Controlling and Preventing Household Mold and Moisture Problems:

Lessons Learned and Strategies for Disseminating Best Practices

A Report to Congress

U.S. Department of Housing and Urban Development

April 1, 2005

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EXECUTIVE SUMMARY

This Report to Congress describes ongoing and recently completed residential mold- and moisture-related work conducted by different offices within the Department of Housing and Urban Development (HUD). The results of that work are presented, and the Department's strategies for reaching out to key groups with information about moisture control and mold prevention are discussed.

Mold and moisture problems in housing are not new phenomena, but they are receiving more attention than in the past. Concerns in recent years have turned to the relationship between mold and allergies, asthma, and concerns about exposure to mold-produced toxins, and the resulting implications for occupant health. At the same time, it is accepted that preventing mold requires keeping exterior moisture out of the building and controlling moisture from internal sources.

HUD's programs addressing residential mold and moisture problems are primarily conducted by the Department's Office of Healthy Homes and Lead Hazard Control (OHHLHC), Office of Policy Development and Research (PD&R), and Office of Public and Indian Housing (PIH). These offices conduct mold- and moisture-related activities appropriate to their areas of focus, while also coordinating with each other and sharing findings. Collectively, these offices are addressing a wide range of mold and moisture issues, including interventions and health issues in homes with mold; measurement and detection technologies; moisture management and control practices; moisture modeling and research; assessments and remediation; and outreach.

The greatest amount of the Department's mold- and moisture-related work has been sponsored by OHHLHC, primarily through grants and interagency agreements. Many of these projects have involved demonstration and evaluation of interventions aimed at mold and moisture problems, often in conjunction with steps to address other healthy home issues. Highlights of results from completed projects involving urban homes, performed under grants to Cuyahoga County (Ohio) and the Illinois Department of Public Health, are presented, along with information about other selected demonstrations involving low-income populations in Washington State and Alaska. As a complement to demonstration projects, OHHLHC has also funded related technical studies on topics including developing new and improved technologies for identifying damp areas in buildings, measuring the overall wetness of indoor spaces, identifying and quantifying loads of fungal spores in dust and air, and determining normal and typical concentrations of fungi in "non-problem" homes. In addition, OHHLHC has commissioned development of a housing inspection manual and related software and training materials designed for environmental health specialists and code inspectors, and funded development of a culturally-specific asthma training program for the Native American community. Other relevant OHHLHC projects include publishing an issue paper summarizing mold from a public health standpoint; convening a workshop on mold and moisture with stakeholders from throughout the building industry and scientific community; and sponsoring a project which developed performance criteria for proper moisture control which are included in the latest consensus performance standards for

residential buildings. OHHLHC also plans to field the "American Healthy Homes Survey" during 2005, which will include collecting household dust samples and testing them for mold.

The Office of Policy Development and Research (PD&R), working through the Partnership for Advancing Technology in Housing (PATH) Program, has also sponsored significant technical work relating to mold and moisture problems. PD&R commissioned a guidebook published in 2002, *Durability by Design*, that gives residential designers and builders extensive information about practices that enhance the durability of homes, including resistance to moisture intrusion. The development of a PATH *Moisture Best Practices Guidebook* aimed at mainstream builders and remodelers is underway, with completion expected in late 2005. In partnership with the Federal Emergency Management Agency (FEMA), PATH examined the performance of various construction materials when subjected to flooding. Another PATH-sponsored project led to development of a comprehensive research agenda on moisture in residential buildings and a series of studies performed for PD&R which specifically examined moisture problems and moisture control in manufactured homes, particularly homes located in hot, humid climates.

The Office of Public and Indian Housing, acting through the Office of Native American Programs, has been working over the last several years to determine the extent of mold and moisture problems in tribally-owned or managed homes and to provide residents and housing managers with the information and skills they need to take preventive or corrective action. Work conducted through late 2003 is described in a November 2003 Report to Congress, which includes estimates of the proportion of managed housing units with mold conditions and the projected cost of remediation and a training program. The site visit program has continued since that time. This work has underscored a series of factors that may make Indian housing more susceptible to mold and moisture problems, including overcrowding, insufficient thermal insulation, physical deterioration, poor site conditions and depressed socioeconomic conditions. In recent years the site visits have been supplemented by preparation of three guidebooks on mold prevention and detection, aimed at Native American audiences, as well as development and presentation of training programs on the subject.

Results to date from the overall body of HUD work on mold and moisture point to a variety of lessons learned. Among other things, they establish that multi-hazard intervention in high-risk housing is feasible and effective, and provide evidence that intervention can reduce certain symptoms in asthmatic children. They show the feasibility of new rapid, non-destructive methods of detecting mold and moisture. They highlight the key elements in building design and construction that minimize the likelihood of mold and moisture problems. They further show the strengths and viability of taking advantage of the skills and energy of state and local health departments, and underscore the lack of reliable information about the extent of different types of mold and moisture problems in the national housing stock. Finally, they make clear the need to tailor mold and moisture guidance by type of building, geographic location and occupant group.

HUD recognizes that dissemination of best practices is an essential step in developing the capability to understand and address mold and moisture problems within the consumer, construction, housing management, public health and research sectors. Therefore, OHHLHC, PD&R and PIH all emphasize the delivery of best practices for preventing or addressing these problems. Due to the diverse audiences that HUD reaches, the variability in complexity and scope of substantive outputs, and the multidisciplinary aspects of mold problems, HUD uses several types of outreach including communication through multiple channels, strategic partnering with other organizations, tailoring information for specific audiences, and packaging guidance in formats designed for the ultimate user. Key methods include publication of technical papers in peer-reviewed journals or presentation at scientific meetings, sponsoring training seminars, outreach through community health fairs and similar programs, and publication of brochures, pamphlets and books with distribution in printed form (at cost) and over the internet (for free). This approach allows HUD to deliver tailored information to its target audiences, while leveraging the efforts and outreach capabilities of its partner groups. Through this ongoing process of dissemination HUD is building an infrastructure of state and local agencies, builders, residents and other interested groups that will minimize the occurrence and impact of mold and moisture problems in homes.

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1. INTRODUCTION

This report describes ongoing and recently completed residential mold- and moisture-related work conducted by different offices within the Department of Housing and Urban Development (HUD). The results of selected projects are presented, and the Department's strategies for reaching out to key groups with information about moisture control and mold prevention are discussed. The report is submitted pursuant to the directive of the conferees to the Consolidated Appropriations Act of 2005, enacted December 8, 2004. The conferees wrote:

> "The conferees agree with Senate direction to the Department to continue mold and moisture initiatives within the Healthy Homes program and direct the Department to report to the Committees on Appropriations by March 1, 2005 on lessons learned and strategies for disseminating best practices on controlling and preventing household mold and moisture. The report should include a discussion of the unique needs in Native American housing."[1]

Mold and moisture problems in housing are not a new development, but they are receiving more attention than in the past. Concerns in recent years have turned to the relationship between mold exposure and allergies, asthma, and other respiratory diseases, as well as the possible effects of exposure to mold-produced toxins. The latest scientific assessment comes from a 2004 report by the Committee on Damp Indoor Spaces and Health of the Institute of Medicine (IOM), *Damp Indoor Spaces and Health*, which presents a comprehensive review of the research on this subject.[2] The Committee found there was sufficient evidence to establish an association between exposure to mold or damp indoor environments and the development of cough and upper respiratory tract symptoms, wheeze, and asthma symptoms in sensitized persons.[3] The Committee also found that there was insufficient evidence to determine if any association exists between exposure to mold or mold-produced toxins and acute idiopathic pulmonary hemorrhage in infants, or a variety of other adverse health outcomes.

Based on technical work by HUD and others, the general approach to preventing mold growth in homes is widely understood: keep exterior moisture out of the building, and control moisture from internal sources. Avoiding moisture problems also provides the added benefit of helping to prevent infestation by insects that are sources of important allergens (e.g., asthma triggers), such as dust mites and cockroaches. By

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[1] An extension of the submission date for this report to April 1, 2005 was granted on February 17, 2005.

[2] Damp Indoor Spaces and Health, Institute of Medicine, Committee on Damp Indoor Spaces and Health, Board on Health Promotion and Disease Prevention. Washington D.C.: National Academy Press, 2004.

[3] A previous IOM report similarly found sufficient evidence of an association between fungal exposure or dampness and symptom exacerbation in sensitized asthmatics. See Clearing the Air: Asthma and Indoor Air Exposures, Institute of Medicine, Committee on the Assessment of Asthma and Indoor Air, Division of Health Promotion and Disease Prevention. Washington, D.C.: National Academy Press, 2000.

contrast, the degree to which homes experience different types of mold and moisture problems is not well understood. The HUD-sponsored American Housing Survey (AHS) estimates the number of homes with leaky roofs or pipes (for example, according to the 2001 AHS, 6.1 percent of occupied U.S. homes had roof leaks in the preceding 12 months), but does not address mold or overall dampness. Other more detailed surveys are geographically limited and do not use standardized definitions or assessment protocols. As a result, the available information about the frequency and severity of mold and moisture problems in U.S. housing remains largely anecdotal. There is no shortage of evidence that problems exist, but their magnitude is unclear.

Concerns about problems resulting from indoor dampness and mold have led HUD and other agencies to engage in research, demonstrations, and outreach. These activities are designed to address existing mold and moisture problems and prevent future ones. HUD work on mold and moisture is currently being carried out primarily by three offices within the Department: the Office of Healthy Homes and Lead Hazard Control (OHHLHC), the Office of Policy Development and Research (PD&R), and the Office of Public and Indian Housing (PIH). Each of these offices is pursuing work within its areas of focus in the Department, while also coordinating with each other to collaborate and share findings. Taken together, this body of work addresses mold and moisture issues in housing to improve the situation in the near-term and reduce vulnerability to these problems over the long term.

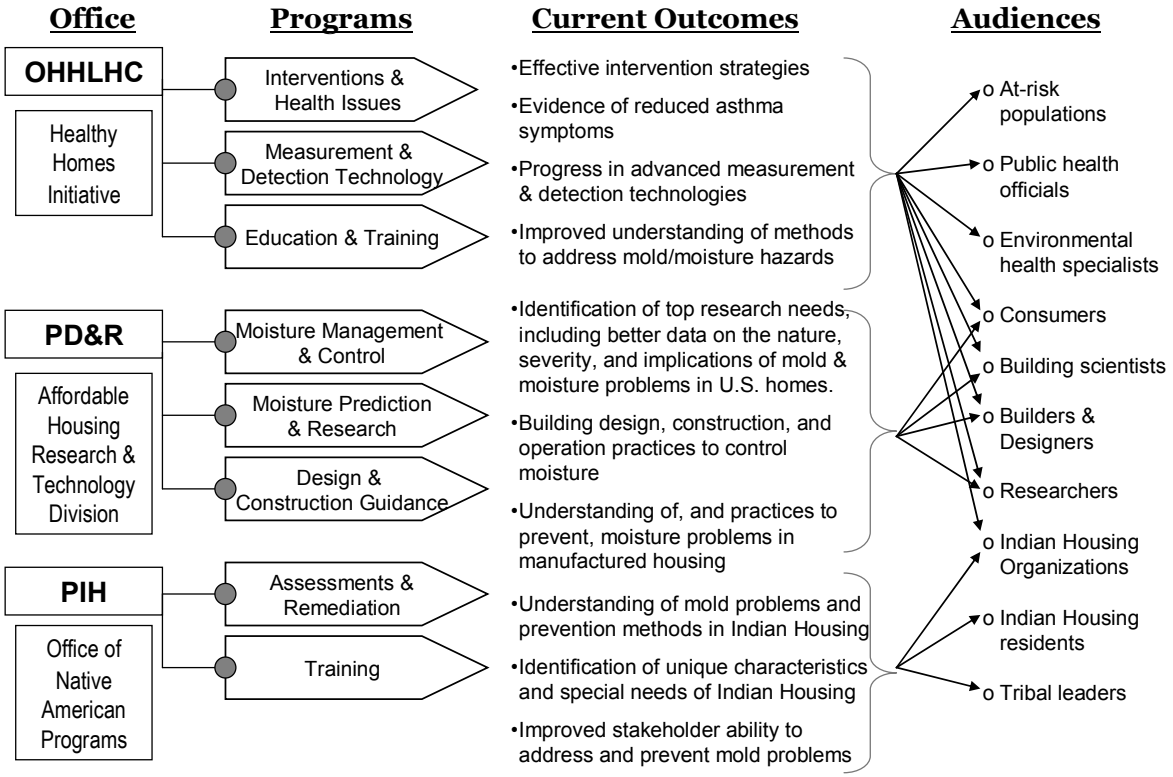
- OHHLHC has made grants to many state and local agencies, nonprofit organizations and universities, to demonstrate and evaluate healthy home interventions, and to conduct research on specific healthy home topics. Some of the projects are focused primarily on mold and moisture issues; however, most address multiple housing-related health hazards, including mold and moisture, consistent with the intent of the Healthy Homes program. OHHLHC has also sponsored several interagency agreements and grants for research projects to improve the science of mold and moisture detection, as well as grants specifically focused on education and training.

- PD&R has focused on moisture control from a building technology standpoint, with studies over the last few years incorporated as part of the Partnership for Advancing Technology in Housing (PATH) Program. It has sponsored projects to compile and document the key building practices and technologies that help prevent moisture intrusion and improve management of internally generated moisture in homes. PD&R also developed a research agenda for future work to improve the control of moisture and management of water vapor in homes.

- PIH has worked with Indian housing organizations throughout the country to assess mold and moisture problems in their housing units, and to train and educate housing staff and residents about how to identify and deal with the problem.

Figure 1 provides an overview of HUD programs focusing on mold and moisture, current outcomes, and the key audiences for outreach and dissemination, all of which are discussed later in this report.

FIGURE 1
OVERVIEW OF HUD MOLD AND MOISTURE PROGRAMS



Section 2 of this report presents more information about specific projects and work products from each of the HUD offices involved in mold and moisture work. While the principal focus is on projects that are completed or substantially completed, some references to ongoing work are also included. Section 3 highlights the most significant and notable results and lessons learned from these projects. Section 4 describes the strategies and dissemination efforts employed to deliver best practices and other results to the appropriate audiences.

2. OVERVIEW OF HUD ACTIVITIES RELATED TO MOLD AND MOISTURE PREVENTION AND CONTROL

2.1 OFFICE OF HEALTHY HOMES AND LEAD HAZARD CONTROL

The Fiscal Year 1999 appropriation for the HUD Office of Lead Hazard Control provided initial funding of $10 million for the HUD Healthy Homes Initiative (HHI), a new program focusing on the full range of health and safety hazards encountered in residential environments. The importance of moisture as part of this overall picture has been recognized from the outset. For example, the April 1999 HHI Program Plan, developed for the HHI with extensive input from outside experts, identified four basic categories of hazard control methods: excess moisture reduction, dust control, improving air quality, and education.[4] This basic approach has continued to guide HHI's direction. Moisture control is recognized not only as the key to eliminating the development of mold, but also as a method for managing other common sources of allergens including dust mites and cockroaches.

The FY99 appropriation set aside $4 million of the HHI budget to fund preventive projects on mold and moisture in inner city housing in neighborhoods where it was associated with bleeding lung disease in infants (acute idiopathic pulmonary hemosiderosis or IPH), an often-fatal condition. Two competitively awarded grants were funded under the set-aside, one to the Cuyahoga County (Ohio) Department of Development, and the other to the Illinois Department of Public Health. An additional $4 million was used to fund other Healthy Homes Demonstration projects designed to demonstrate consolidated physical and educational interventions aimed at reducing multiple hazards and to systematically evaluate their effectiveness using methods employed in public health studies. The balance of $2 million was used for outreach efforts and to support interagency agreements with the Centers for Disease Control (CDC) and the National Institute of Standards and Technology (NIST).

The Healthy Homes Initiative soon changed from an initiative of the Office of Lead Hazard Control to a core function of that office, which was renamed the Office of Healthy Homes and Lead Hazard Control (OHHLHC). HUD budgets for years since FY99 have provided approximately $10 million per year in support of the Healthy Homes work of OHHLHC. That office has continued to make competitive grants to national, state, and local organizations, currently divided into "Demonstration" projects for housing assessment, maintenance, renovation and construction techniques that identify and correct housing-related illness and injury risk factors, and "Technical Studies" projects that research new methods of evaluating and controlling housing-based hazards. In prior years, some HHI grants were awarded within a separate "education/outreach" category; however, this is now an eligible focus area for HH Demonstration grants. To date a total of 63 HHI grants with a mold/moisture component have been awarded, totaling approximately $50 million. This includes 41 demonstration/education grants, 20 technical studies grants, and the 2 grants under the

[4] Office of Lead Hazard Control, The Healthy Homes Initiative: A Preliminary Plan (Full Report), U.S. Department of Housing and Urban Development, April 1999, pp.4, 14.

1999 mold and moisture control set-aside. A table listing grantees, the type of grant, and grantee location is provided in Appendix A.

Many of the HHI grants address mold and moisture problems along with other hazards. These are usually aimed at remediating or preventing mold and moisture problems and assessing the effectiveness of low-cost interventions, especially in older, low-income housing, where there is a high prevalence of lead and other housing-related health and safety hazards. In addition to its grants program, OHHLHC has also supported work by several other federal agencies on projects related to mold and moisture assessment and prevention.

Some HHI-funded projects are essentially complete, including the two grants from the first year set-aside for mold research. Many others are ongoing, often with tangible interim results suggesting important progress. Brief descriptions of several of the HHI studies that are most relevant to the mold and moisture issue are below. They are divided into four sections: projects related to the demonstration and evaluation of interventions; technical studies focusing on mold and moisture issues; education and training projects; and other projects. All of the HHI projects described in the following sections focus directly on the mold and moisture issue; some involve the development of relatively low cost protocols or approaches that address moisture problems in different contexts (such as weatherization and new construction) and could be widely adopted. Projects involving Native American housing have also been included.

2.1.1 Demonstration and Evaluation of Interventions to Address Mold and Moisture Problems

It is important to understand that practically all of the Demonstration grants funded through HHI address mold and moisture issues to some extent. This is natural, because identifying and addressing mold and moisture problems is an essential component of a complete healthy homes protocol. This section describes selected HHI Demonstrations that have focused specifically on residential mold and moisture problems, or have other characteristics of particular relevance to this report.

Cuyahoga County Urban Mold and Moisture Program (1999 grant). This program has involved research and intervention aimed at preventing moisture- and mold-related illness among low income children living in high-risk urban areas of Cleveland and Cuyahoga County (Ohio). The primary diseases of interest were idiopathic pulmonary hemosiderosis (IPH or "bleeding lungs"), asthma, and lead poisoning. The Executive Summary of the project report is reproduced in Appendix B; key findings are described in this section.

One part of the project focused specifically on asthma. It was performed by the Department of Pediatrics at Case Western Reserve University, the Cuyahoga County Board of Health, and Environmental Health Watch (a non-profit organization). The asthma study investigated the potential for home remediation aimed at moisture sources to reduce illness in inner-city children who had poorly-controlled asthma and lived in homes with documented indoor mold. Qualifying households were randomized

into treatment and control groups. The treatment group received environmental interventions including reduction of water infiltration, removal of water-damaged building materials, modification of duct systems to limit the distribution of mold spores from wet basements, lead hazard control, and environmental cleaning. The control group only received general home cleanliness instructions. The study included clinical visits for monitoring of symptoms as well as home visits where assessments, sampling, and remediation were performed. The average remediation cost was $3,449 per household. Ultimately, 29 homes that were remediated and 33 homes in the control group completed the study (control group homes were remediated at the end of the study). Data from the project indicated that children living in treatment group homes experienced significantly fewer symptoms of asthma and significantly fewer exacerbations requiring hospital or emergency room visits following the home remediations, while children in control group homes experienced no significant improvement in these measures. This is the first study to show that low-cost mold and moisture remediation can result in a significant reduction in symptoms among asthmatic children, along with the savings realized from fewer hospital visits. At the end of the study, the remediated homes also had less mold than the control homes. The report notes that, due to the small sample size, results should be regarded as preliminary.[5]

In a second arm of this project, referred to as the "Composite Study", 59 water-damaged homes of low-income women with infants or young children at risk of respiratory health problems were evaluated for mold and moisture problems and remediated. The remediation used similar procedures to the asthma study, described above. Environmental testing conducted before and after the remediation work showed reductions in visible mold and reductions in endotoxin and mouse antigen in bedroom dust. A symptom questionnaire that was administered to care givers before and after the interventions were performed identified statistically significant reductions in 11 of 14 respiratory symptoms and in four of 13 non-respiratory symptoms among 65 resident children (> 2 years old) following intervention.

A third significant line of work under the Cuyahoga County grant was performed in collaboration with scientists from the U.S. Environmental Protection Agency's (EPA) Office of Research and Development in Cincinnati. The EPA adapted a technique called "quantitative polymerase chain reaction" (PCR) that uses DNA probes to measure the types and amounts of fungal species in house dust or air samples. Early results from PCR analysis indicate promise for distinguishing homes with abnormal mold profiles from "normal" homes. That work is further discussed in section 2.1.2 below

The grantee also developed a detailed visual assessment tool (VAT) for conducting residential mold and moisture assessments. The VAT has been used by other HH grantees and was also used by the CDC during an investigation of mold problems in housing on the Turtle Mountain Reservation in North Dakota.

[5] C. Kercsmar, et al., Urban Mold and Moisture Project: Asthma Intervention (2004) (to be submitted for publication).

Mold and Moisture in Inner-City Housing: Chicago (1999 grant). This Demonstration project, considerably smaller than the Cuyahoga County grant, was a competitively awarded grant led by the Illinois Department of Public Health. It was designed to investigate the relationship between different types and amounts of fungi and fungal metabolites, allergens, and moisture in urban homes, and their impact on children's health including symptoms of asthma and IPH.[6] The Executive Summary of the project report is reproduced in Appendix B under the title "Illinois Mold and Moisture Demonstration Project," and key findings of the project are described in this section.

The Chicago Demonstration involved performing healthy homes environmental interventions in a total of fourteen study homes occupied by families with children diagnosed with mold-sensitive asthma or IPH. The average cost of intervention was $6,828 per home. Children in seven of these homes participated in up to 3 clinical visits over a 24-month period, designed to collect data for analyzing the impact of the environmental intervention on the course of their asthma. Enough clinical data was available to perform this analysis on six children. Two of the six demonstrated clear improvement in their conditions post-intervention, while the other four did not demonstrate a clear improvement. The two children who improved were allergic to multiple allergens, including mold. The small numbers notwithstanding, project results support the premise that eliminating excessive moisture and allergens associated with moisture can offer health benefits to occupant children with allergic asthma, consistent with the findings of the Cuyahoga County asthma study. Environmental sampling in the homes of three children with IPH also detected fungi that are known to be capable of producing toxic compounds (mycotoxins), supporting the possible causative or contributory association between IPH and exposure to certain types of toxin-producing fungi.

One potentially very useful product developed as part of the Chicago Demonstration is a comprehensive mold and moisture assessment tool designed to be implemented by a health department or housing agency representative. The tool is a set of worksheets with detailed instructions about inspecting a housing unit from foundation to attic for evidence of leaks and mold infestation, and documenting the results. It is intended for users without extensive training in building science or moisture issues. The tool is accompanied by a catalog of mold and moisture specification codes, corresponding to particular remediation activities and triggered by particular inspection findings. The specification codes address cleaning, drainage and rainwater control, mold remediation, ventilation and other topics. They greatly simplify the process of developing work orders to correct specific problems. While the assessment tool was developed specifically for use in inner-city Chicago housing, it has broad potential application in large areas of the U.S., and has been used by other HH grantees. Finally, the Chicago Demonstration also used a new method for monitoring and measuring dampness in the study homes, the "moisture balance" method, further described in the section on Mold and Moisture Technical Studies.

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[6] A. Martin et al., Illinois Mold and Moisture Demonstration Project. Report to U.S. Department of Housing and Urban Development, HUD Grant Number ILLHH0064-99. January 2005.

Opportunity Council (2000 grant). The Opportunity Council, a nonprofit community action organization located in Washington State, received an HH grant to demonstrate potentially cost-effective, preventive measures to correct housing-based hazards, including mold and moisture problems, by implementing them in conjunction with activities under the DOE Weatherization Assistance Program. The idea was to explore efficiencies that can be achieved when healthy home steps are performed by crews that are on site to weatherize a house. The project plan called for targeting 10 homes belonging to very low income families with asthmatic children, and another 10 homes of family day-care providers where the children receive care. Most of the participants were from Native American and Ukrainian families. One of the notable outputs of this project is a protocol for incorporating healthy homes interventions as part of a weatherization project. The protocol, known as "Weatherization *PLUS* Health" has been adopted by the Opportunity Council and several other programs to the extent feasible given available funding.

University of Illinois at Urbana-Champaign (2003 grant). This HHI-funded grant is investigating ways to improve thermal protection at the tops of exterior walls in older "ranch style" homes with low-slope roofs. The homes are located on the Turtle Mountain reservation in North Dakota. Installing adequate insulation at the wall/ceiling junction is difficult or impossible due to lack of clearance; the inadequate insulation results in lowered interior surface temperatures which can promote condensation and development of mold, especially in severe climates. This type of construction is commonly found in Native American communities as well as in other low-income rural and suburban communities, so an effective retrofit could have wide application. Three alternative retrofit methods are being tested in a total of 18 rental homes under management of the Turtle Mountain Housing Authority. Three of the homes are extensively instrumented for data collection while the others will be evaluated with infrared thermography. Data collection is going on during winter 2004-05 with a final report due later in 2005.

Advanced Energy (2003 grant). Advanced Energy, a North Carolina nonprofit organization, is leading a team of organizations, including Habitat for Humanity, that are assessing the impact of different new home construction practices on the presence and level of various allergens. The study calls for building 15 (or more) experimental houses using enhanced practices designed to control indoor humidity (e.g., mechanical ventilation, tightly sealed ducts, properly sized heating and cooling equipment), and a comparable number of control houses that meet local code requirements but include no special features. Dust samples and air samples from the completed homes will be collected at 6-month intervals over an 18-month period. Air samples will be tested for spore content and dust samples will be tested for a variety of common allergens, including a common mold. Test results will be analyzed to determine whether the levels of airborne spores or allergens in dust are lower in the experimental group than in the control group. Findings are not yet available; the study is scheduled to run until early 2006.

Alaska Housing Finance Corporation (2001 grant). The Alaska HHI grant was used for a project involving ten homes in Fairbanks, occupied by families that had at least one person with asthma or other upper respiratory problems, and ten homes in Hooper Bay, a remote Yupik Eskimo village on the west coast of Alaska. Homes in both locations were inspected to identify causes of mold and other irritants, and were upgraded for moisture mitigation with crawl space vapor retarders, air sealing, measures to control water from leaky roofs and broken pipes, high-efficiency air filtration and ventilation fans. Work on the homes in both locations leveraged HHI funds with Residential Rural Rehabilitation program funds. Test data are not yet in, but according to the investigators, a majority of families report substantial improvements in the health of the occupants.

2.1.2 Technical Studies with a Mold and Moisture Focus

Some moisture problems are obvious from the outset, while others occur in places where they can remain concealed for weeks or months and support the growth of microbes or fungi. Conventional methods for identifying moisture problem areas in buildings involve using handheld meters relying on electrical resistance or capacitance measurements, together with visual inspection which may require removal or destruction of components to access building cavities or concealed spaces. This approach is labor-intensive, destructive, and prone to error. The "overall" level of indoor dampness in a house is another relevant concept that has proven elusive. The 2004 Institute of Medicine report concluded that excessive indoor dampness was associated with adverse health effects, and that excessive indoor dampness was a public health problem. At the same time it acknowledged that there is no generally accepted definition of dampness or of what constitutes a "dampness problem" and no generally accepted method for measuring how damp an environment really is. Previous work has generally characterized overall dampness using relatively subjective methods such as questionnaire responses or inspection.[7] The lack of standardized, science-based protocols to quantify overall dampness hampers inspection, remediation, and research.

Testing for mold is a closely related issue. Standard approaches to mold testing include: (1) viable count methods that involve collecting spores in air and dust samples dust samples or through direct contact with the mold, then culturing the spores on nutrient media and counting the number of colonies that grow and classifying them by species; and, (2) spore counts that involve counting the number of mold spores in air or dust samples and, if possible, identifying individual species or groups. These techniques are time consuming and require considerable technical expertise. Another problem is the difficulty in interpreting test results, since mold spores are ubiquitous and there is no consensus among experts regarding what constitutes acceptable indoor spore concentrations in indoor air or house dust, or which species are most problematic. As a result, experts generally advise consumers that they do not need to test for mold in their homes, but should rather remove all mold once discovered and eliminate the

[7] G. Tsongas, "Case Studies of Moisture Problems in Residences," Manual on Moisture Control in Buildings ASTM MNL 18, ed. Heinz Trechsel (American Society for Testing and Materials, 1994).

underlying water source.[8] Yet even now there are situations where reliable test methods are needed, including the identification of hidden problems and in a research context to better define mold-related hazards based on significant associations with adverse health effects in residents. In the future there may be other applications as well. At present the situation with mold is very different than for other recognized hazards such as lead-based paint or indoor radon, where testing is routinely used to determine if a problem exists and to confirm when it has been resolved.

Several HHI-funded projects are responding through the development, testing, and deployment of next-generation methods for mold and moisture testing, as described below.

Testing for Moisture

National Institute of Standards and Technology (multi-year Interagency Agreements). The National Institute of Standards and Technology (NIST) has been supported through the HHI to develop a method for identifying damp areas in buildings, including dampness inside wall cavities and other concealed spaces. The method uses ultra-wideband radar. Mapping software can be used to convert data from the radar unit into three-dimensional images of the target showing any wet areas. This work has moved beyond proof of concept to demonstration of the method with simulated wall sections, with results published in *ASHRAE Transactions*.[9] Ultimately this technology could be incorporated into a diagnostic tool for rapid, non-destructive mapping of moisture levels in any part of a building envelope or concealed interior space. Such an instrument would be the moisture counterpart of the X-Ray fluorescence (XRF) analyzer, a tool that has allowed for the current approach of low-cost, nondestructive identification of lead-based paint hazards.

University of Illinois Building Research Council (sub-grantee on two grants). The Building Research Council (BRC) of the University of Illinois has used HHI funding to develop and demonstrate a new technique for quantifying the overall wetness of an indoor space. This method, the "moisture balance method", was implemented as part of the HHI-funded projects in Chicago, IL and Providence, RI. It requires monitoring indoor and outdoor temperature and relative humidity at intervals (e.g. hourly) using small, wall-mounted instruments over a prolonged period, preferably an entire year. Each pair of simultaneous indoor and outdoor observations allows calculating the "moisture balance" (the difference between the absolute moisture content in the indoor air and in the outdoor air). Monitoring for a prolonged period allows statistical analysis of how the moisture balance behaves over time. A consistently higher moisture content in indoor air than in outdoor air is evidence of a damp indoor space, with the degree of dampness directly related to the difference in moisture content. Results from the Providence study showed the influence that basement humidity can have on humidity levels in upper levels of smaller, multifamily apartment buildings. A description of the

[8] See, for example, A Brief Guide to Mold, Moisture and Your Home, EPA 402-K-02-003, Environmental Protection Agency, Indoor Environment Division, http://www.epa.gov/mold/images/moldguide.pdf.

[9] W. Healy and Eric van Doorn, "A Preliminary Investigation on the Use of Ultra-Wideband Radar for Moisture Detection in Building Envelopes," ASHRAE Transactions, Volume 110, Part 2 (2004).

method and results of the Providence study have recently been presented at a conference sponsored by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), and published in the conference proceedings.[10]

Testing for Mold

University of Cincinnati (2001 grant). This 2001 grant to the Department of Environmental Health at the University of Cincinnati was to develop and demonstrate a new method for rapidly measuring airborne fungal spores as a way of assessing maximum potential exposure from identified sources. This method uses a "Fungal Spore Source Strength Tester" (FSSST) as an alternative to conventional air sampling, and is designed to avoid problems with short-term tests caused by variability in the rate of spore release over time. The FSSST pumps air over mold to dislodge spores, and collects the spores from the resulting airstream. The investigators found that a 10-minute sample was sufficient to characterize the potential for spore release from a moldy surface. Initial results were presented in a scientific journal article.[11] Follow-up tests compared results derived with the FSSST to results from swab, air and dust sampling. Those tests found the FSSST results were correlated with swab test results, but not with air test results. Additional testing and comparisons were recommended.[12]

Cuyahoga County. Another novel way to measure fungal concentrations was explored under the Cuyahoga County grant work (described in the previous section). The researchers collaborated with EPA scientists and used an EPA-developed DNA polymerase chain reaction (PCR) methodology to measure fungal concentrations in dust. PCR is potentially more valuable than traditional methods that require culturing spores on nutrient media not just because PCR is much faster, but also because it can detect spore fragments that are not viable or culturable, yet are capable of inducing allergic responses. For this project, dust was collected from two groups of homes in Cleveland, Ohio: six homes of infants who had developed idiopathic pulmonary hemosiderosis ("IPH homes") and 26 reference homes with no known fungal contamination ("Reference homes"). The dust was assayed to estimate the amounts of 82 fungal species or groups of related species. The PCR technique was successfully applied, and analysis of the results identified statistically significant differences in the concentrations of certain types of fungi found in IPH homes vs. reference homes.[13] Fungi of types that are known to produce mycotoxins were on average found in higher concentrations in the dust in IPH homes than in the reference homes. This included more than 10 species of the genus *Aspergillus*, more than 5 species of the genus *Penicillium*, *Stachybotrys chartarum*, and *Trichoderma viride*. This finding is relevant due to the possibility that exposure to fungal particles containing mycotoxins could be related to the development of “bleeding lungs” in infants.

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[10] W. Rose and P. Francisco, "Field Evaluation of the Moisture Balance Technique to Characterize Indoor Wetness," Performance of the Exterior Envelopes of Whole Buildings IX (2004).

[11] Sivasubramani et al, "Assessment of the Aerosolization Potential for Fungal Spores in Moldy Homes," Indoor Air (2004): 14:405-412.

[12] Niemeier et al, "Assessment of Fungal Contamination in Moldy homes: Comparison of Different Methods," August 5, 2004. (Submitted to Journal of Occupational and Environmental Hygiene).

[13] Vesper et al., "Quantitative PCR Analysis of Fungi in Dust," Journal of Occupational and Environmental Medicine (2004): 46:596-601.

Radiation Monitoring Devices (2001 grant). A third new approach to mold measurement was the subject of a grant to Radiation Monitoring Devices, a private developer and distributor of scientific instruments. The goal of the project is to develop a portable device to rapidly and accurately measure the total spore load in an air sample using polyclonal antibodies coupled with microelectronic circuitry, and to determine concentrations of selected species of "problem indicator molds" using monoclonal antibodies. This project has leveraged antibody technology developed at the USDA Forest Products Laboratory. Difficulties in completing development of the required library of monoclonal antibodies have prevented full achievement of the grant objectives, but the method is considered viable and may ultimately prove usable for "real time" mold detection.

Air Quality Sciences (2001 grant). Air Quality Sciences, Inc. (AQS) performed an HHI-funded study to establish a baseline of "normal and typical" types and concentrations of airborne and dustborne fungi in urban homes that were not known to have significant moisture problems or fungal growth.[14] While this does not represent a new test method, it is important because mold test results cannot be properly interpreted without this kind of data. The study was designed to expand on airborne mold data from an earlier U.S. Environmental Protection Agency (EPA) study of indoor air quality in 100 commercial office buildings not selected for moisture problems, the "Building Assessment, Survey and Evaluation" (BASE) study. For the AQS study, data was collected from 50 homes in metropolitan Atlanta, Georgia, a location considered to be representative of the southeastern U.S. climate. Air and dust samples were taken in summer and winter, and cultured to allow identification and counting of individual species. The investigators divided the different species encountered into three categories: leaf surface fungi, soil fungi and water fungi. They observed that leaf surface fungi, presumed to originate outdoors, constituted more than 20 percent of all fungi in at least 85 percent of dust samples from the study homes, and concluded that in the southeastern U.S. climate, dust samples with less than 20 percent of colonies from leaf surface fungi were unlikely to be from buildings free of moisture or mold growth problems. The researchers also found a very low prevalence of "problem indicator molds" such as *Stachybotrys chartarum* in their samples, which supports the value of indicator fungi in identifying mold problems and environments that are potentially hazardous to occupants.

2.1.3 Education and Training

Centers for Disease Control and Prevention (2003 Interagency Agreement). OHHLHC provided support to the CDC to update and revise the *Basic Housing Inspection Manual*, re-titled as the *Basic Healthy Housing Inspection Manual*. The first edition of this document, published in 1976, has been out of print since 1989, yet it is still being requested. Construction practices and scientific understanding of how those practices impact health have changed considerably since publication of the first edition.

[14] W. Elliott Horner, Anthony G. Worthan, and Philip R. Morey, "Air- and Dustborne Mycoflora in Houses Free of Water Damage and Fungal Growth", Applied and Environmental Microbiology (Nov. 2004): p. 6394-6400.

The Manual addresses health issues related to every area of construction. It is designed to allow field personnel to assess, identify and remedy housing construction and maintenance deficiencies, including moisture and mold problems, that may lead to adverse health effects. In addition to revising the Manual, CDC is working with Eastern Kentucky University to develop a computerized assessment tool, "Hazard Assessment and Reduction Program for Healthy Housing." This software is designed to be used by environmental health specialists and code inspectors as a way to streamline the inspection process. The inspector enters information based on visual observations or information from the occupants, and the software generates reports and fact sheets to be left with the homeowner. As part of this effort, CDC is also developing and piloting a "National Healthy Homes Training Center and Network." Major goals of the training include the education of public health and housing professionals on the identification and treatment of housing-related health hazards, and the creation of a forum for practical guidance on healthy housing strategies among various stakeholders. The updated inspection manual and the computerized assessment tool will be incorporated into the training curriculum.

Montana State University Extension Service Housing Program (2002 grant). The University is working with Native Americans in seven Montana reservations to develop, implement and evaluate a culturally-specific asthma education program for the Native American community. The focus is on known asthma triggers, including but not limited to elevated levels of molds and household pests that are sources of allergens. The project was prompted by evidence suggesting that Indian children suffer from asthma at a level almost twice that of the general U.S. population. The approach calls for educating 5,000 Native American children aged 8-11 about the basics of asthma, home asthma triggers and asthma prevention solutions. These children will in turn share their knowledge as peer mentors with another 7,500 younger Native American children, and ultimately induce all these children and their families to deal with and control asthma triggers in their homes.

2.1.4 Other Projects

American Healthy Homes Survey (AHHS). The OHHLHC is planning to conduct the AHHS in partnership with the EPA's Office of Research and Development, with data collection starting in spring 2005. While the primary objective of the survey is to study a nationally representative sample of U.S. housing in order to estimate the prevalence of lead based paint hazards, the homes will also be assessed for moisture damage and sampled for mold. Samples of settled dust will be collected with a vacuum sampler and the types and concentrations of fungi will be determined using both the viable count and PCR methods. Dust samples from residents' vacuum cleaner bags will also be tested. This will provide an opportunity to test the ability of the PCR methodology to identify homes with potential mold problems among this nationally representative sample (see discussion of the promising research results using PCR methods in Section 2.1.2).

Healthy Homes Issues Paper on Mold. OHHLHC developed a review paper, titled "Healthy Homes Issues: Mold" in October 2001. The paper, which was peer reviewed by several outside experts, is posted on the HHI website at

http://www.hud.gov/offices/lead/hhi/Mold_v2_12-01.pdf, and is one of several background papers presenting information about healthy homes issues. The paper discusses the nature of mold hazards in the home and methods to assess and mitigate those hazards. It also summarizes information needs in the field of mold research. While the paper was designed to provide authoritative guidance to HHI grantees and grant applicants regarding the state of scientific knowledge about mold and the hazards it presents in homes, the contents are of interest to much broader audiences in the public health, housing and research communities. The paper will be updated in 2005.

Codes and Standards. Staff at the National Institute of Standards and Technology (NIST) have worked on healthy homes codes and standards issues, especially standards relating to moisture control, under multi-year Interagency Agreements with HUD. The focus to date has been on supporting development of voluntary consensus standards sponsored by professional societies rather than mandatory codes, with the understanding that such standards often are incorporated by reference in the codes. One part of the standards work has been the drafting of an indoor air quality guide for the American Society for Testing and Materials (ASTM), published in 2003 as ASTM E 2267-03, "Standard Guide for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings - Indoor Air Quality." This is one of a set of ASTM guides presenting a complete set of performance standards for specifying and evaluating single family attached and detached dwellings. Performance statements in the guide address topics including kitchen and bath exhaust, control of groundwater and rain runoff, control of crawl space moisture, control of water penetration through walls, windows and doors, control of water vapor within walls and control of plumbing leaks. A second part of the HHI-funded standards work was preliminary work on drafting of ASHRAE Guideline 24P, "Ventilation and Indoor Air Quality in Low-Rise Residential Buildings." The outline for this ASHRAE Guideline includes a chapter on moisture, and another section on mold and moisture diagnostics and repair.

Industry Workshop on Mold and Moisture. In October 2002, OHHLHC and NIST sponsored a workshop to evaluate the issue of excessive moisture and its impacts on durability and livability in new and existing houses. The workshop convened owners and occupants; financers and underwriters; product manufacturers and builders; code officials and inspectors; remediators; and research and regulatory personnel. The workshop was designed to address four objectives:

1. Identify what is known and what is not known about mold mechanisms, effects, and impacts.
2. Determine how to apply existing knowledge to avoid moisture and mold problems.
3. Catalog effective remediation techniques and recommend methods for disseminating guidance to the building community.
4. Define knowledge gaps and research needs to address mold assessment and remediation.

Consensus recommendations that emerged from the workshop included focusing on moisture control and mold *prevention*, expanding training and education efforts, improving public awareness, improving data that characterizes mold and moisture problems, and establishing incentives for the use of best practices.

2.2 OFFICE OF POLICY DEVELOPMENT AND RESEARCH

The Affordable Housing Research and Technology Division within the Office of Policy Development and Research (PD&R) has worked for decades with the mainstream home building and remodeling industries to introduce and evaluate new building technologies, and to document and resolve performance issues with building products and systems. Within this framework, PD&R has approached mold problems in housing as a *moisture* problem, with the problems and the solutions both rooted in the design, construction, and operation of the building systems that make up a house. The programs described in this section illustrate this approach, concentrating on building practices and the development and application of building technologies to provide houses that manage moisture properly.

In recent years HUD, working through PD&R, has been the lead federal agency involved in the Partnership for Advancing Technology in Housing (PATH), a public-private partnership designed to accelerate the development and use of technologies that improve the quality, durability, energy-efficiency, environmental performance, and affordability of American housing. The PATH goals clearly encompass moisture control and moisture management, and all of the PD&R projects described below are elements of a larger overall program of research and related work in support of PATH.

2.2.1 Builder Technical Guidance

Durability by Design is a publication sponsored by PD&R that promotes an awareness of durability as a distinct design consideration. The document was published in May 2002. The intended audience for *Durability by Design* is residential designers and builders, and the manual contains dozens of recommended design and building practices that enhance the durability of homes. In many cases the design recommendations are tailored to specific climates based on temperature and precipitation levels.

The majority of the recommendations in the manual deal with techniques to manage moisture in and around a house. Specific chapters are dedicated to Ground and Surface Water, Rain and Water Vapor, and Decay and Corrosion. The recommended practices do not involve mold in any direct way, but instead deal directly with moisture, the underlying cause of mold problems in homes.

The durability recommendations cover topics such as:

- Foundation drainage systems
- Roof overhang sizing
- Drainage plane design for wall systems
- Exhaust ventilation systems

- Bathroom design considerations
- Crawlspace ventilation techniques

Durability by Design is disseminated through multiple channels, including hard copy and electronic versions available through the HUD User document service at http://www.huduser.org, as well as at industry events such as the annual International Builders Show sponsored by the National Association of Home Builders.

Given the increased need for good moisture management practices in housing, PD&R is currently developing a *Moisture Best Practices Guidebook* that deals exclusively with techniques to manage moisture, with completion anticipated in late 2005. The Guidebook is based upon a review of current best practices drawn from U.S. and international studies of building performance and construction practices. The intended application of the Guidebook is for building plan development and review, such that builders and designers can review their house plans for moisture performance in much the same way that they review them for energy code compliance, architectural features, or any other design criteria. The Guidebook will assist builders and designers in evaluating and improving how their houses manage moisture by identifying design issues and offering recommended practices. To support this application, the Guidebook is being developed with the same organizational structure as found in building plan sets, with best practices grouped by building system (e.g. Roof, Foundation and Mechanical sections).

The selection of best practices presented in this publication will concentrate on high impact moisture management considerations such as weather barrier design for exterior walls, flashing details, and vapor retarder selection and location. Moisture control approaches will also be presented as a function of climate and other environmental characteristics (e.g. annual rainfall), so that appropriate practices may be selected based on location. In addition to best practice recommendations that can be added as details to building plans, the Guidebook will also feature a section on Quality Management (QM) practices that address the *implementation* of best practices during the construction cycle. For example, the QM section will include inspections to flag potential moisture issues during construction, and guidance on coordinating different building trades to address moisture-related details that might otherwise go unnoticed.

Both *Durability by Design* and the *Moisture Best Practices Guidebook* concentrate on the most common moisture problems, building materials, and housing designs. This approach makes the publications and their findings broadly applicable to mainstream houses. Information on dissemination of these materials is presented in Section 4.

Another recent moisture-related PATH project, sponsored by PD&R, is the development of an HVAC sizing methodology for insulated concrete homes. Proper sizing of HVAC equipment is essential to regulating moisture levels in homes, and oversized HVAC equipment has been implicated in the development of mold and moisture problems. Insulated concrete homes represented a niche construction system

that traditional sizing methods do not cover, which presented the need for improved guidance on HVAC design in these homes. The PATH project involved research to compile available information regarding energy use in concrete homes, develop additional information as needed, and use that information to develop a methodology to properly size heating, ventilating, and air-conditioning (HVAC) equipment for concrete homes in the U.S. and Canada.

An additional PATH project focused on the performance of construction materials when subjected to flooding and flood waters. PD&R, through the PATH program, partnered with FEMA and DOE to evaluate the performance of construction materials when they were subjected to flooding. Materials in flooded homes were allowed to dry and then compared to their properties when new. Based on these evaluations, the project identified strategies for the remediation of damage in flooded homes and for the mitigation of future damages. Among the strategies identified were the use of alternative insulation materials, disposal of some components where the cost of rehabilitation exceeds the cost of replacement, and allowing for drainage pathways in building envelope assemblies. PATH now offers a list of recommendations to be implemented when designing for flood resistance or when recovering from a flood event. The PATH recommendations include information for homeowners and for reconstruction professionals.

2.2.2 Moisture Research Needs

In response to the need for improved science to understand and predict moisture problems in various types of building systems, PD&R recently sponsored development of *Building Moisture and Durability – Past, Present, and Future Work* (2004). The persistence of moisture problems in housing and the emergence of new types of moisture-related problems both have highlighted the need for a comprehensive research agenda for future work – which was the main output of this project. Currently the basic dynamics of moisture movement are well understood, but the exact scenarios and combinations of materials that will result in moisture problems are not. This PD&R program developed a research agenda to improve the science needed to manage moisture in buildings by reviewing extensive literature on moisture problems, investigating ongoing research efforts and gaps in current research, and convening a panel of moisture experts to review research needs and recommendations.

The resulting research agenda was focused on three overarching goals:

- Building improved knowledge about the nature, extent, and implications of moisture problems.
- Pursuing a variety of methods for preventing and detecting moisture problems.
- Taking greater advantage of the potential offered by moisture modeling tools.

The research agenda included project descriptions and highlighted specific research priorities, along with key organizations that should take part in the research, timeframes, and funding estimates. Top research priorities included the following projects:

- Compile statistically valid data on the relative frequency and severity of different moisture problems in new and existing houses.
- Perform an in-depth analysis of existing American Housing Survey data on moisture problems.
- Characterize the moisture performance of existing homes through a field testing protocol.
- Assess the drying performance of typical wall systems in U.S. climates and disseminate the results.
- Develop educational tools to enable certification programs that recognize good moisture control practices.
- Develop statistically validated procedures to assess internal moisture loads for use in hygrothermal analyses and related engineering studies.

This project also included a review of possible approaches to coordinating moisture-related programs among public agencies and private-sector organizations.

2.2.3 Manufactured Housing

Manufactured homes in the U.S. must be built in compliance with the federal Manufactured Home Construction and Safety Standards, a set of regulations administered by HUD that is essentially a national building code for manufactured housing. Given this landscape, HUD is in a unique position to investigate performance issues in manufactured houses and to effect changes in their design. Manufactured housing differs from other housing in the way it is constructed and installed on site. Key differences include:

- **Production Methods**. Manufactured homes are built in factories, sometimes in separate sections, using methods and materials not common in site-built houses.
- **Integrated Frame**. Manufactured homes are built on steel frames integrated into the floor system, which is then enclosed with a cover on the bottom.
- **Site Installation**. Manufactured homes are designed to be installed quickly and efficiently on site. Key features such as perimeter skirting, insulation and flashing details, and protection from ground moisture may or may not be addressed during installation.

Due to these differences, HUD's role in the manufactured housing industry, and the emergence of moisture and mold problems in manufactured housing, PD&R has supported the development of moisture prevention resources specifically tailored to this segment of the housing industry. *Moisture Problems in Manufactured Homes* (2000) is a manual intended to help those involved with manufactured housing to understand, recognize, and address moisture problems in these housing units. The intended audience is manufactured housing producers, retailers, installation crews, and occupants. The manual contains an overview of how manufactured houses differ from site-built houses, together with detailed recommendations for improving the moisture resistance of these houses. Many of the moisture problems addressed in the recommendations are specifically encountered in manufactured homes due to their

design and production methods. This work is consistent with PD&R's overall approach to mold, in that it focuses on the underlying moisture problems that result from improper building design, construction, and operation.

Manufactured homes in hot and humid climates face particularly challenging environmental conditions and have been the subject of further study by PD&R. *Alternatives for Minimizing Moisture Problems in Homes Located in Hot, Humid Climates* (2003) involved data collection inspections of manufactured houses in the Gulf Coast region, including homes with and without moisture problems. This data on the as-built house characteristics was then analyzed to determine which factors may be strong indicators of moisture problems. The most significant set of contributing factors was pressure imbalances in a house, including imbalances caused by uneven distribution of conditioned air, duct air leakage, and air leakage through the building shell.

A complementary research program completed later in 2003 resulted in the report *Minimizing Moisture Problems in Manufactured Homes Located in Hot, Humid Climates – Response of Interior Air Pressures to Various Operating Conditions.* This research examined building performance characteristics that affect airflow patterns in manufactured houses, and sought to identify sets of conditions that would create a neutral or positive indoor pressure relative to outdoors. In a hot, humid environment such a pressure gradient helps to prevent the infiltration of moisture-laden air and keeps a building dry.

Each of the reports described above is available through the HUD User website (www.huduser.org).

2.3 OFFICE OF PUBLIC AND INDIAN HOUSING

Work relating to mold and moisture problems in Native American housing has been conducted through the Office of Native American Programs (ONAP) located within the Office of Public and Indian Housing (PIH), and has been performed in consultation with OHHLHC and the Indian Health Service of the Department of Health and Human Services. Over the last several years, the Department has worked closely with Indian housing organizations to improve understanding of how to deal with mold and moisture among affected groups, and assist in providing solutions.

2.3.1 Report to Congress Dated November 17, 2003

In November 2003 the Department described the results of its study of mold and moisture issues in Native American housing in *Mold and Moisture Problems in Native American Housing on Tribal Lands: A Report to Congress*. The report, mandated by the Native American Housing Assistance and Self-Determination Reauthorization Act of 2002, presented the findings of a study on mold in Indian housing. Key elements of the study included an analysis of Indian housing and demographic data, data on reported mold problems in assisted housing on tribal lands, a literature review on mold and moisture issues in housing, evaluations and inspections of Indian housing, and estimates for remediation and training costs.

The report estimates that about 15 percent of the 66,580 housing units under management of Indian tribes or Indian housing organizations had resident-reported mold conditions. Site visits and inspections were performed at 175 units in 21 locations, all conducted at the request of tribal authorities. Units were visited because they were believed likely to have mold and moisture problems. During these visits visible mold was found in 62 percent of the units, and identifiable moisture problems were found in 85 percent of the units. Since there are currently no data that address the extent or incidence of mold problems in building structures nationwide, these findings cannot be used to indicate whether housing on tribal lands experiences a higher incidence of mold problems than other housing.

The report presents the following major findings based on the study of mold problems in Indian housing:

- The review of current literature found no definitive evidence that inhaled mold toxins have generally adversely affected human health.
- Mold conditions were reported in 15 percent of housing units based on data collected from tribes.
- Mold and moisture problems are commonly caused by physical conditions reflecting design, construction and site characteristics.
- The root causes of moisture problems are 1) design and construction issues, 2) management and maintenance, 3) occupant maintenance and practices, and 4) low-income and overcrowding issues. These root causes define the points of intervention for developing long-term solutions.
- Resident reports of mold were found to be reliable indicators of actual mold and moisture problems.
- Indian housing organizations and residents have widely ranging levels of concern, knowledge bases, and approaches to addressing mold problems in homes.
- Remediation and training are needed to support Indian housing clean-up and prevention efforts.

2.3.2 Site Visits and Assessments

Since completion of the 2003 Report to Congress described above, ONAP has continued to conduct site visits to assess mold and moisture problems in Indian housing. As of February 2005, roughly 550 housing units at 55 locations had been assessed by ONAP subcontractors (including the 175 units referenced in the 2003 Report to Congress). The availability of these services is publicized through ONAP's six regional offices, which have routine contact with the Indian housing organizations. Site visits are done only at the tribe's request, and inspections are only conducted at buildings specified by the housing organization. Therefore the findings of the site assessments do not represent a random sample of Indian housing, but rather a subset of buildings with moisture and mold problems.

The approach of the site visits is to focus on the *source* of a mold problem and the best way to address and remediate the problem. Therefore, these visits have not involved mold testing, but rather focused on visual inspections of building systems supplemented by other measurements such as wood moisture content or humidity. Each site visit results in a report to the tribe and ONAP with an assessment of moisture problems and recommendations for repair. Recommendations may be specific for more basic problems (e.g. re-connect the bathroom exhaust fan), but the inspectors do not provide exact remediation steps which may be required in more complex situations. At the conclusion of each site visit, the ONAP contractors de-brief housing personnel, residents, and tribal officials to explain the moisture problems that were found and the recommended steps for addressing them.

ONAP has found that the site visits conducted since the 2003 Report to Congress have revealed problems similar to those reported from the earlier visits. While these problems were directly responsible for the development of mold in Indian housing, the underlying root causes that gave rise to these problems included design and construction issues, maintenance issues, occupant practices, and overcrowded housing and other issues associated with low-income residents. These root causes are viewed as possible intervention points where moisture and mold problems can be prevented, and are addressed in part by ONAP's outreach and training programs.

The site visits have also been instrumental in learning about unique needs and characteristics in Native American housing that contribute to mold problems. While the list of unique issues below is certainly not *exclusive* to Indian housing, the site visits did uncover these particular factors which would not be considered as common in the overall stock of U.S. housing:

- **Overcrowding**. Indian housing was more than 2-1/2 times as likely as U.S. housing in general to be classified as "crowded" or "severely crowded", based on data from the 2000 U.S. Census.[15] Overcrowding in Indian housing can lead to higher indoor moisture loads from showering, cooking, laundry, respiration, etc. Overcrowding not only affects the quality of the living environment, it also makes it more likely that routine storage of household possessions will block air registers, reduce indoor air circulation and create cold wall surfaces which may promote condensation. Overcrowding also may induce use of marginal spaces such as crawlspaces for storage, which can lead to mold growth on boxes and other items.
- **Insufficient Insulation**. Some Indian housing – especially older units – was found to lack adequate insulation for a given climate. When combined with the cold-climate location of many Indian housing sites, insufficient insulation can lead to cold surfaces, dampness, and mold growth.
- **Physical Deterioration**. Some Indian housing units inspected during site visits were found to be in poor condition due to insufficient maintenance. This

[15] Bennefield, R., and R. Bonnette, "Structural and Occupancy Characteristics of Housing: 2000", Census 2000 Brief. U.S. Department of Commerce, Economics and Statistics Administration, U.S. Census Bureau (November 2003), p.7.

condition can lead to water intrusion and other moisture problems which result in mold growth.

- **Poor Site Conditions**. Some Indian housing units are built in high water-table areas, areas with poor drainage topography, or areas prone to flooding. These conditions can lead to chronic foundation water problems and mold growth.
- **Socioeconomic Conditions**. The American Indian and Alaska Native (AIAN) population has the highest poverty rate (24.5%) of any group in the U.S., based on U.S. Census Bureau three-year average data on income and poverty rates (1999-2001). The AIAN population also has the highest percentage of households without adequate plumbing and households lacking complete kitchen facilities. These economic and housing conditions can impact housing maintenance and operations and lead to moisture issues in homes.

2.3.3 Education

ONAP's education and outreach is designed to address several audience groups in a variety of formats, such as publications, training sessions, and video. This section describes major PIH/ONAP publications on mold, while ONAP's training and dissemination programs are discussed in the Information Dissemination section of the report (Section 4).

The most comprehensive ONAP publication on mold and moisture is *Mold Prevention and Detection: A Guide for Housing Authorities in Indian Country, Second Edition* (February 2003). The first edition of this Guide was produced in September 1998. The Guide is based on the findings of the site visits described above and surveys of Indian housing groups, and contains useful information for the following audiences:

- Indian housing organizations
- Residents
- Inspectors
- Tribal council members
- Health providers
- Contractors and other building specialists

The guide contains a wide breadth of information on mold and moisture issues, ranging from general guidance to detailed construction techniques to methods for selecting a remediation contractor. The publication includes information on:

- Successful repair strategies from previous mold cleanups of Indian housing
- Actions that occupants can take to prevent mold
- Symptoms, causes, and solutions to some commonly seen mold problems
- Construction techniques that housing organizations can employ to prevent mold problems
- Mold cleanup guidance for occupants for manageable problems
- Guidance for managing larger mold remediation projects

- Recommended practices for new construction
- Sources for special help and finding equipment

A second technically-oriented guidebook is *Mold Prevention and Detection: A Guide for Maintenance Staff and Housing Counselors in Indian Country* (February 2004). The publication is specifically intended for tribal housing maintenance departments. It contains examples of mold maintenance programs, housing maintenance recommendations, renovation recommendations, guidelines for mold remediation, and communication techniques to discuss mold issues with occupants.

The third guidebook in this series is *Mold and Moisture Prevention: A Guide for Residents in Indian Country* (May 2004). This easy-to-read pamphlet discusses why mold problems occur, how they can be addressed, long term prevention methods, and occupant rights and responsibilities.

Both of the *Mold Prevention and Detection* guides and the *Guide for Residents* have been broadly distributed to Indian housing audiences and used for training and education. These activities are discussed in Section 4.3.

3. LESSONS LEARNED AND BEST PRACTICES

HUD's recent projects on mold and moisture issues in houses have yielded many useful "lessons learned" and identified numerous best practices. These results show progress on several fronts as OHHLHC, PD&R, and PIH conduct programs to address multiple dimensions of residential mold and moisture problems and target different audience groups. It should also be noted that these findings represent the leading edge of what is likely to be a sizeable body of new knowledge resulting from many HHI grant programs that are currently in progress.

Significant lessons learned to date are summarized below. The findings are grouped into categories that reflect the array of mold and moisture programs conducted by HUD. The categories are:

- Interventions in Moldy Houses – Effective Approaches and Impacts on Occupant Health
- Detecting and Measuring Mold in Houses – Developing New Tools
- Moisture Management and Control – Building Design, Construction, and Operation Practices
- Researching and Understanding Moisture Behavior in Building Systems
- Building Assessments and Remediation – Evaluating, Addressing, and Preventing Mold Problems
- Outreach, Training, and Education – Sharing Findings and Enabling Affected Groups

Interventions in Moldy Houses – Effective Approaches and Impacts on Occupant Health

- Moisture and mold-related interventions can be carried out effectively and at relatively low cost in conjunction with other hazard reduction or home improvement strategies, including lead hazard control and weatherization.
- Training experienced lead hazard control and weatherization contractors can be an effective approach to developing mold and moisture remediation capacity for low-income housing.
- There is preliminary evidence from the Cuyahoga County asthma study that interventions to eliminate mold and correct moisture problems can reduce the symptoms and the need for emergency medical care in asthmatic children.
- Testing and demonstration of intervention methods is logistically simpler in owner-occupied housing than in apartments, where consent of the landlord is required.

Detecting and Measuring Mold in Houses – Developing New Tools

- Existing data regarding mold and moisture problems in housing is very difficult to interpret due to the wide variety of methods used to identify problems.

- Although mold problems can be and usually are corrected without testing to determine which species are involved, new, more sensitive methods for identifying mold spores or spore fragments may ultimately be useful in screening homes quickly and inexpensively for evidence of indoor mold problems once baseline data from homes in different local environments is in hand.
- Ultra-wideband radar can be used to locate wet spots inside building envelopes without the need for destructive testing and inspection.
- Additional field validation of visual assessment tools for detecting mold and moisture problems, together with training of environmental health field professionals in their use, is needed for the development of the public health infrastructure to effectively address this issue.

Moisture Management and Control– Building Design, Construction, and Operation

- Steps that can be taken during building construction to help minimize the likelihood that a dwelling will develop moisture and mold problems include selection of appropriate foundation type and building materials, use of proper construction detailing like flashing and moisture barriers, and the provision of adequate ventilation to control indoor humidity.
- Local construction practices can be an important factor in the development of moisture problems or the exacerbation of the health effects of mold problems.
- Examining sets of houses with similar design and construction characteristics through field inspections, survey tools, and modeling analyses can yield useful information that indicates major types of moisture and mold problems. Such data lays the groundwork for identifying effective solutions for new houses and retrofit techniques to correct problems in existing housing.
- Because mold problems can be avoided by addressing moisture problems at an early stage, it is important that building maintenance and operations staff be aware of moisture problems in their buildings and the importance of addressing them promptly. This is facilitated by encouraging tenants to report moisture problems in a timely manner.

Researching and Understanding Moisture Behavior in Building Systems

- Building improved knowledge about the nature, extent, and implications of moisture problems in the U.S. housing stock is among the top research needs within the industry. Current knowledge regarding the extent and severity of mold problems is based on many individual sets of disparate data, which prevents a valid analysis of mold problems throughout the housing industry.

Building Assessments and Remediation – Evaluating, Addressing, and Preventing Mold Problems

- State and local health departments and housing agencies that HUD has worked with throughout the country have shown a strong willingness to

identify, investigate, and correct mold and moisture problems in housing in their jurisdictions, and the tools for them to conduct this work are increasingly available.

- The moisture problems in homes included in HHI Demonstration projects (typically older homes in urban areas) most often result from localized water sources, such as entry of water through the building envelope or plumbing leaks, rather than from improper water vapor management.
- Addressing the primary causes of mold problems in Indian housing requires a strategy which combines education, training, assessment, and remediation. Approaches must also recognize special Indian housing issues, such as overcrowding, inadequate insulation, poor site and building conditions, and challenging socioeconomic conditions.
- Similar Indian housing units on a given reservation tend to have similar mold problems, making standardized assessments an effective tool for addressing numerous housing units through a fairly limited set of inspections.
- As large blocks of Indian housing units reach 20-30 years in age, integrating special attention to moisture considerations when conducting planned and unscheduled maintenance activities is a relatively cost-effective approach to addressing mold and moisture issues.

Outreach, Training, and Education – Sharing Findings and Enabling Affected Groups

- Differences in production methods, construction and assembly techniques, and occupancy issues among different housing segments require tailored guidance and outreach strategies. HUD's mold and moisture initiatives therefore address specific stakeholders (e.g. at-risk populations, manufactured home producers, mainstream builders and Indian housing groups) with targeted information in a format appropriate for the audience.
- Partnering with other Federal organizations and groups with common interests in housing (e.g., public health organizations and Indian housing organizations) is an effective method to leverage existing dissemination channels, address the interdisciplinary aspects of mold problems, and efficiently deliver guidance to specific audiences.

4. BEST PRACTICES DISSEMINATION

HUD's dissemination of best practices for mold and moisture control is designed to create an infrastructure of housing residents, builders, researchers, and scientists equipped with the knowledge and tools to minimize the occurrence and impact of mold in homes. By combining its research work with strategic dissemination, HUD is working to improve the understanding and capabilities of key audience groups:

- **Home Residents** will have a better understanding of the conditions that lead to moisture problems and mold growth, health implications, remediation strategies, and actions they can take to prevent problems.
- **Builders and Contractors** will be knowledgeable of best practices to implement in the design and construction of homes to prevent mold and moisture problems, and will recognize symptoms of moisture problems.
- **Housing Management and Maintenance Staff** will better understand maintenance actions to prevent problems and good practices for managing and remediating problems that do occur.
- **Researchers and Building Scientists** will be aware of the latest findings on building performance issues, mold measurement and detection technologies, and approaches to and impacts of remediating housing hazards.
- **Health and Environmental Specialists** will understand techniques to assess indoor environments from a health perspective, and will better understand the impacts of housing-related health hazards.

To communicate information to these groups effectively, HUD's dissemination strategy includes:

- Communicating through multiple channels
- Strategically partnering with other organizations
- Delivering information tailored for the audience
- Packaging guidance in appropriate formats

OHHLHC, PD&R, and PIH all conduct strategic dissemination efforts to ensure that their respective audiences are provided with the most appropriate and current information on residential mold and moisture issues. Table 1 illustrates the breadth of HUD's mold and moisture information dissemination efforts and the audience groups that are reached.

Table 1: HUD Mold and Moisture Dissemination Activities

	Target Audience					
Outreach Tool	Home Occupants	Special Sub-Populations (e.g. at-risk, Indian)	Builders, Contractors, and Housing Manufacturers	Housing Maintenance and Managers	Researchers and Building Scientists	Public Health and Environmental Specialists
Inspections and Follow-Up Recommendations	✓	✓	✓	✓		
Technical Papers			✓		✓	✓
Demonstrations & Interventions	✓	✓	✓	✓	✓	✓
Training Seminars and Technical Presentations		✓	✓	✓	✓	✓
Publications, Manuals, and Video	✓	✓	✓	✓	✓	✓
Community Programs (e.g. Health Fairs, Head Start)	✓	✓				
Websites	✓	✓	✓	✓	✓	✓

HUD engages a wide range of groups to address mold and moisture issues, as indicated in the table. Accordingly, dissemination tools vary from office to office, and even from one specific project to another. HUD combines wide-reaching dissemination - such as sending a mold prevention manual prepared for Native American audiences to Indian housing organizations - with more targeted means that directly engage an audience, such as training seminars for Indian housing staff. In the case of Healthy Homes technical outreach, the scientific and engineering communities are provided with project results through papers in peer-reviewed professional journals, while researchers also commonly make presentations before their peers at technical conferences. While this process is incremental by nature, it is also the principal means by which industry and scientific advances become generally accepted and are integrated into an overall body of knowledge. A review of dissemination efforts in OHHLHC, PD&R, and PIH follows.

4.1 Office of Healthy Homes and Lead Hazard Control

There are many groups with an interest in the results of HHI-funded work on mold and moisture. These include technical audiences in the health sciences and engineering fields, state and local agencies, nonprofits, consumer audiences, and elements of the building industry.

As noted in Section 2.1, many HHI-funded projects have led to the publication of scientific papers presenting research results in peer-reviewed scientific journals. Examples include recent papers published in *Applied and Environmental Microbiology* and the *Journal of Occupational and Environmental Medicine.* This is the primary strategy for ensuring that the broader public health and building research communities are kept informed about Healthy Homes research studies. Healthy Homes program staff also regularly participate in conferences attended by important stakeholder audiences, in addition to those conferences where HHI grantees present their technical papers. HHI staff participate in annual conferences for professional groups such as the American Industrial Hygiene Association and the American Public Health Association (APHA), as well as conferences for the building trades such as Affordable Comfort, and the Energy and Environmental Builders Association. OHHLHC staff distribute literature at these conferences and organize sessions on healthy homes themes. For example, a staff scientist organized a well-attended session at the 2004 APHA conference at which HHI grantees made presentations on residential interventions to reduce asthma morbidity in children.

HHI educates consumers and building professionals through complementary methods. As one strategy for reaching consumers, OHHLHC developed an interagency agreement with USDA to leverage the extensive outreach network established by the USDA Cooperative State Research, Education and Extension Service (CSREES). CSREES includes extension educators in nearly all of the nation's 3,150 counties, and professional staff at over 100 land-grant colleges and universities. OHHLHC has worked with CSREES and the University of Wisconsin to develop and disseminate a self-help booklet for consumer audiences titled *Help Yourself to a Healthy Home: Protect Your Children's Health*. This illustrated 56-page publication systematically describes all the risks addressed by the HHI program in plain, non-technical language. It includes sections on Indoor Air Quality, Asthma and Allergies, Mold and Moisture, Carbon Monoxide, Lead, Drinking Water, Hazardous Household Products, Pesticides and Home Safety. Each section discusses "Should You Be Concerned", suggests "Questions to Ask", lists "Action Steps" to address identified problems, and identifies additional resource materials. Over 100,000 copies of this well-received publication have been distributed, and a Spanish language version has also been published.

HHI also funds CSREES and the University of Wisconsin to host an interactive, consumer-oriented website, "Help Yourself to a Healthy Home", hosted at http://www.uwex.edu/healthyhome/tool. Visitors to the website are prompted with questions about their home environment. Based on the answers, they are presented with diagnostic comments and recommendations about how to correct any problems identified.

Read This Before You Design, Build or Renovate is an HHI-funded publication aimed primarily at building industry audiences. The document presents essential elements of a healthy home, and lists numerous building techniques designed to reduce mold and moisture problems or to address other healthy home issues. It also identifies

various practices to avoid. The publication includes recommendations that go beyond minimum code requirements or typical construction practices and is likely to be well received within the building community. The document should also be useful as a resource to consumers who are interested and actively involved in design and construction of their new home or remodeling of their existing home. It has been successfully piloted in training sessions with contractors and housing officials in New England, and is currently going through internal HUD clearance.

The HHI program also reaches a large number of consumers directly through its grants. Projects funded through Demonstration grants generally have an outreach/education component that provides home occupants with information on preventing and remediating mold and moisture problems. Grantees often distribute materials at community events such as health fairs, and form strategic partnerships with organizations such as Head Start programs to reach high risk populations. HHI grantees also train small contractors on residential interventions to address mold and moisture problems, thus helping to create a local infrastructure of skilled workers to address this issue.

Future dissemination plans for HHI programs will utilize many of the current strategies: publishing in scientific journals; presenting and distributing materials at key conferences; strategically partnering with other organizations; developing consumer-oriented materials, and producing non-English guidance materials. In addition, HHI grants place an emphasis on program sustainability, since grants may be one-time awards. This emphasis is intended to help to ensure the key program components and materials are disseminated even after HUD support has terminated.

4.2 Office of Policy Development and Research

PD&R's mold and moisture programs focus on the building design, construction, and performance aspects of moisture problems in houses. Accordingly, its outreach concentrates on delivering information on building design, construction, operation, and research issues to designers, builders, researchers, and consumers.

The companies that build and design homes often receive their information through non-federal sources operated by trade associations and other industry groups. PD&R utilizes these dissemination channels to deliver its research findings – as well as best practices compiled from other sources - to industry stakeholders. For example, PD&R includes authoritative information about mold and moisture problem prevention and correction on the ToolBase web portal (http://www.toolbase.org), which is operated by a subsidiary of the National Association of Home Builders. Selected HUD-funded publications, such as *Durability by Design* and *Building Moisture and Durability: Past, Present and Future Work,* are available for sale or download at ToolBase. While these resources are available to any user, the ToolBase portal is marketed primarily to home building firms.

PD&R also delivers content on designing and building homes to manage moisture through trade shows like the annual International Builders Show (IBS). IBS is

a major building industry event with approximately 90,000 attendees. PD&R personnel and contractors for PD&R research programs typically present at IBS technical seminars and provide publications like *Durability by Design* as handouts.

PD&R reaches consumers by providing information about new building technologies and performance issues on PATHnet (http://www.pathnet.org), a HUD-sponsored website designed primarily for consumer use. The site contains fact sheets and articles about mold and moisture control, and electronic copies of PD&R publications including its work on manufactured housing and *Durability by Design.* PATHnet also contains select guidance and best practice content compiled from other sources.

In addition to disseminating these publications through industry group websites and events, all of the PD&R publications mentioned in Section 2.2 are available in print and electronic versions through the HUD User document service and website (http://www.huduser.org/). The HUD User service is highlighted to industry groups during presentations, newsletters, websites, and the publications themselves. This direct dissemination channel also allows PD&R to monitor the usage of its documents. For example, the *Building Moisture and Durability - Past, Present, and Future Work* report has been downloaded roughly 250 times per month since it was made available in late 2004.

4.3 Office of Public and Indian Housing

The PIH/ONAP mold initiatives have concentrated on recommending remediation and prevention practices. Accordingly, a major component of these projects has been disseminating useful information to Indian housing organizations, residents, inspectors, contractors, and maintenance firms. ONAP has accomplished this by partnering with Indian housing groups and developing outreach activities such as training seminars, post-inspection de-briefings, and guidance manuals and brochures.

ONAP's training seminars on mold problems in Indian housing have included 19 programs offered throughout the country, from October 2001 through December 2004, usually in a two-day format. The availability of seminars is publicized through the ONAP Area Offices, and specific locations for the training sessions are chosen based on demand. Once a training session is scheduled, the program is publicized to all tribes and Indian housing organizations through newsletters, fax communications, and announcements on the CodeTalk website (see below).

The training seminars held to date have been almost equally divided between two topics: "Mold Prevention" and "Mold Assessment". The Mold Prevention training is based on *Mold and Moisture Prevention - A Guide for Housing Authorities in Indian Country* and was presented on nine occasions from October 2001 through July 2003. The target audience for this training is housing organizations and environmental health specialists. The Mold Assessment training is based on *Mold Prevention and Detection: A Guide for Maintenance Staff and Housing Counselors in Indian Country,* and was presented on ten occasions from October 2003 through December 2004. The target

groups for this workshop series are construction, maintenance and inspection teams, and housing counselors. It is estimated that a total of 300 students have attended these training seminars.

In addition to the formal training sessions, the 55 site assessments described in Section 2.3.2 also resulted in informal de-briefings at the conclusion of each set of inspections. This activity provided direct feedback to housing staff and residents on the causes of mold problems and steps for remediation and prevention.

While the two guides have served as the basis for the training workshops and been distributed through these events, another ONAP publication designed for broader dissemination is *Mold and Moisture Prevention: A Guide for Residents in Indian County.* This document is available for download from CodeTalk, an ONAP-sponsored interagency website that delivers information from government agencies and other organizations to the Native American community, at http://www.hud.gov/offices/pih/ih/codetalk/docs/moldprevention.pdf. In addition to downloads from CodeTalk, approximately 8,000 copies of this resident-oriented pamphlet were distributed in 2004 to approximately 560 Indian tribes and over 300 Indian housing organizations.

In 2005 ONAP will also release an instructional video based largely on the mold assessments and prevention guides. One section of the video is designed to educate Indian housing staff and give them enough knowledge about mold and moisture to counsel residents and conduct targeted maintenance and repairs. The second section of the video provides information to educate residents on mold problems and prevention.

APPENDIX A

HHI GRANTS SUMMARY

Summary Table of HHI Grants

Name of Grantee	State	Grant Category	Fiscal Year
Illinois Department of Public Health	IL	Mold and Moisture Control	1999
Cuyahoga County	OH	Mold and Moisture Control	1999
Boston Public Health Commission	MA	Demonstration	1999
City of Providence	RI	Demonstration	1999
City of Long Beach	CA	Demonstration	1999
Environmental Health Watch	OH	Technical Studies	1999
Medical Health and Research Assoc of NYC	NY	Demonstration	1999
1999 Grants Sub-Total			**$8,410,165**
Children's Health Environmental Coalition	CA	Education	2000
Esperanza Community Housing Corporation	CA	Demonstration	2000
Child Abuse Prevention Council	CA	Education	2000
Northeast Denver Housing Center	CO	Demonstration	2000
Harvard School of Public Health	MA	Technical Studies	2000
Erie County	NY	Demonstration	2000
The Opportunity Council	WA	Demonstration	2000
University of Wisconsin-Madison	WI	Technical Studies	2000
2000 Grants Sub-Total			**$7,576,283**
Alaska Housing Finance Corporation	AK	Demonstration	2001
University of Alabama at Birmingham	AL	Education	2001
Alameda County	CA	Demonstration	2001
City of Stamford	CT	Demonstration	2001
University of Maryland-Baltimore	MD	Demonstration	2001
Medical and Health Research Association of New York City, Inc.	NY	Demonstration	2001
Seattle and King County	WA	Demonstration	2001
Air Quality Sciences	GA	Technical Studies	2001
Radiation Monitoring Devices, Inc.	MA	Technical Studies	2001
Duke University	NC	Technical Studies	2001
Research Triangle Institute	NC	Technical Studies	2001
Columbia University	NY	Technical Studies	2001
University of Cincinnati	OH	Technical Studies	2001
University of Tulsa	OK	Education	2001
2001 Grants Sub-Total			**$8,062,503**
City of Phoenix, Arizona	AZ	Demonstration	2002
Healthy Homes Network	KS	Demonstration	2002
University of Massachusetts Lowell Research Foundation	MA	Demonstration	2002
Coalition to End Childhood Lead Poisoning	MD	Demonstration	2002
Montana State University Extension Service	MT	Technical Studies	2002
Mount Sinai School of Medicine	NY	Demonstration	2002

Name of Grantee	State	Grant Category	Fiscal Year
Urban Homesteading Assistance Board	NY	Demonstration	2002
City of Philadelphia	PA	Demonstration	2002
City of Milwaukee	WI	Demonstration	2002
St. Louis University, School of Public Health	MO	Technical Studies	2002
Advanced Energy Corporation	NC	Technical Studies	2002
University of Medicine and Dentistry of New Jersey	NJ	Technical Studies	2002
2002 Grants Sub-Total			**$7,586,202**
Cuyahoga County Board of Health	OH	Demonstration	2003
Erie County Department of Health	NY	Demonstration	2003
Mahoning County	OH	Demonstration	2003
Neighborhood Housing, Inc.	WA	Demonstration	2003
City of Minneapolis	MN	Demonstration	2003
NY Indoor Environmental Quality Center, Inc.	NY	Demonstration	2003
The Medical Foundation (NE Asthma Regional Council)	MA	Demonstration	2003
University of Illinois	IL	Technical Studies	2003
Georgia Tech Applied Research Corp.	GA	Technical Studies	2003
Tulane University	LA	Technical Studies	2003
University of Minnesota	MN	Technical Studies	2003
2003 Grants Sub-Total			**$7,926,104**
University of Colorado Health Sciences Center	CO	Technical Studies	2004
Georgia Tech Applied Research Corp.	GA	Technical Studies	2004
University of Illinois at Urbana-Champaign	IL	Technical Studies	2004
University of Texas Health Science Center at San Antonio	TX	Technical Studies	2004
City of Long Beach	CA	Demonstration	2004
City of Riverside, Department of Public Health	CA	Demonstration	2004
Philadelphia Housing Authority	PA	Demonstration	2004
St. Louis County	MO	Demonstration	2004
Columbus Health Department	OH	Demonstration	2004
Eastern Virginia Medical School	VA	Demonstration	2004
Healthy Homes Resources	PA	Demonstration	2004
2004 Grants Sub-Total			**$9,506,988**
Total Grants Awarded			**$49,068,080**

APPENDIX B

EXECUTIVE SUMMARIES OF OHHLHC MOLD AND MOISTURE SET-ASIDE GRANTS

EXECUTIVE SUMMARY

CUYAHOGA COUNTY URBAN MOLD AND MOISTURE PROGRAM

The Cuyahoga County Urban Mold & Moisture Program (UMMP) explored the relationship between mold, moisture, asthma triggers and the respiratory health of children living in inner city neighborhoods throughout Greater Cleveland.

Most of the inner city homes were pre-WWII single family bungalows but post-WWII bungalows with finished basements and ranches built on slabs were also included. Approximately 83% of the homes had been occupied by the participating families for more than one year prior to enrollment. The data collected with the extensive visual assessment was translated into remediation specifications which were then carried out by trained contractors. Home interventions focused on the reduction of water infiltration, removal of water-damaged building materials, HVAC alterations, lead hazard control, and environmental cleaning. Common interventions to reduce water infiltration often focused on basements, and included reducing water infiltration through foundation walls, repairing gutter systems, and altering porches to prevent water leaks into underlying basements. A common alteration of heating systems involved repairing the "Cleveland drop," a system in which heating make-up air is drawn directly from basements, which can result in biological contaminants from wet basements, such as mold spores, being transported throughout the home.

A total of 104 homes received environmental interventions with an average remediation cost of $5,470 (average cost of $3,147 for mold and moisture remediation and cleaning and $2,323 for lead hazard control) per house. Quality assurance measures found the visual assessment to be generally accurate and the interventions properly performed.

Asthma and Composite Study Results

Participating families were enrolled based on their homes having visible water-damage (or history of water damage) and/or mold growth. Almost all of the houses were within the City of Cleveland or the inner ring suburbs and were predominantly wood frame houses built before 1950. The Asthma Study families had a child with moderately severe asthma and the Composite Study families had a young infant or child at-risk for respiratory health problems due to the moldy home environment. Following optimization of medical care and baseline clinical and home environmental assessments, the Asthma Study subjects were randomized into those receiving home interventions targeting mold and moisture versus those receiving only general home cleanliness instructions. In contrast, the families in the Composite Study all received the targeted home interventions (59 of these families had home interventions; an additional seven were evaluated but dropped out prior to any interventions, usually due to a decision to move). Simultaneous clinical and environmental assessments and sampling occurred at intervals over a 12 month period.

Clinical samples were collected from the asthmatic child and in the Composite group from the index child, siblings and primary caregiver. These samples were analyzed for allergen-specific IgE antibodies, fungal-specific IgG antibodies, urinary cotinine, and blood lead. Environmental assessments included an in-depth visual assessment, humidity measurements and collection of settled dust samples from the index child's bedroom. The dust samples were assayed for dust mite, cockroach, rodent urinary protein, and endotoxin. Fungal testing conducted on the dust compared β-glucan (a measure of total mold mass), culturing on three different media and quantitative Polymerase Chain Reaction (PCR) for 33 fungal species.

Clinically, the moderately severe asthmatic children had a significant decrease in symptom score (American Academy of Pediatrics Asthma Health Survey; $p<0.006$) and symptom days ($p<0.003$) following remediation while these parameters in control children in homes not receiving the interventions did not significantly change. During the six month period following remediation (or the equivalent time for controls), asthmatics receiving home interventions had a lower rate of exacerbations requiring hospitalization or an emergency room visit compared to control asthmatics (1/29 vs. 11/33, respectively, $p=0.003$). The children in the Composite Study (>2 years old, n = 65) had a significant decrease (Bonferroni-corrected $p<0.05$) in 11 out of 14 upper and lower respiratory symptoms following the home interventions and four out of 13 non-respiratory symptoms.

Mold Remediation and Sampling Results

At baseline, the surface moisture measured in the basement primary structural beam correlated positively with the amount of visible mold growing on cellulose material in the basement (Spearman, $r = 0.26$, $p=0.017$). Most of the visible mold in assessed homes was found in basements and kitchens. Environmental assessments before and after the remediation found a significant decrease in the visual mold ($p=0.004$) in remediated versus control homes in the asthma study, especially apparent for basements. The significant decrease in visual mold was observed over a period greater than six months following remediation.

Vacuum dust samples were analyzed by viable culturing and polymerase chain reaction (PCR). Viable culturing is a widely used method to assess environments for fungi. While it does not require pre-selection of which fungal species are to be detected, it is limited to finding only those fungal components that will grow in culture and requires mycological expertise for species identification. The results are expressed as Colony Forming Units (CFU) per gram dust collected (concentration) or per square meter sampled (loading). In contrast, PCR is a newer approach for measuring environmental fungi that is based on species or species group-specific genomic probes for quantification of the number of those genomes present (it is thus limited to the species/species groups for which probes have been developed). This method does not require viable samples, nor mycological identification expertise (once each probe has been authenticated), and is very sensitive and highly accurate. Since PCR is dependent upon the fungal DNA in the sample, it measures all fungal fragments, spores, and hyphal components without regard to viability. The results are expressed

as fungal DNA elements per gram or m^2. A total of 82 species-specific genomic probes, developed by the U.S. EPA, were used in an initial PCR analysis, which was later decreased to 33 species/species groups for further sample analysis (see below). Thus, while the two methods produce similar data, they measure different fungal parameters and are not fully comparable. As would be expected, the PCR-based concentrations were commonly several orders of magnitude greater than those of the culturing method and PCR analysis detected specific fungi at a higher frequency than the viable culture methods. For some species with short viability half-lives the quantitative disparity can be very large. For example, *Stachybotrys chartarum* was found by culture in only 3.5% of study homes but in 71.1% by PCR.

PCR Study of Dust in Homes of Children With Acute Idiopathic Pulmonary Hemorrhage (AIPH)

Dust from six homes with visible mold and in which there had been an infant with acute idiopathic pulmonary hemorrhage or "bleeding lungs" (AIPH homes) was analyzed by PCR using 82 species-specific genomic probes. Dust from 26 houses (RH for reference houses) from the same geographic area but in which no mold or water damage was found, were similarly analyzed. The quantitative concentration data from these two sets of homes were compared by calculating the ratio of the geometric means for each of the species/species groups and categorizing the results into those that had geometric mean ratios (AIPH/RH) of >1 and <1. There were 26 species/species groups that had geometric mean ratios >1 and 10 species/species groups with ratios <1, differences which allowed the clear statistical differentiation of the two groups of houses (see Vesper et al, "Quantitative PCR Analysis of Fungi in Dust", J Occup Environ Med. 2004;46:596-601). Subsequently, these 36 species/species groups were further reviewed and 33 were selected for analysis of the Asthma and Composite study homes. Fungal species that occurred in larger amounts in the AIPH houses included > ten of the genus *Aspergillus*, > 5 of the genus *Penicillium*, *Stachybotrys chartarum* and *Trichoderma viride*. The average total concentrations of mold in AIPH and Reference homes were 33,100 and 28,000 genomes/5mg dust, respectively, concentrations that were not significantly different.

Other PCR Results

Baseline dust samples from 128 homes had PCR concentration data (genomes/gm) and 89 homes had loading data (genomes/m^2). Twelve species/species groups were found in 90% or more of the homes, 16 in >75%, and 29 in >50%. Thirty-three species/species groups were found in 25% or more of homes. The five most frequently occurring species/species groups were also the most abundant both by concentration and loading (*Aureobasdiium pullulans, Cladosporium cladosporiodes, Eurotium amstelodami, Epicoccum nigrum, and Aspergillus penicillioides*). *Aureobasidium pullulans* and *Cladosporium cladosporiodes* were also among the most abundant species observed by the culturing method. When tested for seasonality, nine species/species groups demonstrated significant seasonality.

Of the 33 most frequently occurring species/species groups, only one individual mold was significantly decreased in dust samples collected approximately three months

following intervention; *Stachybotrys chartarum* (p=0.006) based on loading with adjustment for surface type. Similar significant decreases were seen with this species with the concentration data, all differences were significant with or without adjusting for surface type.

Viable Count Results

Baseline fungal levels were determined by the viable count method for 115 homes by concentration and 104 homes by surface loading. 124 different fungal species or species groups were identified, 42 of them represented in ≥10% of the homes and 87 found in two or more homes. The five most abundant species or species groups in descending order were *Cladosporium* spp., *Alternaria alternata*, *Penicillium* spp., *Aureobasidium pullans*, and *Aspergillus vesicolor*. The first two of these are commonly found outdoors while the Penicillium and Aspergillus species are usually amplified indoors under damp conditions. Seasonality of the cultured fungal levels was analyzed using all baseline and follow-up data based on loadings (CFU/m^2) with a sample size of 204. Seventeen fungi showed significant seasonality ($p<0.05$). Among the five most abundant species found, *Alternaria alternata* and *Cladosporium* spp. showed significant seasonality. Corrections for seasonality were used in subsequent statistical analyses.

Data from the Composite and Asthma studies were combined and changes in the mean levels of mold species were assessed (both concentration and surface loading) before and approximately three months following remediation. There were no significant changes seen with the concentration data. Data analysis based on loadings, also adjusting for surface type (smooth floors or carpets), found three molds, *Trichoderma harzianum* (p=0.038), *Penicillium crustocem* (p=0.038), and *Penicillium decubens* (p=0.044), with significantly reduced mean loading levels (FDR-adjusted $p<0.05$), with one mold (*Curvularia lunata,* p=0.044) showing a significant increase.

The large database generated by the extensive semi-quantitative culturing of fungi and the quantitative PCR measurements continues to be analyzed.

Changes in Levels of Other Biological Contaminants

The amount of endotoxin in the dust from a square meter of the floor of the bedrooms of the index children was seen to decrease significantly within the remediated group (p=0.002) and between remediated and control groups (p=0.006). Parallel measurements of mouse antigen also decreased significantly (p=0.019 and p= 0.014). Decreases seen in the other measured allergens did not reach statistical significance.

Conclusions

The UMMP was among the first remediation programs targeted to mold and moisture problems in children's homes which investigates the impact of these interventions on the respiratory health of children. While its significance is limited due to the small number of families and homes investigated, the observed clinical improvements are very encouraging and underline the need to expand on these observations in larger studies.

EXECUTIVE SUMMARY

ILLINOIS MOLD AND MOISTURE DEMONSTRATION PROJECT

Through existing partnerships, the Illinois Department of Public Health collaborated with the Chicago Department of Public Health, the John H. Stroger, Jr. Hospital of Cook County, the Community and Economic Development Association of Cook County, the University of Illinois at Chicago Environmental and Occupational Health Sciences Division, the University of Illinois at Champaign-Urbana Building Research Council, and the Department of Commerce and Economic Opportunity to demonstrate a cost-effective means to control moisture and associated mold growth in inner-city housing of Chicago occupied by low-income families with young children.

The primary research objective of this demonstration project was to investigate the relationship between different types and amounts of fungi and fungal metabolites, allergens, and moisture in urban homes, and their impact on children's health, specifically asthma and Acute Idiopathic Pulmonary Hemosiderosis (AIPH).

Two types of low-income households were enlisted as recruits for this project: Households with a child with AIPH, and households with a child with mold-related allergenic asthma. The households were eligible if the children were less than 16 years of age and if the homes had signs of mold and/or moisture damage. The household study subjects were enlisted and provided consent forms according to human subject research protocols.

IDPH and its partners approached approximately 195 potential clients and requested their participation in this project, and a total of twenty seven signed consent forms and received moisture assessments. Seventeen of these households were ultimately enrolled in the project, three with children diagnosed with AIPH who were referred by their pulmonologist and fourteen families with children with mold-sensitive asthma. A total of one child with AIPH and seven children with mold-sensitive asthma completed one or more clinical evaluations, as well as the environmental intervention and environmental sampling phase of the project.

Ultimately, fourteen families in the Chicago area, many in the inner city, received an environmental intervention from May 1, 2000 to April 30, 2004. The total cost (for materials and labor) for the fourteen environmental interventions was $95,952 and the average cost for each intervention was $6,828. The maximum intervention cost was $9,000, and only three interventions exceeded $7,000.

Moisture assessments were performed at the properties to identify and characterize moisture and mold issues with the houses. The evaluations were conducted by IDPH using an assessment tool developed specifically for this project. The assessment tool features a room-by-room inspection format. Room assessment forms, subdivided into topical sections, prompt for the inspection and documentation of conditions regarding bulk moisture problems, sources of elevated winter moisture loads,

and visible signs of mold contamination. Questions for the building's residents, relating to past experiences such as flooding, winter condensation problems, plumbing issues and other historical events, are integrated into the assessment tool. The assessment tool was designed to prompt a comprehensive moisture assessment and diagnosis by staff with relatively little experience in building construction. The assessment tool served the purposes of the project, and could also serve as a valuable training tool in teaching residential moisture assessment in other healthy homes projects.

The moisture assessments showed that bulk moisture problems (those resulting from leaks and leading to acute, but localized, water damage) far exceeded wintertime condensation-based problems. In only two of the fourteen cases (14%) was a condensation-based problem identified as the source of the major mold contamination, while bulk water damage was the cause of major problems in 86% of the cases. Foundation moisture from bulk water entry was the most common moisture source problem, and interior finishes in basements proved to be the most common location for mold contamination. Analysis of moisture data confirmed the visual assessment, as 79% of the houses were rated “dry” or “very dry” with respect to winter moisture levels.

A number of tertiary colonizers (i.e., fungi requiring repeated, high moisture levels) were identified in surface samples collected in most of the homes prior to environmental intervention, most notably *Ulocladium* species (more than 80%) and *Stachybotrys chartarum* (56% of homes). Two homes with children who tested positive to multiple allergen tests as well as *Stachybotrys* IgE contained the highest number of individual species groupings (44 and 26, respectively) of the clinical subject homes. *Stachybotrys spp.* were also present in these homes.

There were five study homes occupied by five children who tested positive for mold-allergies and asthma. One of these homes was also occupied by a second child with asthma, but that child had no positive responses to clinical RAST testing (a blood test that measures levels of allergen-specific IgE antibodies). In these five homes, 63% of the time dust dilution plating of fungi in the vacuum dust samples detected fungi similar to the fungal allergens that tested positive by RAST testing in the children seen in clinic. Moreover, 50% of the time, fungal surface samples detected fungi similar to the fungal allergens that tested positive by RAST testing in the children seen in clinic.

All six children had sufficient clinical observations to evaluate the effectiveness of the environmental intervention on the course of their asthma. Clinical change was assessed on the basis of reported emergency room visits, days lost from school or kindergarten, frequency of night cough, pulmonary function testing, and clinical examination. Based on these data and in the opinion of the examining pediatrician, two of the six children improved (reduction in ER visits and lost days, improvement of physical findings of rhinitis, and/or improvement in spirometry) following the environmental intervention in their home.

The first child was noteworthy for having a high total serum IgE (446-486 KU/L) (KU = kilounits of IgE per liter) and being RAST test positive for multiple allergens. This

child also tested positive for *Stachybotrys* IgE (0.99 KU/L). The environmental intervention in this child's home was effective in eliminating visible mold growth and reducing house levels of all allergens tested, except for the dust mite allergen *Dermatophagoides farinae* and endotoxins.

The second child was also noteworthy for having an elevated total serum IgE (268-310 KU/L) and being RAST test positive to multiple allergens, including *Alternaria,* which was detected in the surface samples collected from home. The environmental intervention in this home eliminated visible mold growth and reduced all allergens except endotoxins.

Among the four children who did not demonstrate a clear improvement, two children tested positive for cotinine in their urine, suggesting concurrent exposure to environmental tobacco smoke. While based on small numbers, the case studies provide rich observational data on both environmental allergens and clinical course among inner-city children with asthma prior to and after housing rehabilitation. The small numbers preclude definitive conclusions but do offer intriguing observations that should be evaluated in future studies.

The clearest benefit of intervention was observed in the two children who had a high total IgE and who were RAST positive for molds that comprised, in part, the visible mold that was the target of the intervention. This observation is consistent with the hypothesis that the children who may benefit most from mold remediation are those who are at high risk for allergy due to elevated total IgE and who are demonstrated to be RAST positive to the specific molds that are identified in the visible mold growth. While clear improvement post-intervention was not observed among two other asthmatic children with elevated total IgE and RAST positivity to molds identified in the visible mold growth, their clinical courses may have been confounded by concurrent exposure to environmental tobacco smoke.

Children who live in homes with visible mold and with detectable *Stachybotrys* appear to have higher odds of developing IgE positivity to *Stachybotrys* than children who live in homes in which *Stachybotrys* does not contribute to the visible mold growth. The relative prevalence observed in this study, while not statistically significant due to small sample size and low statistical power, is suggestive of the connection between IgE positivity and the presence of *Stachybotrys* in the homes.

The overall results of this project support the premise that there are health benefits to occupant children who have mold-related asthma from the elimination of moisture and organisms associated with moisture.

The project also found an apparent association between the presence of moisture problems, fungal organisms, and AIPH. Three families with AIPH children were enrolled for pre-intervention sampling. In the first family, no visible fungi were present in the home, but it was discovered that the child had been at the grandparents' home for several days prior to disease onset. Visible fungi were found and air sampling in the

grandparents' home found relatively high concentrations (3-20 times outdoor levels) of total fungi, including a potentially pathogenic species, *Aspergillus fumigatus.* Surface sampling was not performed in the home because the method had not been added to the study at the time. Air sampling in the other two subject homes also found *Aspergillus fumigatus*. Several high moisture indicator species, including *Stachybotrys chartarum,* were found in air samples in one of the three homes tested and in surface samples in one of the two AIPH homes in which this sampling was performed. *Stachybotrys chartarum* was found in surface samples in 56% of the homes in the study. Although *Aspergillus fumigatus* is relatively common in outdoor air samples (2 of 16 outdoor air samples in this study), it was not found on surface samples in any other study homes. Two of the AIPH families dropped from the study before intervention.

The following are the recommendations of the project report:

1. Local housing and enforcement agencies should enhance and enforce building codes so that appropriate incentive exists to encourage property owners to address moisture issues in occupied properties in a timely manner. This enforcement could be utilized in conjunction with programs for moisture evaluation and assistance with medium cost and/or matching fund repairs. This demonstration project provides a valid model for such programs.

2. In order to enhance subject participation in future projects of this type, the projects should be organized so that the clinical evaluations could be carried out in participants' homes or that the project solicits cooperation of regular subject physicians.

3. Other moisture and fungi reduction intervention projects, designed to incorporate the lessons learned described in this report, should be funded in the future.