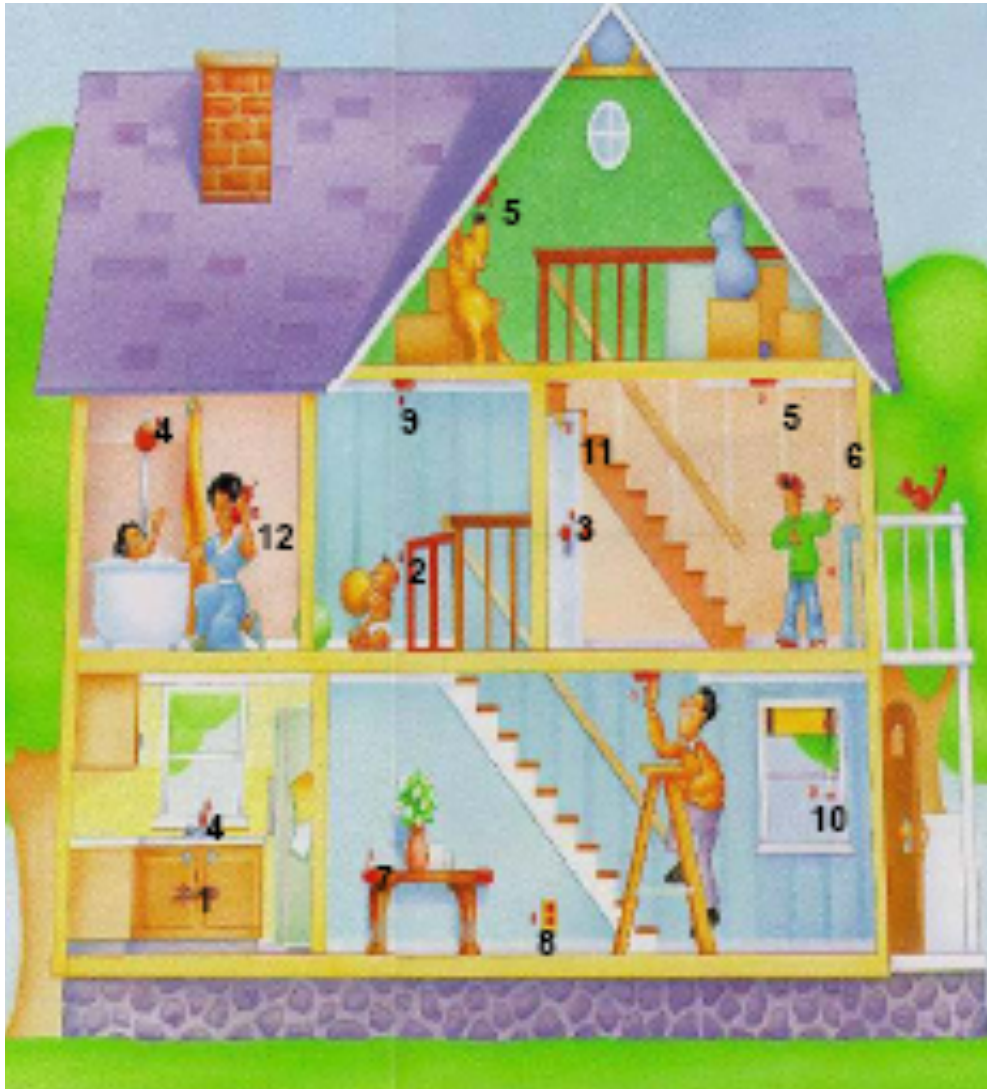
### Safety/Injury Hazards

Injury hazards can be identified through home safety questionnaires and/or home inspections such as those detailed in the HUD/CDC Healthy Housing Inspection Manual. Questionnaires focusing on the presence or absence of certain safety devices (e.g., CO alarms, smoke alarms, ground fault circuit interrupters (GFCI) and arc fault circuit interrupters) are generally more reliable than responses to questions about safety practices (e.g., safe medicine storage).<sup>15</sup> Users have found the HOME Injury Survey, a 55-item tool that quantifies unintentional injury hazards in the indoor environment of homes with young children, to be reliable, valid, and reproducible<sup>16</sup>. Figure 4.17 illustrates categories of home injury hazards.

### Falls

Bathrooms, stairs, windows, and outdoor play equipment should be evaluated to ensure that safety devices such as grab bars and non-slip surfaces are installed, especially for the elderly; that safety gates are used to block

Figure 4.17 Main Injury Hazards in the Home



### Assess for the Presence of These Items

1. Safety latches and locks for cabinets.
2. Safety gates.
3. Door knob covers and door locks.
4. Anti-scald devices for faucets and showers.
5. Smoke detectors on every level of the home.
6. Window guards and safety netting.
7. Corner and edge bumpers.
8. Outlet covers and outlet plates.
9. Carbon monoxide (CO) alarms outside bedrooms.
10. Window blind cords secured.
11. Door stops and door holders.
12. Cordless phones make it easier to continuously watch young children.

stairs for children; that windows presenting fall hazards have permanent window guards affixed; and that outdoor play equipment is placed on an impact-absorbing surface. Stairs should be evaluated for structural defects and the presence of adequate railings on both sides. Cords that present trip hazards should be moved and secured. Throw rugs should be attached to the floor or used with non-slip pads to secure them. Also, check for trip hazards related to changes in elevation, such as with steps, ramps, or where there is a change in surface level. The visual examination should also check for adequate lighting over steps and other uneven surfaces.

### Poisoning/ Storage of Household Chemicals

The visual examination should examine how household chemicals are stored and whether or not they are within the reach of children. In homes with, or visited by, young children bathrooms and kitchens should be assessed for the presence of safety locks on cabinets that contain medicine and dangerous substances, such as cleaning supplies or biocides to control pests. These types of products should not be stored with food supplies. Flammable and volatile substances such as gasoline and paint thinner are best stored in a detached building such as a shed or garage. All pre-1978 homes should be inspected for deteriorated lead-based paint, lead dust, and soil-lead hazards. Home visitors can be easily trained to visually identify deteriorated paint and refer these potential hazards to trained inspectors or risk assessors.

### Fire and Burns

Homes should be inspected for the existence of at least one smoke alarm on each floor, including the basement and outside each sleeping area. Smoke alarms should be mounted high on walls or ceilings and away from windows and doors. It is not recommended that smoke alarms be installed in kitchens since they are more likely to be disabled from this location. Hot water temperature should be measured using a thermometer to ensure that it does not exceed 120°F and water heaters should be set to 120°F. Safety covers for electrical outlets should be used if young children reside in or frequently visit the home.

### Choking

Home environments should be assessed for objects accessible to children that may result in a choking incident. This includes toys with small parts, coins and other small items that could be ingested by young children. Education should be provided related to choke hazards for children and the infirm elderly.

### Drowning

Pools and hot tubs should be inspected for fencing on all sides to prevent drowning. Non-rigid pool covers can also be used to reduce the occurrence of drowning when pools are not in use. Uncovered rain barrels and five-gallon buckets used for cleaning are also a potential danger and should be used with caution when toddlers are around.

### Suffocation and Strangulation

Sleep and play environments should be assessed for safety. The Consumer Product Safety Commission has published mandatory standards for cribs, including requirements for side height, slat spacing, and mattress fit. Co-sleeping (infants sleeping with adults) should be avoided. Toy boxes should be inspected to ensure that they have proper lid supports and window covering cords should be secured and out of reach of children. Plastic bags should be kept out of children's reach.

### Tip-Over Hazards

Furniture and appliances such as televisions that are not well secured represent tip-over hazards to young children in particular. Children can be subject to injuries from tip-overs, in particular crush and head injuries. Home inspectors should ensure that furniture and appliances are stable and not prone to tipping. Large appliances and furniture (e.g., bookcases) should be anchored to the wall and televisions should be on sturdy, low bases and should be pushed as far back on stands as possible. Remote controls, toys, and other items that might attract children should be kept off of TV stands or furniture that represent tip-over hazards.

### Firearms

While questioning families about the presence of firearms may not be comfortable, a discussion about the presence of guns should be initiated



when possible. Guns should be removed from a child's environment. When stored, firearms should be unloaded and ammunition locked up separately from guns. Trigger locks should also be used.

### Structural Defects

The visual examination should include all elements of the structure of dwellings to ensure they are properly maintained to ensure they remain safe and stable. The dwelling should be assessed for signs of structural movement, such as cracks and/or bulges to external walls, open joints in brick, stone or block work, in external walls or chimney stacks. Also look for siding defects, such as loose, missing, or other insecure external finish to external walls, disrepair to lintels/sills, and poor roof conditions, such as sagging, distorted, or missing shingles, and loose missing or improperly fastened gutters/downspouts. The goal is not to make healthy homes assessors experts on building structural issues, rather they should be able to identify possible problems that could be referred to those with more expertise on the topic.

### Insulation and Temperature Regulation

In many climates, poor temperature regulation can result in hazardous conditions, especially for vulnerable populations. Although an assessor may not encounter extreme conditions at the time of the assessment, information on the occupant's thermal comfort can be obtained during the resident interview or by a combination of visual assessment and interview. The visual examination should check for adequate insulation (where possible), the adequacy of caulking and weather-stripping, the age and condition of the heating and/or cooling system, and holes or other voids in the building envelope that should be repaired. In many instances, ventilation from open windows may be limited or non-existent due to concerns with crime or noise (i.e., windows locked or barred shut).

### Cleanliness and Clutter

Because house dust is the primary medium through which residents are exposed to toxins (e.g., lead, pesticides) and allergens (e.g., cockroach, dust mite) it is important that residents engage in regular and effective cleaning. Regular cleaning is also an important aspect of integrated pest

management and is essential in food preparation areas for preventing bacterial contamination of food. Excess clutter can prevent effective cleaning, interfere with IPM implementation, and pose a fall hazard for occupants, especially seniors. Visual assessment instruments should include one or more items for the assessment of cleanliness and clutter and questionnaires often include a question on cleaning habits. A key consideration with this assessment is whether the residents are capable of maintaining cleanliness in the dwelling, or whether other characteristics (e.g., arrangement of furniture, condition of surfaces) interferes with cleaning. For example, the lack of smooth, cleanable surfaces in the kitchen can make cleaning difficult. Clutter may also pose trip or fall hazards and may block access to exits and entrances.

### Hoarding

Compulsive hoarding is a psychological condition characterized by the acquisition of, and failure to discard, a large number of possessions that appear to be useless or of limited value. Hoarding is defined as having the following three components: 1) the acquisition of and failure to discard a large number of possessions that may appear to be useless or of little values; 2) living spaces sufficiently cluttered so that the clutter precludes activities for which those spaces were intended; and 3) significant impairment in functioning or distress caused by the clutter.<sup>17</sup>

Hoarding represents an extreme type of clutter that may result in filth, infestations and serious maintenance problems. Hoarding is only a focus on the number of possessions, and can range from mild to life threatening. Squalor is filth and/or degradation from neglect. Commonly associated with hoarding are health and safety hazards (including building code violations). It is possible to have hoarding and squalor together but both conditions can also exist independently. Many hoarders have one or more other mental health conditions (e.g., depression, generalized anxiety, obsessive-compulsive disorder, social phobia, failure to process or organize information).

Hoarding situations must be handled in a multidisciplinary manner. Healthy homes programs should address hoarding as part of a team that may include the sufferer, family members, the housing provider, local health departments, representatives of the judicial

system, and providers of therapeutic, social and clean-up services. Long-term case management and monitoring is needed.

## Prioritizing Visual Assessment Results

The results of the visual assessment should be presented as a prioritized list of items requiring repair or remediation. Priorities depend to some extent on the program's focus but the level of health risk posed by the condition must be considered regardless of the focus. Hazards that

might result in immediate harm or death must be corrected first. Although there is no universally accepted system of weighing each item for its likely health impact, two rating systems have been used.

As mentioned previously, HUD's Healthy Home Rating System uses an approach that prioritizes health hazards based on the likelihood of the hazard resulting in harm, and the extent of the harm should it occur.

Healthy Homes programs have used a variety of methods for prioritizing the results of the visual

**Table 4.1 Priority List of Better Homes for Asthma (adapted from Seattle/King County Health Department)<sup>18</sup>**

High priority items are indicated with an [A] and lower-priority items with [B] or [C].

Description
Vent clothes dryer to exterior using rigid metal ducting, not flexible plastic. [A]
Repair plumbing leaks [A]
Correct mold problems [A]
Clean evaporator pan under refrigerator [A]
Install range hoods that vent to exterior [A for gas; B for electric]
Repair dry floor drain traps if sewer gases detected [A]
Assure that at least one window in each room can open [A]
Remove basement, bath and kitchen wall to wall carpet [A]
Install smoke and carbon monoxide alarms [A]
Repair deteriorated bath and tub caulk [B or C]
Install pleated filter in forced-air heating system. [A]
In the crawl space, seal /cover soil with poly. [A]
Seal crawl space from house air. [A]
Assure adequate runoff from downspout away from house. [A: wet walls; B: other]
Caulk windows. [A]
Caulk wood siding vertical seams. [A]
Caulk door seams. [A]
Repair roof and chimney flashing if damaged or evidence of interior leaking is observed. [A]
Check furnace chimney draft and, if inadequate, check cleanout opening. [A]
Redirect flow from gutters to functioning downspout. [B]
Check return and supply ducts (only if in garage, crawl space, or attic) for leaks. [B]
Remove debris from the crawlspace, make rodent-proof. [B]
Wood-earth contact—assure 6 inch minimum gap. [C]
Repair or replace leaky chimney flue. [A]
Seal basement concrete if moisture probe indicates high moisture content. [C]

## Figure 4.18 Prioritizing Interventions—Field Practices

Better Homes for Asthma Program in Seattle prioritizes interventions based on interview data, visual assessments, environmental sampling, caregiver knowledge and practices, a child's allergy test, and assessment of potential moisture problems.

Cincinnati Children's Hospital's Injury Prevention Program reviews options with parents who choose interventions based on a presentation

of alternatives in rank order from the most passive and permanent to the least passive and non-durable (e.g., self-closing and locking stair gate bolted to a wall compared with a pressure mounted stair gate).

Healthy Homes Program in Baltimore prioritizes interventions in part by client-identified concerns and needs.

assessments. Usually this involves preparing an action plan in consultation with the residents and property owner. Table 4.1 provides an example of priority rankings from the Neighborhood House in Seattle's "Better Homes for Asthma" Demonstration project and Figure 4.18 show other examples from the field. HUD's Public Housing Assessment System (PHAS) uses pre-established weighting of items on the physical assessment checklist and allows the assessor to assign severity scores based on specific criteria for some of the items. (see: [www.hud.gov/offices/reac/products/prodpass.cfm](http://www.hud.gov/offices/reac/products/prodpass.cfm)).

### Environmental Sampling and Measurement Methods—General Considerations

Depending on the goals of your program, visual assessment can be used in conjunction with environmental testing, sometimes called "sampling and analysis," and building performance testing (e.g., as conducted by Weatherization Assistance Programs). The purpose of environmental sampling is to determine levels of harmful substances and agents in air, soil, dust, water, or on surfaces or other media. Some contaminants may be odorless (such as radon or carbon monoxide) or not amenable to examination by the naked eye (such as lead or pesticide residues). The results are typically compared to either existing exposure limits or to levels in the outdoor air. Interpretation of sampling results may prove difficult since, with few exceptions such as lead and radon, environmental exposure standards for residential environments have not been established. Levels of allergens in settled dust such as dust mite and cockroach can be measured to characterize hazards in a program's target housing, or collected pre- and post-intervention to determine if program efforts have produced desired changes.

Information on levels of contaminants in a home can be obtained by collecting samples for subsequent analysis by a laboratory (e.g., lead wipes) or by using portable instruments (sometimes called "grab sampling" or "real-time analysis") to provide instantaneous measurements during the home assessment (e.g., a CO meter). A sample can be collected during the initial visit or a sampler can be left in the home to be collected at a follow-up visit (e.g., a longer term air sample). In general, samples or measurements collected over a longer period of time (typically termed a "time-weighted average") are more likely to provide an accurate indication of typical values than short-term, grab samples. The simplest real-time measurements include temperature and humidity; instruments are often also used to measure carbon monoxide concentrations or to determine if there are atypical levels of volatile organic compounds or particulates in the air.

Before deciding whether to collect environmental samples or measurements it is important to consider the following factors: (1) how the data will be used (e.g., will it inform mitigation decisions or is it suitable for assessing the effectiveness of interventions?); (2) whether there is a standard or guideline for the analyte that is suitable for the home environment; (3) the ease of sample collection; and (4) the cost. For example, if pets or pests are present in a home, it can be inferred that elevated levels of the associated allergens would be found in dust samples. Also, guidance from authoritative sources on mold/moisture issues generally discourages environmental sampling for mold because of difficulty interpreting the results and the fact that mold/moisture problems that are observed should be mitigated regardless of the



findings from environmental sampling.<sup>19,20</sup>

Once a program has made the decision to collect environmental samples or to take measurements the choice of sampling methods will depend on: (1) the type of media sampled; (2) how rapidly results are needed; (3) available expertise; and (4) cost. The HUD/CDC Healthy Housing Inspection Manual and the HUD/CDC Healthy Homes Reference Manual each contain a list of sampling methods that can be used in a healthy homes inspection. Lead-based paint testing must be done by licensed lead-based paint risk assessors or inspectors. In most states, lead dust testing may be performed by a lead sampling technician or risk assessor. Healthy homes programs that will be doing environmental sampling should determine what training, licensing, and other legal requirements apply for their jurisdictions. Environmental sampling and analytical methods for lead in the residential environment have been established by law and are detailed in the HUD Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing.<sup>21</sup> A brief review of sampling methods follows.

**Passive versus active systems.** In general, there are two types of environmental sampling: passive and active. Passive systems rely on the contaminant being adsorbed onto special collection media via diffusion. One example is formaldehyde, for which the sorbent is opened to the air for a measured period and then analyzed in a laboratory. Active systems typically require

an air sampling pump, which pulls air at a known flow rate through a filter or other collection media, which is then sent to a laboratory for analysis.

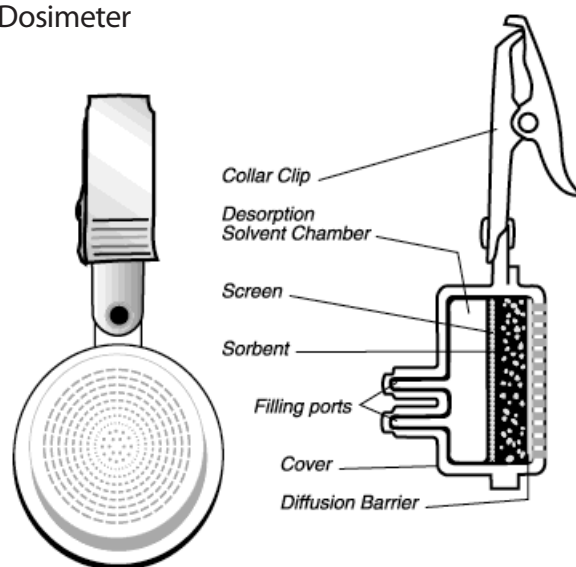
Each of these approaches has its strengths and weaknesses. For example, passive systems, if available, tend to be simple; they do not require a great deal of training and cost less (see Figure 4.19). Active systems may have greater accuracy and precision and may achieve the lower detection limits that are especially important for the home environment. In all cases, approved sampling and analysis systems should be used.

**Costs.** Costs associated with environmental testing include the purchase or rental of equipment and, for some devices, regular periodic calibration or servicing by the manufacturer; staff time to collect the sample; sampling media; and laboratory shipping and analysis. In order to contain costs, the question to be answered by the sampling should be articulated and various approved methods considered by asking the lab.

**Prior consultation.** If laboratory analysis is contemplated, it is essential that field personnel communicate with the laboratory before samples are sent. This will help determine laboratory capabilities, shipment procedures, and turnaround times. In addition, industrial hygienists may be helpful in designing field-based sampling efforts. A listing of board-certified industrial hygienists is available from the American Board of Industrial Hygiene, <http://abih.org/members/roster/rostersearch.cfm>. Healthy Homes programs should assure that laboratory and field personnel are properly trained, licensed, and accredited.

**Adapting air pollution and workplace sampling to the home environment.** For many contaminants found in the home environment, scientifically based health exposure limits do not yet exist. Several options are available to overcome this deficiency. One approach is to compare indoor to outdoor levels. Another is to compare the indoor level to exposure limits established for the occupational setting, although these limits are typically set for healthy adults who are exposed over a typical eight-hour workday. Clearly, these may not be a valid comparison for housing occupants who may have longer-term exposures or be in poor health and may include children, the elderly, and other sensitive populations. A list of indoor exposure levels has been published by the Air Infiltration and Ventilation Centre (AIVC) in

Figure 4.19 Passive Diffusion Dosimeter



**Figure 4.20 Most Frequently Reported Samples Collected by Healthy Homes Programs**

- Dust mite allergens (64 percent)
- Relative humidity (64 percent)
- Temperature (56 percent)
- Mold (52 percent)
- Lead (50 percent)

**Table 4.2 Environmental Testing and Sampling Methods**

Environmental Hazard	Sampling Method
Lead dust	Dust wipe
Cockroach allergens	Dust vacuum/filter-type material
Carbon monoxide	Direct-reading instrument or detector tube
Carbon dioxide	Direct-reading Instrument or detector tube
Volatile Organic Compounds	Passive dosimeter or canister/GC-MS
Cat allergens	Dust vacuum/filter-type material
Dog allergens	Dust vacuum/filter-type material
Dust mite allergens	Dust vacuum/filter-type material
Mouse allergens	Dust vacuum/filter-type material
Pesticide residues	Wipe or vacuum
Mold sampling	Air pump/filter
Nitrogen Dioxide	Passive badge
Particulate matter	Air
Formaldehyde	Passive badge
Temperature:	Digital sensor
Relative humidity:	Digital sensor
Radon: Short-term	2-7 day canister or data logger
Long term	3-month canister or data logger

Europe<sup>22</sup> and by the World Health Organization in 2010 (see: [http://www.euro.who.int/\\_data/assets/pdf\\_file/0009/128169/e94535.pdf](http://www.euro.who.int/_data/assets/pdf_file/0009/128169/e94535.pdf)).

Seventy-nine percent of healthy homes programs (more than 50 surveyed) collected environmental samples as part of their healthy homes projects (Figure 4.20). Twenty-one percent of the healthy homes programs collected only one set of environmental samples in each home, while 65 percent collected two sets of samples or more. A “set” means a group of samples collected at the same time. Examples of environmental testing and sampling methods are shown in Table 4.2.

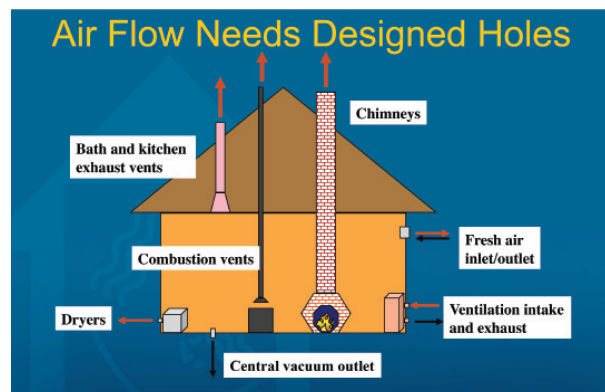
## Specific Testing Methods

### Testing Ventilation Systems

Testing ventilation systems can be a useful addition to the visual assessment described earlier in this chapter. Good ventilation can help to keep exposures to contaminants, odors, moisture, and other substances low. However, controlling the source of the contaminant is always the primary approach because ventilation cannot always be expected to do the job. If a contaminant exists in a home, its source should be investigated. A source reduction strategy should be implemented before a ventilation system is installed or otherwise improved. Ventilation systems generally fall into two categories: Local exhaust ventilation is designed to move a relatively small amount of air containing the contaminant at the point it is generated before it can enter the indoor air at large. Examples in the home include kitchen and bathroom exhausts, chimneys, clothes dryers, vented combustion appliances (furnaces, water heaters) and range hoods over gas ovens and ranges.

General dilution ventilation moves larger volumes of air, and, as the name implies, operates by diluting contaminants with uncontaminated air. While some multi-family buildings in the U.S. have a planned fresh air supply, relatively few single-family dwellings do. Instead, outside air enters the home in an uncontrolled manner through movement of air through the building envelope or through open windows and doors (referred to as passive ventilation). In some homes, outside air is brought directly into the home through mechanical ventilation, with more sophisticated systems recovering the heat from indoor air before it is exhausted. As building envelopes

Figure 4.21 Air Flow Exhaust and Entries



are tightened for energy conservation purposes and building leakage declines, it is important that a system for an adequate supply of fresh air be planned and installed. As a result of research demonstrating that passive ventilation was not sufficient to provide adequate air exchange rates, in 2009 the State of California revised its building code to require that newly constructed homes incorporate mechanical ventilation<sup>23</sup>.

Airflow patterns can be quite complex and flow in unexpected directions if properly designed entry and exhausts ("holes") are not included (Figure 4.21). Air moves from higher to lower pressure areas, and warm air rises while cold air settles. The buoyancy of warm air rising creates a "stack effect" in the building, just like hot air flowing up through a chimney. In tall buildings, this can sometimes cause apartments on the lower floors to be cold while those on the upper floors are hot. These air flows also move contaminants such as environmental tobacco smoke between units of multi-unit buildings.

Regulating pressure differentials so that air moves as intended is essential for good building design. Failure to regulate these pressure differentials can have serious consequences. For example, if a new air exhaust system is added without balancing air pressure, air that would normally rise through a chimney or fireplace can actually reverse direction and enter the living area, introducing carbon monoxide and other contaminants to the home.

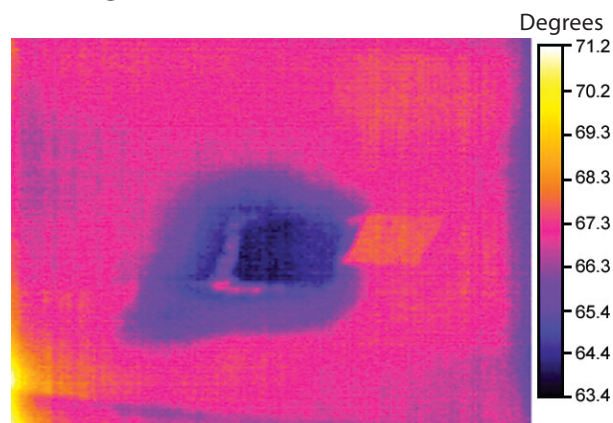
Many tools are available to evaluate ventilation and airflow, including smoke tubes or bottles, flow hoods, pressure gauges duct air-tightness

testers, and blower door tests. Smoke tubes can be used to identify "back-drafting" of exhaust from combustion appliances (e.g., water heaters) that do not have closed exhaust systems. In most healthy homes inspections, ventilation problems are identified visually. However, for healthy homes programs that partner with weatherization programs, the blower door test and pressure diagnostics are options. During a blower door test, the house is placed under negative pressure using an exhaust fan sealed in a doorway or other large opening. This method determines breaches or leaks in the building envelope. It can help pinpoint the pathways that allow contaminants into the living space. By identifying where the holes or leaks are, they can be repaired more cost-effectively.

### Moisture Measurement

In addition to the visual assessment methods described earlier in this chapter, moisture measurements can help identify places needing attention. Moisture meters measure water content in building materials through gauging changes in electrical resistance/capacitance (Figure 4.12). Two major types of moisture meters include one that gauges surface moisture by measuring the current between two electrodes. The second type has two pins that can be inserted into building materials to measure moisture content or water activity. Most moisture meters are calibrated to a specific type of wood at a particular temperature and are accompanied by charts that have adjustment factors for different types of wood and different temperatures. If the adjustments are not

Figure 4.22 Infrared Thermograph of a Ceiling with a Hidden Water Leak



Note: The blue section reveals the location of the water leak.

done properly, inspectors are likely to get false conclusions from the meter reading.

Another method of identifying moisture problems behind walls and other building cavities is thermography. Here, a special camera photographs infrared spectra. Because building components with higher water content are “cooler” than those without water, components with higher water content appear bluer than those with lower water content (Figure 4.22).

Relative humidity is the measure of the amount of water vapor in the air at a specific temperature compared with the maximum amount of water vapor that air could hold at that temperature. It is expressed as a percentage. Total humidity depends on the temperature since warm air holds more moisture than cold air. Dew point is the temperature at which air becomes saturated and condensation forms on cooler surfaces, which can in turn lead to mold problems.

### Mold Sampling

Mold sampling is generally not recommended because a visual examination and odor detection are usually adequate to identify a mold problem. Testing procedures do exist to determine the species of mold present in a house, but most healthy homes programs and others involved in mold remediation have come to the conclusion that such speciation does not yield the kind of information needed to inform remediation.<sup>24,25</sup> Similarly, measuring the mold spore concentrations in air is generally not recommended because results can vary widely and are difficult to interpret.

### Testing for Gases

Carbon monoxide (CO) and oxides of nitrogen (NOx) are odorless, colorless gases that can cause health problems. CO can be fatal if present in high concentrations. As byproducts of combustion, they can enter the living space if there is inadequate venting and/or improper indoor use of combustion appliances (e.g., gas ovens to heat homes). Inspectors should test both the fuel-burning device to determine whether it is producing high levels of CO and NOx, as well as the ambient room air. Two systems available for testing for CO and NOx are:

- Direct-reading, real-time carbon monoxide and

oxides of nitrogen analyzers, which require periodic calibration from the manufacturer; and

- Detector tubes, which involve pulling a small volume of air through a glass tube filled with a resin that changes color in proportion to the concentration of CO or NOx in the air. The length of stain is read on a scale on the tube. (Figure 4.23).

Additional details on measurement of combustion by-products in the home environment are available from the Building Performance Institute.

Radon is an odorless, colorless radioactive gas that, next to smoking, is the leading cause of lung cancer in the United States. The two principal means of laboratory-based measurement for radon used by healthy homes practitioners are:

- Systems that employ activated charcoal canisters; or
- Alpha-tracking devices, such as those that contain film.

Ideally, measurements should be taken over a long period and under conditions in which outdoor air incursion is at its lowest (e.g., winter) although short term measurements (e.g., two-to-seven days) are also useful. If a short-term test registers a radon level of 4 pCi/L (picocuries per liter of air) or more, a long-term test or a second short-term test should be conducted to verify an actual problem before deciding that mitigation is needed. If the long-term result or the average

Figure 4.23 Detector Tubes





of two short-term tests is 4 pCi/L or more, mitigation is recommended. Residents should be instructed not to move the radon test kits or devices. For valid test results, it is important that test devices be returned to the laboratory immediately after completing the test.

Formaldehyde and Other Volatile Organic Compounds (VOCs) can be measured by healthy homes practitioners using passive dosimeters, which are analyzed in a laboratory. Detector tubes are also available for formaldehyde and individual VOCs. Interpretation of VOC results is difficult because residential standards have not been developed; there are many individual compounds with different toxicities and concentration can be very low. Standard and approved methods should be used whenever possible.

### Testing for Allergens in Settled Dust

Allergens in settled dust and the resulting resuspension into the air from normal foot-traffic and from soft furniture and bedding are associated with asthma and other respiratory health problems. Estimates of sensitization and asthma exacerbation thresholds, based on concentrations of allergens in dust, have been developed from epidemiological studies. (Table 4.3). Sampling for allergens in settled dust before and after a healthy home intervention has been used to estimate the effectiveness

of the intervention. The National Survey of Lead and Allergens in Housing showed that housing conditions are linked with allergen levels. Of the surveyed homes, 51.5 percent had at least six detectable allergens and 45.8 percent had at least three allergens exceeding thresholds. Race, income, housing type, absence of children, and presence of smokers, pets, cockroaches, rodents, and mold/moisture-related problems were independent predictors of high allergen burden.<sup>26</sup>

Most healthy homes programs use a single sampling method whereby a vacuum is fitted with a dust collection device. The dust is sent to a laboratory where it is sieved and analyzed using several differing analysis methods. One recent development is the MARIA™ (Multiplex Array for Indoor Allergens) method which enables the rapid determination of multiple allergens from a smaller quantity of dust. This method may not provide results that are directly comparable to the common allergen-specific ELISA (enzyme-linked immunosorbent assay) analysis for some allergens, so healthy homes programs should work with their analytical laboratories to be sure that the same analytical method is used for dust samples collected before and after remediation. Research is underway to improve standardization of both field and laboratory methods. Personnel collecting these samples

Table 4.3 Current Threshold Levels for Assessing Common Residential Hazards

Allergen	Asthma Symptom Threshold
Dust mite allergen (Der f 1 and Der p 1) in the bedroom	10 µg/g (Platt-Mills et al., 1995)
Cockroach allergen (Bla g 1 and Bla g 2) in the kitchen	8 Units/g (Eggleston and Arruda, 2001)
Cat allergen (Fel d 1) in the bedroom	8 µg/g (Ingram et al,1995; Custovic et al., 1998)
Dog allergen (Can f 1) in the bedroom	10 µg/g (Ingram et al.,1995; Custovic et al., 1998)
Mouse allergen (Mus m 1) in the kitchen	1.6 µg/g23 (Phipatanakul et al., 2000)

(Note: Thresholds are subject to change and may not reflect actual risk. References: Custovic A, Chapman M. Risk levels for mite allergens. Are they meaningful? *Allergy*. 1998; 53(suppl 48): 71–76. Eggleston PA, Arruda LK. Ecology and elimination of cockroaches and allergens in the home. *J Allergy Clin Immunol*. 2001; 107(suppl 3): S422–S429. Ingram, J.M., Sporik, R., Rose, G., Honsinger, R., Chapman, M.D., Platts-Mills, T.A.E., 1995. Quantitative assessment of exposure to dog (Can f 1) and cat (Fel d 1) allergens: relationship to sensitization and asthma among children living in Los Alamos, New Mexico. *J Allergy Clin Immunol*. 96, 449–456. Phipatanakul W, Eggleston PA, Wright EC, Wood RA. Mouse allergen, part I: the prevalence of mouse allergen in inner-city homes. The National Cooperative Inner-City Asthma Study. *J Allergy Clin Immunol*. 2000; 106(6): 1070–1074. Platts-Mills, T.A., Sporik, R.B., Wheatley, L.M., Haymann, P.W., 1995. Is there a dose response relationship between exposure to indoor allergens and symptoms of asthma? *Journal of Allergy and Clinical Immunology* 96, 435–440.)

need to be trained to collect dust samples using a standard protocol. Asthma symptom thresholds have been published and are useful in interpreting allergen sampling results, although the use of new standards and sampling and laboratory analytical methods may not permit easy comparison (Table 4.3). HUD has developed sampling guidelines for allergens in settled house dust: [www.hud.gov/utilities/intercept.cfm?/offices/lead/library/hhts/DustSampleCollectionProtocol\\_v2\\_05.08.pdf](http://www.hud.gov/utilities/intercept.cfm?/offices/lead/library/hhts/DustSampleCollectionProtocol_v2_05.08.pdf).

### Monitoring for Pests

Like other healthy housing issues, pests in housing and the methods of detecting and controlling them are often intertwined with other housing deficiencies, especially inadequate moisture control; deferred maintenance associated with structural defects that create entryways and harborage for pests; leaks; clogged drains and gutters; improperly graded soil around the house; and clutter. Holes and penetrations in the building envelope permit pests to enter the dwelling. Poor moisture control provides the necessary water for pests to flourish. Access to nutrients can often be prevented by ensuring proper storage of food, trash, and garbage, and cleaning of all food preparation surfaces, utensils, and other equipment. (See Figure 4.24 for links to additional information.)

Resident complaints about pests are often the first indication of an infestation, and they should be encouraged to report evidence immediately so infestations do not spread. A trained pest management professional (PMP) will use this information to conduct a visual inspection that can identify the type of pest and its location(s)

#### Figure 4.24 Methods of Pest Detection

Methods of detecting pests are varied and described in detail in the CDC manual on integrated pest management: [http://www.cdc.gov/nceh/ehs/docs/IPM\\_Manual.pdf](http://www.cdc.gov/nceh/ehs/docs/IPM_Manual.pdf). The Healthy Housing Reference Manual also provides detailed guidance on how to identify the most common types of pests in different regions of the country. IPM training material can also be found at <http://www.stoppests.org>

in the dwelling. Fecal matter released by insects and rodents along common pathways around the perimeters of rooms provides relevant information. Insect fecal matter is typically spherical while fecal matter from rats or mice is usually elongated with one pointed end due to the presence of a sphincter. Other body parts, such as cast off exoskeletons or fur, may be visible. Of course, the most obvious visual evidence of the pest is the actual live or dead animal.

Rub marks and burrows are also signs of pest activity. Exterior evidence may include ant mounds, burrows, and nests. A trained observer looks in food storage areas and trash and garbage disposal systems, such as trash chutes. Penetrations in walls, under kitchen sinks, in basements, and in other areas suggest that pest infestations may be present. Some practitioners have found that the use of a heat gun can drive cockroaches into the open where they can be observed easily.

Monitoring with glue traps is also effective for cockroaches. Since cockroaches often do not emerge in daylight hours, monitoring with overnight traps may be more reliable than looking for the pests themselves (Figure 4.25). Cockroach glue traps are glue-covered strips of cardboard available in many shapes and styles. The two most basic types come in a triangle or flattened tube. If cockroaches are seen, they are likely to be found in cracks and crevices.

All visual survey systems attempt to identify potential harborage sites. Harborage simply means those areas where pests are able to take shelter (e.g., unused boxes in basements, clutter, brush and bushes near structures, and standing water containers).

#### Figure 4.25 Cockroach Monitoring



Roach monitoring stations

Cockroach baits and traps can be placed in corners, under refrigerators, and under sinks. If glue traps reveal an increase in pest prevalence, then quick action can help to avert a large infestation. Useful instructions on proper placement of sticky traps can be found at: [healthyhomestraining.org/ipm/HUD\\_M2M.htm](http://healthyhomestraining.org/ipm/HUD_M2M.htm).

The most common signs of rodent infestations are those that can be seen, such as feces, urine stains that can be detected with a UV flashlight, stored food that has been opened or shows gnaw marks, nests, burrows, and rub marks along walls and other linear surfaces.

Bed bug infestations are becoming increasingly common, especially in multifamily housing. Bed bugs cannot be controlled by common IPM techniques such as denying pests access to food and water since they do not need food or water for extensive periods. Their survival depends simply on a human host who can offer a blood meal every few months. Signs to look for when inspecting for bed bugs include dark spots (about this size: •), which are bed bug excrement that may bleed onto the fabric; tiny white eggs and eggshells (about 1mm); skins that nymphs shed as they grow larger; live bed bugs; and rusty or reddish stains on bed sheets or mattresses caused by bed bugs being crushed. See: [epa.gov/pesticides/controlling/bedbugs.html](http://epa.gov/pesticides/controlling/bedbugs.html).

Finally, a healthy housing inspection should explore information on previous use of pesticides, if known. Routine monthly spraying of pesticides may be an early indication of both pest infestation and exposure to pesticides. Routine spraying indicates an ineffective pest control strategy that does not follow IPM principles. Protective gear and tools for healthy homes inspectors investigating pest infestations are listed in Figure 4.26.

### Sampling for Lead

Procedures for identifying lead-based paint and lead-based paint hazards are contained in the HUD Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing and regulated by EPA and many state governments. Dust-wipe sampling is performed by trained sampling technicians or lead-based paint inspectors or risk assessors. Measurements taken via x-ray fluorescence (XRF) or paint chip, soil, and water samples all require specialized training and licensing/certification. The extent of training and certification needed to perform these sampling techniques varies from state to state. Make sure your program adheres to state or EPA requirements. Laboratories that analyze paint, soil, and dust for lead must be EPA-recognized through the National Lead Laboratory Accreditation Program (NLLAP).

Figure 4.26 Healthy Homes Pest Inspection Gear

Inspectors should wear protective gear when investigating sites with potentially heavy pest infestations. EPA and CDC recommend the following tools and equipment:

- Building or floor plan to mark areas that need follow-up or regular ongoing inspections.
- UV flashlight for detecting urine stains that fluoresce under ultraviolet light.
- Standard flashlight.
- Knife or flat spatula for scraping narrow crevices where pests like to hide. If a spatula fits in a crack in concrete, baseboards, or wallboards; behind a kitchen or bathroom backsplash; or any other space 1/16" or greater, insects can use that space to enter a building.
- Hand lens or jeweler's loupe magnifying glass for insect identification.
- Vial for collecting specimens.
- Pest identification guide book.
- Telescoping mirror (one that extends from 6" to 36" is perfect for seeing behind or under hard-to-reach places).
- Dust mask.
- Small portable HEPA vacuum.
- Hard hat.
- Protective eyewear.
- Small ladder.



## Energy Audits

An effective programmatic strategy that provides additional benefit to program clients is to integrate a home energy audit with the healthy homes assessment. A home energy audit, as conducted by a Department of Energy (DOE)-funded Weatherization Assistance Program, includes a comprehensive assessment of the current condition of a home followed by a detailed evaluation of the energy conservation measures that can improve the building's performance (see: <http://waptac.org/Technical-Tools/Energy-Audits.aspx>). The first step is a comprehensive assessment that includes visual and diagnostic assessments of the whole home as a system, including the building shell, heating and cooling systems, and appliances. Combustion appliances are tested for safety and efficiency, existing insulation levels are determined, air leakage is measured, electrical appliances are metered, moisture and other health hazards are evaluated, and the residents are interviewed about energy usage, trouble areas in the home, and health issues that may be connected to the indoor environment (Figure 4.27 shows a blower door test to estimate air leakage).

The data collected during the comprehensive assessment, or site audit, is then entered into an approved energy audit software tool, such as the DOE's Weatherization Assistant. Based on the local climate, energy rates, the costs of materials and labor, and the current condition of the home, the software evaluates the cost-effectiveness

Figure 4.27 Blower Door



of home energy retrofit measures. Typical cost-effective measures include air sealing and insulating the building shell, heating and cooling system tune-ups, repairs, or replacements, and duct sealing and insulation. In addition to the energy conservation measures, the auditor will recommend measures to improve the health and safety of the residents. Typical health and safety related measures include adding mechanical ventilation to kitchens and bathrooms to manage moisture and other indoor pollutants, installing vapor barriers on dirt-floored basements or crawl spaces, and installing smoke and CO detectors. The successful energy audit results in a work order of measures that, when installed, will reduce energy consumption and potentially improve the health of occupants.

## Chapter 4 References\*

- <sup>1</sup> U.S. Department of Housing and Urban Development. 2007. An Evaluation of HUD's Healthy Homes Initiative: Current Findings and Outcomes.
- <sup>2</sup> Centers for Disease Control and Prevention and U.S. Department of Housing and Urban Development. 2006. Healthy Housing Inspection Manual. Atlanta: U.S. Department of Health and Human Services. Available: <http://www.cdc.gov/nceh/publications/books/inspectionmanual/>.
- <sup>3</sup> Wilson, J., Breyse, P., Dixon, S., Jacobs, D.E., Chew, G.L., Dearborn, D., Krieger, J., Spanier, A., Sandel, M., and Adamkiewicz, A. 2010. Housing characteristics and allergens associated with childhood asthma morbidity: A pooled analysis of nine studies. *Environmental Research*. 110:189–198.
- <sup>4</sup> U.S. Department of Housing and Urban Development. 2006. Healthy Homes Issues: Asthma. Version 3. Office of Healthy Homes and Lead Hazard Control. Available: [http://www.hud.gov/offices/lead/library/hhi/Asthma\\_Final\\_Revised\\_04-26-06.pdf](http://www.hud.gov/offices/lead/library/hhi/Asthma_Final_Revised_04-26-06.pdf)
- <sup>5</sup> Centers for Disease Control and Prevention and U.S. Department of Housing and Urban Development. 2008. Healthy Housing Inspection Manual. Atlanta: U.S. Department of Health and Human Services. Available: <http://www.cdc.gov/nceh/publications/books/inspectionmanual/>.
- <sup>6</sup> Centers for Disease Control and Prevention and U.S. Department of Housing and Urban Development. 2006. Healthy Housing Reference Manual. Atlanta: U.S. Department of Health and Human Services. Available: <http://www.cdc.gov/nceh/publications/books/housing/housing.htm>.
- <sup>7</sup> Institute of Medicine. 2002. Clearing the Air: Asthma and Indoor Air Exposures. Washington, DC: National Academy Press.
- <sup>8</sup> Institute of Medicine. 2002. Clearing the Air: Asthma and Indoor Air Exposures. Washington, DC: National Academy Press.
- <sup>9</sup> Institute of Medicine. 2004. Damp Indoor Spaces and Health. Washington, DC: National Academy Press.
- <sup>10</sup> Jacobs, D.E., Brown, M.J., Baeder, A., Scalia Sucusky, M., Margolis, S., Hershovitz, J., Kolb, L., and Morley, R.L. 2010. A systematic review of housing interventions and health: Introduction, methods, and summary findings. *Journal of Public Health Management and Practice*, 16(5) (Suppl):S3-S8. Available: <http://journals.lww.com/jphmp/toc/2010/09001#-1750774083>.
- <sup>11</sup> Phipatanakul, W., Eggleston, P.A., Wright, E.C., and Wood, R.A. 2000. Mouse allergen. I. The prevalence of mouse allergen in inner-city homes. The National Cooperative Inner-City Asthma Study. *The Journal of Allergy and Clinical Immunology*. 106(6):1070–1074.
- <sup>12</sup> Dales, R., Liu, L., Wheeler, A.J., Gilbert, N.L. 2008. Quality of indoor residential air and health. *Canadian Medical Association Journal*. 179(2):147–152.
- <sup>13</sup> Matsui, E.C., Wood, R.A., Rand, C., Kanchanaraks, S., Swartz, L., Curtin-Brosnan, J., Eggleston, P.A. 2003. Cockroach allergen exposure and sensitization in suburban middle-class children with asthma. *The Journal of Allergy and Clinical Immunology*. 112(1):87–92.
- <sup>14</sup> Jacobs, D.E., Clickner, R.L., Zhou, J.L., Viet, S.M., Marker, D.A., Rogers, J.W., Zeldin, D.C., Broene, P. and Friedman, W. 2002. The prevalence of lead-based paint hazards in U.S. housing. *Environmental Health Perspectives*. 110:A599–A606.
- <sup>15</sup> Hatfield, P.M., Staresinic, A.G., Sorkness, C.A., Peterson, N.M., Schirmer, J. and Katcher, M.L. 2006. Validating self-reported home safety practices in a culturally diverse non-inner city population. *Injury Prevention*. 12(1):52–57.
- <sup>16</sup> Phelan, K.J., Koury, J., Xu, Y. and Lanphear, B.P. 2009. Validation of the HOME Injury Survey. *Injury Prevention*. 15(5):300–306.
- <sup>17</sup> Frost, R.O., Hartl, T.L. A cognitive behavioral model of compulsive hoarding. *Behav Res Ther*. 1996, Apr; 34(4):341–350.
- <sup>18</sup> Final Report, Better Homes for Asthma, Neighborhood House, Seattle, WA, November 2006, pp.6–8.

\*Websites were verified during the drafting of this document but may have changed.

<sup>19</sup> U.S. Environmental Protection Agency. 2001. Mold Remediation in Schools and Commercial Buildings. Washington, DC: Office of Air and Radiation. Available: [www.epa.gov/iag](http://www.epa.gov/iag)

<sup>20</sup> Centers for Disease Control and Prevention and U.S. Department of Housing and Urban Development. 2006 Healthy Housing Reference Manual. Atlanta: U.S. Department of Health and Human Services. Available: <http://www.cdc.gov/nceh/publications/books/housing/housing.htm>

<sup>21</sup> U.S. Department of Housing and Urban Development. 1995. The HUD Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing. Washington DC.: Available: <http://www.hud.gov/offices/lead/lbp/hudguidelines/index.cfm>

<sup>22</sup> Air Infiltration and Ventilation Centre (AIVC). 2003. Indoor air pollutants—Part 1: General description of pollutants, levels and standards. Ventilation Information Paper No 2. Brussels, Belgium. Available: <http://www.aivc.org>

<sup>23</sup> Offerman, F.J. et al. 2009. Ventilation and Indoor Air Quality in New Homes. California Air Resources Board. Available: <http://www.arb.ca.gov/research/apr/past/04-310.pdf>

<sup>24</sup> U.S. Department of Housing and Urban Development. 2006. Healthy Homes Issues: Mold. Version 3. Available: [http://www.hud.gov/offices/lead/library/hhi/Mold\\_Final\\_Revised\\_04-26-06.pdf](http://www.hud.gov/offices/lead/library/hhi/Mold_Final_Revised_04-26-06.pdf)

<sup>25</sup> American Industrial Hygiene Association. 2008. Recognition, Evaluation, and Control of Indoor Mold. Prezant, B., Weekes, D.M., and Miller, J.D., (editors). AIHA Product IMOM08–679. Available: [https://webportal.aiha.org/Purchase/ProductDetail.aspx?Product\\_code=3f9e0a5a-4778-de11-96b0-0050568361fd](https://webportal.aiha.org/Purchase/ProductDetail.aspx?Product_code=3f9e0a5a-4778-de11-96b0-0050568361fd)

<sup>26</sup> Arbes, S.J., Cohn, R.D., Yin, M., Muilenberg, M.L., Burge, H.A, Friedman, W. and Zeldin, D.C. Thorne, P.S., Cohn, R.D., and Zeldin, D.C. 2003. House dust mite allergen in U.S. beds: Results from the First National Survey of Lead and Allergens in Housing. The Journal of Allergy and Clinical Immunology. 111(2):408-414.

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